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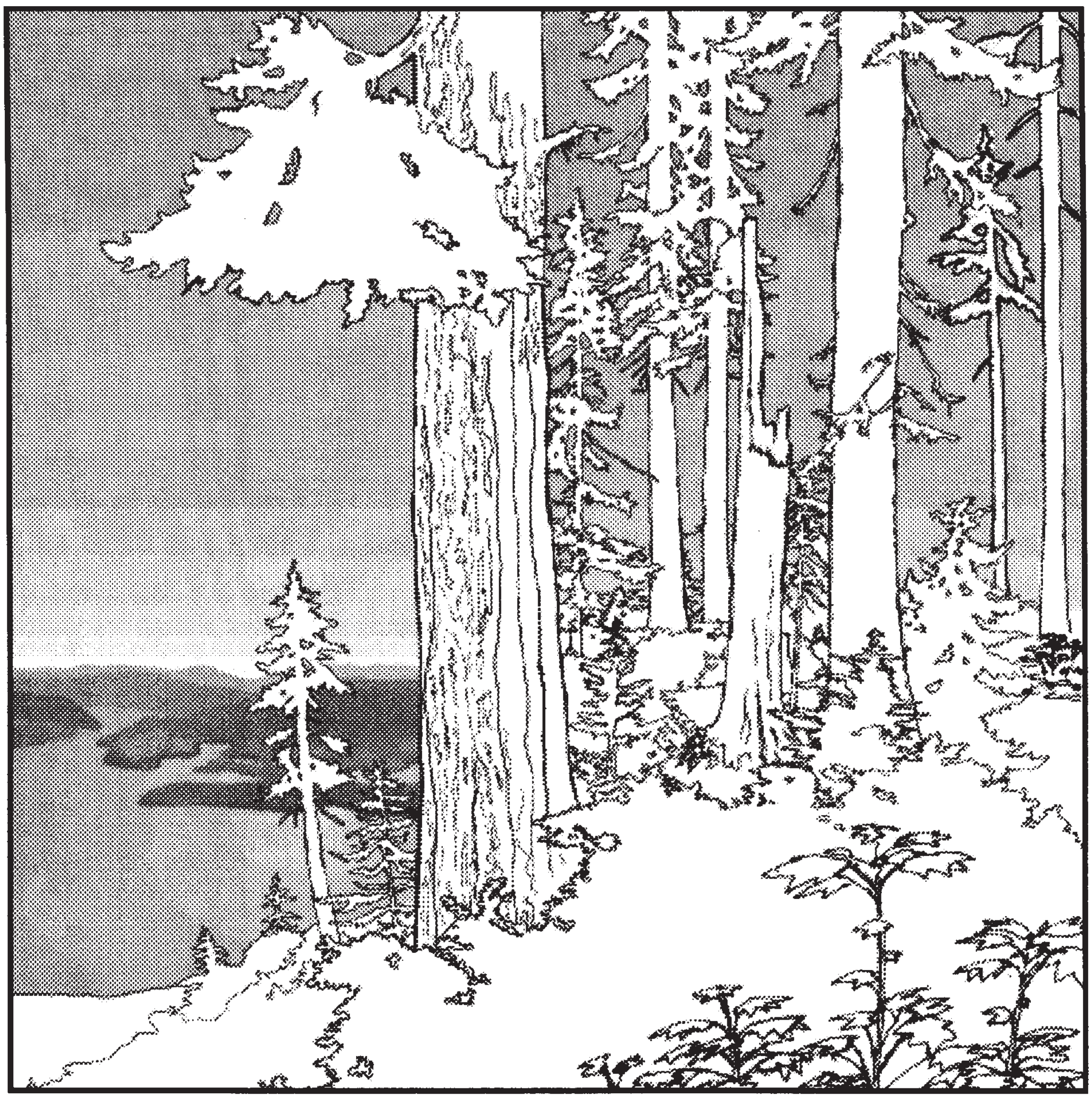
A Conservation Assessment for the Marbled Murrelet in Southeast Alaska

Anthony R. DeGange



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Conservation and Resource Assessments for the Tongass Land Management Plan Revision

Charles G. Shaw III, Technical Coordinator

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Abstract

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This assessment summarizes available information on the marbled murrelet in southeast Alaska and evaluates its current status. Marbled murrelets are broadly distributed across marine waters throughout southeast Alaska. They are abundant, numbering at least in the low hundreds of thousands. Marbled murrelets are believed to be at increasing risk in biogeographic provinces of the Tongass National Forest subject to extensive harvest of old-growth forests, on which they are believed to be dependent for nesting. Over the short term, risk to their persistence in the Tongass National Forest seems low; however, gaps in their nesting distribution likely will occur in some biogeographic provinces of the Tongass if current forest harvest practices are continued over the long term. Forests on private lands in southeast Alaska are being rapidly clearcut, and murrelet nesting habitat is disappearing rapidly from these lands.

Keywords: *Brachyramphus marmoratus*, marbled murrelet, conservation, management, natural history, old-growth forests, status.

Summary

This conservation assessment summarizes available information on the marbled murrelet in southeast Alaska. Because information on marbled murrelets in southeast Alaska is limited, this assessment borrows heavily from studies done on this species in other parts of Alaska and in the Pacific Northwest.

Marbled murrelets are broadly distributed across marine waters in southeast Alaska. They spend nearly all their time at sea, coming to land only to visit nesting areas, incubate eggs, and feed chicks. They are abundant, numbering at least in the low hundreds of thousands. There are few data available from which to assess population trends. Statistical analysis of Christmas bird count data, the only long-term data set available in southeast Alaska, was inconclusive. Only six nests of marbled murrelets have been found in southeast Alaska. Four were classic tree nests found on wide, moss-covered branches in large, old trees in old-growth forests. The other two nests were found on the ground, also in old-growth forests. Both ground nests were peculiar in that one was situated on the top of a small cliff and the other in a very steep gully. Both ground nests had features similar to tree nests when approached from below. Quantification of activity through dawn watches suggests that marbled murrelet activity is greater in old-growth forests, particularly in higher wood volume forests, than in other habitats in southeast Alaska. Uneven-aged, old-growth forest is likely the dominant nesting habitat for marbled murrelets in southeast Alaska. Ground-nesting does occur, but its significance to the marbled murrelet population in southeast Alaska is uncertain. Ground-nesting may be important in some areas, particularly in previously glaciated terrain and perhaps in alpine areas close to the coast.

The conservation status of the marbled murrelet in southeast Alaska is currently unclear, given our poor understanding of its biology, habitat characteristics, mortality factors, nesting distribution, and population trend. Given the declines in this species in the Pacific Northwest associated with logging, and the apparent importance of old-growth coniferous forests as nesting habitat in southeast Alaska, marbled murrelets may be at increasing risk in the Tongass National Forest. In the short term (e.g., decades), the persistence of this species in the Tongass National Forest seems highly likely. In the long term (e.g., 100 years or more), under current forest management practices, gaps in its nesting distribution could occur in some biogeographical provinces in southeast Alaska.

There currently is no conservation strategy for marbled murrelets in the Tongass National Forest, but development of a strategy, particularly in those biogeographical provinces where the largest proportions of old-growth forests have been cut, would assist managers in addressing the long-term habitat needs of this species. Research is critically needed on the nesting habitat of marbled murrelets in southeast Alaska and the effectiveness of various management tools in maintaining marbled murrelets on old-growth forest lands subject to future logging. Habitat conservation areas and estuarine, beach, and riparian management areas offer promise as components of a conservation strategy. Lengthening the rotation age on cut portions of the forest also holds promise as a conservation tool.

Preface

This conservation assessment focuses on the marbled murrelet (*Brachyramphus marmoratus*), a small seabird found in coastal areas of North America from central California to Alaska. Comparatively little is known of this species because of its secretive, inland nesting habits. Throughout the forested part of its range, most individuals of this species nest in old-growth forests within 80 kilometers (129 miles) of the coast.

Mounting evidence suggests that the marbled murrelet population has declined in recent years in California, Oregon, and Washington and that this decline is related to the logging of coastal old-growth forests used by marbled murrelets for nesting. Other factors that may have contributed to this decline include increased predation and mortality from oil spills and fishing nets. Evidence of a population decline of marbled murrelets was considered compelling enough for this species to be listed by the U.S. Fish and Wildlife Service as threatened in California, Oregon, and Washington, as well as by the States of California and Washington and the Province of British Columbia.

The geographic focus of this assessment is southeast Alaska. Although a range-wide conservation assessment for marbled murrelets recently was published, its treatment of marbled murrelets in southeast Alaska was less comprehensive than for other areas within the species' range, largely because of a lack of data and incomplete analyses of completed research.

This conservation assessment was prepared specifically for use in the revision of the Tongass National Forest land management plan (TLMP). The TLMP is being designed to ensure the long-term viability of wildlife populations dependent on forested habitats within the Tongass National Forest, as required under the National Forest Management Act of 1976. This assessment was prepared under the auspices of a memorandum of understanding among the U.S. Fish and Wildlife Service, USDA Forest Service, and Alaska Department of Fish and Game, which calls for cooperation among these agencies for conservation of species that are tending toward listing under Federal and State endangered species acts.[1]

Goals of the Assessment

The primary goals of this assessment are to consolidate and synthesize existing information on the marbled murrelet in southeast Alaska and to consider how various forest management practices may affect the long-term viability of marbled murrelet populations. Most of the existing information on this species in southeast Alaska is in the form of unpublished data collected by various agency scientists and other individuals. Studies on marbled murrelets have not yet been undertaken to provide information such that habitat needs for viable populations of marbled murrelets in southeast Alaska can be determined. Therefore, suggestions for additional research that could be undertaken to fill important data gaps are included.

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[1] The primary objective of the MOU was to foster interagency cooperation for the conservation of candidate and sensitive species to avoid the need for listing and protection under the Endangered Species Act. The marbled murrelet, in addition to the northern goshawk (*Accipiter gentilis*) and Alexander Archipelago wolf (*Canis lupus ligoni*), were identified as priority species for conducting a conservation assessment to achieve MOU objectives.

Recognizing limitations in the data available for marbled murrelets in southeast Alaska, I drew heavily on research results from other areas within the range of the species for establishing habitat relations. Not an optimal strategy, but I feel that what has been learned about marbled murrelet-forest relations elsewhere can provide a general understanding of habitat requirements likely existing in much of southeast Alaska. In applying research results on marbled murrelets from areas outside southeast Alaska to the Tongass National Forest, I have tried to do so cautiously.

Organization of the Conservation Assessment

This assessment is organized into six sections. The first is an abbreviated account of the ecology of marbled murrelets in North America and is designed to provide a brief overview of the life history and habitat relations of this species. The second expands on this review but emphasizes southeast Alaska. The results of several studies are synthesized in this section. Relevant literature on this species is used to describe likely habitat relations for marbled murrelets in southeast Alaska when data from southeast Alaska are lacking. The third section provides an overview of forest management history. This section also includes a description of current management practices within the Tongass National Forest and the implications for marbled murrelets. It attempts to predict the long-term effects on the population of maintaining current management practices. The fourth section poses a series of questions regarding the life history requirements and habitat needs of marbled murrelets in an attempt to explain their current conservation status and their prognosis in southeast Alaska. This section also includes a brief summary of the results of the viability risk assessment panel conducted by the USDA Forest Service in 1995. The fifth section attempts to evaluate the response of marbled murrelet populations to various forest management prescriptions and considerations and, perhaps most importantly, discusses conservation strategies for this species in southeast Alaska. Finally, there is a summary and analysis of research and management needs for this species in southeast Alaska.

Contents

Review of Marbled Murrelet Life History and Ecology

The assessment by Ralph et al. (1995a) contains the most recent information on marbled murrelets. What follows is taken mainly from various chapters in that volume.

The marbled murrelet is a member of the Alcidae (auks, murres, auklets, and puffins), a family composed of 22 extant species and 12 genera of seabirds found exclusively in the Northern Hemisphere. The greatest diversity of species occurs in the North Pacific. Two races of the marbled murrelet are currently recognized: the North American race (*Brachyramphus marmoratus marmoratus*) and the Asian (*B. m. perdix*). Konyukhov and Kitaysky (1995) contrast the two races.

The North American race is found from the Aleutian Islands in Alaska to central California. The geographic center of the population is in northern southeast Alaska. In Alaska, large populations of marbled murrelets are found in southeast Alaska, Prince William Sound, Cook Inlet, and the Kodiak Archipelago (Agler et al. 1994, 1995, in prep.; Piatt and Naslund 1995). Large numbers of marbled murrelets also are found in British Columbia (Burger 1995). Marbled murrelets are distributed almost without interruption from Kodiak Island east and south through British Columbia. West and south of that area, populations are more disjunct (Ralph et al. 1995b). In California, Oregon, and Washington, the disjunct distributions are believed to reflect the distribution of remaining late successional and old-growth forests along the coast on public lands, which form the principal nesting habitat for this species throughout much of its range (see numerous citations in Ralph et al. 1995a).

The size of the North American population of marbled murrelets is not known with certainty. Because of their secretive nesting habits, they cannot be censused on land like most other seabirds. Consequently, all estimates of marbled murrelet populations are based on at-sea surveys (Burger 1995, Klosiewski and Laing 1994, Piatt and Naslund 1995, Ralph and Miller 1995, Strong et al. 1995, Varoujean and Williams 1995). Ralph et al. (1995b) estimate the North American population at 300,000; this estimate may be low as it does not include updated estimates of two populations in Alaska (Cook Inlet and southeast Alaska) that are considerably larger than previously reported (Agler et al. 1994, 1995, in prep.). Inclusion of those estimates increases the North American population estimate to more than 600,000.

Few data are available with which to assess trends in population of marbled murrelets in North America; however, trends generally are considered to be downward for all populations that rely on large, commercially valuable conifers for nesting (Ralph et al. 1995b). Forest nesting populations amount to more than 95 percent of the marbled murrelets residing in North America. Beissinger (1995) estimates an annual decline of 4 to 6 percent of the population throughout the range of the species.

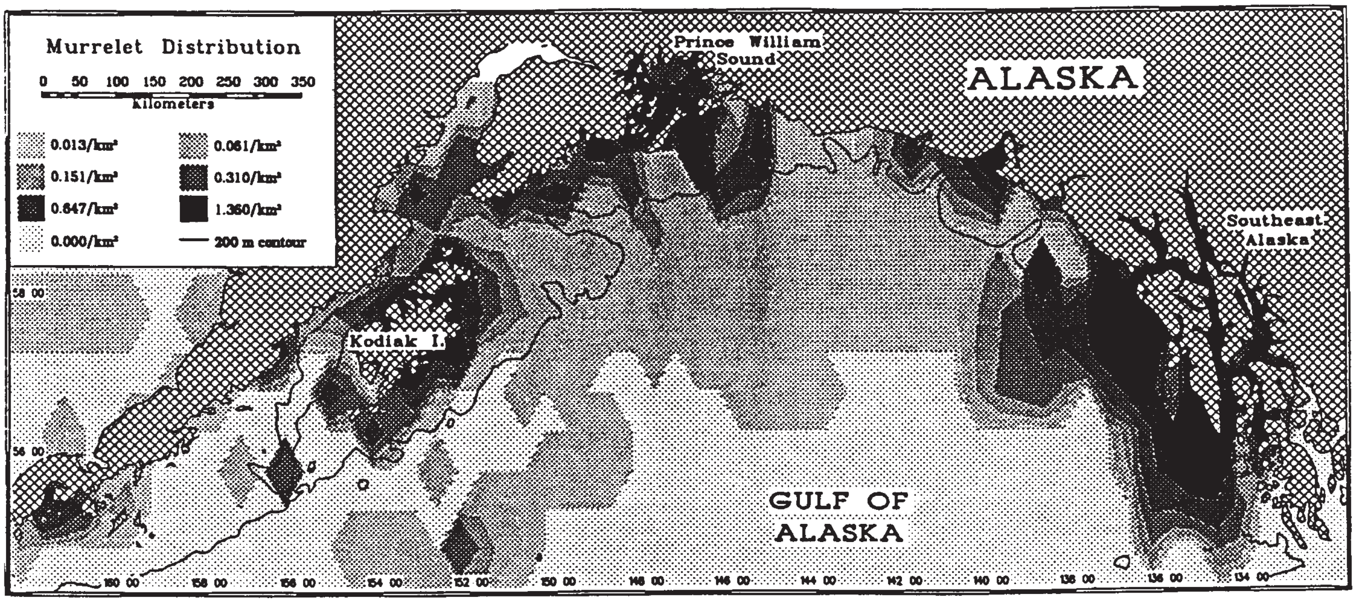

Figure 1—Distribution and densities of marbled murrelets in the northern Gulf of Alaska (from Piatt and Ford 1993).

Throughout most of their range, marbled murrelets are associated with old-growth forests for nesting (Ralph et al. 1995b). Piatt and Ford (1993), using broad-scale at-sea surveys, found three main areas of concentration during the breeding season in Alaska: waters of the Kodiak Archipelago, Prince William Sound, and the Alexander Archipelago (fig. 1). All three areas are adjacent to extensive stands of coastal coniferous forests used by marbled murrelets for nesting. Mendenhall (1992) and Piatt and Ford (1993) estimate that less than 5 percent of the marbled murrelet population in Alaska breeds on the ground in nonforested habitats of the Gulf of Alaska and Aleutian Islands. Some marbled murrelets in Alaska, including southeast Alaska, also nest on the ground where forests are available nearby. In all forested areas where marbled murrelets are found, most nests have been found in the largest trees and in the oldest forests. The mere presence of old-growth forest does not assure its suitability for nesting, however, as the physical condition of trees and forest stands also is important. Marbled murrelets seem to prefer trees with high, broad platforms for nesting and takeoff, and stands with sufficient canopy openings to permit access. Other important attributes of nest sites include low elevation, large tree diameter, number of potential nesting platforms, and moss cover (Hamer and Nelson 1995, Kuletz et al. 1995b).

Murrelets do not form dense colonies as do many other seabird species. Some evidence indicates that they may loosely aggregate to nest, which may be a reflection of forest stand size (Naslund et al. 1994) and availability of large nesting trees and nest platforms. The cryptic coloration of marbled murrelets during the nesting season, crepuscular activity patterns, and behaviors suggest that predation has had a strong influence in shaping their life history strategy and noncoloniality (Ralph et al. 1995b). Road building in forested areas and fragmentation of forest habitat is thought to increase predation as a result of increased access to marbled murrelet nesting stands by avian predators, especially jays, crows, and ravens (Nelson and Hamer 1995a).

Limited data suggest that marbled murrelets are one of the least productive of all alcids (DeSanto and Nelson 1995). Only 28 percent of all nesting attempts with known reproductive outcomes (n=32) were successful. The loss of eggs and chicks to avian predators was the most important cause of nest failure among nests studied to date (Nelson and Hamer 1995b). Although data are few, the low rate of production of young suggests that survival of adult murrelets must be high; therefore factors increasing adult mortality, such as oil spills and fishing nets, could markedly affect population dynamics.

With the exception of the ground-nesting population in south-central and southwestern Alaska, marbled murrelet populations in North America are believed to be limited by the amount of nesting habitat. Foraging areas do not seem to be limiting, especially in California, Oregon, and Washington where populations are small (Ralph et al. 1995b). Because they may have high rates of adult survival, destruction of their forest nesting habitat may not be accompanied by an immediate decline in the population of adult birds at sea. Because of this lag, at-sea counts to determine trends in marbled murrelet numbers must be conducted over long periods. Further reductions in nesting habitat presumably will be accompanied by a reduction in the proportion of juvenile birds found at sea after fledging and later by an actual reduction in counts of birds at sea.

Review and Synthesis of Available Data

Systematics and Legal Status

There is no evidence that marbled murrelets in southeast Alaska are morphologically or genetically distinct from marbled murrelets elsewhere in North America, but studies designed to address this question have not been undertaken. Recently, Pitocchelli et al. (1995) found no morphological or genetic divergence between tree- and ground-nesting marbled murrelets. Their samples included marbled murrelets from southeast Alaska, but they did not specifically compare the southeast birds with those collected from other regions.

At this time, the marbled murrelet in Alaska has no special status with the State of Alaska (Schoen 1996) or any official designation under the Endangered Species Act. Because it is vulnerable to various human activities, including logging, oil spills, and commercial fishing with gillnets, the U.S. Fish and Wildlife Service is concerned about its status. Currently, there is insufficient information to properly evaluate its population status and trend.

Distribution and Abundance

Summer distribution—Marbled murrelet distribution in summer is dictated primarily by the spatial overlap of terrestrial breeding habitat and suitable marine foraging areas. During the breeding season, most marbled murrelets in Alaska are in sheltered inside waters, including bays, fjords, and island passes (Piatt and Naslund 1995).

Four primary sources of data were used to examine local, at-sea distributions of murrelets in southeast Alaska: systematic small-boat surveys in Glacier Bay in 1991 (Piatt et al. 1991), systematic shipboard surveys in Glacier Bay and Icy Strait (Lindell 1995a), systematic small-boat surveys throughout southeast Alaska in 1994 (Agler et al. 1995), and opportunistic shipboard surveys throughout southeast Alaska in the 1980s (McAllister 1996a). Offshore survey data for marbled murrelets also are available from the Yakutat area (Harke and Lucey 1995). The Yakutat surveys reveal that marbled murrelets are the most abundant marine bird in this area, but the results were not analyzed with methodology allowing comparison with survey results from other areas in southeast Alaska.

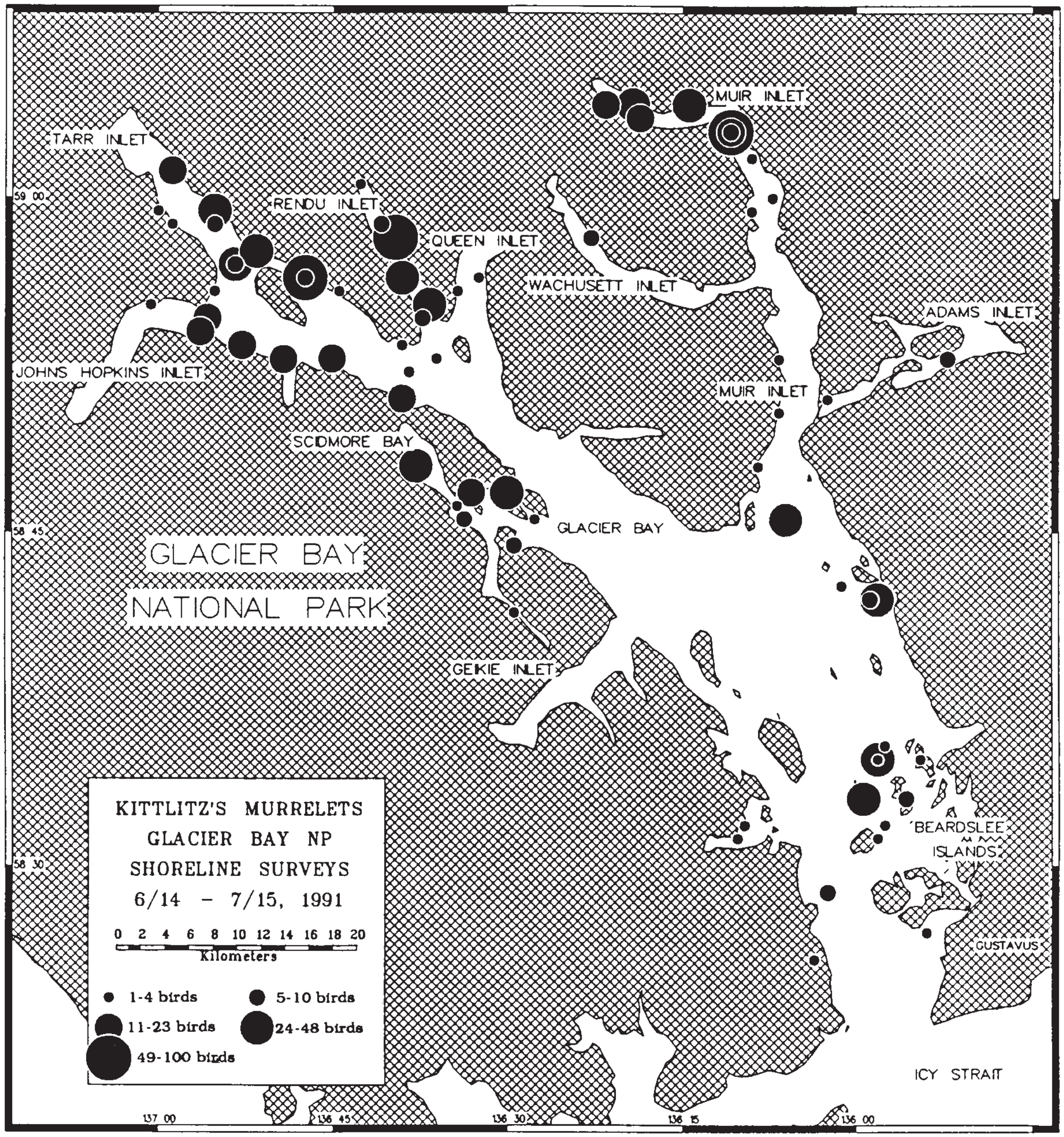

Figure 2—Distribution and relative abundance of Kittlitz's murrelets on shoreline surveys in Glacier Bay in June and July 1991 (from Piatt et al. 1991).

Piatt et al. (1991) surveyed marine birds in Glacier Bay from small boats in a 200-meter-wide (656-foot-wide) coastal strip in June 1991. They counted 9,095 murrelets, with marbled murrelets outnumbering Kittlitz's murrelets by a ratio of 4:1. Kittlitz's murrelets were restricted mostly to the upper reaches of Glacier Bay, reflecting their preference for tidewater glaciers and glacial river outflows (fig. 2); marbled murrelets were most abundant in the outer and middle portions of Glacier Bay (fig. 3). The count by Piatt et al. could be considered a first-order minimum estimate for the murrelet population in Glacier Bay.

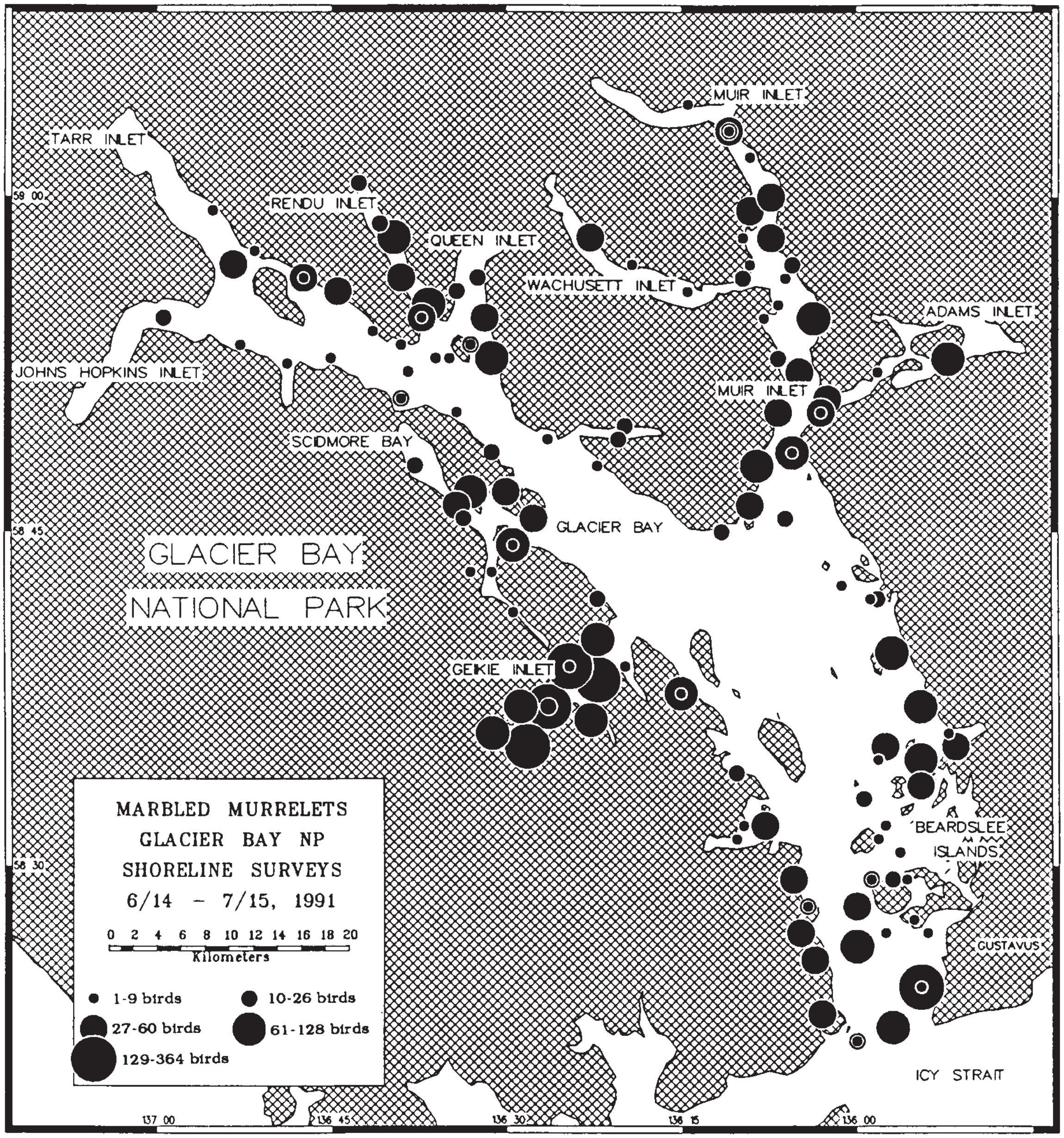

Figure 3—Distribution and relative abundance of marbled murrelets on shoreline surveys in Glacier Bay in June and July 1991 (from Piatt et al. 1991).

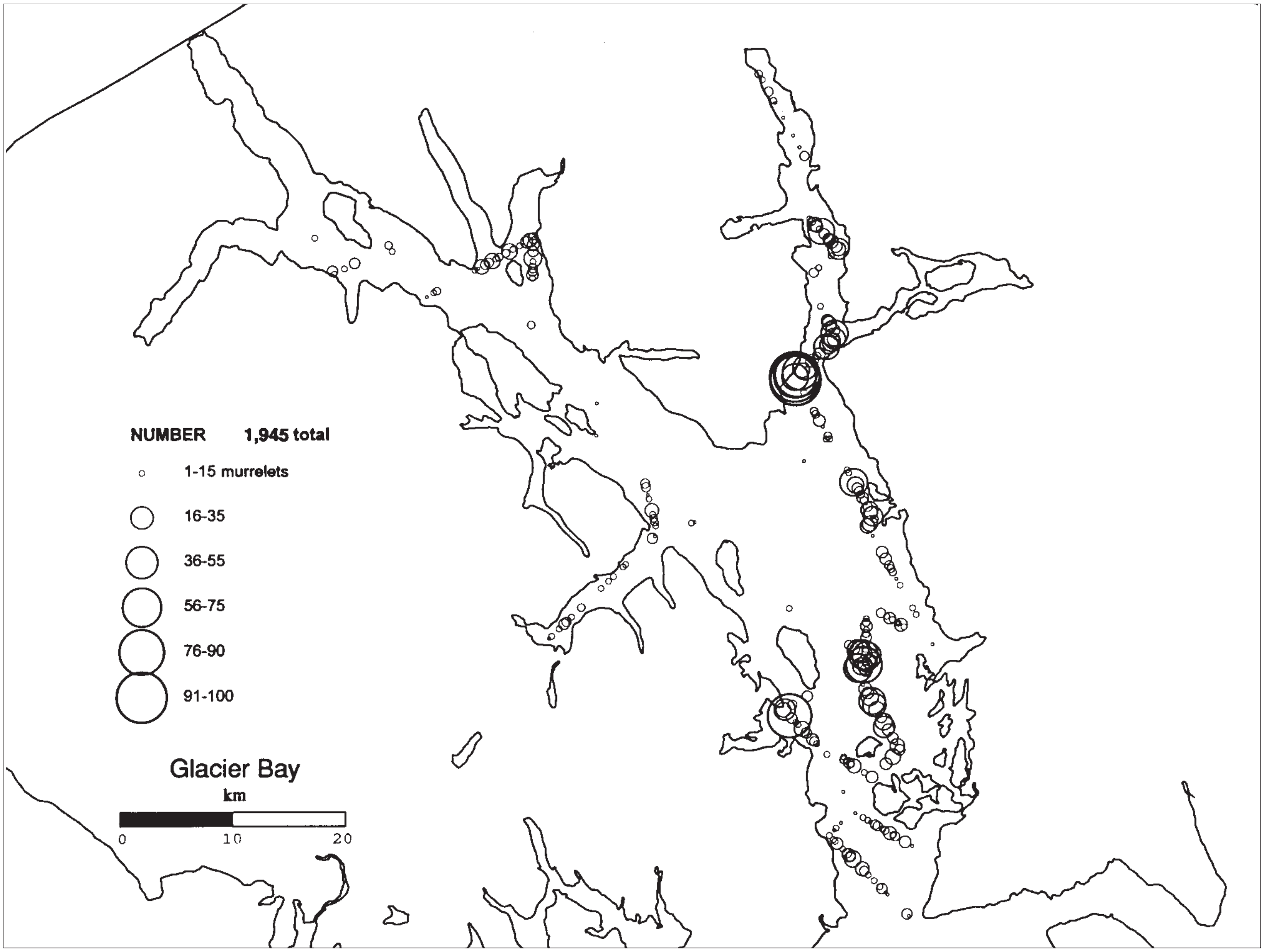

Figure 4—Distribution and relative abundance of marbled murrelets on pelagic transects in Glacier Bay on 23 June 1993 (from Lindell 1995a)
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Lindell (1995a) surveyed marbled murrelets in Glacier Bay on 23 June and 13 August 1993 by using a standard U.S. Fish and Wildlife Service marine shipboard protocol, whereby all birds within 150 meters (492 feet) of each side of a moving ship are counted. The same continuous-transect layout was used during both surveys. The mean density of marbled murrelets during the June survey was 23.3 per square kilometer (60.6 per square statute mile; range, 0 to 236 per square kilometer [0 to 613.6 per square statute mile] on individual transects). The mean density of marbled murrelets during the August survey was 17.7 per square kilometer (46.0 per square statute mile; range, 0 to 231 per square kilometer [0 to 600.6 per square statute mile] on individual transects). During both surveys, but especially in August, the mouth of Muir Inlet stood out as an important area of concentration (figs. 4 and 5). During the June survey, Berg Bay and waters north of the Beardslee Islands also had large numbers of marbled murrelets (fig. 4).

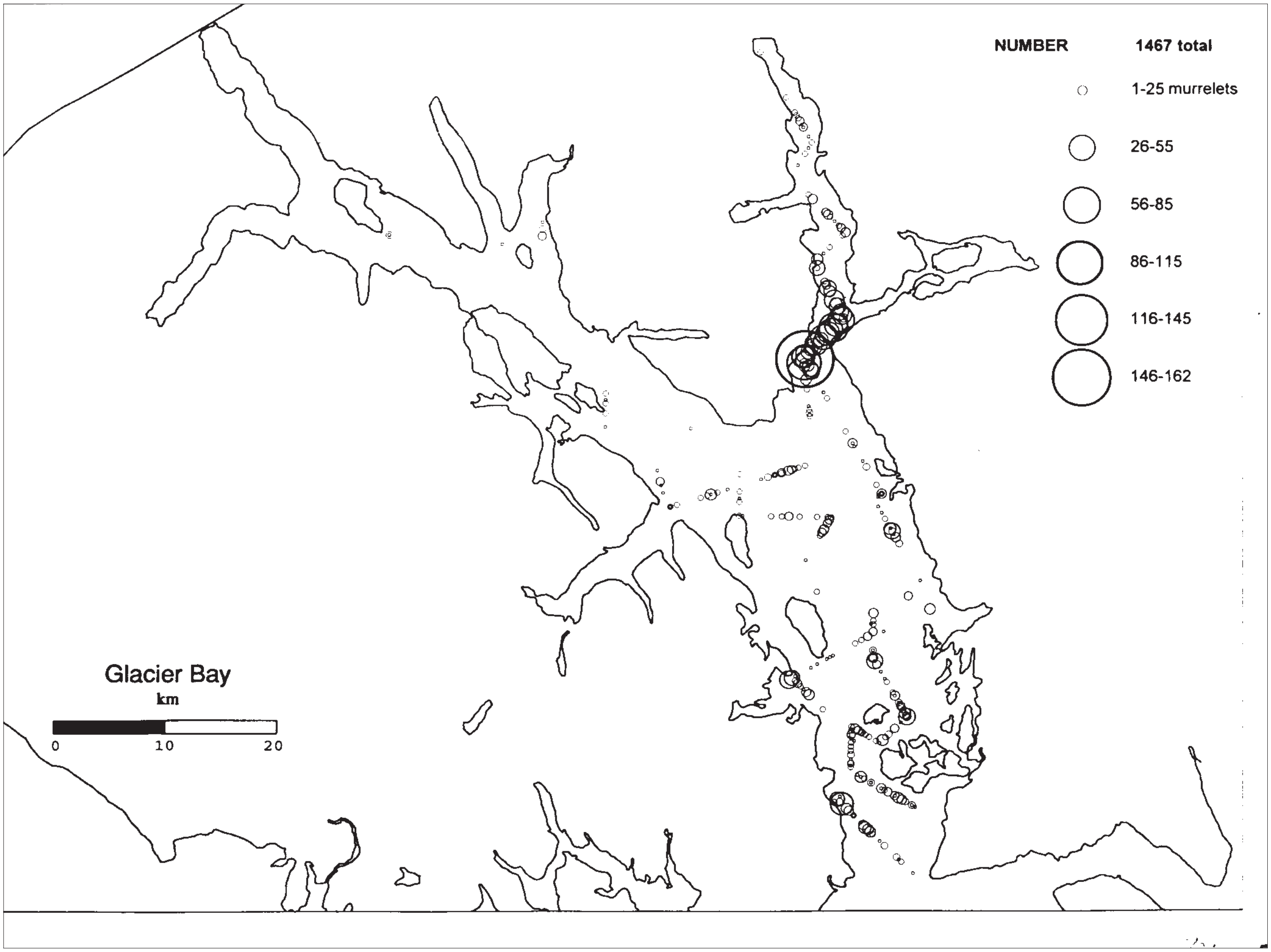

Figure 5—Distribution and relative abundance of marbled murrelets on pelagic transects in Glacier Bay on 13 August 1993 (from Lindell 1995a).

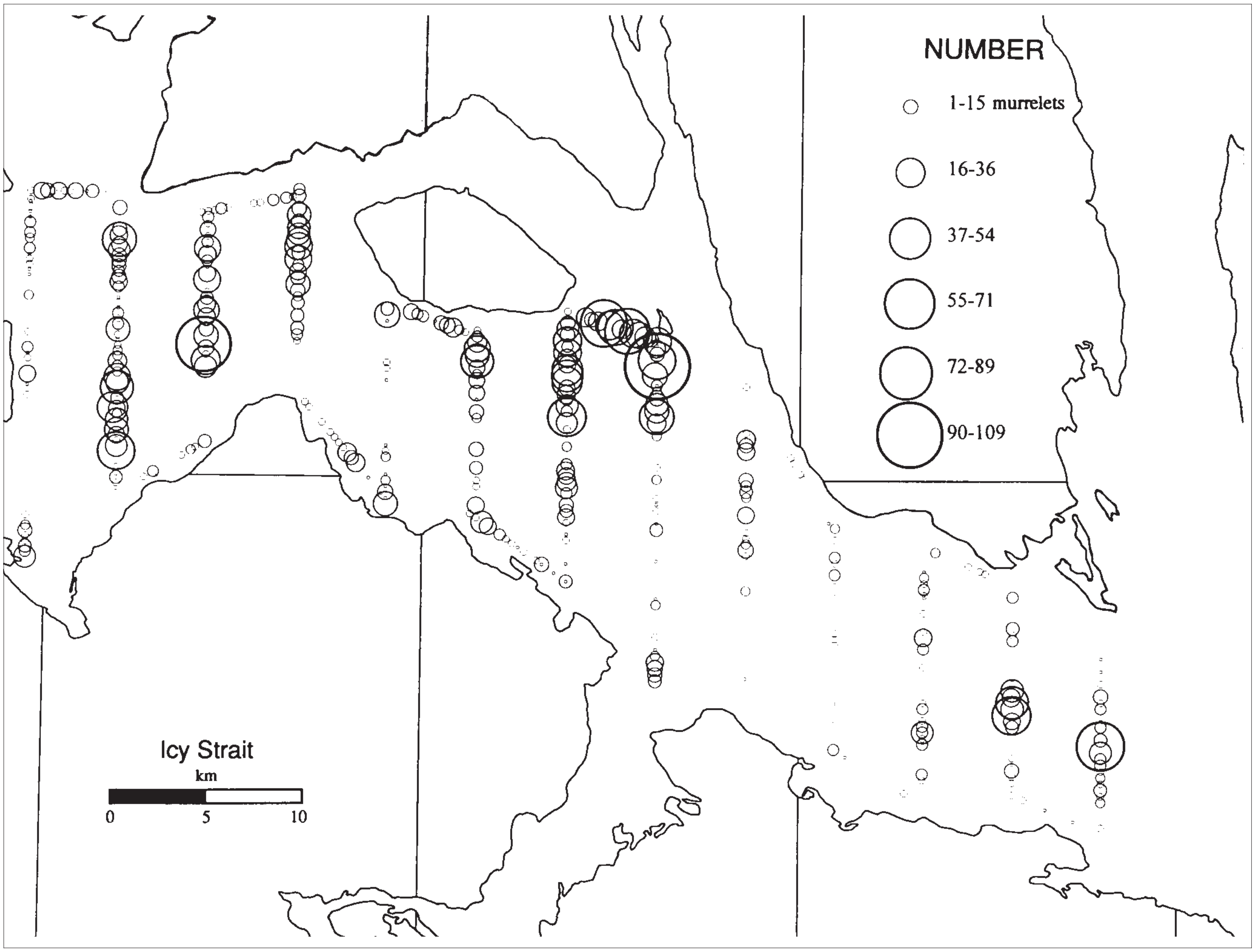

Figure 6—Distribution and relative abundance of marbled murrelets on pelagic transects in Icy Strait on 21 June 1993 (from Lindell 1995a).

Lindell (1995a) surveyed marbled murrelets in Icy Strait on 21 June, 15 July, 11 August, and 25 August 1993, on 3 August 1994, and on 9 July, 11 July, and 7 August 1995 by using the same survey protocol as used in Glacier Bay. Mean densities per survey were 39.2, 19.4, 22.5, and 16.1 per square kilometer (101.9, 50.4, 58.5, and 41.9 per square statute mile) for the June, July, and two August surveys, respectively, in 1993 (range on individual transects for all 1993 surveys, 0 to 187.9 per square kilometer [0 to 488.5 per square statute mile]). The distribution of marbled murrelets in Icy Strait was quite variable. In the 21 June survey, when the most murrelets werecounted, they were more widely distributed (fig. 6) than in the later surveys when the highest densities were found near the mouth of

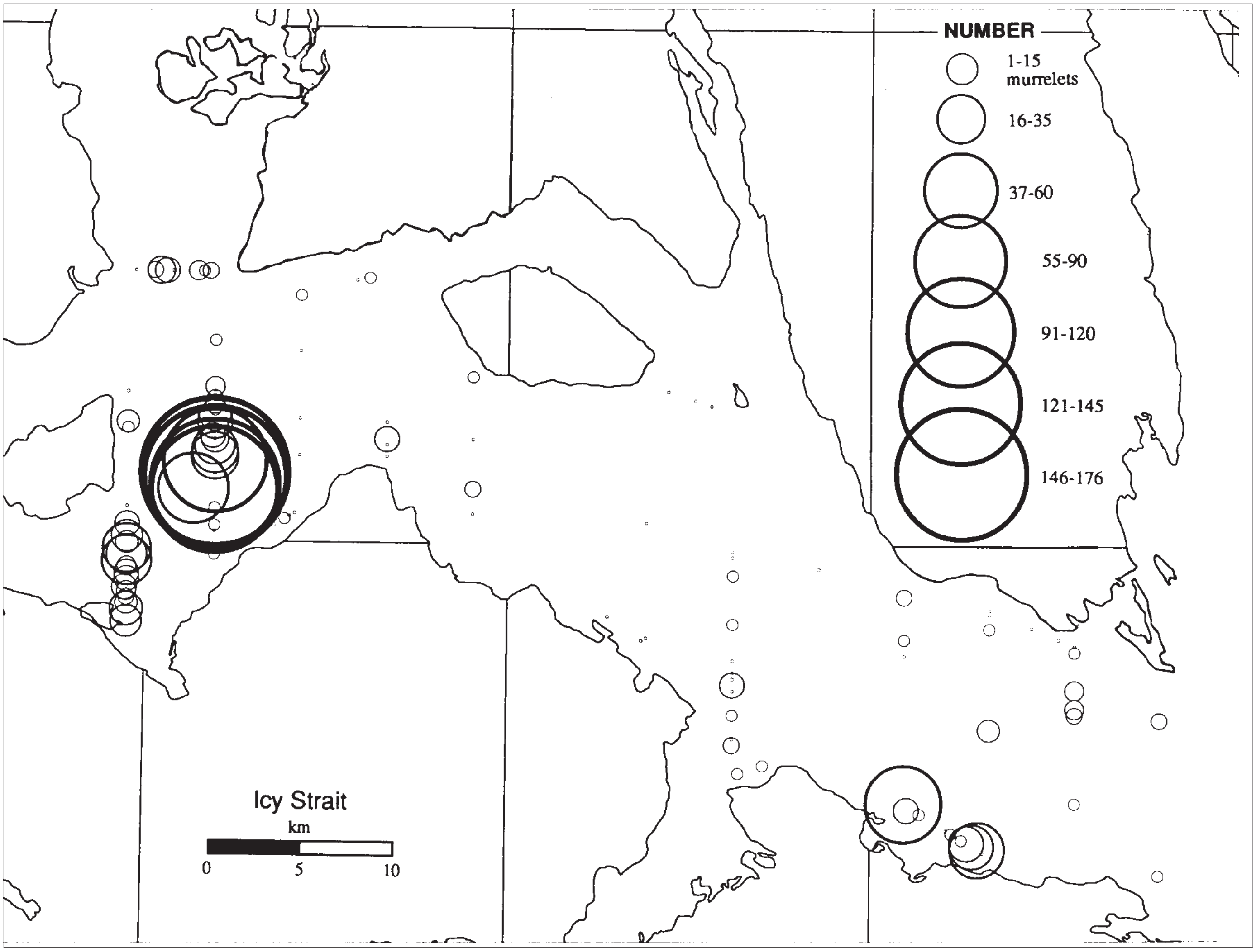

Figure 7—Distribution and relative abundance of marbled murrelets on pelagic transects in Icy Strait on 3 August 1993 (from Lindell 1995a).

Glacier Bay and east of Lemesurier Island (fig. 7). The mean density of marbled murrelets in the 3 August 1994 survey was 18.1 per square kilometer (47.1 per square statute mile; range, 0 to 194.0 per square kilometer [0 to 504.4 per square statute mile]). The distribution was highly clumped, with most birds found east of Lemesurier Island (fig. 7). In 1995, the mean density of marbled murrelets per survey was 21.3, 19.3, and 25.1 per square kilometer (55.4, 50.2, and 65.3 per square statute mile; range, 0 to 231.7 per square kilometer [0 to 602.4 per square statute mile]). The mean density for all eight surveys conducted in Icy Strait in 1993, 1994, and 1995 was 22.4 per square kilometer (58.2 per square statute mile).

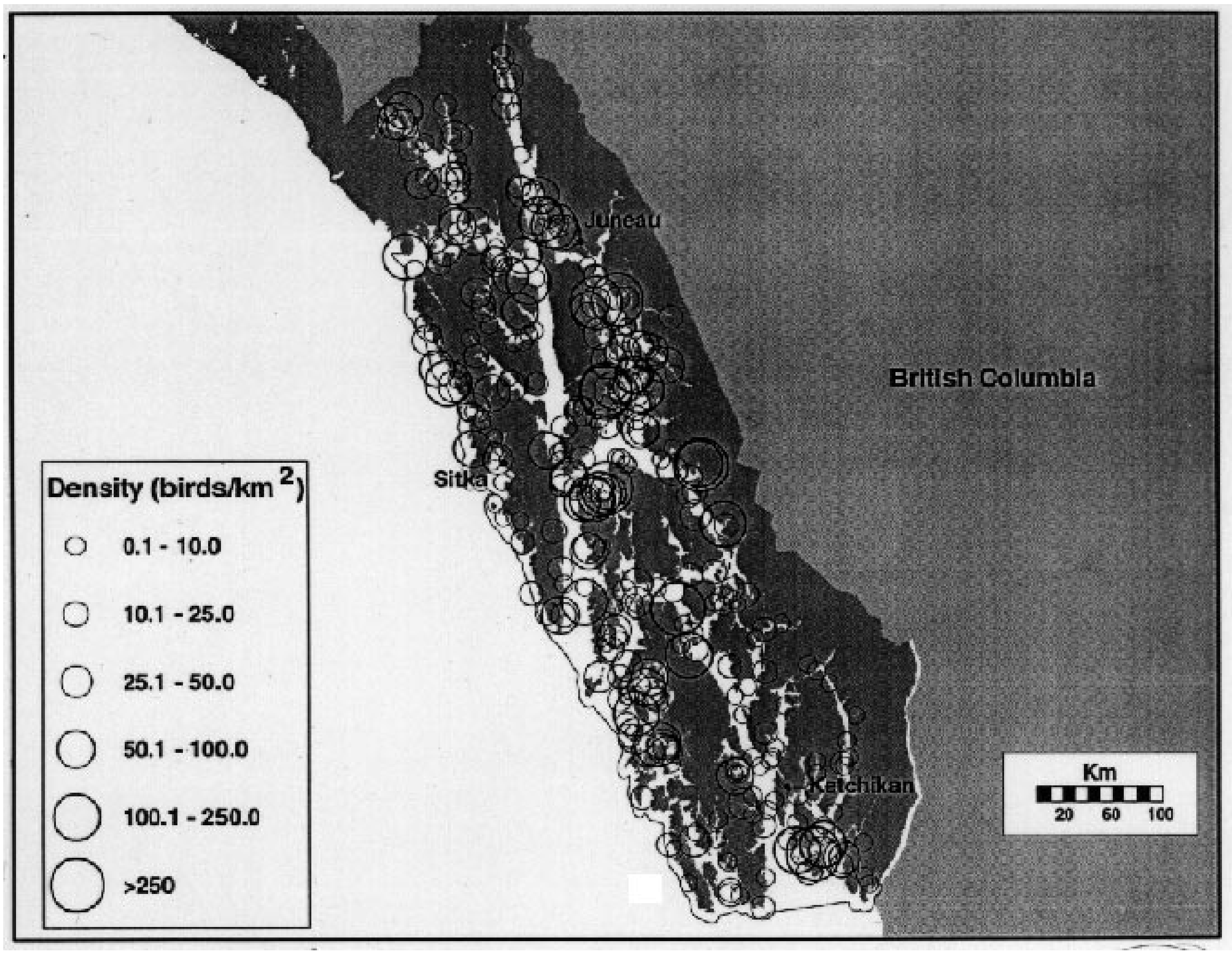

Figure 8—Distribution and densities of murrelets by transect during small boat surveys in southeast Alaska during summer 1994 (from Agler at al. 1995).

Agler et al. (1995) provide the most recent and comprehensive view of murrelet distribution in southeast Alaska based on 631 randomly placed small-boat transects. Sampling technique was the same as that used by Piatt et al. (1991) in Glacier Bay and followed a standard U.S. Fish and Wildlife Service coastal bird survey protocol (Klosiewski and Laing 1994), where all birds were counted from both sides of a slowly moving boat out to 100 meters (328 feet) for a total transect width of 200 meters (656 feet). The survey by Agler et al. (1995) indicated that marbled murrelets are widely and ubiquitously distributed in southeast Alaska (fig. 8). Densities of murrelets were highly variable, averaging 18.1 per square kilometer (47.1 per square statute mile) in the shoreline strata (within 200 meters [656 feet] from shore) and 19.6 per square kilometer (50.9 per square statute mile) in the pelagic strata (outside of 200 meters [656 feet] from shore). These values are similar to Lindell's mean density estimates for Icy Strait based on eight surveys completed in 1993, 1994,

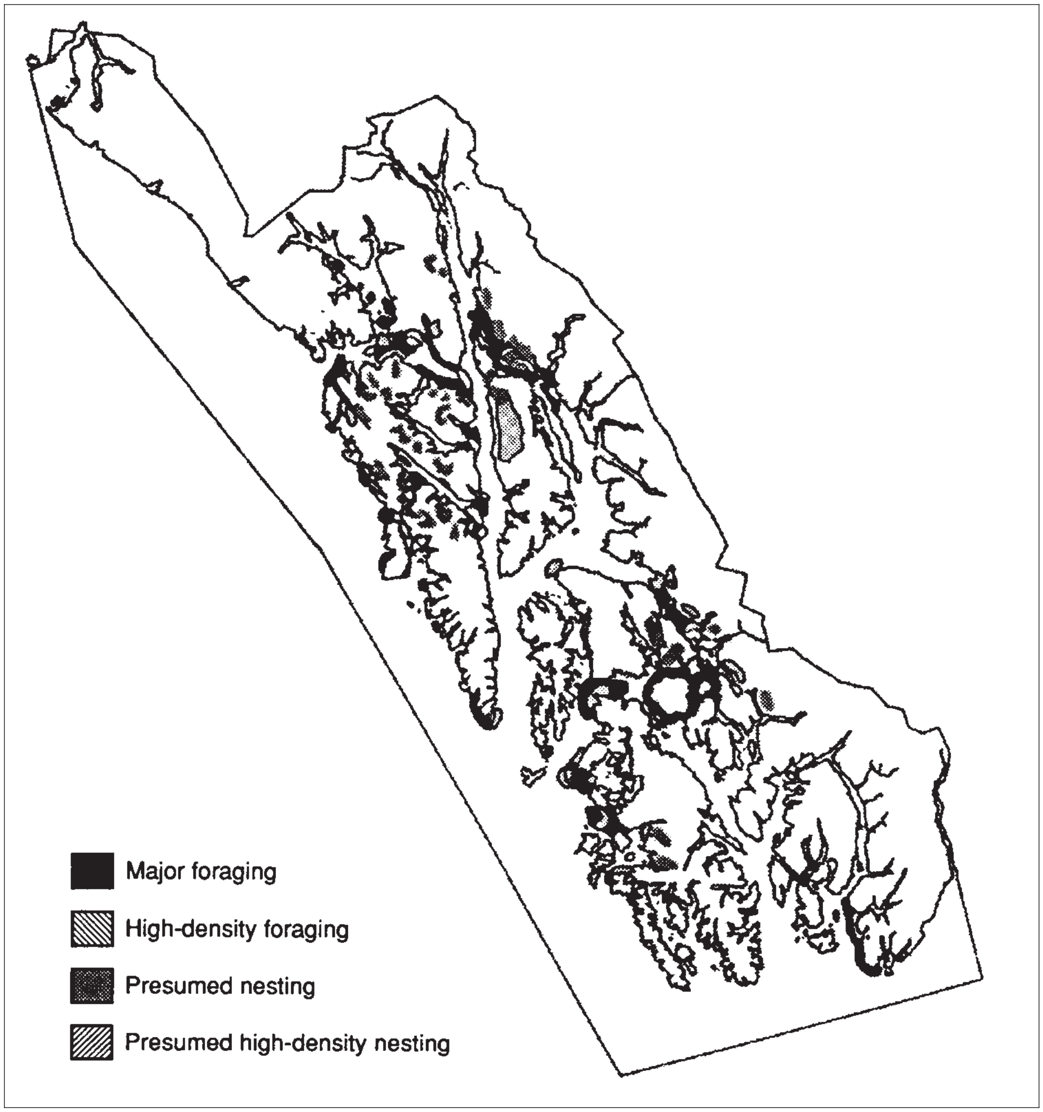

Figure 9—Distribution of marbled murrelet foraging and nesting areas in southeast Alaska (produced from a map hand drawn from memory by McAllister 1996a).

and 1995. Several marine areas stand out as important points of aggregation; from south to north they are Revillagigedo Channel and the south end of Clarence Strait, the northwest side of Prince of Wales Island, the confluence of Clarence Strait and Sumner Strait, the north end of Keku Strait in Frederick Sound, the east side of Kupreanof and Mitkof Islands, Stephens Passage, and the confluence of Chatham Strait and Icy Strait. Protected, inside waters were of greater importance to murrelets than were outside waters.

McAllister (1996a) conducted opportunistic shipboard surveys of marbled murrelets in southeast Alaska through the 1980s. He produced a qualitative map of murrelet distribution (fig. 9) that, although incomplete in geographic coverage, has relatively high concordance with the distribution map by Agler et al. (1995; fig. 8). Important at-sea concentration areas identified by both McAllister (1996a; fig. 9) and Agler et al. (1995) include Revillagigedo Channel, the northwest side of Prince of Wales Island, the confluence of Clarence Strait and Frederick Sound, the west sides of Kupreanof and Mitkof Islands, Stephens Passage, and the east end of Icy Strait. McAllister (1996a) also identified a number of other areas of local importance for foraging marbled murrelets (fig. 9).

Although surveys completed to date have identified marine areas possibly of some importance to marbled murrelets in southeast Alaska, it is unclear how complete our information on their marine range is at this time. Piatt (1995a) remarked that concentrations of murrelets he has observed in southeast Alaska are ephemeral; i.e., shifting from one area to another within short time frames. Within a localized area, the data of Lindell (1995a) support this view. With the exception of Lindell's surveys (1995a) in Icy Strait, other surveys in Alaska provide only single snapshots of distribution that may change depending on the proportion of birds breeding, dependence on foraging sites close to terrestrial nesting areas, fidelity of birds to foraging areas, predictability of certain locations as good foraging areas, and seasonal changes in distribution.

The relation between the at-sea distribution of murrelets and their nesting distribution also is unclear. Most investigators believe that because most marbled murrelet nests have been located relatively close to the coast (usually within 35 kilometers [21.7 statute miles]; see Hamer and Nelson 1995), there are energetic constraints on the distances adults can routinely travel and successfully provision chicks. Given these foraging constraints, figure 8 (from Agler et al. 1995) may provide a very crude guide to important breeding areas in southeast Alaska. Based on dawn counts on land and from ships anchored in bays, McAllister (1996a) produced a map of what he believes are some important nesting areas in southeast Alaska (fig. 9). At best, this is an incomplete map of the nesting distribution of marbled murrelets in southeast Alaska. A nesting area identified by McAllister as perhaps the most important in southeast Alaska is the west side of Admiralty Island (fig. 9). Ralph (1995) currently is analyzing McAllister's data and, when finished, may be able to provide additional information on murrelet nesting and at-sea distribution.

Winter distribution—Marbled murrelets are found throughout southeast Alaska during winter, but there are no comprehensive data comparable to Agler et al. (1995) for this season. Counts at specific sites during winter and summer suggest a seasonal decline of marbled murrelets from portions of their range in northern southeast Alaska (Duncan and Climo 1991, King 1991); however, these declines might be the result of localized movements from spacially limited count areas.

Abundance—Population estimates of marbled murrelets for southeast Alaska range widely and their number is not known with certainty. The earliest estimate I am aware of was developed by Nelson and Lehnhausen (1983) and was based on small-boat surveys of marine birds conducted on the outside coast of southeast Alaska. Nelson and Lehnhausen surveyed about 1700 linear kilometers (1,055.9 statute miles) of transects and observed 2,767 marbled murrelets. They expressed their survey results in birds per kilometer, and it is not clear how they developed a density estimator for estimating the marbled murrelet population. "By making a number of assumptions concerning murrelet densities and distribution," Nelson and Lenhausen (1983) calculated a "rough" population estimate of 250,000 birds in southeast Alaska.

McAllister (1996a) kept detailed records of marbled murrelets in southeast Alaska while working as a commercial fishermen in the 1980s. Based on his extensive observations, he estimated the summer marbled murrelet population in southeast Alaska at 45,000 to 70,000 (cited in Mendenhall 1992, Piatt and Ford 1993, Piatt and Naslund 1995).

Piatt and Ford (1993) estimate that 96,200 marbled murrelets are in southeast Alaska during the breeding season, based on data collected primarily during the Outer Continental Shelf Environmental Assessment Program. This estimate, as indicated by the authors, may be low because the survey effort was not random, transects were sequential and probably not independent, and surveys were conducted mainly from large offshore ships, where few marbled murrelets could be seen during the breeding season.

Agler et al. (1995) found that the marbled murrelet was the most abundant species seen during their comprehensive small-boat surveys in southeast Alaska in 1994. They estimate that 687,061 (±201,162) murrelets *(Brachyramphus* spp.) were present in southeast Alaska. Based on actual identifications, at least 434,129 (±166,525) of the total estimate were marbled murrelets; however, Agler (1996) believes the actual ratio of marbled murrelet to Kittlitz's murrelet to be >10:1. The estimate by Agler et al. (1995) may be inflated because the study included all flying birds, which may result in multiple counting (Gould and Forsell 1989). Removing all flying birds from the analysis, including those flushed from the water at the approach of the survey craft, reduced the overall murrelet (*Brachyramphus* spp.) population estimate to 526,074 (±179,850) and the identified marbled murrelet portion of the estimate to 365,193 145,778). Some double counting of murrelets may have occurred if there were large-scale shifts in distribution of murrelets during the survey; however, the fact that the survey ended before juvenile birds began appearing suggests that postbreeding changes in distribution had not yet occurred (Agler 1996.)

Several investigators of marbled murrelet distribution at sea (e.g., Agler et al. 1995, Ainley et al. 1995, Ralph and Long 1995, Ralph and Miller 1995) have stratified marine habitat based on distance from shore. It is unlikely that distance offshore is a feature that directly explains murrelet distribution. Rather bathymetry, which in many areas is directly correlated with distance offshore, may be a more appropriate variable for stratifying marine habitat used by marbled murrelets. It would be useful to examine the effect on marbled murrelet population estimates of poststratifying marine waters in southeast Alaska using bathymetry rather than distance from shore.

Several other population estimates are available for marbled murrelets in smaller portions of southeast Alaska. Lindell (1995a) conducted eight at-sea surveys of marbled murrelets in Icy Strait during the summers of 1993, 1994, and 1995. Based on calculated densities for individual surveys, the marbled murrelet population estimate for Icy Strait averaged 20,575 (range, 14,763 to 36,043). Using data from Agler et al. (1995), Kendall (1995) calculated a marbled murrelet density in Icy Strait of 11.3 per square kilometer (29.4 per square statute mile) and a population estimate of about 10,000 birds.

Van Vliet (1993) counted marbled murrelets flying from Lynn Canal and Chatham Strait into the Icy Strait-Glacier Bay area near Point Adolphus on 5, 11, and 13 August 1992. His results provide concordance with Lindell's (1995a) data on the size of the population using Icy Strait and the importance of this area to marbled murrelets. By using the number of birds he saw per hour, van Vliet calculated that this area is used as a daily flyway by 10,000 to 20,000 marbled murrelets.

Lindell (1995a) also conducted two surveys in Glacier Bay, one on 23 June 1993 and the other on 13 August 1993. Based on densities of 23.3 and 17.7 birds per square kilometer (60.6 and 46.0 birds per square statute mile), respectively, an estimated 22,300 to 29,350 marbled murrelets were found in Glacier Bay. This is very similar to an estimate of 27,200 birds calculated from Agler et al. (1995) (Kendall 1995). The large number of murrelets in Glacier Bay is interesting given the lack of productive old-growth forests there. Either large numbers of marbled murrelets are nesting in small trees or on the ground, or they routinely travel to Glacier Bay from nesting areas outside the area to exploit productive foraging grounds.

Winter surveys for murrelets also have been conducted. Conant (1991) conducted aerial surveys in winter from 1982 to 1984. Based on ground-to-boat comparisons, only 8 to 22 percent of the murrelets were seen from the air. After adjusting the data with a correction for visibility, he estimated the marbled murrelet population for northern southeast Alaska to be 24,113 (± 29,176). Conant (1996) also conducted a complete aerial survey of waterbirds in southeast Alaska nearshore waters in winter 1996. Counts were made in 130 stratified, random plots representing southeast Alaska. Using a numerical expansion, Conant calculated an uncorrected, winter, murrelet population estimate of 39,296. Correcting this estimate for visibility by using an average visual correction factor of 7.5, developed from similar surveys in 1982 to 1984, resulted in a revised population estimate of 294,720, the only available winter estimate for southeast Alaska. Although the winter timing of this survey and the use of aircraft make comparisons with the results of other surveys difficult, it provides concordance on the approximate order of magnitude of the murrelet population in southeast Alaska.

Although population estimates for marbled murrelets in southeast Alaska are widely divergent, it is reasonable to conclude that this species is still numerous, widely distributed, and probably numbers at least in the low hundreds of thousands.

Population Trend

Few data are available to assess the trend of the marbled murrelet population in southeast Alaska. Piatt and Naslund (1995) estimate a 50-percent decline in the Alaska population during the past 20 years, which represents about a 3.4-percent average annual decline (Beissinger 1995). Piatt and Naslund attribute this decline to loss of forest nesting habitat, gillnet mortality, oil spills, and perhaps broad-scale changes in the marine environment. The estimated 50-percent decline was based on a reported population decline in Prince William Sound (Klosiewski and Laing 1994) and on analysis of Christmas bird count (CBC) data for south-central and southeast Alaska. Klosiewski and Laing (1994) conducted extensive small-boat surveys in Prince William Sound from 1989 to 1991 after the Exxon Valdez oil spill, similar to surveys conducted from 1972 to 1973. Comparison of these surveys suggest a 67- to 73-percent decline in total murrelets in summer between the two survey periods.

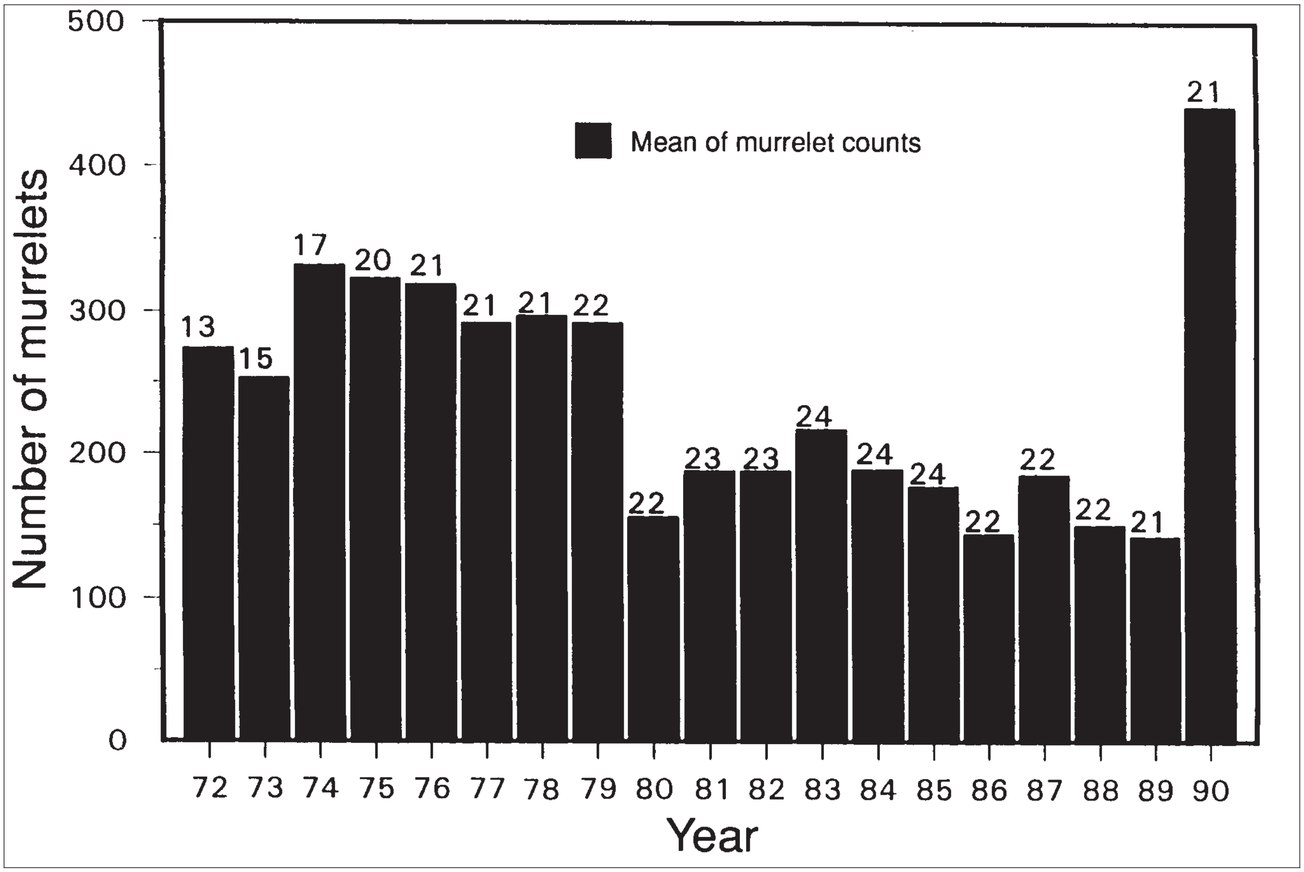

Figure 10—Numbers of marbled murrelets observed during Christmas bird counts at five coastal sites in Alaska, presented as 5-year running means (from Stevens 1995a).

Piatt and Naslund (1995) analyzed CBC data in southeast and south-central Alaska from 1972 to 1990 from five locations: Sitka, Juneau, Glacier Bay, Cordova, and Kodiak. They smoothed the time series by taking 5-year running averages of the annual count data (fig. 10). Unsmoothed data were highly variable. This series of running means suggest a decline in abundance of murrelets. Stevens (1995a) repeated the analysis of Piatt and Naslund (1995) for the same five sites, but with the addition of data from 1970, 1971, and 1992 (fig. 10). Those results were similar to Piatt and Naslund (1995) for 1974 to 1989, but the running mean for 1990 showed an abrupt increase. Addition of running means for 1972 and 1973 caused only a small change in the apparent trend, because numbers of murrelets counted in 1970, 1971, and 1972 were only slightly lower than numbers counted from 1974 to 1979. The abrupt increase in the running mean for 1990 was caused by inclusion of the 1992 Glacier Bay count of 1,487 murrelets, which was higher than the next highest count of 891 murrelets in 1972. A linear regression of summed counts across sites each year was not significant.

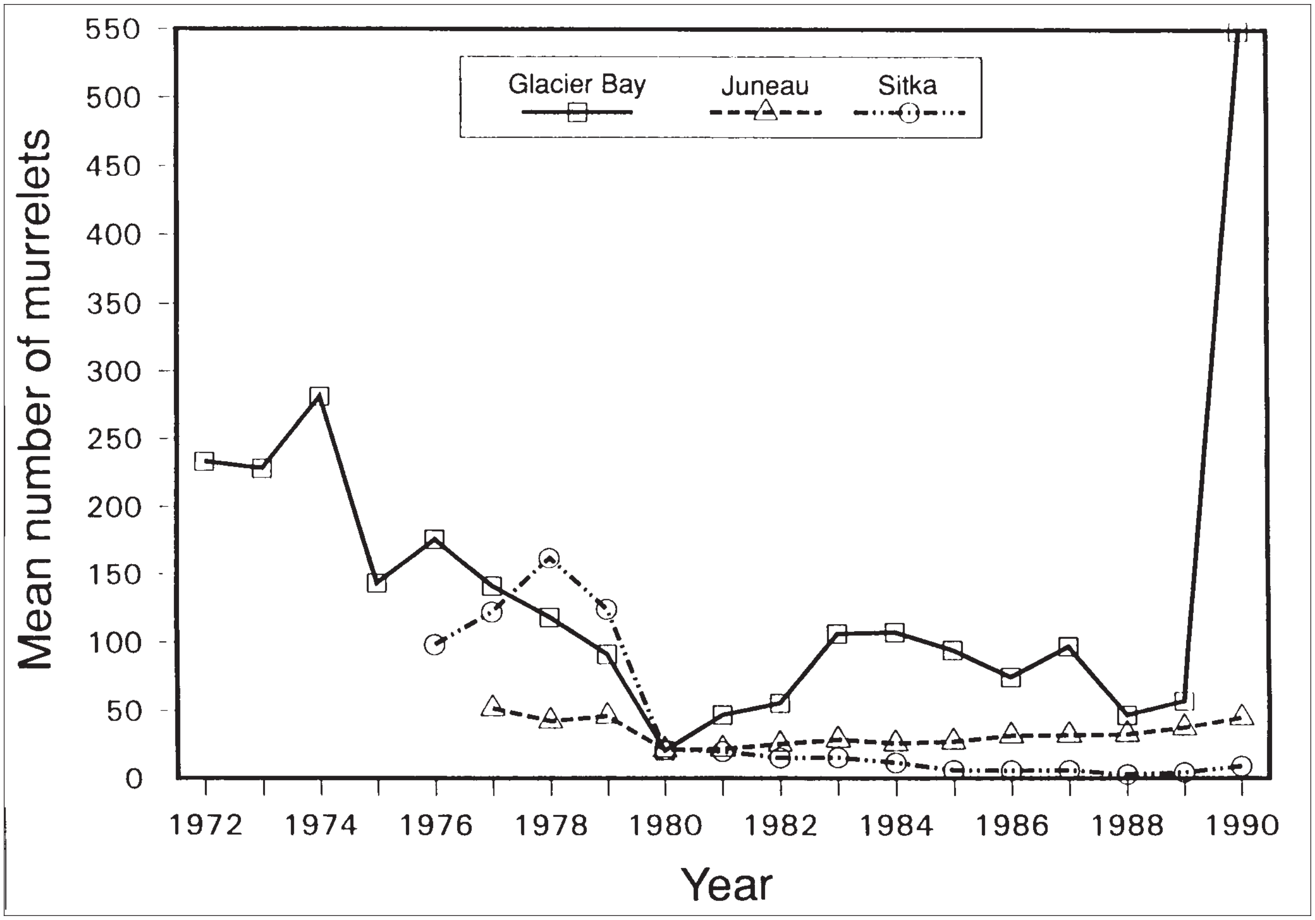

Figure 11—Numbers of marbled murrelets observed during Christmas bird counts at three coastal sites in southeast Alaska, presented as 5-year running means (from Stevens 1995a).

Stevens (1995a) also graphed 5-year running means of CBC data for three sites in southeast Alaska (Glacier Bay, Juneau, Sitka) from 1972 to 1990. As reported above, inclusion of the running mean for 1990 at Glacier Bay, which included the high count in 1992, changed the apparent trend of murrelet counts from a threefold decline to an abrupt increase (fig. 11). No trend was apparent at Juneau, and counts appeared to decline at Sitka (fig. 11). Linear regression of counts at Sitka did not confirm the trend. It is clear that 5-year running means masked variability in the data. Stevens (1995a) concludes that using 5-year running means of CBC data for marbled murrelets in southeast Alaska precludes detection of trends.

Both Stevens (1995a) and Hayward (1995) undertook analyses of CBC data for murrelets in Alaska by using a variety of statistical approaches, ranked and unranked data, and data pooled and unpooled across regions. Stevens conducted linear regressions for counts at 13 CBC sites in Alaska and for sites combined across regions (Aleutians, south-central, southeast) with count data and rank-transformed data. Linear regressions of rank-transformed counts were mostly nonsignificant. Three sites in Alaska with significant regressions (Ketchikan, Mitkof, and Homer) had increasing trends, although Stevens believes this may be due to isolated low counts and increasing count effort. Results of linear regressions of CBC data pooled by region were similar; only south-central was significant when sums of counts across regions were corrected for the number of sites surveyed per year. The trend in south-central for this analysis was increasing; however, the regression coefficient was low. Variability of the data for these tests was high and powers of the tests were low (Stevens 1995a).

Hayward (1995), using a variety of parametric and nonparametric statistical procedures, found no strong evidence for a linear trend or a nonrandom pattern for the CBC sites in southeast Alaska. Hayward (1995) did find, however, relative concordance in the counts across southeast Alaska and examined CBC data for trends for the region as a whole; he again found little evidence for a long-term trend. The results of Stevens and Hayward are similar to those of Rodway et al. (1992), who found no evidence of a declining trend in marbled murrelets at 13 sites in the Straits of Georgia despite extensive logging of old-growth forests.

These analyses suggest that CBC data are inadequate for detecting trends in murrelet populations. The CBC data are best used for common and well-dispersed species (Bock and Root 1981). Marbled murrelets, like many seabirds, often have clumped distributions, which are affected by several environmental variables. A nonuniform distribution would suggest that counts at sites may fluctuate, as is apparent in the CBC data. Because CBCs are conducted in winter, it is uncertain what portion of the population is being counted. Although breeding birds may reside in the general vicinity of their breeding sites, many CBC sites in southeast Alaska may be populated by transient migratory birds, and this may help to explain the high variability in the CBC data. The high variability in CBCs suggest they are not a precise estimate of a local breeding population.

The marbled murrelet has disappeared or become rare in large portions of the Pacific Northwest. Current population trends for the Pacific Northwest remain unknown (Beissinger 1995). Using a demographic model of the marbled murrelet based on the best data available, mostly from the Pacific Northwest States, Beissinger (1995) predicts a rate of decline in marbled murrelet populations of 4 to 6 percent per year. He believes it could be twice as large. All scenarios in the demographic model predict that marbled murrelet populations are likely to be declining. Because of low estimates of reproductive rates, population growth requires high adult survivorship (0.908-0.924) (Beissinger 1995).

Stevens (1995a) estimates the precision necessary in CBC counts to detect a 4-percent-per-year decline in marbled murrelet abundance over 5, 10, 15, and 20 years, assuming the probability of rejecting a true null hypothesis (alpha) is 0.10 and the probability of detecting a trend if one exists (power) is 0.75. Assuming one survey was done per year and surveys were conducted for 5 years, a coefficient of variation of 0.05 is required to detect a decline of 4 percent per year. If surveys are conducted for 10, 15, and 20 years, the required coefficients of variation are 0.16, 0.30, and 0.45, respectively.

The inconclusive nature of the CBC data point to the need for development of other indices for evaluating marbled murrelet population trends.

Movements

Seasonal movements—Marbled murrelets are a common bird in southeast Alaska throughout the year (Gabrielson and Lincoln 1959, Mendenhall 1992). There are few data, however, suggesting that populations may decrease in some areas outside the reproductive season. Data collected near the Beardslee Islands in Glacier Bay between 1987 and 1991 (Duncan and Climo 1991) suggest an influx of murrelets into the area in May with peak numbers occurring in early to mid August, followed by a large decline in murrelets in September through November (fig. 12). Data were not collected during the period from December through April, but Vequist (1995), a long-time National Park Service employee in Glacier Bay, says there are fewer murrelets there in winter than summer. The CBC data indicate that murrelets do not exit the area altogether in winter and that their numbers differ markedly from year to year. King (1991) had similar results in spring at nearby Lynn Canal and Berner's Bay. He counted marbled murrelets from a helicopter from 10 December to 3 June and found very few in the area through winter. Numbers of marbled murrelets increased rapidly beginning in early May and continued to increase through early June (fig. 13).

Surveys to assess seasonal attendance at forest stands, conducted at sites in southeast Alaska, indicate that some marbled murrelets visit forest stands throughout the year, with the exception of during the prebasic molt in late summer and fall (Brown 1995a; Brown et al., in prep.; Doerr and Walsh 1994; Falk 1995). It is unknown how attendance at forest stands relates to the size of the murrelet population remaining in the area during winter.

Data from Prince William Sound suggest a major winter exodus from this, the most northerly portion of the marbled murrelet's range. Klosiewski and Laing (1994) document a 75-percent decrease in marbled murrelets in Prince William Sound between summer and winter surveys. It is not known where Prince William Sound murrelets go in winter; however, Zwiefelhofer and Forsell (1989) found a twofold to threefold increase of murrelets in bays on Kodiak Island in winter compared to fall. Piatt and Ford (1993) believe that murrelets in the northern Gulf of Alaska disperse south and west in winter. This information, in concert with survey results from King (1991) and Duncan and Climo (1991), suggest that marbled murrelet populations in northern southeast Alaska may decline in winter as birds move to more hospitable areas to the south. Piatt and Ford (1993) state that murrelet numbers in the Alexander Archipelago decline to the low tens of thousands in mid-winter; however, the recent survey results from Conant (1996) suggest the winter murrelet population is considerably larger.

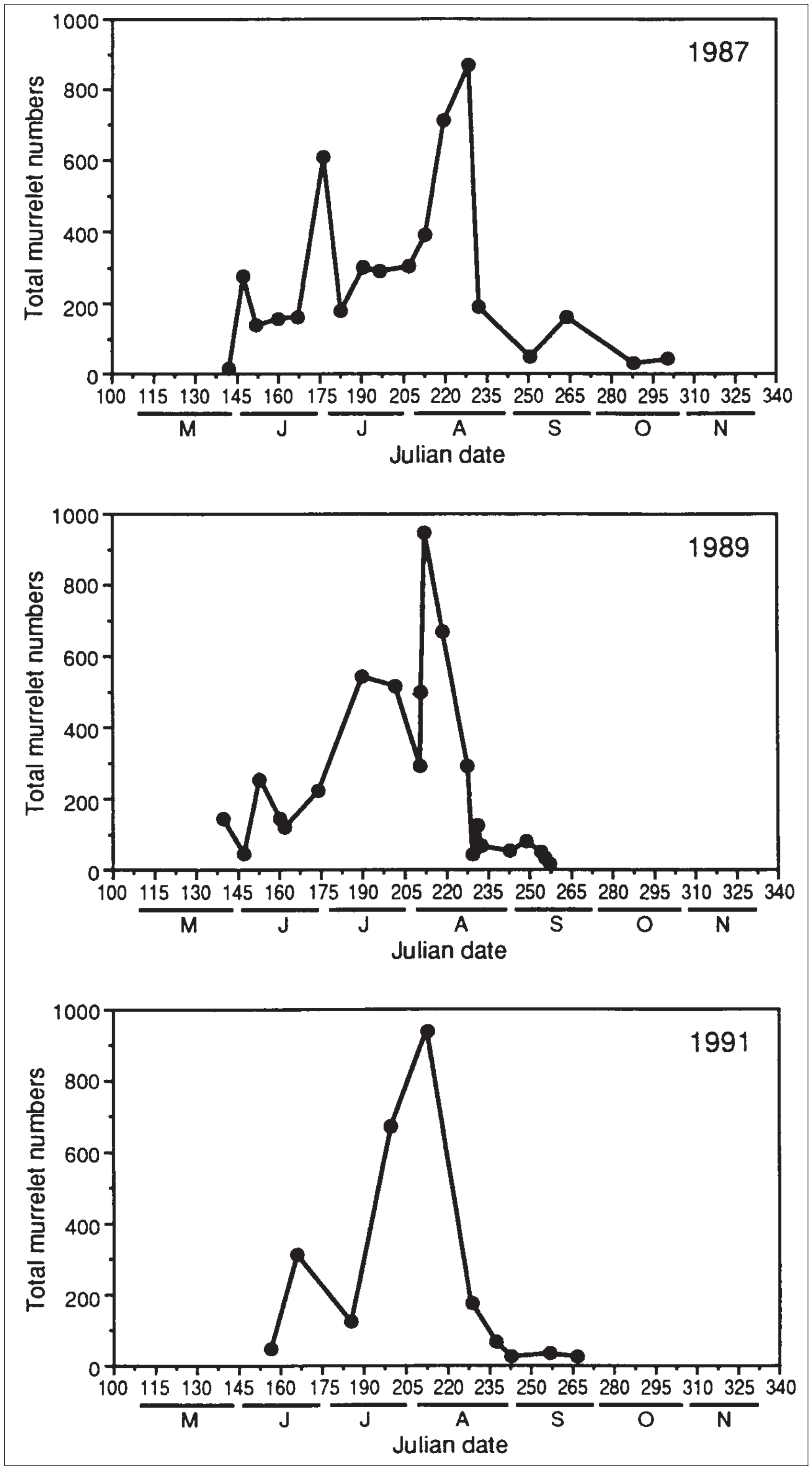

Figure 12—Counts of murrelets at the Beardslee Islands in Glacier Bay in 1987, 1989, and 1991 (from Duncan and Climo 1991).

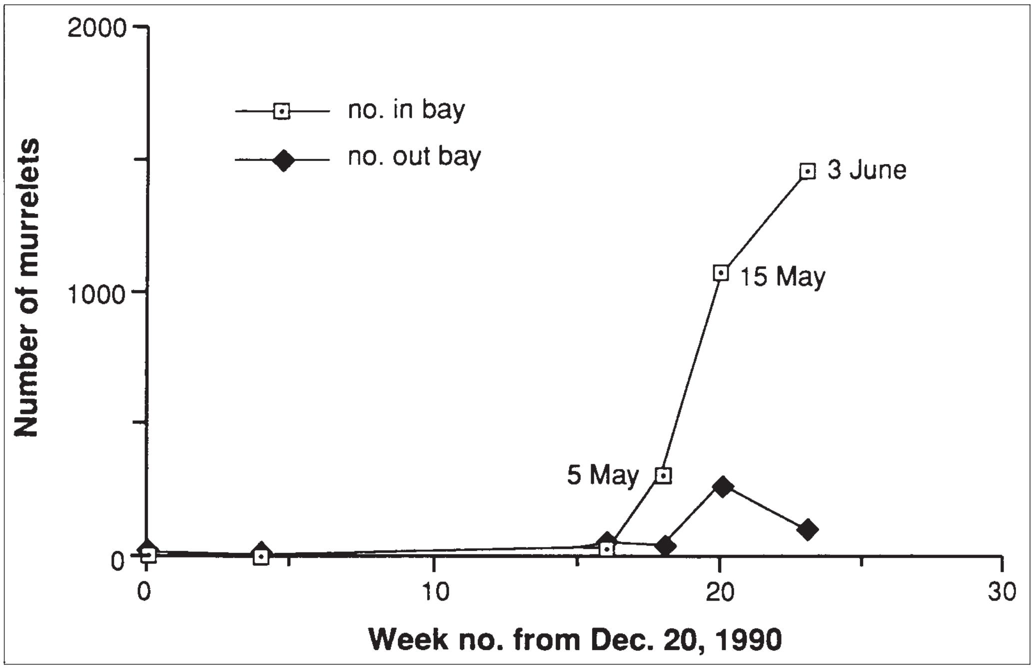

Figure 13—Numbers of murrelets seen inside and outside Berner's Bay during helicopter surveys in 1990 and 1991 (from King 1991).

Within-season movements—Both van Vliet (1993) and McAllister (1996a) document extensive daily movements of marbled murrelets on foraging flights to and from Icy Strait and presumed nesting areas in Lynn Canal and on Admiralty Island. Van Vliet conducted counts of transiting marbled murrelets between 5 and 13 August 1992 at three locations in Icy Strait: near the Sisters, a small group of islands at the eastern entrance to Icy Strait; at Pleasant Island; and at the southwest tip of the Chilkat Peninsula. At the Sisters on 5 August, van Vliet counted a mean of 73 marbled murrelets per minute flying from Lynn Canal and Chatham Strait towards Point Adolphus in Icy Strait. He estimated that 4,380 marbled murrelets passed his location per hour and that the movement of murrelets lasted at least 3 hours. He estimated the number of marbled murrelets moving into Icy Strait on 5 August to be on the order of 10,000 to 20,000 and estimated the size of a foraging "flock" halfway between Point Adolphus and Lemesurier Island at 10,000 to 15,000 birds.

On 11 August at Pleasant Island, van Vliet's estimates of the rate of passage of marbled murrelets into Icy Strait from nesting areas to the east ranged from 585 murrelets per hour to 1,071 per hour. On 13 August, van Vliet counted marbled murrelets streaming eastward from foraging grounds in Icy Strait during the evening. Estimates of rates of passage ranged from 1,265 murrelets per hour to 1,460 per hour. Van Vliet noted "lots of fish holding" by these eastward-moving birds.

During August 1993 and July and August 1995, Lindell (1995a) also conducted counts of murrelets transiting Icy Strait at the southwest tip of the Chilkat Peninsula. During survey periods on six separate days, Lindell (1995a) counted murrelets passing his location for 19 one-hour segments. He observed an average of 1,094 murrelets per hour (median = 744 murrelets per hour; range = 77 to 4,681 murrelets per hour). Lindell also noted a pattern in murrelet movements correlated to time of day. It appears that a majority of murrelets flying past Point Couverden fly from east to west during the morning (entering Icy Strait from Lynn Canal) and from west to east in the evening (exiting Icy Strait). Lindell (1995a) observed this trend during five of the six survey days. The differences in flight direction were often dramatic. For example, on the evening of 26 August 1993, Lindell counted 2,995 murrelets exiting Icy Strait and only 66 murrelets flying into Icy Strait. In contrast, on the morning of 14 July 1995, Lindell counted 7,867 murrelets flying into Icy Strait and only 54 exiting Icy Strait.

Van Vliet's (1993) and Lindell's (1995a) observations are important because they suggest large-scale, relatively long-distance, daily movements of marbled murrelets from nesting grounds to a predictable, productive foraging area. Van Vliet hypothesizes that the round-trip distance these birds travel may approach 200 kilometers (124.2 statute miles). Van Vliet's and Lindell's observations also confirm those of Piatt (1995a) that Icy Strait is an important foraging area for marbled murrelets and perhaps a good at-sea site for population monitoring. McAllister (1996a) also identified important flyways for marbled murrelets in Stephens Passage, Sumner Strait, and Frederick Sound.

Walsh (1991) conducted an assessment of the feasibility of using radio transmitters on murrelets in southeast Alaska in July 1991. The data on movements were inconclusive. Five marbled murrelets were fitted with instruments between 24 and 29 July and were followed through 5 August. Three of the instrumented murrelets were later found. Two were followed for 3 days before contact was lost, the third was followed for 10 days. Little movement was noted for two of the murrelets. The third moved about 24 to 26 kilometers (14.9 to 16.1 statute miles) from where it was captured.

Habitat Characteristics—Terrestrial Environments

Limited research has been undertaken in southeast Alaska to assess terrestrial habitat characteristics, use, and suitability. This topic remains the single largest data gap for this species in this portion of its range in North America.

Known nests in southeast Alaska—Only six nests of marbled murrelets have been discovered in southeast Alaska (tables 1 and 2): four tree nests and two ground nests. Details of these nests are reviewed below.

Tree nest BI-1—This nest was found on Baranof Island in 1984 by following a radio-instrumented marbled murrelet (Quinlan and Hughes 1990). The nest was in a mountain hemlock (*Tsuga mertensiana* (Bong.) Carr.) in an uneven-aged, old-growth stand. The nest was at an elevation of 348 meters (1,141.8 feet), about 1.2 kilometers (1.9 statute miles) from the coast. The nest tree was 25 meters tall (82 feet) with a diameter at breast height (d.b.h.) of 120 centimeters (47.2 inches). The tree was in a state of declining health as suggested by its dead top and the presence of heartrot. The nest was about 15.5 meters (50.5 feet) from the ground and about 124 centimeters (48.8 inches) from the trunk of the tree on a horizontal limb. The nest was a platform of moss about 10 centimeters (3.9 inches) deep.

(*text continues on p. 26*)

Table 1—Characteristics of marbled murrelet tree nests in Alaska[a]

	Nest									
Characteristic	BI-1[b]	PWI-1[c]	PWI-2	TUX-1[d]	N-1[e]	N-2	N-3	N-4	N-5	N-6
Aspect	SE	NW	WSW	WSW	WNW	NW	WNW	NW	W	WNW
Slope (°)	25°	75	15-50	15	33	31	35	31	40	35
Elevation (m)	348	274	30	60	115	100	75	100	100	75
Stand size (ha)					17.5	62.6	17.5	62.6	62.6	17.5
Tree density (no./ha)					1070	407	979	407		610
Canopy height (m)		30								
Canopy closure (%)			60	80		75	85	75	40	70
Distance to coast (km)	1.2	0.5	6.4	0.8	0.38	0.25	0.38	0.25	0.51	0.28
Distance to stream (km)		1.5	1.6	0.8	0.15	0.20	0.33	0.20		0.005
Stand age	Old-growth, uneven age	Old-growth, uneven age	Old-growth, uneven age	Old-growth, uneven age						
Diam. nearby trees (cm)	60	20	60	60	25	30	27	30		27
Tree species	Mountain hemlock	Western hemlock	Western hemlock	Western hemlock	Western hemlock	Mountain hemlock	Western hemlock	Mountain hemlock	Mountain hemlock	Mountain hemlock
Tree diameter (cm)	120	74	79	69	30	49	76	71	49	48
Tree height (m)	25	34	26	29	21	20	22	30	20	16
Tree diameter at nest height (cm)			74	63						
Branch height (m)	15.5	24	18	20.8	9.7	15.6	17.4	13.3	15.4	10.5
Branch diameter at bole (cm)	18	24	19	17.5	16.2	10.5	14.6	22.3	11.8	27.1
Distance trunk to nest (cm)	124	200	150	105	14	32	135	138	74	3
Nest platform l x w (cm)		8.4 x 8.4	46 x 46	25 x 27	15 x 15	8 x 9	13 x 7		8 x 8	11 x 9
Nest material	Moss	Moss and lichens	Moss and lichens	Moss, lichens, and sticks	Moss and lichens	Moss and lichens	Moss	Moss and lichen	Moss and lichen	Moss and lichen
Material depth (cm)	~10		8	15	3.3	3.5	2.0	5.0		3.5
Cover above nest (%)	Overhanging branches		100	100	91	82	68	25	93	89
Tree condition	Heartrot, top dead	Declining, top dead	Declining, broken top	Declining, broken top	Declining	Declining	Declining	Dead	Declining	Declining
Notes			No red squirrels on island	No red squirrels on island						
Source	Quinlan and Hughes 1990	Brown 1995a	Russell and Walsh 1996	Russell 1996	Naslund et al. 1994	Naslund et al. 1994	Naslund et al. 1994	Naslund et al. 1994	Naslund et al. 1994	Naslund et al. 1994

Table 1—Characteristics of marbled murrelet tree nests in Alaska (continued)

	Nest								
	N-7	N-8	N-9	N-10	OB-1[f]	KI-1[g]	KI-2	A-1[h]	A-2
Aspect	NW	WSW	SSW	WSW	W	ENE	N	WNW	W
Slope (°)	40	25	45	25	37				
Elevation (m)	70	105	260	100	305	65	65	80	30
Stand size (ha)	60.7	3.6	4.2	3.6					
Tree density (no./ha)	480	754	391						
Canopy height (m)									
Canopy closure (%)	75	60	60	60		40	40		
Distance to coast (km)	0.1	0.73	1.04	0.6		0.8	0.8	1.2	0.4
Distance to stream (km)	0.08	0.002	0.01	0.01					
Stand age									
Diam. nearby trees (cm)	33	27	35						
Tree species	Sitka spruce	Mountain hemlock	Mountain hemlock	Mountain hemlock	Mountain hemlock	Sitka spruce	Sitka spruce	Sitka spruce	Sitka spruce
Tree diameter (cm)	72	60	45	65	64	61	65	90	104
Tree height (m)	30	22	20	25	23	27	27	26	21
Tree diameter at nest height (cm)					51				
Branch height (m)	15.0	14.8	9.6		9.2				
Branch diameter at bole (cm)	12.7	14.3	19.4		20.3	14.6	13.4		8.9
Distance trunk to nest (cm)	224	6	3	0	46	23	101		61
Nest platform l x w (cm)	9 x 8	14 x 10	9 x 8	10 x 10	10 x 10	9 x 10	10 x 10		
Nest material	Moss and lichen	Moss and lichen	Moss and lichen	Moss	Moss	Moss and lichen	Moss	Moss	Moss and lichen
Material depth (cm)	2.5	4.0	6.0	6.0		2.5	3.2		
Cover above nest (%)	95	91	94						
Tree condition	Healthy	Declining	Healthy	Declining	245 years old	Healthy	Healthy	Healthy	Declining
Notes									
Source	Naslund et al. 1994	Naslund et al. 1994	Naslund et al. 1994	Naslund et al. 1994	Yukey 1995	Naslund et al. 1994	Naslund et al. 1994	Nalsund et al. 1994	Naslund et al. 1994

[a] Missing values were not given in the original cited source.
[b] Baranof Island, southeast Alaska.
[c] Prince of Wales Island, southeast Alaska.
[d] Tuxecan Island, southeast Alaska.
[e] Naked Island, Prince William Sound.
[f] Olsen Bay, Prince William Sound.
[g] Kodiak Island.
[h] Afognak Island.

Table 2—Characteristics of marbled murrelet ground nests in Alaska[a]

	Nest						
Characteristic	PWI-1[b]	CI-1[c]	NI-1[d]	PI-1[e]	PNJ-1[f]	KP-1[g]	KP-2
Location	Log Jam Creek	Catherine Island	High peak on West Naked Island	West Wind Bay, Perry Island	Kings Bay, Port Nellie Juan	Rugged Island, Resurrection Bay	Northwestern Lagoon
Year found	1993	1995	1994	1989	1994	1990	1993
Aspect	W	SW	SW	W	NW	N	SE
Slope (°)	38	70	25	35-40	85	17	45
Elevation (m)	195	200		180	7	100	20
Canopy closure (%)		80	60				
Distance to coast (km)	13	2.5	1	0.4	0	0.3	0.03
Distance to stream (km)				0.01			
Located in forest	Yes	Yes	At edge	No; over-looking forest	No	Yes	No
Stand age	Old-growth, uneven age	Old-growth, uneven age	Old-growth, uneven age			Second growth	
Diameter nearby trees (cm)	23.6	40.8	106			23-50	
Nest built on cliff	Yes	No	Yes	Yes	Yes	No	
Cliff height (m)	11				7		
Nest foundation	Tree roots	Rock outcrop		Rock	Rock, moss and litter	Soil	
Nest platform l x w (cm)	65 x 35	25 x 15	15 x 18		~9		4 x 10
Nest material	Moss	Moss	Club moss	Rock and duff	Moss and litter		Moss
Material depth (cm)	4	3.8	Flat		3.5		4-5
Cover above nest (%)		25		Partially obscured by *Vaccinium* bush	100	100	Concealed by alder and willow
Notes		Steep site			Nest in rock crevice	Nest in rock crevice below alder trunk	50% of area covered by alder
Source	Ford and Brown 1995	DeSanto 1996	Kuletz 1995b	Mickelson 1996	Kuletz et al. 1995b	Hughes 1995	Kuletz et al. 1994a

Table 2—Characteristics of marbled murrelet ground nests in Alaska (continued)

	Nest							
	KP-3	KP-4	PC-1[h]	AI-1[j]	BI-1[k]	BI-2	BI-3	KI-1[m]
Location	Northwestern Lagoon	Gore Point	Port Chatham	Augustine Island	East Amatuli Island	East Amatuli Island	Ushagat Island	Kodiak Island
Year found	1991	1990	1981		1978	1979	1993	1962
Aspect	NW	S		N or NW	N	NE	SE	SE/S
Slope (°)	20-30	90		10				
Elevation (m)	30	330	710	120	68	~68	250	690
Canopy closure (%)							80	
Distance to coast (km)	~1.0	0		<1	0.08	0.08	0.8	6.2
Distance to stream (km)								
Located in forest	No	No	No	No	No	No	Dwarf Sitka spruce	No
Stand age								
Diameter nearby trees (cm)							4-5	
Nest built on cliff	No	Yes			No	No	No	
Cliff height (m)								
Nest foundation	Gravel and sand	Organic debris		Bare lava	Bare soil and matted vegetation			
Nest platform l x w (cm)								
Nest material	None	Organic debris			None		Tree litter, moss and grass	
Material depth (cm)								
Cover above nest (%)	Nest in depression beneath boulder	100			0	Under rock ledge	80	
Notes		Under exposed spruce tree root	In small grotto			Protected by rock outcrop		In shallow niche
Source	Rice and Spencer 1991	Hughes 1995	Day et al. 1983	Day et al. 1983	Simons 1980	Hirsch et al. 1981	Gracz 1994	Hoeman 1965

[a] Missing values were not given in the original cited source.
[b] Prince of Wales Island, southeast Alaska.
[c] Catherine Island, southeast Alaska.
[d] Naked Island, Prince William Sound.
[e] Perry Island, Prince William Sound.
[f] Port Nellie Juan, Prince William Sound.
[g] Kenai Peninsula.
[h] Port Chatham.
[j] Augustine Island, Cook Inlet.
[k] Barren Islands.
[m] Kodiak Island.

Tree nest PWI-I—This nest was found on Prince of Wales Island near 12-Mile Arm in 1992 after the discovery of egg shell fragments on the ground (Brown 1995a). The nest was in a western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), in an uneven-aged, old-growth stand of conifers. The nest was at an elevation of about 274 meters (898.7 feet) and about 0.5 kilometer (0.3 statute mile) from the coast. The nest tree was 34 meters (111.5 feet) tall and 74 centimeters (29.1 inches) d.b.h. This tree was in a state of declining health as suggested by its dead top. The nest was on a branch about 24 meters (78.7 feet) above the ground and about 200 centimeters (78.7 inches) from the trunk of the tree. The nest was composed of moss and lichens.

Tree nest PWI-2—This nest was found on Prince of Wales Island in 1996 (Russell and Walsh 1996). A single bird was observed flying into a western hemlock on two consecutive days during a dawn count. The tree was subsequently climbed. The nest tree had a broken top and was in an old-growth, uneven-aged, commercial stand of conifers. The nest tree was 26 meters (85.3 feet) tall and 79 centimeters (31.1 inches) d.b.h., and was at an elevation of about 30 meters (98.4 feet). It was 6.4 kilometers (3.9 miles) from the coast. The nest tree was among the largest in the stand. The nest was on a forked branch 18 meters (59.0 feet) aboveground and about 150 centimeters (59.1 inches) from the trunk of the tree. The nest consisted of moss and lichens.

Tree nest TUX-1—This nest was found in 1996 on Tuxecan Island, a small island on the outside coast of Prince of Wales Island (Russell 1996). This nest was found during a dawn count by watching a murrelet fly into a western hemlock and then climbing the tree. The nest tree had a broken top and was in an old-growth, uneven-aged commercial stand of trees. The nest tree was 29 meters (95.1 feet) tall, had a d.b.h. of 69 centimeters (27 inches) and was at an elevation of 60 meters (196.8 feet). It was 0.8 kilometer (0.5 statute mile) from the coast. This nest tree was among the largest in the stand. The nest was on a forked branch 20 meters (65.6 feet) above-ground and was 105 centimeters (41 inches) from the trunk of the tree. This nest consisted of moss and lichens.

Ground nest PWI-1—This nest was discovered near Log Jam Creek on Prince of Wales Island in 1993 (Ford and Brown 1995). Although I consider it a ground nest for the sake of organizing nest records (see tables 1 and 2), it had characteristics of both ground and tree nests. The nest was built on a bed of moss growing on tree roots. These roots were at the top of an 11-meter (36.1 feet) cliff within the forest. Approached from below, the nest appeared more similar to tree nests because of its location at the top of the cliff; approached from above, it appeared more like a ground nest. The stand of trees in which the nest was found was characterized as uneven-aged old growth. The nest was at an elevation of 195 meters (639.6 feet) and was about 13 kilometers (8.1 statute miles) from the coast.

Ground nest CI-1—This nest was found in 1995 on Catherine Island at the confluence of Peril and Chatham straits by a group of researchers of the Forestry Sciences Laboratory-Juneau (Pacific Northwest Research Station) as they were collecting data for a silvicultural project (DeSanto 1996). They flushed an incubating bird from its nest as they walked through their research plot. The nest was found in a nearly vertical V-notch (50-70 degrees) of an ephemeral streambed. The nest was in moss, litter, and organic matter on the backside of a small uprooted tree perched on a rock face. A splintered piece of wood projected outward from the nest. A landing pad was present at the base of this piece of wood, next to the nest. The nest was 3 meters (10 feet) above a 1-meter (3-foot) wide bench used as an animal trail. The ground below this trail was nearly vertical. Although this nest was on the "ground," the general placement of the nest was more treelike. The nest platform was at the base of the splintered wood. This piece of wood resembled a tree limb and the nest was placed at the base of this "branch." The location of the uprooted tree on the face of a steep rock outcrop gave the impression of a tree. The nest was in a moderate-volume, old-growth forest within 100 meters (328 feet) of a 20-year-old clearcut. It was at an elevation of 200 meters (656 feet) and was about 2.5 kilometers (1.6 statute miles) from the coast.

Features common to all six southeast Alaska nests include relatively low elevation, relatively close proximity to salt water (especially compared to nests in other states), location in uneven-aged old-growth stands of conifers, and use of moss as a nesting substrate. Significantly, all tree nests were located in trees substantially larger in diameter than most of the surrounding trees and in trees of declining health, suggesting old age.

These nests provide scant data from which to generalize about nesting habitat characteristics in southeast Alaska. Five of the nests were found in the course of conducting other activities. Only one nest was discovered in an unbiased fashion— through radio telemetry. Most USDA Forest Service research and monitoring activities in the Tongass National Forest occur on tracts of forest scheduled to be harvested or under consideration for harvest. Thus discovery of nests may be biased towards those that are located in forest stands with certain characteristics amenable to harvest, such as slope, elevation, size of trees, and accessibility. In addition, the high proportion of ground nests found in southeast Alaska is biased as well because of our inability to effectively search tree canopies.

Characteristics of other marbled murrelet nests found in Alaska—Twenty-seven other nests of marbled murrelets have been found in Alaska and these provide additional insights into nesting habitat characteristics. Of the 27 nests, 15 were found in trees and 12 were found on the ground (tables 1 and 2). These nests were found in Prince William Sound, along the outer coast of the Kenai Peninsula, on islands in Cook Inlet, or in the Kodiak Archipelago. In addition, a variety of evidence indicative of nesting of marbled murrelets in Alaska has been collected anecdotally over the years (table 3).

Table 3—Additional evidence of marbled murrelet nesting in Alaska, but where specific data on nests and nesting are lacking

Location	Year	Notes and comments	Source
Kuiu Island, southeast Alaska	Mid-1970s	Unconfirmed report from a logger who saw a murrelet and egg fall from a tree as he felled it.	USDA Forest Service 1995
Prince of Wales Island, Polk Inlet	1992	Fragments of an egg were found on the ground on west ridge of 12-Mile Arm; search for nest unsuccessful.	USDA Forest Service 1995
Prince of Wales Island, Old-Franks	1992	Unverified report of eggshell fragments on ground.	USDA Forest Service 1995
Prince of Wales Island, Polk Inlet	1992	Unverified report of eggshell fragments on ground.	USDA Forest Service 1995
Prince of Wales Island, Calder Creek	1992	Unverified report of a logging engineer who observed a fledgling on the forest floor.	USDA Forest Service 1995
Prince of Wales Island, Neck Lake	1992	A logging engineer found a fledgling on the road. The fledgling was captured, taken to a laboratory, photographed, and released.	USDA Forest Service 1995
Prince of Wales Island, Staney Creek	1996	Mostly intact eggshell found at the base of a large (122 centimeter d.b.h.) western redcedar. A search was made for a nest, but none was found.	Russell 1996
Prince of Wales Island, Staney/Election Creek	1993	Eggshell fragments found by an engineer at the base of a tree on the edge of a remnant stand (CPOW unit 590-231), adjacent to the road clearing.	Russell 1996
Heceta Island, Warm Chuck	1996	Eggshell fragments, including shell membranes, were found by a wildlife technician in the middle of a logging road.	Russell 1996
Knight Island, Prince William Sound, between Cathead Bay and Copper Bay	1990	Adult flushed off greenish egg on the ground above tree line at elevation of about 458 meters. Shrub cover was less than 50% within 50 meters of nest. Photograph of nest available.	Burn 1995
Cabin Lake Road, 3.2 kilometers from Cordova Airport	1978	Unfledged chick found on road in heavily timbered area about 11 kilometers from tidewater. Attempt was made to raise chick but it died.	Mickelson 1996
58 kilometers from Cordova along Copper River Highway	1994	A fledgling was found on the road. It was captured but died in captivity.	Bishop 1995
Naked Island, Prince William Sound, McPherson Bay	1994	Greenish egg found in ground nest located beneath overhanging root at edge of steep, 15-meter cliff at water's edge. Cold egg was collected but identification not certain.	Kuletz et al. 1995b
Port Nellie Juan, Prince William Sound, West Finger Inlet	1994	Approximate location of nest found by repeated relocation of radio-marked murrelet. Nest site on cliff above tree line approximately 2.3 kilometers from shore.	Kuletz et al. 1995b
Port Nellie Juan, Prince William Sound, near Cotterel Glacier	1994	Nest location found through radio telemetry. Nest site located on face of vertical cliff with only small ledges and little vegetation approximately 5.7 kilometers from shore.	Kuletz et al. 1995b
Port Nellie Juan, Prince William Sound, East Finger Inlet	1994	Approximate location of nest found using radio telemetry. Nest was likely in a conifer tree about 0.9 kilometer from shore.	Kuletz et al. 1995b
Port Nellie Juan, Prince William Sound, East Finger Inlet	1994	Approximate location of nest found using radio telemetry. Nest was likely in a conifer tree about 0.4 kilometer from shore.	Kuletz et al. 1995b
Port Nellie Juan, Prince William Sound, East Finger Inlet	1994	Approximate location of nest found using radio telemetry. Nest was likely in a conifer tree about 0.2 kilometer from shore.	Kuletz et al. 1995b

Table 3—Additional evidence of marbled murrelet nesting in Alaska, but where specific data on nests and nesting are lacking (continued)

Location	Year	Notes and comments	Source
Patton River on Montague Island, Prince William Sound	1987	Dead marbled murrelet chick found on ground in spruce/hemlock forest about 100 meters from Patton Creek and about 60 meters elevation. Largest trees were 19 centimeters d.b.h., but most in 9- to 14-centimeter range. Tree heights were 21 to 30 meters and canopy cover was 75%. Chick was 15 centimeters long and contour feathers were not fully developed. It was not damaged. Observer believes bird came from close by—showed no evidence of being taken by raptor.	Kuletz 1995b
North of Seward, Alaska along Seward Highway	1994	Fledgling marbled murrelet was found and released in a forested area along the Seward Highway, about 8 kilometers north of Moose Pass (about 1.6 kilometers north of Trail Lake Fish Hatchery).	Jones 1995
Pye Islands, Kenai Peninsula	1976	Ground nest in heavy grass, 150 meters elevation, east aspect, 90° slope, 0.25 kilometer from coast. Bailey (1977) identified as Kittlitz's murrelet nest, but Day et al. (1983) believe it was a marbled murrelet nest.	Bailey 1977, Day et al. 1983
East side of Discoverer Bay, Afognak Island	1976	Fledgling marbled murrelet found on ground in old-growth Sitka spruce forest in USDA Forest Service unit 21 on 17 August (Afognak map B-2, T.22S, R.19W, section 3).	MacIntosh 1996
East side of Discoverer Bay, Afognak Island	1976	Dead adult marbled murrelet found on ground in old-growth Sitka spruce forest in USDA Forest Service unit 33 (Afognak map B-2, T.21S, R.19W, section 34) at Slough Creek.	MacIntosh 1996
Afognak Island near Kazakof Bay	1988	Two "nests" found 2 days apart after felling Sitka spruce during logging. Marbled murrelet chicks were found approximately 2 kilometers inland from coast. Trees in area about 150 to 200 years old. Both chicks were raised (and released?).	Kuletz 1995b
Afognak Island, Izhuit Bay	1992	Murrelet recovered from felled Sitka spruce. Bird held for several days and then flew off. Spruce was large. On-site Alaska Department of Fish and Game biologist could add no additional details.	Kuletz 1995b
Mill Bay, Kodiak Island	1976	Adult found under large Sitka spruce tree in trailer park about 300 meters inland of Mill Bay. A few canopy trees had been removed prior to finding the bird. Adult positively identified by R. MacIntosh.	MacIntosh 1996
Monashka Bay, Kodiak Island	1977	Adult marbled murrelet found on ground by dog on 25 May, about 500 meters from southeast shore of bay in heavily wooded, low-density residential area.	MacIntosh 1996
Island Lake, Kodiak Island	1986	A large downy chick was found on the ground in a forest in the Island Lake area of the town of Kodiak. The chick was brought to the Kodiak National Wildlife Refuge Office where it was photographed.	MacIntosh 1996
57 kilometers from Kodiak along Chiniak Highway	1990	A downy chick was found on the ground 30 meters from house on 7 July. Elevation was about 46 meters in area heavily forested with large Sitka spruce. Marbled murrelets seen on ocean nearby. Bird held overnight but would not eat. Bird released next day and looked fine—believed to have flown off(?). An egg was found in same spot as bird on 8 July. Identification of bird and egg not certain.	Kuletz 1995b

The most intensive searching efforts for marbled murrelet nests in Alaska were those reported by Naslund et al. (1994) and Kuletz et al. (1995b). In 1991 and 1992, Naslund et al. (1994) found 14 tree nests on Naked, Afognak, and Kodiak Islands in south-central Alaska (table 1) as a result of searches in forest stands thought to contain nests. Details of each nest are compiled in table 1. At Naked Island, 9 of 10 nest trees were in western or mountain hemlock; one nest was in a Sitka spruce (*Picea sitchensis* (Bong.) Carr). All four nests on Kodiak and Afognak Islands were in Sitka spruce. Species of the nest tree generally reflected availability in the area. Diameters of nest trees averaged 63 centimeters (24.8 inches; range = 30 to 104 centimeters [11.8 to 40.9 inches]). Nest trees tended to be larger in diameter than surrounding trees and were among the tallest in the area. Nest trees generally were more than 200 years old, and one nest tree on Naked Island was about 495 years old. At Naked Island, where the largest sample of nests was found, nest trees had significantly more platforms and significantly higher levels of epiphyte cover than surrounding trees. All 14 nests were found on substrates of moss or a combination of moss and lichens. Another important feature of nest sites was the amount of canopy cover above the nest. For eight nests in this study, canopy cover above nests ranged from 81 to 95 percent. The remaining tree nest from outside southeast Alaska was found in a 245-year-old mountain hemlock at Olsen Bay, Prince William Sound (table 1).

Kuletz et al. (1995b) radio tagged 48 marbled murrelets at Prince William Sound in 1994. They found one ground nest on a cliff, identified the location of three tree nests within one or two trees, and found the approximate location of three additional nests. Radio telemetry is a less biased method for locating nests than conducting searches on the ground, and Kuletz (1995a) believes radio telemetry is more efficient.

Naslund et al. (1994) also determined several stand or landscape characteristics common to the nests they found. In general, nests were in stands of high-volume, uneven-aged, old-growth trees. Wood volume of stands in which the Naked Island nests were found ranged from 130 to 391 cubic meters per hectare (1,883 to 5,649 cubic feet per acre), which corresponds to the old[1] USDA Forest Service volume classes 4 and 5 (Kuletz et al. 1994b). These are the largest volume classes of any significance in Prince William Sound (Kuletz 1995a). Sizes of contiguous forest stands in which the nests were found ranged from 3.6 to 62.6 hectares (89 to 153.6 acres) on Naked Island. Slopes were generally gradual or moderate and elevations at nest sites were low, ranging from 30 to 260 meters (76.2 to 852.8 feet). Nest stands usually were found at the heads of bays with aspects tending to face westward.

The 12 additional ground nests found in Alaska were all either at Prince William Sound or west of there (table 2). Habitats where ground nests were found included treeless islands, scrub-tree stands on predominantly treeless islands, previously glaciated terrain, or areas above treeline or at the forest edge. Four of nine ground nests were at the tops of cliffs. Elevation of ground nests ranged from 7 to 710 meters (23.0 to 2,329 feet). Many of the ground nests also had some cover directly overhead, usually overhanging rock or vegetation. Most ground nests in south-central Alaska were extremely close to the coast.

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[1] These volume classes are referred to as "old" because the volume class system has been revised, as explained in Julin and Caouette (in prep.).

Nesting habitat associations by dawn activity counts—Nests of marbled murrelet are very difficult to find. Because of this difficulty, sample sizes are small and most nest searches have concentrated in habitats having the highest probability of finding nests, namely low-elevation, old-growth stands of conifers where murrelets were previously found. Consequently, data collected during studies designed to describe nest sites have not been useful for developing unbiased models of habitat associations. A number of studies have been undertaken, however, that used the number of murrelet detections (sighting or hearing one or more murrelets acting in a similar manner [Paton 1995]) or occupied behaviors (birds flying below the top of the canopy, circling above the canopy, landing or perching, or calling from a stationary location [Paton 1995]) as the dependent variable and sampling a variety of habitats, which have allowed investigators to construct models of murrelet habitat associations (Burger 1995, Grenier and Nelson 1995, Hamer 1995, Kuletz et al. 1995a). Because of variation in sampling design, these models differ in their applicability across landscapes. For example, Hamer (1995) limited his analysis to old-growth forest stands in Washington. Kuletz et al. (1994b, 1995a), on the other hand, included forested and unforested sites in south-central Alaska because ground nesting occurs in south-central Alaska, but these sites were not chosen randomly in all areas, and caution is therefore required in broadly interpreting their results.

Only one study of habitat associations using marbled murrelet detections has been conducted in southeast Alaska. Stevens (1995b) analyzed dawn watch counts made in 1993 and 1994 at 103 sites in the Tongass National Forest. Unfortunately, no habitat data were recorded for the sites, greatly degrading the usefulness of the data. In a Geographic Information System (GIS) database, a 243-hectare (600-acre) buffer was established around each count site, and a small amount of habitat data (primarily volume class [see “Forest Management History,” below, for definitions of volume class] and stand type) were extracted from the Forest Service’s computerized database.

Activity (detections) of marbled murrelets was significantly and positively related to the proportion of the buffer in productive, old-growth forest. The proportion of the buffer in old volume classes 5 and 6 produced a slightly better correlation than did the proportion of the buffer in old volume classes 4, 5, and 6, and both were much better than the proportion of the buffer in old volume class 6 alone. Total detections were negatively correlated with the proportion of the buffer in a clearcut. The inclusion of riparian buffers, fringes on beaches and estuaries, and second growth produced weaker relations. Activity of murrelets was low in areas where less than 30 percent of the buffer was in old volume classes 4, 5, and 6 and increased rapidly as the proportion of the buffer in volume classes 4, 5, and 6 increased from 30 to 60 percent. Activity of murrelets was related to distance from salt water. Between 1 and 7 kilometers (0.6 to 4.3 statute miles) from the coast had greater mean number of detections than sites within 1 kilometer (0.6 statute mile) of the coast or sites more than 7 kilometers (4.3 statute miles) from the coast.

A multiple regression model integrating effects of the proportion of the nearby area in productive old growth (old volume classes >4), Julian date, and distance from salt water was highly significant, but it explained only 22 percent of the total variation in numbers of marbled murrelet detections. Since this study was completed, the USDA Forest Service has revised its forest volume class designations because of difficulties in distinguishing among the volume classes and timber types in its GIS (Julin and Caouette, in prep.).

Several other studies have attempted to relate murrelet activity and habitat characteristics. These studies are summarized below.

Kuletz et al. (1995a), south-central Alaska—The most important habitat variables across study areas and the best predictors of marbled murrelet activity and occupied behaviors were location relative to heads of bays, tree size (d.b.h.), epiphyte cover on trees, and number of platforms. The investigators found extremely low levels of activity and occupied behaviors at nonforested sites, suggesting that nonforested sites are of less importance than forested sites when both are available. It is unknown, however, if murrelets act similarly in nonforested and forested habitats, which may have biased the results.

Burger (1995), British Columbia—Detections of murrelets were highest in low-elevation forests and consistently higher in old-growth forests than in second-growth forests. Detections in second-growth forests usually were associated with nearby patches of old-growth. Sitka spruce and western hemlock were important components of high activity sites. Burger believes that lack of structural development of vegetation at increasing elevation is a key factor responsible for low detection levels, and not elevation *per se*. All known nests in British Columbia have been associated with platforms of moss. Burger found no evidence of marbled murrelets nesting in subalpine scrub forests, lowland bog forests, or alpine tundra in British Columbia, which may be relevant to southeast Alaska because such habitats are common there.

Hamer (1995), Washington—Probability of occupancy increased with total number of potential nest platforms, percentage of cover by mosses on limbs of dominant trees, percentage of slope, and stem density of dominant trees greater than 81 centimeters (32 inches) d.b.h. Probability of occupancy decreased with increasing lichen coverage, stand elevation, and increasing canopy closure. Rates of detections decreased markedly with elevations greater than 1067 meters (3,500 feet) and with distances from the coast greater than 63 kilometers (39.1 statute miles). Hamer believes that total platforms are the best indicator for assessing habitat quality.

Raphael et al. (1995), Washington—At the landscape level, proportions of old-growth forest and large sawtimber were greater at occupied sites than at sites where murrelets were not detected. The mean size of old-growth patches and large sawtimber patches were greater among occupied sites than at sites where murrelets were detected or undetected. Old growth and large sawtimber combined comprised 36 percent of occupied sites vs. 30 percent and 18 percent for detected and undetected sites, respectively. Occupied sites tended to have more complexity including greater edge, more cover types, and more complex stand shapes than the unoccupied sites.

Grenier and Nelson (1995), Oregon—Occupied sites had older trees, had larger midstory trees, and had larger and greater densities of dominant trees than did random sites. Important habitat components at occupied sites included dominant tree height and density, midstory and understory tree diameter, percentage of cover, and percentage of canopy closure. Nest sites had fewer trees per hectare and less canopy closure than adjacent sites. In Oregon, stand structure was more important than age. Murrelets used stands with old-growth characteristics.

An increasing body of data (including surveys of marbled murrelet activity and occupied behaviors across habitats) and characterization of habitat at marbled murrelet nests, now allow some generalizations to be made about terrestrial habitats used by marbled murrelets across their range. In general, marbled murrelets seem to prefer low-elevation, old-growth, or late-successional coniferous forests with moderately open canopies and structural heterogeneity. Relatively open canopies allow murrelets access to the interior of the forest; however, murrelets seem to prefer dense cover above the nest platforms. Sitka spruce, western and mountain hemlock, Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), coastal redwood (*Sequoia sempervirens* (D. Don) Endl.), and perhaps western redcedar (*Thuja plicat*a Donn ex D. Don) and Alaska-cedar (*Chamaecyparis nootkatensis* (D. Don)) are the predominant species in which marbled murrelets nest. Of these, Sitka spruce, western hemlock, and mountain hemlock are the most common nesting trees in Alaska. Other key habitat features include the number of potential nesting platforms, which is related most importantly to age and tree size, and the presence of epiphytes (primarily mosses) on these platforms. Kuletz et al. (1995a) believe that locations near the heads of bays also are important in the complex bay and fjord coastal areas in Alaska.

Marbled murrelets will use second-growth forests for nesting provided conditions are suitable. In Oregon, McAllister (1996b) found marbled murrelets nesting in second-growth stands of western hemlock. Although the canopies in these forests are relatively closed, murrelets are gaining access to nest sites along roads through the forest. It is unknown if second-growth forests are used by marbled murrelets in southeast Alaska. It is believed that, as second-growth forests mature, they will become increasingly attractive to murrelets.

Marbled murrelets on Naked Island nest in stands of the old volume classes 3 and 4, which are the largest classes available at Prince William Sound. If murrelets in southeast Alaska commonly nest in these volume classes, then it would greatly increase the amount of habitat available to them. I compared the sizes of trees in productive old-growth forests in south-central and southeast Alaska and found that for most forest types, trees in southeast Alaska are bigger (table 4). Nevertheless, if lower volume forests are used in southeast Alaska to any extent, it suggests there is considerably more habitat available to them. Numerous authors have commented that marbled murrelets prefer the larger trees within a stand for nesting (e.g., see Naslund et al. 1994); the nest trees discovered in southeast Alaska support this contention (table 1). Although Stevens' (1995b) preliminary analysis suggests greater marbled murrelet activity in productive vs. nonproductive forests in southeast Alaska, this is an obvious and important topic for future research.

Table 4—Comparison of height and diameter of larger trees in various forest types for south-central and southeast Alaska

	South-central old growth				Southeast old growth			
	Height		Diameter		Height		Diameter	
Forest type	Range[a]	Maximum	Range[a]	Maximum	Range[a]	Maximum	Range[a]	Maximum
	Meters		*Centimeters*		*Meters*		*Centimeters*	
Sitka spruce-alluvial	27-30	49	41-102	160	30-40	61	89-130	206
Sitka spruce-other	21-34	49	33-76	180	24-40	61	69-109	201
Western hemlock - well-drained	21-37	43	36-89	140	37-49	61	79-104	203
Western hemlock - poorly-drained	12-27	40	25-51	101	24-34	—	69-79	—
Mountain hemlock	12-21	43	18-53	102	18-30	—	53-89	—

[a] Range refers to the height or diameter of most trees in the sample plots. The range does not include the largest trees.
Sources: Capp et al. 1992a, 1992b.

Marbled murrelets nest on the ground in Alaska, particularly in western areas of the State where trees are lacking. The relatively high proportion of ground nests vs. tree nests found in Alaska to date probably reflects the higher probability of finding ground nests. Nevertheless, the fact that marbled murrelets nest on the ground, including within old-growth forests in southeast Alaska, suggests that the species has some behavioral plasticity when it comes to nest site selection. The results of Kuletz et al. (1995a) and Burger (1995) suggest that activity and nesting of murrelets in nonforested areas is less than in forested areas where both occur; however, more work needs to be done on this problem, particularly in southeast Alaska. Burger (1995) further suggests that nesting of marbled murrelets in British Columbia does not occur commonly in alpine scrub forests, lowland bog forests, or alpine tundra, all common habitats in southeast Alaska. Ground nesting may be more common in previously glaciated areas, such as in Glacier Bay, or above treeline in areas adjacent to productive marine waters. I believe the widely held view that marbled murrelets are strongly tied to coniferous forests having large, old trees with numerous, moss-covered platforms for nesting holds for forested areas in southeast Alaska as well. Details of this relation for marbled murrelets in southeast Alaska await further investigation.

Seasonal patterns of forest use—Studies have been undertaken at four locations in southeast Alaska to document seasonal use of forest stands by marbled murrelets: Mitkof Island (Doerr and Walsh 1994), Douglas Island (Falk 1995), Herring Cove on Revillagigedo Island (Brown 1995b), and Thorne River on Prince of Wales Island (Russell 1996).

Data from the Thorne River study were not available to me in time to include in this assessment. Doerr and Walsh (1994) monitored detections of marbled murrelets at 2-week intervals for 2 years at a forested location believed to be used by marbled murrelets for nesting. The length of each survey ranged seasonally from up to 2.5 hours in summer to 0.75 hour in winter, but tended to be long enough to capture most detections at the site. Brown's (1995b) survey was similar to Doerr and Walsh's in that he monitored one site about every 2 weeks; however, the length of his surveys tended to be uniform at 2 hours. Falk's (1995) survey was considerably different than the previous two. She conducted biweekly surveys at Eaglecrest on Douglas Island but monitored three sites for 10 minutes each during each survey.

The results from these studies are consistent across survey location. At all three sites, detections were greatest in late July and early August. Higher detection levels in late July and early August are believed to correspond with increased vocal activities of the adults, increased number of feeding visits to large chicks, and the onset of fledging. There were no detections in September and October, presumably corresponding to the prebasic molt. Marbled murrelets were detected in forests throughout winter, albeit in substantially lower numbers than in summer.

Results from the southeast Alaska studies are similar to others during the breeding season in Alaska, British Columbia, Washington, and Oregon, and to several sites in northern and central California where site attendance was monitored year-round (see review in O'Donnell et al. 1995). Marbled murrelets are consistent in that they attend old-growth forest stands year-round with the exception of about a 2-month period after fledging when they are undergoing molt (see O'Donnell et al. 1995). It would be interesting to explore latitudinal differences in attendance patterns in light of the data suggesting that marbled murrelets undergo seasonal migrations from some breeding areas (Klosiewski and Laing 1994).

The reasons marbled murrelets attend forest stands throughout the year are unclear. Naslund (1993) believes that murrelets visiting nesting areas in winter probably represent a portion of the breeding population that is resident year-round. Visiting nest sites year-round may confer a reproductive advantage to adult marbled murrelets. Naslund (1993) hypothesizes that high-quality nest sites in trees, characterized by large platforms, sufficient moss or debris, cover from predators and inclement weather, and flight accessibility, are rare. Winter attendance could enhance the murrelet's ability to retain or secure high-quality nests. Winter attendance also could enhance maintenance of pair bonds (Naslund 1993). In Prince William Sound, the most northerly part of their range where many marbled murrelets appear to migrate from nesting areas (Klosiewski and Laing 1994), the advantages of winter attendance may be offset by the costs of remaining in an environment made less hospitable by severe weather and reduced food availability.

Naslund (1993) suggests that monitoring of winter attendance may be advantageous for four reasons: (1) attendance counts are less variable in winter; (2) monitoring may track the most important component of the population—breeders; (3) less competition for personnel and resources to do the monitoring; and (4) in some regions, fewer landbirds in the forest in winter reduces confusion. The utility of conducting winter monitoring studies in forest stands in Alaska would benefit from further evaluation.

Habitat Characteristics—Marine Environments

Agler et al. (1995), Lindell (1995a), Piatt (1995b), McAllister (1996a), Piatt et al. (1991), Piatt and Ford (1993), and Piatt and Naslund (1995), collectively, provide an overview of the distribution of marbled murrelets in southeast Alaska (see "Distribution and Abundance," above). All data collected to date in southeast Alaska, as well as most other studies within the species' range, indicate that marbled murrelets are primarily birds of nearshore marine waters. Within Alaska, they are most abundant in sheltered inside waters, which include bays, fjords, and island passes (Piatt and Naslund 1995).

Although the distribution of marbled murrelets is now well-known throughout their North American range, few quantitative attempts have been made to relate their distribution to the physical and biological variables that constitute their marine environment. On a large spatial scale, Hunt (1995) believes the Alaska Current and Alaska Coastal Current, which are part of a large counter-clockwise circulating gyre in the Gulf of Alaska and which are both seaward of murrelet distribution, are indirectly important because they influence the transport of plankton into coastal waters. On a smaller, more local scale, currents interacting with bathymetry can create fronts and upwellings that enhance productivity or cause prey organisms to accumulate. For example, several investigators (Carter and Sealy 1984, Hunt 1995, Kuletz et al. 1995b) have remarked on the importance of currents impinging on sills that cause upwelling as an attractant to foraging murrelets. In addition, tidal processes may serve to concentrate prey organisms. This effect may be particularly important in southeast Alaska and other parts of Alaska where there is a large tidal amplitude. In addition, strong persistent winds, that push surface waters offshore, may create upwellings along the coast. This process is especially important along the coasts of California, Oregon, and Washington.

Distance from land is the habitat variable most frequently addressed by murrelet researchers. For most studies, investigators have found a negative relation between density or abundance and distance from shore. In most studies throughout their range, most murrelets were detected within 5 kilometers (3.1 statute miles) of shore. Ralph and Miller (1995) found highest densities of murrelets within 0.4 to 0.8 kilometer (0.2 to 0.4 statute mile) of the northern California shore and a rapid decline of densities beyond 2 kilometers (1.2 statute miles) from shore. Similarly, Ainley et al. (1995) found most murrelet sightings within 3 to 5 kilometers (1.9 to 3.1 statute miles) of shore in central California. Kuletz et al. (1994c) found a steady and significant decline in marbled murrelets from shore out to 5 kilometers (3.1 statute miles). Agler et al. (1995), on the other hand, found no decline in murrelet densities beyond 3 kilometers (1.9 statute miles) from shore in southeast Alaska.

Although distance from shore is a useful variable for describing the distribution of murrelets relative to the coast, it does little to explain why murrelets choose nearshore habitats. Kuletz et al. (1994c) examined the influence of water depth on abundance and found higher densities of marbled murrelets in shallower water around Naked Island in Prince William Sound. Similarly, Kuletz et al. (1995b) found radio-tagged murrelets at Naked Island over shallow water more frequently than expected compared to deep water.

Ainley et al. (1995) have quantitatively addressed other variables, which perhaps better describe marine habitat characteristics of marbled murrelets. Off central California, Ainley et al. (1995) found that sea surface temperature, salinity, distance to land, distance to nesting areas, and distance to shelf break were all statistically significant. Marbled murrelet densities tended to be higher in cold upwelled water with high salinity that was closer to shore, and closer to terrestrial nesting habitats and shallow waters near the shelf break. Depth, distance to shore, and distance to nesting areas were closely correlated with one another.

Although a quantitative descriptive analysis of marbled murrelet marine habitats has not been completed, data from both southeast Alaska and Prince William Sound suggest that high densities of murrelets are often found over sills at the mouths of bays and fjords. This pattern has been observed in Icy Strait at the mouth of Glacier Bay (Lindell 1995a, Piatt 1995b), at the mouths of Berg Bay and Muir Inlet in Glacier Bay (Lindell 1995a, Piatt 1995b, Piatt et al. 1991), and in Port Nellie Juan in Prince William Sound (Kuletz et al. 1995b). In northern southeast Alaska, Icy Strait appears to be one area where marbled murrelets concentrate in mid to late summer (Lindell 1995a, Nelson and Lenhausen 1983, van Vliet 1993). Three features may be responsible for this concentration of murrelets (Lindell 1995a, Piatt 1995a). First, as mentioned above, currents impinging on the sill at the mouth of Glacier Bay cause upwelling. Second, Icy Strait is an area of intense mixing of tidal waters from Glacier Bay to the north, Lynn Canal and Chatham Strait to the east, and Cross Sound and the Gulf of Alaska to the west, which concentrates prey. Third, prey organisms brought into Icy Strait as the result of this mixing are believed to concentrate along the steep turbidity gradient that exists between clear water from Cross Sound and silt-laden waters of Glacier Bay. Piatt (1995a) observed many marbled murrelets feeding on the clear-water side of the sediment plume outside Glacier Bay.

Food Habits

Foods of marbled murrelets have not been described for southeast Alaska. The diet can be inferred to some extent, however, from data collected in south-central Alaska and elsewhere in the Gulf of Alaska (DeGange and Sanger 1986; Krasnow and Sanger 1982; Kuletz 1995b; Oakley and Kuletz 1979; Piatt 1995b; Sanger 1983; Sanger 1987a, 1987b), and in British Columbia (Carter 1984, Sealy 1975, Vermeer 1992).

Marbled murrelets appear to be opportunistic predators, feeding on a wide variety of crustacea and small fishes (see review of marbled murrelet food habits and prey ecology in Burkett 1995). In Alaska, prey representing at least 18 different taxa have been found in the gastrointestinal tracts of marbled murrelets (Sanger 1983; table 5). Of these, the oceanic euphausiid (*Thysanoessa inermis*), capelin (*Mallotus villosus*), and sand lance (*Ammodytes hexapterus*) were most important. In collections made by Oakley and Kuletz (1979) near Naked Island in Prince William Sound, capelin, a marine nematode, sand lance, calenoid copepods, and walleye pollock (*Theragra chalcogramma*) had the highest frequency of occurrence in the stomachs of 19 marbled murrelets. For marbled murrelets collected in the Shumagin Islands in the western Gulf of Alaska and in the Aleutian Islands in 1990, walleye pollock occurred most frequently in their stomachs followed by sand lance and copepods (Piatt 1995b). Piatt (1995b) and Kuletz (1995b) also collected marbled murrelets in Kachemak Bay and in Prince William Sound in 1989 and 1990. In Kachemak Bay, sand lance occurred most frequently in the birds' stomachs followed to a much lesser extent by walleye pollock. The collections from Prince William Sound in 1989 and 1990 were interesting in that walleye pollock had the highest frequency of occurrence in marbled murrelet stomachs followed by sand lance. None of the stomachs contained capelin, in contrast to 1978 when capelin had the highest frequency of occurrence (Oakley and Kuletz 1979).

In British Columbia, fish also appear to be the most important prey of marbled murrelets (see review by Burkett 1995). Sand lance and Pacific herring (*Clupea harengus*) were the most important species (Carter 1984, Sealy 1975, Vermeer 1992), but murrelets also took seaperch (*Cymatogaster aggregata*), northern anchovy (*Engraulis mordax*; Carter 1984, Sealy 1975, Vermeer 1992), and pricklebacks (Stichaeidae; Sealy 1975). Euphausiids, notably *Thysanoessa inermis* and *Euphausia pacifica*, were locally important.

Seasonal, annual, and geographic variation in diets—No data are available for southeast Alaska, but investigators working elsewhere have noted seasonal differences in the composition of murrelet diets (Carter 1984, Krasnow and Sanger 1982, Sealy 1975). Both Sealy (1975) and Krasnow and Sanger (1982) document dietary shifts from euphausiids in spring to fish in the summer. Carter (1984) found differences in the proportion of sand lance and herring in the diet depending on stage of the annual cycle (e.g., breeding vs. molting). Seasonal shifts in diet may reflect the availability of prey and preference. For example, the euphausiid, *T. inermis*, is more common in spring than in summer in nearshore waters (Sealy 1975), which partially may explain its presence in murrelet diets at this time of year. However, murrelets probably prefer to feed their chicks fish during the nestling phase because of the high energy value of fish and the efficiency of transporting them compared to small crustacea.

Diets of marbled murrelets also appear to differ geographically. For example, Pacific herring has not been recorded in diets of marbled murrelets in Alaska, although it is an important dietary component in parts of British Columbia. Similarly, walleye pollock is important in Alaska and mysids can be of local importance. These prey items have not been recorded elsewhere. Differences largely reflect zoogeographic differences among these prey but also may reflect insufficient sampling in many areas.

Table 5—Prey items for marbled murrelets recorded for Alaska and British Columbia[a]

Prey species or taxon	Alaska	British Columbia
Unid. Nereidae	I[b]	
Littorina sitkana (Gastropoda)	I	
Unid. gastropoda		
Mytilus edulis (Bivalvia)	I	
Loligo opalescens (Cephalapoda)		X[c]
Unid. Cephalapoda	I	
Unid. Mollusca	A[d]	
Acanthomysis spp. (Mysidae)	O[e]	
Neomysis rayii (Mysidae)	I	
Neomysis spp. (Mysidae)	I	
Unid. mysid	I	
Atylus tridens (Amphipoda)		I
Unid. Gammarid (Amphipoda)	I	
Thysanoessa inermis (Euphausiid)	O	
T. raschii (Euphausiid)	I	
T. spinifera (Euphausiid)	I	X
Thysanoessa spp. (Euphausiid)	I	
Euphausia pacifica (Euphausiid)		O
Unid. Euphausiid	I	I
Pandalus borealis (Decapoda)	I	
Unid. Decapod	I	I
Unid. Chaetognatha	I	
Clupea harengus (Clupeidae)		X
Engraulis mordax (Engraulididae)		I
Mallotus villosus (Osmeridae)	X	
Thaleichthys pacificus (Osmeridae)	P[f]	
Unid. Osmeridae	O	I
Oncorhynchus spp. (Salmonidae)	A	A
Theragra chalcogramma (Gadidae)	X	
Unid. Gadidae	I	
Trichodon trichodon (Trichodontidae)	I	
Unid. Scorpaenidae		O
Cymatogaster aggregata (Embiotocidae)		O
Unid. Stichaeidae		I
Ammodytes hexapterus (Ammodytidae)	X	X
Unid. fish	O	A

[a] Updated from Burkett (1995).
[b] I = incidental.
[c] X = major.
[d] A = anecdotal observation.
[e] O = minor.
[f] P = possible.

Diets of marbled murrelets in southeast Alaska likely are similar to those from British Columbia and the Gulf of Alaska in that small forage fish and crustacea are the primary foods. Sand lance, capelin, Pacific herring, eulachon, and pollock are found in southeast Alaska (Carlson 1995, Carlson et al. 1982) but only herring populations are fished commercially and monitored regularly. Diets of other seabird species in southeast Alaska are also poorly known; however, for at least one piscivorous seabird, the rhinoceros auklet (*Cerorhinca monocerata*), two of these species, Pacific herring and sand lance, were important foods for chicks in 1976 (Sander 1983).

Overall, herring populations are not believed to have changed much since the 1970s, although local changes are evident (Muir 1995). For example, the spawning biomass of herring in Auke Bay near Juneau appears to have declined since 1980 (Muir 1995). A commercial fishery for this stock has been closed since 1981. Population data for other potential prey of marbled murrelets are not available.

Changes in marine food webs—Collections made by Oakley and Kuletz (1979), Kuletz (1995b), and Piatt (1995b) suggest that marked changes occurred in the diet of marbled murrelets in Prince William Sound between 1978 and 1989. During that interval, capelin seems to have disappeared as a dietary item and walleye pollock has increased. This apparent dietary shift may have been accompanied by a decline in the marbled murrelet population in Prince William Sound (Klosiewski and Laing 1994). Piatt and Anderson (1996) suggest that long-term changes have occurred in parts of the Gulf of Alaska that are manifested in reduced populations and changes in diets of a number of marine bird and marine mammal populations. Underlying these changes in predator and prey populations were oscillations in sea water temperatures from colder to warmer through the 1980s (Niebauer 1983). Niebauer linked the temperature increase to El Niño southern oscillation events and shifts in the Aleutian low pressure cell. Royer (1993) suggests that the sea temperature cycle is linked to an 18.6-year lunisolar tidal cycle.

Shifts in sea surface temperature were accompanied by the virtual disappearance of capelin and shrimp (*Pandalus borealis*) and an increase in walleye pollock, cod (*Gadus macrocephalus*), and flatfish in trawl surveys along the Alaska Peninsula (Anderson et al. 1994). Concurrently, capelin were replaced by sand lance and pollock as prey of seabirds. Besides marbled murrelets, populations of several other seabird species likely declined in the Gulf of Alaska (Hatch et al. 1991, Klosiewski and Laing 1994, Piatt and Anderson 1996).

These data suggest that long-term but subtle changes in the marine environment can have marked effects on fish populations and on mid to upper level trophic species, such as seabirds and marine mammals. The few data available from southeast Alaska suggest that local changes in abundance have occurred in some fish populations; however, it is not known if large-scale shifts in murrelet prey populations, similar to those in the central and western Gulf of Alaska, have occurred (Carlson 1995b, Piatt 1995a).

Breeding Biology, Demography, and Behavior

Little information exists on the breeding biology, demography, and behavior of marbled murrelets in southeast Alaska. In fact, despite the wealth of new information on this species presented in Ralph et al. (1995a) and in Nelson and Sealy (1994), the marbled murrelet remains one of the most poorly known of North American seabirds.

For detailed information on the biology of marbled murrelets, see reviews by Nelson and Sealy (1994) and various contributons in Ralph et al. (1995a). The life history of marbled murrelets is one that has evolved to minimize exposure to predation near, or on, the nest. This lifestyle is manifested in the laying of single eggs, long incubation shifts, shorter incubation and nesting periods than other alcids, frequent provisioning of chicks, and more rapid growth rates of nestlings than other semi-precocial alcids.

Marbled murrelets are believed to have relatively low reproductive success. Nelson and Hamer (1995a) summarized information on nests with known outcomes and found that only 28 percent were successful. Most of the nest failures (56 percent) were caused by predation. Other causes were nest abandonment and chicks falling from the nest. Avian predators are apparently the most important. Known predators at nests include common ravens (*Corvus corax*), Steller's jays (*Cyanocitta stelleri*), and possibly great horned owls (*Bubo virginianus*) (Nelson and Hamer 1995a). A sharp-shinned hawk (*Accipiter striatus*) took a murrelet at a nest in Prince William Sound, Alaska (Marks and Naslund 1994). Nelson and Hamer (1995a) believe that changes in forest habitats resulting from logging, such as increased amounts of edge, attract certain avian predators and can result in increased predation at nests. They found that successful nests were significantly farther from edges and were better concealed than unsuccessful nests.

Nelson and Hamer (1995b) summarize morphological and behavioral characteristics of marbled murrelets that protect them from predation: (1) concentrating activities in forests when light levels are low; (2) cryptic coloration of eggs, chicks, and adults; (3) rapid flight into and away from the nest; (4) visiting the nest briefly; (5) "freezing" behavior of adults after landing at the nest; (6) use of muted vocalizations at the nest; (7) low, motionless posture of incubating adults; (8) rapid onset of homeothermy in chicks allowing for minimal parental care; (9) motionlessness of chicks for long periods; (10) retention of cryptic down feathers of chicks concealing bright juvenal plumage until just before fledging; (11) fledging of young after dusk; (12) long-distance, indirect flights through forest canopy to access nests; (13) fly-by inspections of nests and nesting areas by adults before a visit; (14) flying in groups; and (15) selecting nesting platforms with high levels of cover above nests.

Little is known of territoriality, nest spacing, and nest density in this species. In south-central Alaska, two pairs of nests found within 50 meters (165 feet) of one another, together with the proximity of landing and nest trees (Naslund et al. 1994), suggest that marbled murrelets nests may be loosely aggregated in forest stands. Marbled murrelets also show fidelity to forest stands (see summary of unpublished data in Divoky and Horton 1995). No direct information is available on the fidelity of individual birds to forest stands, nest sites, or mates; however, many other species of alcids, especially individuals that have reproduced successfully at a particular site, show strong site and mate fidelity (Divoky and Horton 1995). Indirect evidence suggests such is the case for marbled murrelets (DeSanto and Nelson 1995).

Beissinger (1995) estimated survivorship of marbled murrelets based on comparative analyses of allometric relations from 10 species of alcids. Survival of the marbled murrelet was predicted to be 0.845 and ranged as high as 0.90. Juvenile survival has not been estimated. Based on known nests, fledging success is low; this inference is corroborated by at-sea counts along California, Oregon, and British Columbia that indicate that only 0.2 to 4.9 percent of the birds on the water were recently fledged (see summary of data in Beissinger 1995). It is unknown if marbled murrelets breed every year, replace lost eggs, or renest following successful or unsuccessful nesting attempts.

Beissinger (1995) estimates that populations of marbled murrelets need juvenile ratios of 15 to 22 percent to have stable populations along California, Oregon, and British Columbia. He therefore concludes that these populations may be declining by 4 to 6 percent annually. As discussed earlier, data on population trends for marbled murrelets in southeast Alaska are inconclusive.

Sources of Mortality

Marbled murrelets are subject to a variety of events, activities, and forces that result in mortality. For this discussion, the issues are limited to human activities occurring in southeast Alaska that are known sources of mortality to marbled murrelets elsewhere in their range.

Tree cutting—The felling of trees containing nests of marbled murrelets has been documented at least twice in Alaska, both occurrences on Afognak Island (see table 3). It is probably a relatively common event in southeast Alaska in places where nesting and logging occur together.

Fishing nets—Mortality of marbled murrelets in fishing nets in Alaska, particularly salmon gillnets, has been discussed by DeGange et al. (1993), Piatt and Ford (1993), Piatt and Naslund (1995) and in greatest detail for southeast Alaska by Carter et al. (1995). Carter et al. (1995) suggest that thousands to tens of thousands of marbled murrelets may be killed annually in Alaska by fishing nets. The Alaska Peninsula, Kodiak Island, Lower Cook Inlet, Prince William Sound, and southeast Alaska are locations where gillnet mortality of marbled murrelets likely occurs.

Only in Prince William Sound and near the Copper River Delta have data on mortality of marbled murrelets in salmon gillnets been systematically collected; elsewhere, the information is mostly anecdotal. Wynne et al. (1991, 1992) estimate that as many as 923 and 714 murrelets (*Brachyramphus* spp.) may have been killed in the 1990 and 1991 fishing seasons, respectively. Piatt and Naslund (1995), using catch rate data from Prince William Sound to estimate mortality in southeast Alaska, suggest that 900 murrelets are killed annually in southeast Alaska. The validity of applying Prince William Sound data to southeast Alaska has not been evaluated.

Where actively foraging aggregations of marbled murrelets overlap with gillnet gear, the potential for mortality is high (Carter and Sealy 1984). Carter et al. (1995) indicate three fishing subdistricts in southeast Alaska where intensive gillnet fishing overlaps with at-sea foraging aggregations of marbled murrelets (figs. 14 and 15): area 1B, at the south end of Revillagigedo Channel near the Canadian border; area 6A, near Baker Point in Sumner Strait; and area 11B, south of Juneau in the central part of Stevens Passage. All these areas have had long-standing salmon gillnet fisheries that already may have decreased local murrelet populations. The continued effects of gillnet mortality on populations of marbled murrelets in southeast Alaska need to be evaluated.

Oil spills—Marbled murrelets, like most members of the family Alcidae, are highly vulnerable to spilled oil (King and Sanger 1979). The vulnerability of murrelets was graphically illustrated after the Exxon Valdez oil spill when an estimated 8,400 murrelets were killed (Kuletz 1996). For a recent review of the mortality of marbled murrelets resulting from oil pollution see Carter and Kuletz (1995). No data are available on mortality of marbled murrelets as a result of spilled oil in southeast Alaska. The area has considerable shipping traffic, including the transportation of crude oil by tanker from Port Valdez in Prince William Sound along the outside coast to ports in other states. Marbled murrelets also are likely to be killed during small, chronic oil spills.

Predation—Predation likely has been a pervasive force shaping the morphology, coloration, behavior, nest site habitat selection, and other life history attributes of the marbled murrelet (see Ralph et al. 1995b). There is indirect evidence that forest management practices used in coastal coniferous forests, primarily clearcutting and road construction, may increase levels of predation on marbled murrelets in adjacent stands of forest by decreasing forest stand size and increasing forest edge. For example, Nelson and Hamer (1995a) summarized the fate of known marbled murrelet nests in North America and found that successful nests are significantly farther from forest edges and better concealed than unsuccessful nests. A number of studies using artificial nests support these conclusions (see review in Paton 1994).

Goshawks (*A. gentilis*), peregrine falcons (*Falco peregrinus*), bald eagles (*Haliaeetus leucocephalus*), and sharp-shinned hawks are known or suspected predators of adult murrelets (Kuletz et al. 1995b, Marks and Naslund 1994, Nelson and Hamer 1995a). Northwestern crows (*Corvus brachyramphus*) are common in southeast Alaska and may be an important nest predator in this area. Corvids, especially crows and jays, often respond favorably to human-induced changes to the landscape, especially habitat fragmentation (see citations in Nelson and Hamer 1995a). The influence of habitat fragmentation and increasing forest edge on densities of marbled murrelet predators and nest predation needs to be evaluated.

Forest Management History Relative to Nesting Habitat

Forest Management History

Trees have always been an integral part of human economies in southeast Alaska. Alaska natives harvested trees for constructing canoes, framing and planking for homes, totem poles, and other applications. During the period of Russian occupation, beginning in the 1790s, trees were harvested to produce charcoal and used for construction of forts, homes, and ships. Three sawmills were operating by 1853 in Sitka. Early Russian logging was primarily selection harvest with some clearcuts for fuelwood and charcoal.

Russia sold its holdings in Alaska to the United States in 1867, and by 1900 fourteen sawmills were in operation in southeast Alaska with an annual harvest of about 19 000 cubic meters (8 million board feet). Most of the trees were used for sawtimber and pilings. Efforts to establish a pulpmill industry were successful by the late 1940s. The Ketchikan Pulp Company was awarded a 50-year contract of 42.5 million cubic meters (1.5 billion cubic feet) of timber in 1948. The Ketchikan pulpmill was completed in 1954 and ushered in the industrial period of logging in the Tongass National Forest. The Forest Service soon entered into an additional long-term contract for timber from the Tongass National Forest.

Since industrial logging began in the Tongass in 1955, the annual harvests have increased substantially. Between 1909 and 1954, the average annual harvest was 210 000 cubic meters (42 million board feet), whereas between 1955 and 1990 the annual harvest was 1.97 million cubic meters (394 million board feet).

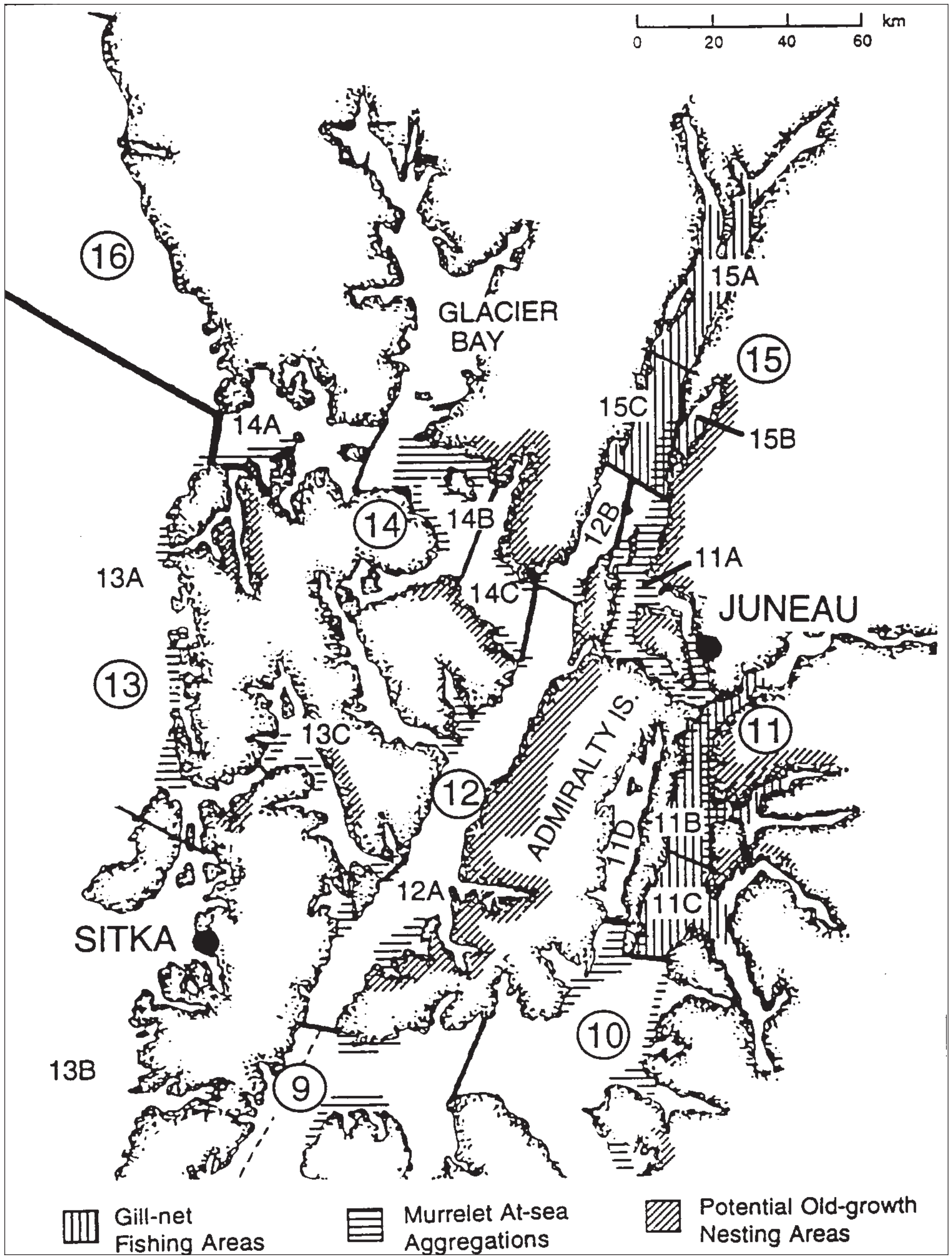

Figure 14—North portion of southeastern Alaska showing fishing districts (numbered) with locations of marbled murrelet at-sea aggregations, potential old-growth forest nesting areas, and gillnet fishing areas (from Carter et al. 1995).

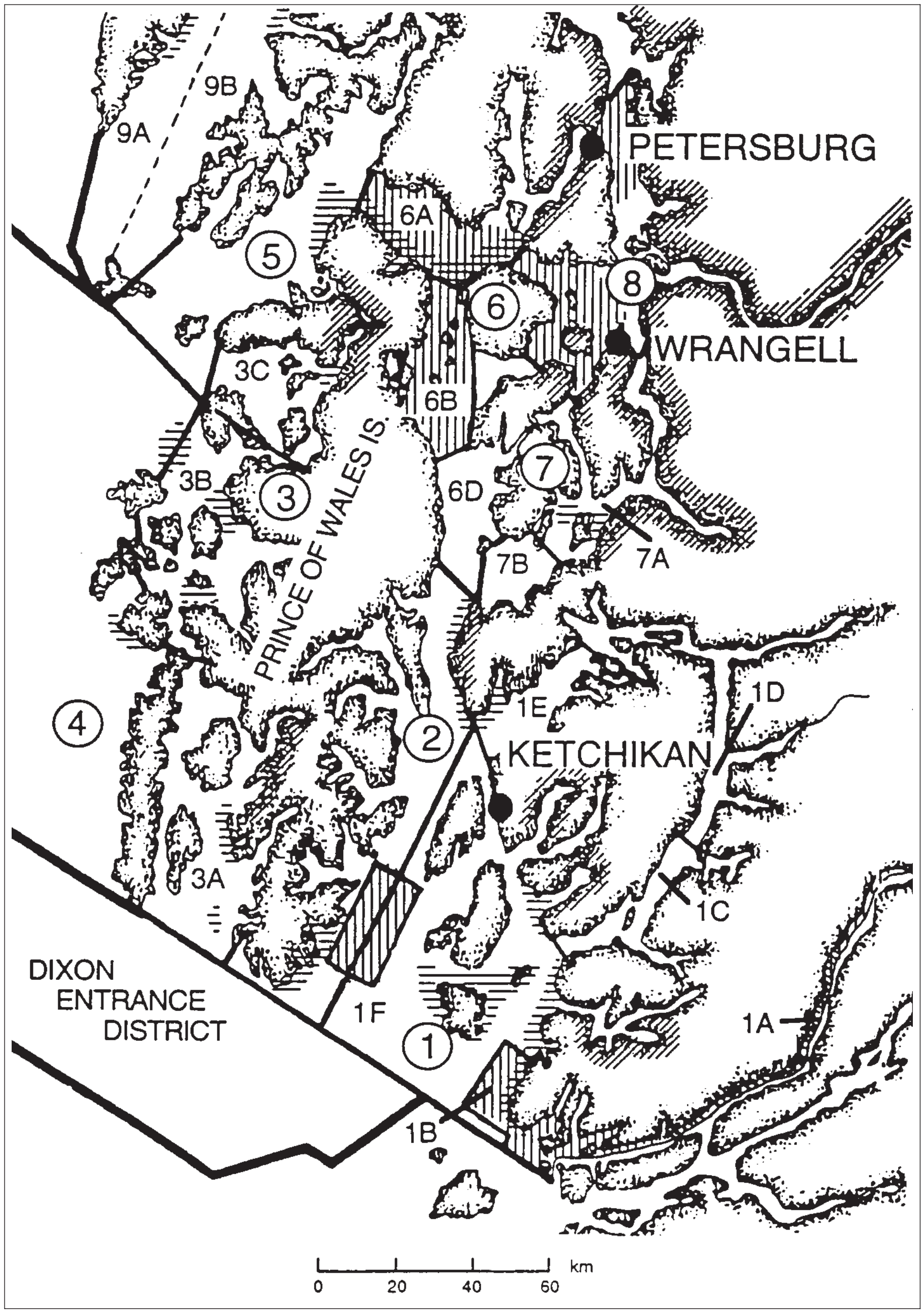

Figure 15—South portion of southeastern Alaska showing fishing districts (numbered) with locations of marbled murrelet at-sea aggregations, potential old-growth forest nesting areas, and gillnet fishing areas. Symbols as in figure 14 (from Carter et al. 1995)

The USDA Forest Service estimates that about 2.3 million hectares (5.6 million acres) of commercially valuable or “productive” forest (capable of producing at least 98.8 cubic meters per hectare [8,000 board feet/acre]) were originally found in the Tongass National Forest. About 147 842 hectares (365,317 acres) of productive forest were harvested between 1955 and 1990. About 20 098 hectares (49,663 acres) of productive forest were harvested during the preindustrial logging phase (Iverson et al. 1996), and an additional 16 916 hectares (41,800 acres) were harvested between 1991 and 1994 (Iverson et al. 1996). Thus an estimated 184 856 hectares (456,780 acres) of productive Tongass National Forest land has been harvested since 1900.

About 303 750 hectares (750,000 acres) of the Tongass National Forest also have been conveyed to the State of Alaska or to Alaska Native Corporations. Most, if not all, is productive old-growth forest. About 60 percent of these forest lands were harvested by 1995 (Iverson et al. 1996, USDA Forest Service 1996). Thus, around 364 500 hectares (900,000 acres) of productive forest in southeast Alaska has been logged and converted to early seral forests.

In the past, productive forest lands in the Tongass National Forest were separated into four classes by stand characteristics discernable in aerial photographs. The four volume or stand classes were volume class 4, 98.8 to 247.1 cubic meters per hectare (8,000 to 20,000 board feet per acre); volume class 5, 247.1 to 370.6 cubic meters per hectare (20,000 to 30,000 board feet per acre); volume class 6, 370.6 to 617.7 cubic meters per hectare (30,000 to 50,000 board feet per acre); and volume class 7, >617.7 cubic meters per hectare (50,000 board feet per acre). These four volume or stand classes did not always accurately reflect the volume of wood in the stand but were a relatively accurate reflection of forest structure and complexity (Iverson et al. 1996). Basically, higher volume class stands are characterized by tall trees with large diameters, multilayered canopies, and relatively high volumes of wood. Because of difficulties in discriminating among volume classes, the Tongass National Forest has collapsed its volume class categories, and used 98.8 cubic meters per hectare (8,000 board feet per acre) as the threshold of a productive forest (Julin and Caouette, in prep.).

Timber in the Tongass National Forest has not been harvested equally across all volumes of productive forest. The average volume per acre of timber harvested from the Tongass National Forest between 1955 and 1990 was 714 cubic meters per hectare (41,500 board feet per acre). This pattern of harvesting the most productive and structurally most complex forest has been consistent through 1994 as well (Iverson et al. 1996). Thus, most, if not all, of the nearly 364 500 hectares logged in southeast Alaska since 1900 represent the higher volume of forest available and are concentrated at low elevations. These sites are generally the most valuable to several old-growth-associated wildlife species (Iverson et al. 1996).

Timber harvest also has not been evenly distributed across the Tongass National Forest. There are 21 biogeographic provinces within the Tongass National Forest (USDA Forest Service 1991). Several provinces have had little or no harvest (e.g., Admiralty and Baranof Islands, and the mainland provinces; table 6). Other provinces, for example northeast Chichagof Island and north Prince of Wales Island, have had significant timber harvest activity (table 6). Province by province, the amount of productive forest removed through logging by 1995 had ranged from 0 to about 21 percent (table 6).

Table 6—Percentage of productive forest harvested in biogeographic provinces in the Tongass National Forest in 1995 and projected to be harvested by 2055 under the current Tongass land management plan[a]

	Productive old growth harvested	
Biogeographic province	1995	2055
	Percent	
East Chichagof Island	8.6	38.6
West Chichagof Island	0.0	6.0
East Baranof Island	8.0	37.0
West Baranof Island	4.5	22.5
Admiralty Island	0.0	3.0
Lynn Canal	3.0	26.2
North Coast Range	0.4	32.0
Kupreanof Island and Mitkof Island	9.1	47.3
Kuiu Island	7.2	37.0
Central Coast Range	2.3	25.6
Etolin Island and vicinity	11.7	49.2
North Prince of Wales Island	20.8	66.9
Revilla and Cleveland Peninsula	4.8	35.5
Southern outer islands	11.6	36.3
Dall Island and vicinity	1.1	55.7
South Prince of Wales Island	1.9	34.3
North Misty Fiords	0.4	3.8
South Misty Fiords	0.0	0.0
Ice fields	2.4	6.3
Tongass National Forest	6.5	31.4

[a] The Yakutat area is excluded from the analysis.

Forest lands allocated to timber production in the Tongass are primarily managed under about a 90- to 120-year rotation. One hundred years after harvest, most forests in southeast Alaska will be in the stem exclusion phase of forest regeneration and stand development. This phase is characterized by high stem density, nearly complete canopy closure and little structural complexity in the forest (Iverson et al. 1996). It is unclear whether marbled murrelets use this type of forest for nesting because the trees lack wide lateral branches used as nest platforms, and epiphyte development is not sufficient for nests. In addition, murrelets may have difficulty in gaining access to the interior of these dense canopy forests because of the homogeneous, closed canopy. Old-growth characteristics, such as irregular canopy gaps, large and old trees, and multilayered canopies, probably do not occur in forests until 150 to 250 or more years after forest reestablishment, but it is still uncertain if those forests can provide habitat suitable for marbled murrelets.

Effects of Current and Future Forest Management

No existing data are available for southeast Alaska that allow a quantitative analysis of the effects on marbled murrelets of existing and future logging of old-growth forests. There also are no data from which to evaluate marbled murrelet population trends. Marbled murrelets in southeast Alaska likely nest in higher volume old-growth forests rather than young growth or nonforested areas. As structural complexity of the forest and number of platforms increases with stand age and tree size, the habitat likely increases in value to marbled murrelets; thus, it is possible to broadly speculate about the effects of tree harvesting on marbled murrelet populations. I believe these assumptions are reasonable given what we know of marbled murrelet habitat relations from southeast Alaska and elsewhere within the range of the species.

Table 6 shows the proportion of productive old-growth forest logged in each biogeographic province in the Tongass National Forest by 1995 and projects future harvest under the current forest management plan through 2055. Although this table refers to productive forests greater than 137.3 cubic meters per hectare (8,000 board feet per acre), at least through 1991 the average stand logged produced more than 714 cubic meters per hectare (41,500 board feet per acre), which might be more important to murrelets than lower volume forests. Table 6 suggests that up to 6.5 percent of marbled murrelet nesting habitat in the Tongass National Forest may have been logged by 1995 and that up to 31.4 percent of the forest potentially used by marbled murrelets may be logged by 2055. The amount of productive old-growth forest logged or projected to be logged differs greatly by biogeographic province.

Logging of high-volume old-growth forests that has occurred in the Tongass National Forest to date might have caused displacement of breeding marbled murrelets to other nesting habitats, assuming that optimum nesting habitat is not limiting. Under the worst case scenario, where optimal habitat is limiting, logging has potentially reduced the size of the marbled murrelet population by the number of birds that nested in those logged forests or permanently reduced the productivity of those birds. It is impossible to state with any certainty what the impacts have been.

Conservation Status

The status of the marbled murrelet in southeast Alaska is evaluated by asking a series of questions about the species and its habitat. Answers to these questions are used to reach one of three conclusions: (1) populations in southeast Alaska are secure and likely will remain so given current land management practices; (2) populations are in peril (declining or experiencing some demographic trauma) or are likely to be in peril in the future given current land management practices; or (3) we currently have insufficient knowledge to determine the conservation status of the species.

Evidence on Status

Is Marbled Murrelet distribution and abundance declining in southeast Alaska?

Based on various data sources, particularly Agler et al. (1995), marbled murrelets seem to be widely distributed in southeast Alaska. There is no evidence that their at-sea distribution has changed as a result of forest management practices or other human activities such as commercial fishing or pollution. However, there are no comprehensive data to compare with the data of Agler et al. (1995) and there are no monitoring studies of any duration that permit testing of various hypotheses related to changes in distribution.

There also are no data to suggest that marbled murrelets are declining in numbers in southeast Alaska. Agler et al. (1995) estimate that there are more than 600,000 murrelets (*Brachyramphus* spp.) in southeast Alaska, of which at least 90 percent are marbled murrelets. Taking a conservative view, there is confidence that the marbled murrelet population in southeast Alaska numbers at least in the low hundreds of thousands. Trend data from systematic surveys at sea are lacking. Although analysis of CBC data using 5-year running means suggests a possible decline in marbled murrelet numbers, more rigorous statistical analyses of those data do not support the suggestion of a trend, either up or down, in the marbled murrelet population (Hayward 1995).

Although marbled murrelets remain numerous and there are no data to support a negative or positive population trend, I advise a cautious and conservative view of existing data for several reasons. First, other than Agler et al. (1995) only one systematic, repeatable survey has been established from which to assess population trends of marbled murrelets (Lindell 1995a, 1995b) and too few data are available from that survey to draw any conclusions. The design by Agler et al. (1995) is repeatable, but the high cost and effort associated with this survey suggest it will not be repeated frequently. Second, as indicated earlier, large tracts of high-volume old-growth forests have been cut from public and private lands in southeast Alaska. Larger trees are preferred by marbled murrelets for nesting throughout most of their range, and there is no reason to conclude otherwise for southeast Alaska. It seems reasonable to conclude that the number of trees and forest stands suitable for nesting in southeast Alaska has declined in the last few decades because of logging. Third, because adult marbled murrelets have high survivorship and are long lived, there may be a lag between loss of nesting sites and actual declines in population.

Do terrestrial habitats differ in their capacity to support nesting murrelet populations?

Marbled murrelets nest both in trees and on the ground. In some areas of south-central and southwestern Alaska, for example in the Aleutian Islands, marbled murrelets nest exclusively on the ground. In south-central Alaska, marbled murrelets nest in both habitats. From British Columbia south through California, nests have been found only in trees, and ground nesting is not suspected to occur or is not significant. Studies conducted to date suggest that where forests are available, marbled murrelet detections are higher in forested than in nonforested habitats. In southeast Alaska, detections were higher in high-volume old-growth vs. low-volume old-growth forest. In southeast Alaska both ground and tree nesting occur, but the two ground nests that have been found were within productive old-growth forests. Ground nesting is likely more common in the northern areas of southeast Alaska, particularly on previously glaciated terrain near the ocean; e.g., in Glacier Bay and perhaps in alpine areas above treeline. Existing data suggest that more than 20,000 murrelets are found annually at Glacier Bay. Most of these probably are marbled murrelets, and there is little productive old-growth forest found there for nesting. Either many marbled murrelets at Glacier Bay nest on the ground or in smaller trees or they move to the bay from elsewhere to exploit productive marine foraging grounds.

Completed research (e.g., Hamer and Nelson 1995, Naslund et al. 1994) indicates that tree-nesting marbled murrelets prefer uneven-aged, old-growth forest stands with structural heterogeneity and large, relatively tall trees with numerous broad platforms covered with moss. These conditions are typical of the high-volume old-growth forests of southeast Alaska. These studies also suggest that within forest stands, murrelets tend to select older and larger trees. Based on the tree nests found to date, marbled murrelets at Prince William Sound nest in smaller trees than those in southeast Alaska, British Columbia, Washington, Oregon, and California, although they are the biggest trees available. Whether trees of the size class used by marbled murrelets at Prince William Sound are used in southeast Alaska and to what degree is an important focus for future research.

Second-growth forests are used by marbled murrelets to some extent in Oregon (McAllister 1996b), but it is unknown if these forests are used by marbled murrelets in Alaska.

From a landscape perspective, marbled murrelets seem to prefer low-elevation forests close to the coast. In south-central Alaska, the heads of bays may be important nesting locations. Streams and rivers may be important movement corridors to and from nest sites.

Are food or other factors in the marine system limiting to marbled murrelets in southeast Alaska?

No data suggest that factors relating to food production and the marine environment are limiting to marbled murrelets in southeast Alaska; however, little is known of the marine system on which marbled murrelets rely. Elsewhere, changes in marine food webs have had profound impacts on seabird populations (Piatt and Anderson 1996) and such changes may be responsible for the decline of this species at Prince William Sound. Little is known of the migration of marbled murrelets and whether the winter environment is limiting.

Murrelet mortality in salmon gillnets has been shown to be locally important to marbled murrelets in Alaska (Wynne et al. 1991, 1992). In southeast Alaska, however, quantitative information on murrelet mortality is lacking, although several areas of likely conflict at sea have been identified (Carter et al. 1995).

Do the life history and ecology of the marbled murrelet suggest that the southeast Alaska population is vulnerable to habitat change or other changes in the environment?

The life history and ecology of the marbled murrelet make it vulnerable to habitat change in southeast Alaska. The apparent reliance of this species on structurally complex old-growth forests for nesting suggests that it is extremely vulnerable to logging of the most economically valuable coniferous forests. Its reliance on nearshore marine habitats, in concert with its high vulnerability, places it at risk from oil spills.

If marbled murrelets select particular terrestrial or marine habitats, are these habitats declining or being stressed by humans?

As stated throughout this paper, habitat data for marbled murrelets in southeast Alaska are minimal. However, I believe mature, structurally heterogeneous forests with large old trees are vital as nesting habitat for this species throughout most of southeast Alaska. Stands of high-volume old-growth forests will continue to decline in southeast Alaska as logging continues on public and private lands. By 1995, nearly 21 percent of the forest in one biogeographic province had been logged, and this is expected to increase to more than 66 percent by 2055 under current forest management practices. The loss of nesting habitat for marbled murrelets will be exacerbated by the short management rotation in place in timber-producing forests of the Tongass. Such a short rotation precludes reestablishment of trees considered suitable for nesting. In addition, fragmentation of forests will continue to occur, perhaps exacerbating the effects of predation.

Little also is known about marine habitats used by marbled murrelets. Gillnet operations in some areas may have a local impact on murrelet populations. Chronic pollution also may have a highly local effect on murrelets. There is, however, no evidence at this time that murrelets in marine habitats are stressed by humans, with the exception of certain gillnetting areas.

What is the conservation status of marbled murrelets in southeast Alaska and is a conservation strategy needed?

Current knowledge of the nesting distribution and habitat requirements for marbled murrelets in southeast Alaska is incomplete and remains the most critical information gap for this species. Information from other forested parts of its range outside Alaska indicate that marbled murrelets are extremely sensitive to losses of high-volume, old-growth stands of coniferous forests and could be in peril from forest management practices on public and private lands. Based on marine surveys, marbled murrelets currently are abundant and seem to be broadly distributed throughout southeast Alaska during the breeding season. In the short term (i.e., decades), risks to the persistence of the marbled murrelet population in southeast Alaska seem low. In the long term (i.e., 100+ years), under current forest management practices (USDA Forest Service 1979), I believe gaps in the nesting distribution will be evident in the biogeographic provinces that continue to be extensively logged.

In the face of considerable uncertainty concerning this species in southeast Alaska, and evidence from California, Oregon, Washington, and British Columbia that logging of coastal coniferous forests is responsible for large population declines, a conservation strategy that considers the habitat needs of marbled murrelets, particularly in those biogeographical provinces scheduled to be extensively logged, would reduce the risk to maintaining well-distributed populations. It is important to address this issue while marbled murrelets are abundant and before more costly management actions are required. Current knowledge is insufficient to determine the details of such a strategy.

Given the lack of information on this species in southeast Alaska, it is important that Tongass forest management and any conservation strategy for marbled murrelets be adaptive in nature, so that increased knowledge can be responded to quickly. A long-term research program for this species in southeast Alaska, jointly designed and funded by the USDA Forest Service, U.S. Fish and Wildlife Service, and Alaska Department of Fish and Game, could quickly enhance the knowledge base for this species. Within a decade, sufficient information on habitat relations, distribution and abundance, and population trends could be gathered to assist with the design of a conservation strategy for this species, or to quantitatively evaluate one based on other species.

Results of the Viability Risk Assessment Panel

On 5-6 December 1995, the USDA Forest Service convened a panel of murrelet specialists to evaluate each alternative being considered in the revision of the Tongass land management plan (TLMP) for its relative likelihood of maintaining viable population levels of marbled murrelets in the Tongass (Smith and Shaw 1996). According to implementation regulations for the National Forest Management Act (NFMA), a viable population shall be regarded as "one which has the estimated numbers and distribution of reproductive individuals to insure its continued existence is well distributed in the planning area." Nine alternatives to TLMP were evaluated (USDA Forest Service 1996). These alternatives differed in the amount of resource protection they offered, and in the level of timber harvest from alternative 1, which emphasized resource protection with little timber harvest and forest uses and opportunities associated with undeveloped settings, to alternative 7, which emphasized providing a supply of timber from the Tongass National Forest intended to meet southeast Alaska timber industry demand. In general, those alternatives emphasizing lower levels of timber harvest contained varying combinations of uneven-aged management, longer stand rotations, greater numbers of set-asides (old-growth reserves, research natural areas, special interest areas, wild, scenic and recreational rivers), and wider and more restrictive estuarine and riparian buffers. Important features of each alternative are included below, but for a detailed discussion of the nine alternatives evaluated in the draft Tongass land management plan see USDA Forest Service (1996).

Alternative 1—All areas identified by the public as deserving of protection are protected; uneven-aged management with 200-year rotation; moderately restrictive riparian management; 305-meter (1,000-foot) beach and estuary corridors.

Alternative 2—Even-aged management with 100-year rotation; least restrictive riparian management; 153-meter (500-foot) beach corridor and 305-meter (1,000-foot) estuary corridor.

Alternative 3—Large, medium, and small old-growth reserves; two-aged management with 100-year rotation; most restrictive riparian management applied to watersheds with highest fisheries values; 305-meter (1,000-foot) beach and estuary corridors.

Alternative 4—Two-aged and uneven-aged management with 200-year rotation; old-growth retention at watershed level; moderately restrictive riparian management applied to watersheds with highest fisheries values; 305-meter (1,000-foot) beach and estuary corridors.

Table 7—Average viability risk assessment ratings for the marbled murrelet in southeast Alaska and projected cut of old-growth by TLMP alternative

	Outcome					
Alternative	1	2	3	4	5	Proj. cut[a]
1	85	15	0	0	0	<100,000
2	18	34	40	9	0	1,106,670
3	41	40	19	0	0	735,800
4	36	38	24	3	0	618,060
5	45	46	6	3	0	572,300
6	26	33	36	5	0	953,900
7	10	20	45	23	3	1,556,900
8	25	38	31	6	0	955,460
9	16	29	38	18	0	1,402,800

[a] Projected cut out 100 years (2095) in acres of productive old-growth.

Alternative 5—Large, medium, and small old-growth reserves in four biogeographic provinces with high level of cut; two-aged and uneven-aged management with 200-year rotation; old-growth retention at watershed level; moderately restrictive riparian management applied to watersheds with highest fisheries values; 305-meter (1,000-foot) beach and estuary corridors.

Alternative 6—Large, medium, and small old-growth reserves in four biogeographic provinces with high level of cut; two-aged and uneven-aged management with 100-year rotation; old-growth retention at watershed level; moderately restrictive riparian management applied to watersheds with highest fisheries values; 305-meter (1,000-foot) beach and estuary corridors.

Alternative 7—Even-aged management with 100-year rotation; least restrictive riparian management; no beach and estuary corridors.

Alternative 8—Large, medium, and small old-growth reserves; two-aged management with 100-year rotation; moderately restrictive riparian management applied to watersheds with highest fisheries values; 305-meter (1,000-foot) beach and estuary corridors.

Alternative 9—Even-aged management with 100-year rotation; retention of key old-growth forest habitat is provided; riparian management follows Best Management Practices; no beach and estuary corridors.

Each panelist assessed the level of risk by assigning 100 “likelihood” points across projected outcomes for each alternative. The planning period under consideration was 100 years. Allocation of all 100 points to a single outcome expressed complete certainty in that outcome. Uncertainty was expressed by spreading points among the outcomes. The five outcomes considered by the panelists were:

1. Habitat is of sufficient quality, distribution, and abundance to allow the species to maintain breeding populations distributed across the Tongass National Forest.

2. Habitat is of sufficient quality, distribution, and abundance to allow the species to maintain breeding populations distributed across the Tongass National Forest. Some local populations are more ephemeral, however, because of reduced population levels and increased susceptibility to environmental extremes and stochastic events associated with reduced habitat abundance and distribution.

3. Habitat is of sufficient quality, distribution, and abundance to allow the species to maintain some breeding populations, but with significant gaps in the historic distribution in the Forest. These gaps are likely permanent and will result in some limitation of interactions among local populations.

4. Habitat allows continued species existence only in refugia, with strong limitations on interactions among local populations.

5. Habitat conditions result in species extirpation from Federal land.

Average panel ratings appear in table 7. In general, the panelists' ratings were closely related to the amount of old growth projected to be cut over the next 100 years. Alternative 1 had the lowest projected cut and had far more points assigned to outcome 1 than any other alternative. Conversely, alternative 7 with the highest projected cut had 70 percent of its likelihood points assigned to outcomes 3 to 5. If the likelihood points in outcomes 1 and 2 (the outcomes that I believe meet the definition of "well distributed" under NFMA) are summed, then four groupings become apparent. Alternative 1 stands by itself with 100 percent of the likelihood points assigned to outcomes 1 and 2. Alternatives 3 and 5 are next best in terms of viability with over 80 percent of their likelihood points in outcomes 1 and 2. Alternatives 2, 4, 6, and 8 fall out next with greater than 50 percent of their likelihood points assigned to outcomes above 2.

Lastly, alternatives 7 and 9 were rated by the panelists as having the lowest likelihood of maintaining well-distributed marbled murrelet populations in the Tongass National Forest. For all alternatives, panelists assigned few likelihood points to outcomes 4 and 5, which are the least desirable conservation perspectives. In terms of viability of marbled murrelets across the Tongass National Forest, alternatives 1, 3, and 5 were determined to pose the least risk to maintaining a well-distributed population. Features of those alternatives that likely contributed to their higher scores, in addition to lower levels of projected cut compared to other alternatives, include uneven-aged or two-aged management with extended rotations, establishment of old-growth habitat reserves, application of restrictive riparian management, and 305-meter (1,000-foot) beach and estuary corridors.

It also should be noted that the panelists unanimously assumed that old-growth forests were the most important nesting habitat for marbled murrelets in southeast Alaska. There was no clear agreement, however, among the panelists on what constituted a well-distributed population. One panelist believed that even if there were large gaps in the nesting distribution of marbled murrelets within a biogeographic province, as long as the birds still nested in every biogeographic province, the population was well distributed. This consideration may contribute to the relatively high viability "scores" given to marbled murrelets compared to other species for which risk assessment panels were conducted (USDA Forest Service 1996).

Management Considerations and Conservation Strategies

Management Considerations

The NFMA and implementing regulations direct the USDA Forest Service to provide wildlife habitats capable of maintaining viable wildlife populations of existing native and desired nonnative vertebrate species across the National Forests. A viable population is defined by the Forest Service as one having the estimated numbers and distribution of reproductive individuals to ensure its continued existence and one that is well distributed within its normal range throughout a National Forest.

The marbled murrelet seems to be broadly distributed throughout southeast Alaska during the breeding season (Agler et al. 1995). Nearly 385 000 hectares (950,000 acres) of old-growth forest in southeast Alaska, most of it higher volume old-growth forest, has been logged and converted to early seral stage forests (Iverson et al. 1996). Marbled murrelets are still numerous, but current estimates of habitat conversion from old growth to early seral stage forests of over 20 percent in at least one biogeographic province, and harvest projections through 2055 from 30 percent to over 60 percent in several biogeographic provinces, suggest that nesting habitat has declined and will decline further under current forest management practices. Under current Tongass plan direction that emphasizes timber production, it is unlikely that regeneration of old-growth forest conditions suitable for marbled murrelets will develop in harvested areas.

The marbled murrelet is somewhat unique among old-growth-associated species in southeast Alaska. For nesting it uses primarily old-growth forest and is present in forested habitats throughout the year except during the prebasic molt. It does not forage in forests, however, and presumably does not require large forest home ranges as do other terrestrial species (Ralph et al. 1995a).

A low-risk conservation strategy for marbled murrelets would be one that results in a well-distributed spatial distribution of their nesting habitat across southeast Alaska. Given our incomplete knowledge and understanding of marbled murrelet ecology in southeast Alaska, it is difficult to design a comprehensive strategy that balances the habitat needs of marbled murrelets with the societal needs for timber products and fully meet the requirements of NFMA. It is possible, however, to examine the potential response of marbled murrelets to various forest management prescriptions and to examine potential conservation strategies in light of what we know about this species.

Timber harvest rotation—Timber harvest rotation could markedly affect the probability that marbled murrelets will persist in the Tongass National Forest and maintain a well-distributed, viable population. The current Tongass land management plan directs that an approximate 100-year rotation is applied where commercial timber harvest occurs. Areas where a 100-year rotation is applied will provide little or no nesting habitat for marbled murrelets in the future in the lands managed primarily for timber production. At 100 years of age, regenerated forests are in the stem-exclusion phase with closed canopies, high stem density, and relatively small lateral branches unsuitable for marbled murrelet nests. Beyond 100 years, it is impossible to state with certainty that a regenerated forest of a certain age will possess features suitable for nesting marbled murrelets. Work by Alaback et al. (1982, 1984) predicts how quickly old-growth forest conditions can be reestablished. Factors such as growth rates, erosion, soil fertility, and slope steepness will affect forest regeneration. At 200 years, forests may have some features suitable for marbled murrelet nesting. A 200-year rotation is, however, not expected to provide much nesting habitat before it is logged again. Rotations longer than 200 years have the least risk of negatively impacting marbled murrelet persistence across the Tongass National Forest.

Silvicultural system—This item refers to the type of silvicultural treatment applied to the Forest. One type is uneven-aged management, which includes alternative cutting methods such as group selection or selective cutting. Group selection results in a finer scale mosaic of successional stages across the Forest and likely maintains some nesting habitat for marbled murrelets so long as some scattered patches of old-growth trees are maintained. Extensive fragmentation of old growth using small patch size may result, however, in increased predation of murrelet eggs, chicks, and adults, thereby reducing habitat suitability and productivity. Forest management that employs group selection may maintain nesting habitat, provided sizes of groups are large enough to maintain low predation levels.

Second-growth forests, up to 200 years old, may possess forest characteristics suitable for nesting, and recent research (McAllister 1996b) suggests that second-growth stands of timber in Oregon can be managed to improve its suitability for nesting murrelets. Research is needed on minimum forest stand size suitable for supporting successfully nesting murrelets and forest management that can be done to improve the suitability for nesting of second-growth forest habitat.

Single-tree selection, lightly applied, might maintain high-value nesting habitat so long as large, old-growth trees and sufficient habitat characteristics remain. In that event, logging in those areas after the breeding season likely will reduce disturbance of murrelets.

Even-aged short rotation is the dominant logging method currently used in the Tongass National Forest. Persistence of marbled murrelet habitat capability across the Forest under even-aged short rotations will depend on the size and distribution of harvested areas.

Two-aged management generally leaves 10 to 20 percent of the trees in a harvested stand. Retention of scattered mature trees likely will accelerate reestablishment of suitable forest conditions for murrelets, provided the rotation is of sufficient length to reestablish forest stands with old-growth characteristics. In addition, marbled murrelets likely would not reoccupy the clearcut portion of the stand until the regenerating forest attained old-growth characteristics. If the residual 10 to 20 percent of the trees were left in a block, then some marbled murrelets might remain to nest, especially if the residual block was adjacent to old-growth forest undisturbed by timber harvest.

Conservation Strategies

Nest buffers—Because nests of marbled murrelets are difficult to find, it is unlikely many would be found in a timber sale area before or during logging. A conservation strategy emphasizing buffers around nests therefore is unlikely to be an effective strategy. It is also uncertain what size of buffer will provide adequate protection for any murrelet nests.

Habitat reserves—Given the uncertainity of what marbled murrelets need for nesting habitat, old-growth forest reserves appear to be a conservation strategy that would reduce risk to nesting murrelets across the forested landscape of southeast Alaska. Factors important to consider in the design of reserves, in addition to location (which includes variables such as elevation and distance from the coast), include size, shape, slope, and the presence of streams and rivers. Marbled murrelets have been discovered nesting in forest stands as small as 3 hectares (7.4 acres; Nelson and

Hamer 1995b); however, smaller stands having a greater proportion of edge may have higher rates of nest predation. Thus stand size may have a great influence on nesting habitat quality. Marbled murrelets also may be prone to disturbance such that buffers around forest stands may be appropriate. Size of reserves in the Tongass also will be influenced by the kinds of natural disturbance regimes that influence forest conditions. For example, windthrow and slope slippage are major forms of disturbance in forested areas in southeast Alaska. Reserves must be large enough, or numerous enough, so that stochastic events do not result in the disappearance of murrelet nesting habitat conditions from specific stands or areas. Shape of reserves also may be important; a circular shape will minimize edge effects and could enhance habitat quality. Slope and the presence of rivers and streams may influence murrelet access to forest stands for nesting. Moderate slopes may enhance access to the interior of forest stands as a result of creating more heterogeneity in canopy levels. Rivers and streams may be used by murrelets as flyways into interior old-growth nesting stands and facilitate the movement of fledglings to sea.

The types of activities allowed in old-growth forest habitat reserves also may influence their suitability for marbled murrelets. Potentially, some type of selective cutting could be allowed in some reserves. Effects will depend mainly on the sensitivity of murrelets to disturbance, the intensity of the harvest regime, and the amount of change in the stand conditions.

Old-growth retention in value comparison units (VCUs)—Old-growth retention within larger areas could greatly influence the value of VCUs to marbled murrelets. If designed properly, old-growth retention in combination with habitat reserves and estuary, beach, and riparian buffers could increase the probability of marbled murrelet persistence across the forest.

Estuary, beach, and riparian buffers—Buffers around estuaries and along beaches and streams presumably would protect some marbled murrelet nesting habitat. Benefits to marbled murrelets may depend on the width of these buffers and how they are applied. For example, a beach buffer of 153 meters (500 feet) with an additional 153 meters where some uneven-aged management would be allowed likely would provide more marbled murrelet nesting habitat than just a 153-meter buffer. How the buffers are applied also will influence their benefit to marbled murrelets. For example, a 153-meter horizontal buffer likely would provide better habitat for marbled murrelets than a 153-meter upslope buffer. Under the latter application, the horizontal width of the buffer is much less than 153 meters, depending on the slope.

It is uncertain how suitable linear buffers are for nesting. Linear buffers will result in increased edge, potentially resulting in increased predation of marbled murrelets. Buffers along streams could be important for juvenile marbled murrelets, if the buffers protect habitat used during their fledgling migration to sea.

Dynamic landscape equilibrium—For some species, management strategies not employing habitat reserves, but providing suitable habitat everywhere across the Forest through uneven-aged silvicultural prescriptions or extended rotations, may result in a higher probability of persistence. This approach may be especially suited to species that use areas encompassing a mosaic of forest cover types and specific habitats not at risk from timber harvesting.

It is unclear if this strategy will increase the probability of marbled murrelets persisting across the forest. Marbled murrelets seem to rely on higher volume old-growth forests. Other habitats, including various types of low-volume forests and second-growth forests do not seem as important for murrelet nesting. It is unclear how marbled murrelets will respond to uneven-aged silvicultural treatments and longer forest rotations, as discussed earlier.

As silvicultural treatments are applied to a landscape over time, a mosaic of stand structures will develop. The consequences for nesting marbled murrelets will depend on the combinations of treatments, sizes of treatments, and their frequency. Because marbled murrelets probably do not nest in early seral stage forests, most timber harvest prescriptions likely will result in higher risk to murrelet nesting habitat.

Suggested Studies and Management Considerations

Southeast Alaska may well be the geographic center of the marbled murrelets range in North America as well as its population center. Despite the overall importance of southeast Alaska to the welfare of this species in North America, little is known of them from this area. Logging likely will continue on public and private lands in southeast Alaska, steadily increasing risk to nesting murrelets. Although marbled murrelets remain numerous in southeast Alaska, conservation measures taken now could do much to maintain their numbers and distribution into the future, while allowing for harvest of old-growth timber.

Meeting this challenge will require additional information on marbled murrelets, particularly on their terrestrial habitat relations. Research and management opportunities that could meet these information needs are suggested below. In the following section, “high,” “medium,” and “low” refer to relative need.

Monitor population trend and abundance:

1. Evaluate accuracy, precision, design, and necessary sampling effort for various boat-survey techniques for broader application in southeast Alaska. (High)

2. Evaluate accuracy and precision of aerial-survey techniques for broader application in southeast Alaska. (High)

3. After completing 1 and 2 above, develop a long-term, at-sea, population monitoring strategy in southeast Alaska using boat-based or aerial survey methods, or both. (High)

Managers also could consider establishing annual monitoring surveys in discrete areas in southeast Alaska to assess the impacts of future logging on at-sea murrelet populations. In addition, monitoring the southeast Alaska-wide murrelet population periodically through repeated small-boat surveys given the methods established by Agler et al. (1995) would be beneficial.

4. Evaluate flyway counts as a monitoring tool in Icy Strait. (High)

Marbled murrelets are known to undertake daily movements from nesting areas to areas with predictable food resources. Systematic counts along these flyways may provide an alternative tool for monitoring marbled murrelet populations.

5. Conduct a southeast Alaska-wide, winter, small-boat survey of murrelets for comparison with the 1996 aerial survey. (Medium)

Marbled murrelets visit forest nesting stands throughout winter. The local population in winter may be more reflective of the breeding population than that during summer. A winter survey also would fill a large gap in the current knowledge of seasonal murrelet distribution in southeast Alaska.

6. Conduct annual and seasonal dawn-watch surveys for murrelets at multiple terrestrial sites in southeast Alaska. (Medium)

In addition to monitoring murrelets in their marine environment, it would be useful to monitor birds in their terrestrial environment. Dawn watches conducted at forested sites by using established procedures (see Kuletz et al. 1995b) could be used to locate key nesting areas. These data could help address questions on causes of local population fluctuations. Replication of these surveys across an array of different, randomly selected forest conditions would greatly expand information on murrelet use of terrestrial environments.

7. Conduct opportunistic dawn surveys at terrestrial sites in southeast Alaska and incorporate into a GIS. (Medium)

Anecdotal but systematically collected data on marbled murrelet terrestrial activity may, over the long term, provide an overview of important nesting areas for murrelets in southeast Alaska and information on habitat relations, provided that concurrent habitat data are collected.

Determine terrestrial habitat relations:

1. Determine terrestrial habitat relations of marbled murrelets by using a random stratified design across habitat types with numbers of detections as the dependent variable. Base the sampling design and size on number of habitat types surveyed and number of samples per habitat type. (High)

Lack of terrestrial habitat data remains the biggest data gap for murrelets in southeast Alaska. This study is important to implement as soon as feasible.

2. Determine nest tree characteristics and forest habitat characteristics by finding marbled murrelet nests. (High)

There are few nest data for marbled murrelets in southeast Alaska. This information gap needs to be addressed as soon as it is feasible.

3. Determine nest tree, nest tree habitat, and marine habitat characteristics by marking marbled murrelets with radio-telemetry equipment. (High)

A combination of nest-finding techniques could be used to accomplish objectives 2 and 3.

4. Determine habitat quality by measuring production of fledglings across murrelet nesting habitats. (Low)

This study is a multiyear effort because it is unlikely that sufficient nests could be found or monitored during one year.

Investigate life history, demography, mortality factors, and monitor productivity:

1. Develop a productivity index and annually monitor productivity of murrelets by counting hatching-year and after hatching-year birds at sea during and following fledging from selected sites. (High)

This technique is being developed in Prince William Sound and in California; it holds promise as an alternative method for monitoring productivity. With sufficient data, it may be possible to link productivity to upland or marine habitat features.

2. Investigate incidental deaths of marbled murrelets in salmon gillnet fishery in southeast Alaska. (Medium)

Salmon gillnets have been identified as a potentially important source of mortality for marbled murrelets in southeast Alaska. No data exist for the impact of salmon gillnet fisheries on marbled murrelets in that area.

3. Monitor nests for life history information. (Medium)

As nests are discovered during other studies and nest-monitoring methods improve, data can be collected on life history and production.

Evaluate the effects of various forest management prescriptions on marbled murrelets:

1. Investigate the persistence of marbled murrelets nesting in stands harvested under various cutting methods and intensities (e.g., clearcuts, selective cuts, shelterwood). (Medium)

This study can evaluate forest management prescriptions (provided they are used) and the effects on the persistence of murrelets.

2. Evaluate the effects of patch or stand size on marbled murrelet detections. (High)

Several studies suggest that marbled murrelets nest in loose aggregations. This study could be of considerable importance in establishing the minimum acceptable size of old-growth reserves or other habitat conservation areas and evaluating the effects of various patch sizes in an uneven-aged forest management regime.

3. Evaluate the influence of increased forest edge on numbers of avian murrelet predators. (Low)

This study would examine the effects of clearcutting with its attendant increase in forest edge, which may result in increases in avian predators and increased access by avian predators to forest stands with nesting murrelets. It also would examine the role of clearcutting in the dynamics of marbled murrelet predators, such as ravens, crows, and jays.

4. Design studies to evaluate the importance of estuary, beach, and riparian fringe habitat for marbled murrelets. (High)

Estuary, beach, and riparian management areas are likely to be established as part of a conservation strategy for old-growth-associated species. It is important to evaluate the importance of these habitats for marbled murrelets both before and after logging.

I suggest the following important management considerations in addressing long-term conservation of the marbled murrelet in southeast Alaska. Initiating this work in southeast Alaska in fiscal year 1997 would be highly beneficial:

- Convene a meeting of interested personnel from the U.S. Fish and Wildlife Service, USDA Forest Service, U.S. Geological Survey—Biological Resources Division, and Alaska Department of Fish and Game to begin development of a long-term research and monitoring plan for marbled murrelets in southeast Alaska.
- Evaluate survey methods, develop a long-term population monitoring plan, and implement the plan.
- Determine terrestrial habitat relations of marbled murrelets through a random stratified design.
- Find marbled murrelet nests by using techniques of Naslund et al. (1994), or if funds are available, radio telemetry. If possible, monitor nests for productivity.

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References

Agler, B.A. 1996. Personal communication. Wildlife biologist, U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503.

Agler, B.A.; Kendall, S.J.; Seiser, P.E. 1994. Estimates of marine bird and sea otter populations in Lower Cook Inlet, Alaska, during June 1993. Report. 73 p. On file with: U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503.

Agler, B.A.; Kendall, S.J.; Seiser, P.E.; Lindell, J. 1995. Estimates of marine bird and sea otter abundance in southeast Alaska during summer 1994. Report. 46 p. On file with: U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK.

Agler, B.A.; Kendall, S.J.; Seiser, P.E.; Irons, D.B. [Ms. in prep.]. Distribution and abundance of *Brachyramphus* murrelets (marbled and Kittlitz's) in south-central and southeast Alaska. Senior author may be reached at U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503.

Ainley, D.G.; Allen, S.G.; Spear, L.B. 1995. Offshore occurrence patterns of marbled murrelets in central California. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 361-369.

Alaback, P.B. 1982. Dynamics of understory biomass in Sitka spruce-western hemlock forests of southeast Alaska. Ecology. 63: 1932-1948.

Alaback, P.B. 1984. Plant succession following logging in the Sitka spruce-western hemlock forests of southeast Alaska: implications of management. Gen. Tech. Rep. PNW-GTR-173. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Anderson, P.J.; Payne, S.A.; Johnson, B.A. 1994. Multi-species dynamics and changes in community structure in Pavlof Bay, Alaska. Report. 26 p. On file with: National Marine Fisheries Service, Kodiak, AK 99615.

Bailey, E.P. 1977. Distribution and abundance of marine birds and mammals along the south side of the Kenai Peninsula, Alaska. Murrelet. 58: 58-72.

Beissinger, S.R. 1995. Population trends of the marbled murrelet projected from demographic analyses. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 385-393.

Bishop, M.A. 1995. Personal communication. Wildlife biologist, U.S. Department of Agriculture, Forest Service, Cordova Ranger District, P.O. Box 280, Cordova, AK 99574.

Bock, C.E.; Root, T.L. 1981. The Christmas bird count and avian ecology. Studies in Avian Biology. 6: 17-23.

Brown, M. 1995a. Personal communication. Wildlife biologist, U.S. Department of Agriculture, Forest Service, Ketchikan Ranger District, 3031 Tongass Ave., Ketchikan, AK 99901.

Brown, M. 1995b. Unpublished data. Wildlife biologist, U.S. Department of Agriculture, Forest Service, Ketchikan Ranger District, 3031 Tongass Ave., Ketchikan, AK 99901.

Brown, M.; Doerr, J.; Walsh, P. [and others]. [Ms. in prep.]. Seasonal activity of marbled murrelets in forest stands in southeast Alaska. Senior author may be reached at: U.S. Department of Agriculture, Forest Service, Ketchikan Ranger District, 3031 Tongass Ave., Ketchikan, AK 99901.

Burger, A.E. 1995. Inland habitat associations of marbled murrelets in British Columbia. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 295-312.

Burkett, E.E. 1995. Marbled murrelet food habits and prey ecology. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 223-246.

Burn, D. 1995. Personal communication. Wildlife biologist, U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503.

Capp, J.; Van Zee, B.; Alaback, P. [and others]. 1992a. Ecological definitions of old-growth forest types in southcentral Alaska. R10-TP-28. Juneau, AK: U.S. Department of Agriculture, Forest Service, Alaska Region. 30 p.

Capp, J.; Van Zee, B.; Alaback, P. [and others]. 1992b. Ecological definitions of old-growth forest types in southeast Alaska. R10-TP-28. Juneau, AK: U.S. Department of Agriculture, Forest Service, Alaska Region. 56 p.

Carlson, H.R. 1995a. Consistent yearly appearance of age-0 walleye pollock, *Theragra chalcogramma*, at a coastal site in southeastern Alaska, 1973-1994. Fishery Bulletin. 93: 386-390.

Carlson, H.R. 1995b. Personal communication. Fisheries scientist, National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Highway, Juneau, AK 99801.

Carlson, H.R.; Haight, R.E.; Krieger, K.J. 1982. Species composition and relative abundance of demersal marine life in waters of southeastern Alaska, 1969-1981. NWAFC Processed Rep. 82-16. Auke Bay, AK: U.S. Department of Commerce, National Marine Fisheries Service. 106 p.

Carter, H.R. 1984. At-sea biology of the marbled murrelet (*Brachyramphus marmoratus*) in Barkley Sound, British Columbia. Winnepeg, MB: University of Manitoba. 143 p. M.S. thesis.

Carter, H.R.; Kuletz, K.J. 1995. Mortality of marbled murrelets due to oil pollution in North America. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 261-270.

Carter, H.R.; McAllister, M.L.C.; Isleib, M.E. "Pete." 1995. Mortality of marbled murrelets in gill nets in North America. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 271-283.

Carter, H.R.; Sealy, S.G. 1984. Marbled murrelet (*Brachyramphus marmoratus*) mortality due to gill-net fishing in Barkley Sound, British Columbia. In: Nettleship, D.N.; Sanger, G.A.; Springer, P.F., eds. Marine birds: their feeding ecology and commercial fisheries relationships. Spec. Publ. Ottawa, ON: Canadian Wildlife Service: 212-220.

Carter, H.R.; Stein, J.L. 1995. Molts and plumages in the annual cycle of the marbled murrelet. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 99-109.

Conant, B. 1991. Marbled murrelet population estimate for southeast Alaska. Report. 3 p. On file with: U.S. Fish and Wildlife Service, 3000 Vintage Park Boulevard, Juneau, AK 99801.

Conant, B. 1996. Population estimates for waterbirds wintering in southeast Alaska. Report. 9 p. On file with: U.S. Fish and Wildlife Service, 3000 Vintage Park Boulevard, Juneau, AK 99801.

Day, R.H.; Oakley, K.O.; Barnard, D.R. 1983. Nest sites and eggs of Kittlitz's and marbled murrelets. Condor. 85: 265-273.

DeGange, A.R.; Day, R.H.; Takekawa, J.A.; Mendenhall, V.M. 1993. Losses of seabirds in gill nets in the North Pacific. In: Vermeer, K.; Briggs, K.T.; Morgan, K.H., Siegel-Causey, D., eds. The status, ecology and conservation of marine birds of the North Pacific. Spec. Publ. Ottawa, ON: Canadian Wildlife Service: 204-211.

DeGange, A.R.; Sanger, G.A. 1986. Marine birds of the Gulf of Alaska. In: Hood, D.W.; Zimmerman, S.T., eds. The Gulf of Alaska: physical environment and biological resources. Washington, DC: U.S. Department of Commerce, National Oceanic and Atmospheric Administration; Mineral Management Service: 479-524.

DeSanto, T.L. 1996. Unpublished data. On file with: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 2770 Sherwood Lane, Juneau, AK 99801.

DeSanto, T.L.; Nelson, S.K. 1995. Comparative reproductive ecology of the auks (family Alcidae) with emphasis on the marbled murrelet. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 33-47.

Divoky, G.J.; Horton, M. 1995. Breeding and natal dispersal, nest habitat loss and implications for marbled murrelet populations. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 83-87.

Doerr, J.G.; Walsh, P.R. 1994. Seasonal activity patterns of marbled murrelets at an inland site on Mitkof Island, southeast Alaska. Report. 12 p. On file with: U.S. Department of Agriculture, Forest Service, Petersburg Ranger District, P.O. Box 1328, Petersburg, AK 99833.

Duncan, T.; Climo, L. 1991. Beardslee Island bird and mammal survey. Report. 14 p. On file with: Glacier Bay National Park and Preserve, Gustavus, AK 99826.

Falk, J. 1995. Unpublished data. On file with: U.S. Department of Agriculture, Forest Service, Juneau Ranger District, 8465 Old Dairy Road, Juneau, AK 99801.

Ford, C.; Brown, M. 1995. Unusual marbled murrelet nest. Wilson Bulletin. 107: 178-179.

Gabrielson, I.N.; Lincoln, F.C. 1959. The birds of Alaska. Washington, DC: Wildlife Management Institute. 922 p.

Gould, P.J.; Forsell, D.J. 1989. Techniques for shipboard surveys of marine birds. Tech. Rep. 25. Washington, DC: U.S. Fish and Wildlife Service.

Gracz, M. 1994. Ground nesting marbled murrelet on Ushagat Island. Report. On file with: U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503 or P.O. Box 15301, Fritz Creek, AK 99603.

Grenier, J.J.; Nelson, S.K. 1995. Marbled murrelet habitat associations in Oregon. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 191-204.

Hamer, T.E. 1995. Inland habitat associations of marbled murrelets in western Washington. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 163-175.

Hamer, T.E.; Nelson, S.K. 1995. Characteristics of marbled murrelet nest trees and nesting stands. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 69-87.

Harke, V.L.; Lucey, W.G 1995. Surveys for marbled murrelets on the Yakutat Ranger District. Report. 8 p. On file with: U.S. Department of Agriculture, Forest Service, Yakutat Ranger District, P.O. Box 327, Yakutat, AK 99689.

Hatch, S.A.; Byrd, G.V.; Irons, D.B.; Hunt, G.L., Jr. 1991. Status and ecology of kittiwakes (*Rissa tridactyla* and *R. brevirostris*) in the North Pacific. In: Vermeer, K.; Briggs, K.T.; Morgan, K.H.; Siegel-Causey, D., eds. The status, ecology and conservation of marine birds of the North Pacific. Spec. Publ. Ottawa, ON: Canadian Wildlife Service: 140-153.

Hayward, G.D. 1995. Examination in trend of marbled murrelets in southeast Alaska based on Christmas bird counts. Report. 9 p. On file with: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Laramie, WY 82007.

Hirsch, K.V.; Woodby, D.A.; Astheimer, L.B. 1981. Growth of a nestling marbled murrelet. Condor. 83: 264-265.

Hoeman, J.V. 1965. Marbled murrelet breeding record from Kodiak. Bulletin of the Alaska Ornithological Society. 5: 9.

Hughes, J. 1995. Personal communication. Wildlife biologist, Alaska Department of Fish and Game, Department of Wildlife Conservation, 333 Raspberry Road, Anchorage, AK 99518.

Hunt, G.L., Jr. 1995. Oceanographic processes and marine productivity in waters offshore of marbled murrelet breeding habitat. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 219-222.

Iverson, G.C.; Hayward, G.D.; Titus, K. [and others]. [In press]. Conservation assessment for the northern goshawk in southeast Alaska. Gen. Tech. Rep. PNW-GTR-387. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 101 p. (Shaw, Charles G., III, tech. coord.; Conservation and resource assessments for the Tongass land management plan revision).

Jones, R.D., Jr. 1995. Personal communication. Wildlife biologist (retired), Eagle River, AK 99577.

Julin, K.R.; Caouette, J.P. [In prep.]. Options for defining timber volume classes: a resource assessment. In: Shaw, C.G., III; Julin, K.R., tech. coords. Conservation and resource assessments for the Tongass land management plan revision. Gen. Tech. Rep. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Kendall, S.J. 1995. Personal communication. Wildlife biologist, U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503.

King, J. 1991. Unpublished data. On file with: 1700 Branta Rd., Juneau, AK 99801.

King, J.R.; Sanger, G.A. 1979. Oil vulnerability index for marine oriented birds. In: Bartonek, J.C.; Nettleship, D.N., eds. Conservation of marine birds of northern North America. Wildl. Res. Rep. 11. Washington, DC: U.S. Fish and Wildlife Service: 227-239.

Klosiewski, S.P.; Laing, K.K. 1994. Marine bird populations of Prince William Sound, Alaska, before and after the Exxon Valdez oil spill. Report. 88 p. On file with: U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503.

Konyukhov, N.B.; Kitaysky, A.S. 1995. The Asian race of the marbled murrelet. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 23-29.

Krasnow, L.D.; Sanger, G.A. 1982. Feeding ecology of marine birds in the nearshore waters of Kodiak Island. Anchorage, AK: National Oceanic and Atmospheric Administration; Outer Continental Shelf Environmental Assessment Program; final reports of principal investigators; vol. 45: 505-630.

Kuletz, K.J. 1995a. Personal communication. Wildlife biologist, U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503.

Kuletz, K.J. 1995b. Unpublished data. On file with: U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503.

Kuletz, K.J. 1996. Marbled murrelet abundance and breeding activity at Naked Island, Prince William Sound, and Kachemak Bay, Alaska before and after the Exxon Valdez oil spill. In: Rice, S.D.; Spies, R.B.; Wolfe, D.A.; Wright, B.A., eds. Exxon Valdez oil spill symposium proceedings.; 1993 February 2-5; Anchorage, AK. American Fisheries Society Symposium. 18: 770-784.

Kuletz, K.J.; Marks, D.K.; Naslund, N.L. [and others]. 1994a. Information needs for habitat protection: marbled murrelet habitat identification. Anchorage, AK: U.S. Fish and Wildlife Service; Exxon Valdez oil spill restoration project; final report; project 93051-B.

Kuletz, K.J.; Naslund, N.L.; Marks, D.K. 1994b. Identification of marbled murrelet nesting habitat in the Exxon Valdez oil spill zone. Anchorage, AK: U.S. Fish and Wildlife Service; Exxon Valdez oil spill restoration report; restoration project R15.

Kuletz, K.J.; Marks, D.K.; Naslund, N.L. 1994c. At-sea abundance and distribution of marbled murrelets in the Naked Island area, Prince William Sound, Alaska, in summer 1991 and 1992. Anchorage, AK: U.S. Fish and Wildlife Service; Exxon Valdez oil spill restoration project final report; project R15.

Kuletz, K.J.; Marks, D.K.; Naslund, N.L.; Goodson, N.J.; Cody, M.B. 1995a. Inland habitat suitability for the marbled murrelet in southcentral Alaska. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 141-149.

Kuletz, K.J.; Marks, D.K.; Burns, R.; Prestash, L.; Flint, D. 1995b. Marbled murrelet foraging patterns in Prince William Sound, Alaska. Anchorage, AK: U.S. Fish and Wildlife Service; Exxon Valdez oil spill restoration project; final report; project 94102.

Lindell, J. 1995a. Unpublished data. On file with: U.S. Fish and Wildlife Service, Southeast Alaska Ecological Services, 3000 Vintage Park Boulevard, Juneau, AK 99801.

Lindell, J. 1995b. Personal communication. Wildlife biologist, U.S. Fish and Wildlife Service, Southeast Alaska Ecological Services, 3000 Vintage Park Boulevard, Juneau, AK 99801.

MacIntosh, R. 1996. Personal communication. Fishery biologist, 909 Mission Road, Kodiak, AK 99615.

Marks, D.K.; Naslund, N.L. 1994. Predation by a sharp-shinned hawk on a marbled murrelet at its nest. Wilson Bulletin. 106: 565-567.

McAllister, M. 1996a. Unpublished data. On file at: 60069 Morgan Lake Road, La Grande, OR 97850.

McAllister, M. 1996b. Personal communication. Wildlife biologist, 60069 Morgan Lake Road, La Grande, OR 97850.

Mendenhall, V.M. 1992. Distribution, breeding records and conservation problems of the marbled murrelet in Alaska. In: Carter, H.R.; Morrison, M.L., eds. Status and conservation of the marbled murrelet in North America. Proceedings of the Western Foundation Vertebrate Zoology. 5: 5-16.

Mickelson, P. 1996. Personal communication. Wildlife biologist, Box 325, Cordova, AK 99574.

Muir, J. 1995. Personal communication. Fishery biologist, Alaska Department of Fish and Game, Commercial Fisheries Division, P.O. Box 240020, Douglas, AK 99824.

Naslund, N.L. 1993. Why do marbled murrelets attend old-growth forest nesting areas year round? Auk. 110: 594-602.

Naslund, N.L.; Kuletz, K.J.; Cody, M.B.; Marks, D.K. 1994. Tree and habitat characteristics and reproductive success of marbled murrelet tree nests in Alaska. In: Nelson, S.K.; Sealy, S.G., eds. Biology of marbled murrelets: inland and at sea. Northwestern Naturalist. 75(1): 12-25.

Naslund, N.L.; O'Donnell, B.P. 1995. Daily patterns of marbled murrelet activity at inland sites. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 129-134.

Nelson, J.W.; Lehnhausen, W.A. 1983. Marine bird and mammal survey of the outer coast of southeast Alaska, summer 1982. Report. 92 p. On file with: U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503.

Nelson, S.K.; Hamer, T.E. 1995a. Nest success and the effects of predation on marbled murrelets. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 89-97.

Nelson, S.K.; Hamer, T.E. 1995b. Nesting biology and behavior of the marbled murrelet. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 57-67.

Nelson, S.K.; Sealy, S.G. 1994. Biology of marbled murrelets: inland and at sea. Northwestern Naturalist. 75(1). 119 p.

Niebauer, H.J. 1983. Multiyear sea ice variability in the eastern Bering Sea: an update. Journal of Geophysical Research. 88: 2733-2742.

Oakley, K.L.; Kuletz, K.J. 1979. Summer distribution and abundance of marine birds and mammals in the vicinity of Naked Island, Prince William Sound, Alaska, in 1978, and aspects of the reproductive ecology of the Pigeon Guillemot. Report. 95 p. On file with: U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503.

O'Donnell, B.P.; Naslund, N.L.; Ralph, C.J. 1995. Patterns of seasonal variation of activity of marbled murrelets in forested stands. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 117-128.

Paton, P.W.C. 1994. The effect of edge on avian nesting success: how strong is the evidence? Conservation Biology. 8: 17-26.

Paton, P.W.C. 1995. Marbled murrelet inland patterns of activity: defining detections and behavior. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 113-116.

Piatt, J.F. 1995a. Personal communication. Research biologist, National Biological Service, Alaska Science Center, 1011 East Tudor Road, Anchorage, AK 99503.

Piatt, J.F. 1995b. Unpublished data. On file with: National Biological Service, Alaska Science Center, 1011 East Tudor Road, Anchorage, AK 99503.

Piatt, J.F.; Anderson, P. 1996. Response of common murres to the Exxon Valdez oil spill and long-term changes in the Gulf of Alaska marine ecosystem. In: Rice, S.D.; Spies, R.B.; Wolfe, D.A.; Wright, B.A., eds. 1996. Exxon Valdez oil spill symposium proceedings; 1993 February 2-5; Anchorage, AK. American Fisheries Society Symposium 18: 720-737.

Piatt, J.F.; Climo, L.; Springer, A.; Duncan, T. 1991. Marine bird distribution in Glacier Bay National Park during the summer of 1991. Report. 17 p. On file with: National Biological Service, Alaska Science Center, 1011 East Tudor Road, Anchorage, AK 99503.

Piatt, J.F.; Ford, G.R. 1993. Distribution and abundance of marbled murrelets in Alaska. Condor. 95: 662-669.

Piatt, J.F.; Naslund, N.L. 1995. Abundance, distribution, and population status of marbled murrelets in Alaska. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 285-294.

Pitocchelli, J.; Piatt, J.F.; Cronin, M.A. 1995. Morphological and genetic divergence among Alaska populations of *Brachyramphus* murrelets. Wilson Bulletin. 107: 235-250.

Quinlan, S.E.; Hughes, J.H. 1990. Location and description of a marbled murrelet tree nest site in Alaska. Condor. 92: 1068-1073.

Ralph, C.J. 1995. Personal communication. Research biologist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, 1700 Bayview Drive, Arcata, CA 95521.

Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. 1995a. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 420 p.

Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F. 1995b. Ecology and conservation of the marbled murrelet in North America: an overview. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 3-22.

Ralph, C.J.; Long, L.L. 1995. Productivity of marbled murrelets in California from observations of young at sea. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 371-376.

Ralph, C.J.; Miller, S.L. 1995. Offshore population estimates of marbled murrelets in California. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 353-360.

Raphael, M.G.; Young, J.A.; Galleher, B.M. 1995. A landscape-level analysis of marbled murrelet habitat in western Washington. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 177-189.

Rice, W.D.; Spencer, P. 1991. Discovery of a marbled murrelet nest. Report. 1 p. On file with: Kenai Fjords National Park, Seward, AK 99664.

Rodway, M.S.; Carter, H.R.; Sealy, S.G.; Campbell, R.W. 1992. Status of the marbled murrelet in British Columbia. In: Carter, H.R.; Morrison, M.L., eds. Status and conservation of the marbled murrelet in North America. Proceedings Western Foundation Vertebrate Zoology. 5: 17-41.

Royer, T.C. 1993. High-latitude oceanic variability associated with the 18.6-year nodal tide. Journal of Geophysical Research. 98: 4639-4644.

Russell, A. 1996. Unpublished data. On file with: U.S. Department of Agriculture, Forest Service. Thorne Bay Ranger District, P.O. Box 19001, Thorne Bay, AK 99919.

Russell, A.; Walsh, P. 1996. Unpublished data. On file with: U.S. Department of Agriculture, Forest Service. Thorne Bay Ranger District, P.O. Box 19001, Thorne Bay, AK 99919.

Sanger, G.A. 1983. Diets and food web relationships of seabirds in the Gulf of Alaska and adjacent marine regions. Anchorage, AK: National Oceanic and Atmospheric Administration; Outer Continental Shelf Environmental Assessment Program; final reports of principal investigators; vol. 45: 631-771.

Sanger, G.A. 1987a. Trophic levels and trophic relationships of seabirds in the Gulf of Alaska. In: Croxall, J.P., ed. Seabirds: feeding ecology and role in marine ecosystems. Cambridge, England: Cambridge University Press: 229-257.

Sanger, G.A. 1987b. Winter diets of common murres and marbled murrelets in Kachemak Bay, Alaska. Condor. 89: 426-430.

Schoen, J. 1996. Personal communication. Wildlife biologist, Alaska Department of Fish and Game, Division of Wildlife Conservation, 333 Raspberry Rd., Anchorage, AK 99518.

Sealy, S.G. 1975. Feeding ecology of ancient and marbled murrelets near Langara Island, B.C. Canadian Journal of Zoology. 53: 418-433.

Simons, T.R. 1980. Discovery of a ground-nesting marbled murrelet. Condor. 82: 1-9.

Smith, W.P.; Shaw, C.G., III. [In prep.]. The risk assessment panel process. In: Shaw, Charles G., III; Julin, Kent R., tech. coords. Conservation and resource assessments for the Tongass land management plan revision. Gen. Tech. Rep. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Stevens, N.G. 1995a. Evaluation of Christmas bird count data for determining trends in abundance of marbled murrelets in Alaska. Report. 8 p. On file with: U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503.

Stevens, N.G. 1995b. Marbled murrelet activity in relation to habitat characteristics on the Tongass National Forest. Report. 5 p. On file with: U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503.

Strong, C.S.; Keitt, B.S.; McIver, W.R. [and others]. 1995. Distribution and population estimates of marbled murrelets at sea during the summers of 1992 and 1993. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 339-352.

U.S. Department of Agriculture, Forest Service. 1979. Tongass land management plan and final EIS. R10-57. Juneau, AK: Alaska Region.

U.S. Department of Agriculture, Forest Service. 1991. Tongass land management plan revision: supplement to the draft environmental impact statement. R10-MB-149. Juneau, AK: Alaska Region.

U.S. Department of Agriculture, Forest Service. 1995. Unpublished data. On file with: M. Brown, Ketchikan Ranger District, 3031 Tongass Ave., Ketchikan, AK 99901; K. Kuletz, U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503.

U.S. Department of Agriculture, Forest Service. 1996. Tongass land management plan revision: revised supplement to the draft environmental impact statement. R10-MB-314a. Juneau, AK: Alaska Region.

van Vliet, G. 1993. Flyways and the marbled murrelet. Report. 4 p. On file with: U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503.

Varoujean, D.H., II; Williams, W.A. 1995. Abundance and distribution of marbled murrelets in Oregon and Washington based on aerial surveys. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: 327-337.

Vequist, G. 1995. Personal communication. Chief Ranger, Carlsbad Caverns National Park, Carlsbad, NM.

Vermeer, K. 1992. The diet of birds as a tool for monitoring the biological environment. In: Vermeer, K.; Butler, R.W., eds. The ecology, status, and conservation of marine and shoreline birds on the west coast of Vancouver Island. Occas. Pap. 75. Delta, BC: Canadian Wildlife Service: 41-50.

Walsh, P.R. 1991. Unpublished data. On file with: U.S. Department of Agriculture, Forest Service, Petersburg Ranger District, P.O. Box 1328, Petersburg, AK 99833.

Wynne, K.; Hicks, D.; Munro, N. 1991. 1990 salmon gillnet fisheries observer programs in Prince William Sound and south Unimak Alaska. Report. 69 p. Prepared by: Saltwater Inc., 540 L. St., Anchorage, AK. On file with: U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503.

Wynne, K.; Hicks, D.; Munro, N. 1992. 1991 marine mammal observer program for the salmon driftnet fishery of Prince William Sound[,] Alaska. Report. 53 p. Prepared by: Saltwater Inc., 540 L St., Anchorage, AK. On file with: U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503.

Yukey, D. 1995. Unpublished data. On file with: U.S. Department of Agriculture, Forest Service, Cordova Ranger District, P.O. Box 280, Cordova, AK 99574.

Zwiefelhofer, D.C.; Forsell, D.J. 1989. Marine birds and mammals wintering in selected bays of Kodiak Island, Alaska: a five-year study. Report. On file with: U.S. Fish and Wildlife Service, 1390 Buskin River Rd., Kodiak, AK 99615.

DeGange, Anthony R. 1996. The marbled murrelet: a conservation assessment. Gen. Tech. Rep. PNW-GTR-388. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 72 p. (Shaw, Charles G., III, tech. coord.; Conservation and resource assessments for the Tongass land management plan revision).

This assessment summarizes available information on the marbled murrelet in southeast Alaska and evaluates its current status. Marbled murrelets are broadly distributed across marine waters throughout southeast Alaska. They are abundant, numbering at least in the low hundreds of thousands. Marbled murrelets are believed to be at increasing risk in biogeographic provinces of the Tongass National Forest subject to extensive harvest of old-growth forests, on which they are believed to be dependent for nesting. Over the short term, risk to their persistence in the Tongass National Forest seems low; however, gaps in their nesting distribution likely will occur in some biogeographic provinces of the Tongass if current forest harvest practices are continued over the long term. Forests on private lands in southeast Alaska are being rapidly clearcut, and murrelet nesting habitat is disappearing rapidly from these lands.

Keywords: *Brachyramphus marmoratus*, marbled murrelet, conservation, management, natural history, old-growth forests, status.

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