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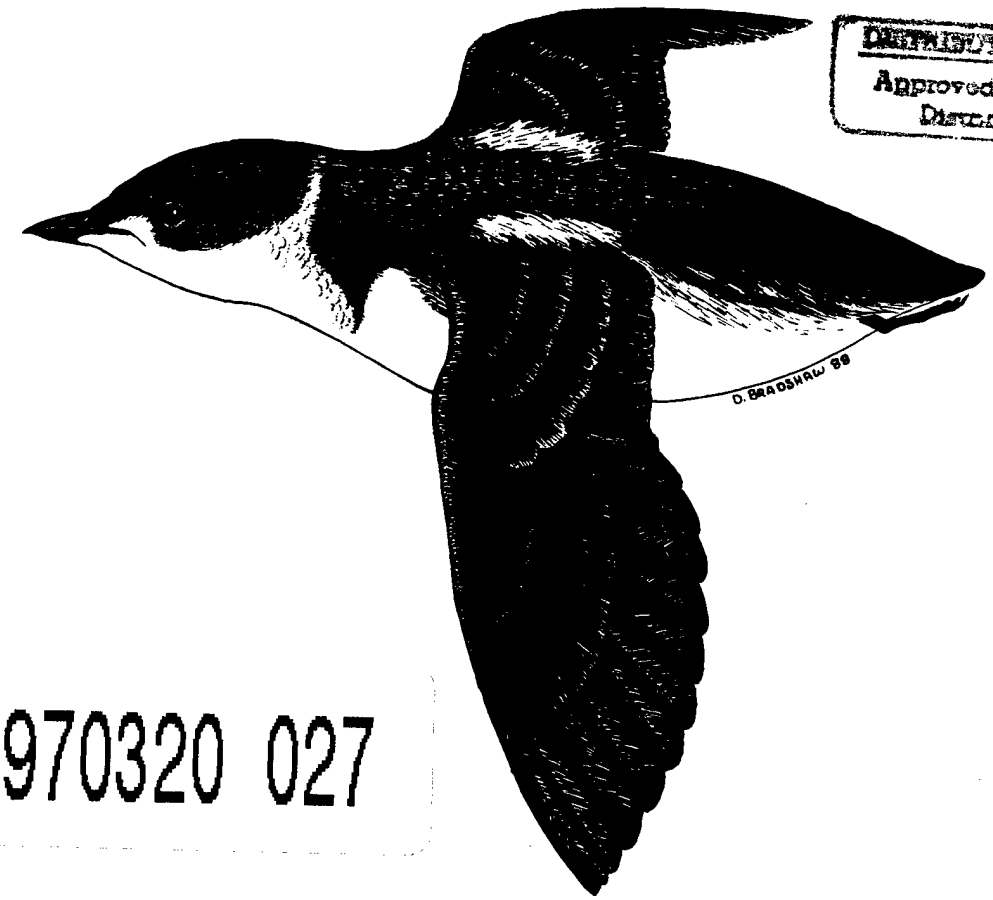
Status of the Marbled Murrelet in North America: With Special Emphasis on Populations in California, Oregon, and Washington



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Biological Report 88(30)
August 1988

Status of the Marbled Murrelet in North America: With Special Emphasis on Populations in California, Oregon, and Washington

by

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Summary

This report summarizes the status of the marbled murrelet (*Brachyramphus marmoratus*) in terms of its conservation needs based on published literature, unpublished reports, and discussions with marbled murrelet research biologists. Due to the bird's unique biology, more life history information is included than is normally incorporated into a status report.

The marbled murrelet is a robin-sized seabird that belongs to the family Alcidae, otherwise called alcids. More familiar members of the family include the guillemots, puffins, and murres. The marbled murrelet has dark upperparts and white underparts in winter, but breeding plumage is mottled brown. Like other alcids, this species has short wings that propel it underwater, a large head, short neck and tail, and a compact body. In flight, the wingbeat is rapid, compensating for the small wing surface.

The marbled murrelet is found throughout the North Pacific. The Asiatic subspecies ranges from Kamchatka south to Japan; the North American subspecies ranges from Alaska's Aleutian Islands, Kodiak Island, and Kenai Peninsula south to central California, with individuals wintering as far south as southern California.

The species feeds below the water's surface on small fish and invertebrates. Ocean feeding areas are closer inshore than for other North Pacific alcids. Inland salt waters, and occasionally inland freshwater lakes, are also used. Unlike most other alcids, it does not nest in colonies, although at some sites it may nest in small aggregations. In those parts of Alaska lacking well-developed coniferous forests, ground nests have been found on steep slopes in tundra or alpine habitats. One nest on the Alaskan tundra was found in a rocky cavity. From southeast Alaska south, the species has been found nesting only in large conifers, making it unique among the alcids. Only four definite tree nests have been found; two in Siberia and two in North America. These nests consisted of depressions in moss or lichens on the branches of old-growth conifers. No nesting material was brought in.

Other evidence of tree nesting includes: (1) stranded downy young and fledglings found on the ground in coniferous forests, including some following tree felling, (2) the cryptic coloration of the bird, (3) the absence of typical alcid leg structure for burrowing, (4) a correlation between presence of old-growth forests and marbled murrelet concentrations offshore during the nesting season, and (5) numerous sightings and aural detections of marbled murrelets flying in or around old-growth and mature forests. Flat tree branches with a thick layer of moss and of adequate size for a nest exist only in conifers that are at least 150 years old. Marbled murrelets occur on a regular basis as far as 55 km inland at old-growth forest stands, and make flights to old-growth stands throughout the year.

Marbled murrelets lay only one egg per clutch. Both parents incubate and feed the young. Inland flights to nest sites are made at dusk and dawn. Young remain in the nest longer than do those of other alcids and molt into a distinctive juvenile plumage before departing from the nest. It has been concluded that fledglings fly from the nest to the sea. Adults probably do not breed until after their second year. In a British Columbia study, 15% of the population consisted of subadults.

More than 100,000 individuals occur in Alaska, and many thousands range off British Columbia coasts and inland waterways. Summer population numbers for Washington are between 4,400 and 8,300 individuals, or between 1,900 and 3,500 breeding pairs when 15% is removed to account for subadults. The current Oregon breeding population was estimated at less than 2,400 breeding pairs, but this figure may be high because the area sampled contains most of the best remaining habitat in 1980. The California population was estimated at about 2,000 birds or less than 1,000 pairs.

The principal factor affecting the continued existence of the species over the southern portion of its North American range is destruction of old-growth and mature forests. The situation is particularly critical in California, Oregon, and Washington, States which have very few coastal old-growth stands of significant size set aside. Mortality from gill-net fisheries has been significant at least in some parts of the bird's range. The marbled murrelet has a very high oil susceptibility rating, but to date this has not been a large mortality factor. The bird's reproductive rate is too low to enable it to sustain high mortality, especially where it occurs in low numbers.

Preservation of old-growth forest is needed to maintain populations of the marbled murrelet outside treeless areas in Alaska. A major research effort must be undertaken to identify other conservation needs, especially to locate and characterize forest habitat used by the species. Population monitoring is required to track population trends and to determine if future conservation measures are effective. Reproductive success, mortality rates, and longevity data are needed for determining acceptable mortality rates.

Introduction

Even before the first tree nest of the marbled murrelet (*Brachyramphus marmoratus*) became known to North American researchers in 1974, ornithologists expressed concern for this species' welfare. However, until recently, understanding of the species was considered insufficient to call for special conservation measures. Although much remains to be learned, sufficient information has emerged in recent years to enable the writing of this summary of the bird's status. The Audubon Society of Portland, OR, supported the preparation of this report—its objective is to provide available information on the marbled murrelet's conservation needs. The Fish and Wildlife Service provided funds for its publication.

This report is based on the published literature, pending literature, presentations made at the marbled murrelet workshop held at the annual meeting of the Pacific Seabird Group, 16–20 December 1987, at Pacific Grove, CA, and discussions with marbled murrelet research biologists.

Taxonomic Status and Description

The marbled murrelet is a robin-sized seabird of the family Alcidae, the members of which are more commonly called alcids. Twenty-one other species of alcids occur in Arctic, Pacific, and Atlantic waters, but the family is best represented in the Pacific and Arctic oceans (Freethy 1987). Other alcids include murres, guillemots, auklets, and puffins. In 1789, the marbled murrelet was first described by Gmelin as *Colymbus marmoratus*, but in 1837 Brandt placed it under *Brachyramphus* (American Ornithologists' Union 1983). It is one of two members of its genus, the other being Kittlitz's murrelet (*B. brevirostris*). The marbled murrelet is a distinct species that differs from Kittlitz's murrelet in bill length, plumage color, behavior, distribution, and habitat requirements. Translated Soviet literature refers to the marbled murrelet and Kittlitz's murrelet as the long-billed murrelet and short-billed murrelet, respectively (Kishchinskii 1965). Two subspecies of the marbled murrelet are recognized: *B. m. marmoratus* is the North American form; *B. m. perdix* occurs in Asia (Dement'ev et al. 1968). The two are separated mainly by bill length and body weight (Sealy et al. 1982).

Both sexes have identical plumages, but breeding and wintering plumages are distinct. Breeding adults have sooty-brown upperparts with dark bars. Rufous-brown flecks may occur on the upperparts. Underparts are light, mottled brown. Winter adults have brownish-gray upperparts except for a white band below the nape that extends up from white underparts. Fall juveniles are similar to wintering adults except for faint brownish mottling on the chest, breast, and sides. Winter juveniles take on characteristics of adult winter plumage.

The marbled murrelet is 25 cm long based on measurements of study skins (Scott 1987), and weighs 220 g (Harry R. Carter, personal communication). Like other alcids, it presents a stubby appearance with its relatively large head, short neck and tail, and heavy, compact body. Its small wings, and rear-placed legs enable this bird to excel at underwater maneuvering in pursuit of fish. On the water's surface, alcids assume a prone position as opposed to an upright one on land. In flight, the marbled murrelet's body seems cigar-shaped. The wingbeat appears to have a whirling motion not unlike that of a swift. The rapid wingbeat compensates for the small wing surface. The marbled murrelet has the least aerial buoyancy of any alcid (H.R. Carter, personal communication). Although the bird can take off from the water with little difficulty, on land it is like many other alcids in that it lands and takes flight from sites which offer an opportunity to attain flight speed through a vertical or near-vertical drop. Requirements for slope and wind, which assist in attaining flight from the ground, are not yet clear. Becking (1987) reports a marbled murrelet attained flight from the ground in a forest. It occurred in a campground in Big Basin Redwood State Park, Santa Cruz County, CA; no mention was made of wind conditions.

McAllister (personal communication) describes the marbled murrelet's flight call as "two distinct, ascending, unbroken, flute-like notes no more than a second in duration." Others, including Udvardy (1977), describe the call as a sharp "keer-keer." For me, the "keer-keer" call is somewhat shrill in nature and resembles a gull flight call. While the "keer-keer" call is commonly uttered in flight, buzzy or soft calls can be heard from the birds at assumed nesting sites (Becking 1987; Sharpe et al. 1988).

There has been some question concerning the marbled murrelet's walking and standing capabilities. M.L. McAllister (personal communication) has taken immature marbled murrelets accidentally caught in seine nets and released them on sandy beaches and boat decks. He found they did not walk or take flight, but attempted to escape in a prone position by propelling themselves along the surface with their wings. A fledgling marbled murrelet found in good condition in a parking lot in Oregon also could not fly or walk but had to be released at sea (R. Lowe, personal communication). However, Simons (1980), Hirsch et al. (1981), and Johnston and Carter (1985) observed adults walking at nest sites in Alaska. S. Singer (personal communication) has observed juveniles walking (albeit clumsily) on the forest floor in Big Basin Redwoods State Park, CA. Storer (1945) analyzed the skeletal characteristics and musculature of the legs of alcids and found the marbled murrelet has the weakest leg

structure. He concluded the species has poor walking and standing capabilities; moreover, the legs are too far back on the body to provide good balance for standing and walking.

Geographical Distribution

The marbled murrelet is a coastal species that occurs mainly in salt water within 2 km of shore, and, in the southern portions of its range, up to 55 km inland from the coast; however, it is not uncommon to find them 5 km offshore at inland freshwater lakes, or inland 75 km (Carter 1984; Sealy and Carter 1984; Carter and Sealy 1986).

North America

The North American subspecies of the marbled murrelet occurs in summer from Alaska's Kenai Peninsula, Barren Islands, and Aleutian Islands, south along the coast of North America to Point Sal, Santa Barbara County, in south-central California. It winters mostly within the same general area, except it tends to vacate the most northern sections of its range and has been recorded as far south as Imperial Beach, San Diego County, CA. Breeding has been confirmed through observations of young offshore, the finding of grounded young or nests, or collections of adults with brood patches or eggs in their oviducts. Such evidence has been obtained from Kodiak Island, the Barren Islands, the Aleutian Islands, Prince William Sound, and Alexander Archipelago in Alaska, the Queen Charlotte Islands, Vancouver Island and adjacent mainland regions in British Columbia, along the Washington and Oregon coasts and into California as far south as Santa Cruz County. This general range was compiled from a variety of sources, including Gabrielson and Lincoln (1959), Binford et al. (1975), Sealy (1975a), Kessel and Gibson (1978), Simons (1980), Sowls et al. (1980), Sealy et al. (1982), American Ornithologists' Union (1983), Carter and Sealy (1984), Carter and Sealy (1987b), Johnsgard (1987), and Varoujean and Williams (1987). The following concentration points for marbled murrelets are defined as areas where hundreds or thousands have been reported.

Alaska. Kodiak Island (Forsell and Gould 1981), Prince William Sound and northern Gulf of Alaska (Gabrielson and Lincoln 1959; Islieb and Kessel 1973), and southeastern Alaska or Alexander Archipelago (Gabrielson and Lincoln 1959; Nelson and Lehnhausen 1983).

British Columbia. The Queen Charlotte Islands (Vermeer et al. 1983; Carter 1984) and the west coast of Vancouver Island (Crowell and Nehls 1975; Carter 1984; Sealy and Carter 1984; Mattocks 1985; Force and Mattocks 1986).

Washington. San Juan Islands and Strait of Juan De Fuca (Jewett et al. 1953; Crowell and Nehls 1968a, 1968b, 1970, 1971, 1975; Wahl et al. 1981; Speich et al. 1987), Great Bend area of Hood's Canal in winter (Wahl and Speich 1983), and entire coast of State (Speich et al. 1988).

Oregon. Yaquina Bay, south to Coos Bay, particularly from Alsea Bay to Hecata Head (Varoujean and Williams 1987; Nelson et al. 1988; Varoujean and Pitman, unpublished).

California. Monterey Bay in winter (1986 Pacific Seabird Group meeting minutes), Oregon border to Eureka, and Santa Cruz to Half Moon Bay in summer (Sowls et al. 1980; Carter et al. 1988).

Asia

The Asiatic subspecies of the marbled murrelet occurs in summer and winter from the Sea of Okhotsk, Kamchatka, and Commander Islands, south to Korea, Japan, and the Kurile Islands (American Ornithologists' Union 1983). Nesting has been confirmed near Okhotsk, Siberia (Kuzyakin 1963), on Sakhalin Island, Siberia (Nechaev 1986), and on the island of Hokkaido, Japan (Hasegawa 1984). The ranges of the Asiatic subspecies and North American subspecies may abut. The American subspecies is thought to breed at least as far west as Adak Island (Sealy et al. 1982), and the species has been confirmed as breeding at the terminus of the Aleutian chain at Attu (Mendenhall and McAllister 1988).

The Asiatic subspecies occurs in North America as a vagrant. Sealy et al. (1982) provides documentation of single birds collected from Mono Lake, CA; Monroe County, IN; and Montreal, Quebec. Since then, others have been found at Mono Lake, CA; in Pitkin County, CO; Plymouth County, MA; Denali National Park, AK; and Florida (H. R. Carter, personal communication). Identification was based on bill length.

Pertinent Life History Information

Knowledge of the marbled murrelet's life history is essential to understanding of its status. While current knowledge is incomplete, available information unravels much of the mystery that has surrounded the species.

Foraging

In summer, the marbled murrelet is most often seen on the ocean immediately offshore and on inland salt waters such as the Puget Sound–San Juan Islands area and the numerous straits of the inland passage area of British Columbia and Alaska. Off Langara Island (which lies off the north tip of the Queen Charlotte Islands in British Columbia) Sealy (1975a) determined that marbled murrelets feed within 500 m of shore. The principal foods were sand lance (*Ammodytes hexapterus*), other fish, and two invertebrates, *Euphausia pacifica* and *Thysanoessa spinifera*. Carter (1984) found that Pacific herring (*Clupea*

harengus) and sand lance were the principal prey in Barkley Sound, British Columbia. Through a limited collection in Kachemak Bay, AK, Sanger and Jones (1981) found that fish were the most important prey there, particularly capelin (*Mallotus villosus*). Sanger (1987) conducted the only serious study of winter diet in Kachemak Bay, where capelin, sand lance, mysids, and euphausiids were taken. M. L. McAllister (personal communication) reports that marbled murrelets feed just past the breaker line along the Oregon coast, but no studies of food habits have been conducted there. During winter, marbled murrelets forage outside some of the main summering areas, but still remain close to shore.

According to Sealy (1975a), while feeding during the breeding season, murrelets "invariably occur in pairs or [as] single individuals. Early in spring adult marbled murrelets feed in pairs while the subadults feed singly; but in early July, when pairs . . . are still feeding young in the nest site, mixed flocks of adults and subadults begin to form." Therefore, socially, they occur as pairs, small groups, and loose aggregations, but seldom in flocks. Carter (1984) found that in Barkley Sound, British Columbia, during nesting, 82.7% of the birds occurred as singles or pairs, but that while loafing, larger flocks of 3 to 55 birds congregated. Other alcids tend to flock more, and cooperatively feed further offshore.

For a short period after the nesting season, juvenile marbled murrelets appear in salt water, often in flocks with adults. Here they are readily separated from adults by their juvenile plumage and egg tooth which is retained longer than in most species. They don't breed until after their second year or later, since subadults occur at sea throughout summer (Sealy 1975a; Carter 1984).

Marbled murrelets have been collected or observed on inland freshwater lakes on several occasions. Carter and Sealy (1986) analyzed 67 freshwater lake records from 33 lakes; 78.6% of those recorded were in British Columbia, 12.1% in Alaska, 6.1% in Washington, and 3% in Oregon. They speculated that lakes may play a role as a food source during nesting, or are located near nesting areas.

In May 1984, S. M. Speich (personal communication) methodically searched Lake Quinault, Grays Harbor County, WA, by boat, and counted 40 or more marbled murrelets. Lake Quinault is 32 km inland. Freshwater lakes seem not to be as important in Oregon and California as they are in Washington, nor are they as numerous near the coast as they are farther north.

Nest Sites

That marbled murrelets (1) did not nest with other seabirds in colonies on offshore rocks or sea cliffs and (2) occurred inland led to considerable speculation from the time ornithologists first observed the species. It was obvious for many years that the species nested in the geographic range discussed previously because of the presence of juveniles offshore and females collected with eggs in their oviducts. Until recently, however, actual nest sites were not discovered. The following offers an historical perspective, more or less in chronological order, of efforts to unravel the mystery of marbled murrelet nesting, and summarizes what has been assembled about marbled murrelet breeding biology.

Evidence of Forest Nesting. Dawson (Dawson and Bowles 1909 *in* Bent 1946) wrote, "At Glacier on the north fork of the Nooksack River, near the foot of Mt. Baker, having risen before daybreak for an early bird walk, on the morning of May 11, 1905, I heard voices from an invisible party of marbled murrelets high in the air as they proceeded down the valley as though to repair to the sea for the day's fishing." This observation, as will subsequently be shown, corresponds to what others have rediscovered more than 50 yr later, and accurately reflects some of what we know about the ecology of the species today. Taylor (1921) speculated, partly based on Dawson's observation, that the marbled murrelet may nest many miles from the ocean. He also mentioned that G. C. Cantwell found the species to be "common" at the mouth of the Columbia River 10–18 May 1918, and that females carrying eggs in their oviducts were collected there.

Willet (1926) noted that marbled murrelets are heard away from the ocean after dark in winter, and pointed out that predation on the mainland would preclude burrow nesting. He also noted that young seen on salt water, unlike those of other alcids, could always fly. He correctly concluded that one egg was laid, and that nesting above timberline on northwest peaks was not plausible because of snow, especially considering that he had seen young as early as 26 June. However, his belief that the bird would "eventually be found nesting in the woods in a cavity in the rocks or under the roots of trees, at a considerable altitude, but not above timberline" turned out to be only partly true.

The famous bird artist, Major Allan Brooks (Brooks 1926), mentioned the presence of marbled murrelets year-round at Cowichan Lake in the interior of Vancouver Island, British Columbia. He also reported that the well-known California ornithologist, Joseph Grinnell, heard and saw pairs of this bird in Humboldt County, CA, flying at daybreak over trees 32 km inland. Two years later, under the heading "Does the Marbled Murrelet Nest Inland?," Brooks (1928) wrote of having examined a female collected on 28 April 1928 from seven or eight pairs in British Columbia at Harrison Lake between the Coast and Cascade ranges. The collected female was carrying two eggs (only one is laid – the other is absorbed). Brooks described this lake as being more than 160 km from the sea; Carter and Sealy (1986) remeasured this distance and found the lake was at least 75 km from salt water.

E. J. Booth (Anon. 1927) obtained an egg of a marbled murrelet at a logging camp office in Whatcom County, WA. It was found 24 km inland near Saxon on the south fork of the Nooksack River on 19 June 1925 in a bed of moss. The report did not describe the nest site. The identity of this egg was recently confirmed by Kiff (1981).

To further suggest that the marbled murrelet nested inland, Jewett (1934) wrote "The Mystery of the Marbled Murrelet Deepens." In it, he told of his son and a companion finding a still-flightless immature – with egg tooth – in a logged-off area about 1.6 km from the beach at Devil's Lake in Lincoln County, OR. Jewett noted that uncut timber was nearby, and his son, Stanley G. Jewett, Jr., confirmed (personal communication) that there was an old-growth stand of Sitka spruce (*Picea sitchensis*) "three or four hundred yards away."

Gabrielson and Jewett (1940) reported having seen a specimen "just out of the down" that was picked up near Minerva, Lane County, OR, on 18 September 1918. Minerva is northeast of Florence and about 12 km from the ocean. Barber (1941) wrote of a "young" marbled murrelet being picked up 22 July 1940 "in timber" along the south fork of the Coos River, 40 km inland from Coos Bay, OR.

Through the first three quarters of the twentieth century, it became evident that the marbled murrelet was a forest nester over much of its range. Observers such as Webster (1941) wrote of seeing marbled murrelets carrying fish to inland forested areas. Guiguet (1956) wrote, "Marbled murrelets move about at night to and from their terrestrial nesting grounds, and their daylight hours are spent on the sea. During the breeding season they become agitated as daylight fails, anxious it seems, to be off to the nesting area in order to relieve the incubating mate, or to feed the young one as the case may be." Guiguet also noted a characteristic pungent odor on those seabird species that occupy burrows, and that the odor was not present on marbled murrelets. This supported the findings of Storer (1945), who noted that marbled murrelets, unlike other alcids, lacked a hind limb structure adapted to burrowing. Guiguet (1956) further supported his hypothesis by reporting on a "stunned marbled murrelet taken from the debris of a large hemlock (presumably *Tsuga heterophylla*) on the Queen Charlotte Islands near Masset, British Columbia. The logger, an amateur bird-watcher, examined the murrelet and found it had a brood patch. Further search of the debris uncovered the fragments of a marbled murrelet's egg, but no evidence of a nest of any kind was found." The occurrence took place on 4 June 1953 (Drent and Guiguet 1961).

Harris (1971) secured one of two birds that dropped out of a cedar (presumably *Thuja plicata*) felled on 24 August 1967 by loggers on Vancouver Island, British Columbia. The bird was a young marbled murrelet with primary feathers still sheathed. This occurred near the town of Holberg, about 6 km from salt water.

Carter and Sealy (1987b) tabulated 10 inland records of downy young involving 13 chicks and 31 records of single fledglings being found – mostly on the ground, but some having fallen from trees or been found on water. All but 10 of the records were made since 1960. A breakdown by Province and State follows: Alaska, 4; British Columbia, 9; Washington, 8; Oregon, 3; and California, 17. Seven of the California records are from Big Basin Redwoods State Park, Santa Cruz County. Since that report was written, another fledgling was found in Oregon and one downy marbled murrelet in Alaska.

Tree nesting confirmed. On 17 June 1961, A. P. Kuzyakin (1963) found a marbled murrelet nest of the Asiatic race containing one egg near the city of Okhotsk, Siberia, 6–7 km from the sea in "tall trunk larch taiga." The nest was described as being in a larch (*Larix dahurica*) in dendroid lichen (*Bryopogon* sp.) on a "branch with a wide flat surface formed by dense intertwining of small twigs situated on almost one plane." The larch was about 12 m high with a diameter of about 17 cm at 1.5 m. Nest height was 6.8 m.

It was not until 1974 that a North American tree nest of the marbled murrelet was adequately described (Binford et al. 1975; Singer and Verado 1975). On 7 August 1974, Hoyt Foster, a tree surgeon working in Big Basin Redwoods State Park (in the Santa Cruz Mountains northwest of Santa Cruz, CA), discovered a nest with a downy chick 10 km from the coast on a large flat limb of a Douglas-fir (*Pseudotsuga menziesii*) 45 m above the ground (Binford et al. 1975). The tree was described as being 61 m high and 167 cm in diameter at 1.2 m. The nest limb measured 41 cm in diameter and was covered with bright green moss (*Isothecium cristatum*) at a depth of 5–10 mm. The nest was simply a depression in the moss. No nesting material was brought in, and the authors suspected the nest had been used over a period of years because of wear and excrement around its edge. The site was in a virgin association of generally smaller Douglas-firs and mostly larger coast redwoods (*Sequoia sempervirens*).

Binford et al. (1975) summarized the above by stating, "The nest was found in a (1) humid (2) virgin forest that was (3) near coastal feeding areas, (4) contained water-filled streams, and was in part composed of (5) a large species of tree (Douglas-fir) with (6) an open crown structure and (7) bark colored like the plumage of breeding adults. The nest was positioned (8) high above the ground, at a point allowing (9) easy access to the exterior of the forest, and (10) next to the trunk on a (11) wide, (12) horizontal, (13) southward-projecting limb that was (14) densely covered with (15) green moss and (16) protected by a slanting trunk and a closely overhanging branch."

As pointed out by Binford et al. (1975), "The California and Siberian nests share several important characteristics: both were located near the trunk on a horizontal branch thickly covered with vegetation; had similar dimensions; were little more than a depression in the natural vegetative growth on the limb; and, although placed at different heights, afforded easy access to the ocean, which was about the same distance away." One of the main differences is that trees in eastern Siberia do not reach the size of conifers in California.

A second Siberian nest was found on Sakhalin Island by Nechaev (1986) on 19 June 1976 about 2 km from the shores of Chaivo Gulf in a "deciduous forest composed of stands of cedar, birch (*Betula middendorfia*), and heavy ground litter. The nest was located on the broken top of a larch with the sides distributed equally on either side of the branch about 5 m from the ground." This nest was not known by Binford et al. (1975), and differs in that it was placed in a broken tree top. The description of this Siberian nest lacks details and is confusing, perhaps because of translation problems.

Also without details is the report of an incubating female taken 15 June 1961 in the forest of Mt. Mokoto, 24 km from the Okhotsk coast in eastern Hokkaido, Japan (Hasegawa 1984).

The most recent nest report is of one found in 1984 near Kelp Bay on the northeast side of Baranof Island in southeast Alaska (Quinlan and Hughes 1984). This was the first nest located as a result of radio-tagging. The nest was in a mountain hemlock (*Tsuga mertensiana*) at 348 m elevation, 1.2 km from salt water. The nest was 15.5 m above the ground and 1.24 m out on an 18-cm diameter (at the base) moss-covered branch. Again, there was no nest material. The site was an open, uneven-aged stand of mountain hemlocks. It is significant that once again a large moss-covered limb supported the nest. Quinlan and Hughes (1984) and Sealy and Carter (1984) pointed out that lush moss growth does not occur on conifers until the forest is 150 or more years old, citing Franklin et al. (1981).

Ground nesting in tundra habitats. Tree nests do not explain the presence of marbled murrelets along tundra-edged coasts of Alaska. This explanation came on 8 July 1978 when an exposed ground nest was discovered on the steep slopes of East Amatuli Island in the Barren Islands group located between Kodiak Island and the Kenai Peninsula (Simons 1980). The Barren Islands are mostly treeless, and presumably devoid of mammalian predators because of their small size. The sea was only 74 m away from this nest. A second nest was found 10 m from the first on 7 July 1979. Day et al. (1983) listed other ground nest records from Alaska, including ones on Augustine Island, Kodiak Island, at Port Chatham at the south tip of the Kenai Peninsula, and a probable one in the Pye Islands. All of these sites are in the same general area near the end of the Kenai Peninsula or on or near Kodiak Island, which lies southwest of the Kenai Peninsula.

The Port Chatham nest actually represented a third type of nesting site. This nest, found 2 July 1981 with a female incubating one egg, was subsequently described in detail by Johnston and Carter (1985). It was in a rocky cavity at an elevation of 710 m in rocky, alpine habitat. The egg was laid on rock. A partially-logged coastline supporting Sitka spruce was 1–2 km away.

These records show the marbled murrelet has adapted to ground nesting in treeless or scrub tree regions; is both a ground nester and tree nester where forest and treeless areas meet; and further south nests only in trees.

Nest site summary. Carter and Sealy (1987b), in a detailed summary of nesting records and inland occurrences of downy young and fledgling marbled murrelets in North America, identify 11 positive nests and 2 probables. The probables include the stunned adult taken from the hemlock debris in the Queen Charlotte Islands and a ground nest on Chicagof Island in Alaska (Gabrielson and Lincoln 1959; Drent and Guiguet 1961). [Kiff (1981) questions the identification of the Chicagof Island nest record.] Of the 13 nests, 4 were in trees with 1 each in Siberia (Kuzyakin 1963), California (Binford et al. 1975), Alaska (Quinlan and Hughes 1984), and British Columbia (Guiguet 1956; Drent and Guiguet 1961). Carter and Sealy (1987b) further mentioned, but did not include in their totals, two probable tree nests where chicks fell from trees being felled. These include one in British Columbia (Harris 1971) and one in Washington (L. L. Leschner, personal communication *in* Carter and Sealy 1987b). They were not then aware of the second Siberian tree nest. The above comprises four known and three probable tree nests. All definite ground nests were from Alaska. As yet, we don't know the nature of the Japanese breeding record except that the incubating female was taken in a forest. Carter and Sealy (1987b) listed the egg reported by Booth (Anonymous 1927) as representing an unknown nest-site type.

Most tabulated nests have been reasonably close to salt water. The exception was the Nooksack River egg reported by Booth (Anonymous 1927), which was 24 km inland, and the incubating female from Hokkaido also was taken 24 km inland. However, an analysis of the location of collected hatching-year birds indicates that nesting close to salt water is not necessarily the norm. Compilations made by Carter and Sealy (1987b) include four records of downy young found between 35 and 40 km inland. Fledglings have been picked up as far as 30 and 55 km from salt water. The presence of marbled murrelets at lakes as far inland as 75 km was documented by Carter and Sealy (1986), and suggests the likelihood of nesting even further inland. The

farthest inland locality known (75 km, Harrison Lake, BC) was a female collected with a well-developed ovum (Brooks 1928). All records of hatching-year young found by Carter and Sealy that were more than 10 km from saltwater were at the more southern portions of the bird's North American range, from southern British Columbia to California. This suggests that tree nesting marbled murrelets travel much farther for nest sites than do ground nesters in Alaska.

Carter and Sealy (1987b) also mentioned that "8 out of 10 records of downy young and 20 out of 31 fledglings were obtained in old-growth forests. The remaining records were near old-growth forests." Fourteen fledglings were found in Big Basin and Portola state parks, San Mateo County Memorial Park, and Loma Mar, all located in one of the last remaining old-growth forests of coast redwood in central California.

Among records not known at the time of writing by Carter and Sealy (1987b) is one of a downy chick found in 1986 on the ground inside a grove of old-growth Sitka spruce in Kodiak, AK (M. L. McAllister, personal communication). This represents a correction to the report of an actual nest finding reported by Mendenhall and McAllister (personal communication) in the preliminary abstracts of papers presented at the Pacific Seabird Group meeting.

Table 1 provides a listing of described tree nests and other situations which strongly suggest tree nesting.

While it is apparent the marbled murrelet is not a colonial nester, there is reason to believe it may sometimes nest in loose groups, or two or more nests may be in close proximity. This is based on two young found at three sites (Carter and Sealy 1987b), observations made of more than two adults circling groups of old-growth trees (Nelson 1986; Varoujean and Williams 1987; Carter and Sealy 1987b; McAllister, personal communication), and vocalizations heard from forest canopies (Becking 1987; Sharpe et al. 1988).

Although a marbled murrelet nest has yet to be found in Oregon, the evidence that it does nest there is clear. Historical records of grounded young were cited earlier. The literature does not contain recent records of such hatchlings in Oregon, but one was found after the paper by Carter and Sealy (1987b) went to press. A grounded

Table 1. *Tree nests and other evidence of tree nesting.*

Location	Date	Tree species where known
Described forest nests		
Okhotsk, Siberia	17 June 1961	Larch
Sakhalin Island, Siberia	19 June 1976	Larch
Baronof Island, AK	1984	Mountain hemlock
Big Basin Redwoods State Park, CA	7 August 1974	Douglas-fir
Stunned adult with brood patch and eggshells found in fallen tree debris		
Masset, BC	4 June 1953	Western hemlock
Young found on ground following tree falling		
Holberg, BC (2 chicks)	24 August 1967	Western redcedar
Sultan River Basin, WA (2 chicks)	1950	
Downy young found on ground in forests		
Kodiak, AK	1986	Sitka spruce
Gilltoyees Inlet, BC	26 August 1919	
Franklin River, BC	13 August 1987	
Rugged Ridge, WA	1982 or 1983	
Aberdeen, WA	7 August 1983	
Devil's Lake, OR	4 September 1933	Sitka spruce
Coos River, OR	22 July 1940	
Humboldt Redwoods State Park, CA	13 September 1979	
San Mateo County Memorial Park, CA	11 July 1982	

fledgling in seemingly good condition was picked up 21 September 1987 in a parking lot in the town of Siletz, Lincoln County, and turned over to personnel of the Oregon Department of Fish and Wildlife and U.S. Fish and Wildlife Service. The bird was photographed and released the following day off the Yaquina Bay jetty (R. Lowe, personal communication). Siletz is about 14 km from the ocean. Interestingly, this is the latest date on which a fledgling has ever been reported, although Carter and Sealy (1987b) suggested that nesting might extend into late September.

Other recent Oregon nesting evidence comes from T. F. Love of Linfield College, who reported (personal communication) seeing two or more marbled murrelets carrying fish toward Young's River from Young's Bay, Clatsop County, on 23 July 1971. H. B. Nehls (personal communication) reported seeing marbled murrelets carrying fish at Coos Bay on 24 July 1969. There are also recent sightings of immature marbled murrelets off the Oregon coast, including an immature with two adults 29 June 1983 north of Florence (Mattocks et al. 1983); young at Barview, Tillamook County, 27 August 1967 (Crowell and Nehls 1968a); a juvenile with an adult at the south jetty of the Columbia River 23 July 1985 (seen by T. F. Love; reported by H. B. Nehls, personal communication); and a juvenile at Three Arch Rocks 23 July 1987 (R. Lowe, personal communication). Of 16 adult marbled murrelets captured by Varoujean and Williams (1987) off the Oregon coast in 1986 and 1987, 14 had brood patches. Young marbled murrelets are seen so regularly off the Oregon coast that they are usually not reported in the literature.

Carter and Sealy (1987b) confirm that nesting currently occurs in Washington and California.

Nesting Chronology

Cantwell (1898) was the first to describe the egg of the marbled murrelet, taken from a female he shot. Kiff (1981) presents a detailed description of other collected eggs. Only one egg is laid. Laying can begin as early as 15 April. Nesting occurs over an extended period from mid-April to late September (Carter and Sealy 1987b). Downy young have been found as late as 4 and 13 September. Incubation takes about 30 d, and the chick fledges in 28 d (Simons 1980; Hirsch et al. 1981). The chick is fed at least once and sometimes twice a night by the adults. Usually only one fish is carried to the young (Carter and Sealy 1987a). Both sexes incubate the egg in 24-h shifts which are changed each evening (Simons 1980).

There was much speculation over how marbled murrelet fledglings reach the sea. There is now agreement among American investigators that they fly there (Binford et al. 1975; Sealy 1975b; Simons 1980). This conclusion is based on the fact that fledglings found at sea can fly; that most nests and fledglings found have not been close to streams with adequate water to carry them seaward; and that an overland journey would be impossible in view of potential predation and considering that murrelets are not anatomically equipped for travelling on land, especially through brushy terrain strewn with downed timber. Furthermore, there are no reports of fledgling murrelets walking or swimming seaward. Although seven records of live fledglings were on water (lakes and creeks), these are considered to be primarily accidental occurrences (Carter and Sealy 1986, 1987b).

Habitat Associations

It can be concluded from the previous information that the North American subspecies of the marbled murrelet (and probably the Asiatic one as well) occupies a feeding niche in the ocean near shore and in inland saltwater areas such as bays, sounds, and saltwater passageways as found throughout the Alexander Archipelago of southeast Alaska. For nesting, it requires tundra-alpine type habitat near the ocean in northern regions where coniferous trees with proper nest site characteristics are absent. Along coastlines that support well-developed coniferous forests, the species utilizes forests for nesting and perhaps other activities, such as roosting. From northern British Columbia south, there is no evidence of nesting except in old-growth forests (Carter and Sealy 1987b; Pacific Seabird Group, unpublished), although I found this probably represents a loose definition of old-growth.

In the southern portions of the bird's breeding range (from southern British Columbia south), there have been additional observations of interest. These observations provide more evidence of the bird's association with old-growth forests and probable nesting in old-growth forests much farther inland than would be expected for a seabird.

However, it needs to be pointed out, before going into the additional evidence, that some of the observers who have written about marbled murrelets in old-growth have not defined what they meant by the term "old-growth." Most technical definitions of old-growth indicate the presence of trees that are 200 or more years old (Franklin and Spies 1984; Hall et al. 1985). Some of the forests described in marbled murrelet literature as old-growth may in fact have been in late stages of the mature or large sawtimber stand condition, as described by Hall et al. (1985). This condition includes trees that are from 80 to about 200 yr old, and is especially typical of some conditions found in Oregon where forests have not been logged but have been disturbed by fire in relatively recent times. As I have described elsewhere, moss in which marbled murrelets nest forms on the limbs of Douglas-firs that are more than 150 yr old, making mature forests a possibility for nesting, especially where relatively open crown canopies or

slopes exist to provide adequate ingress and egress to and from large limbs.

Marbled murrelets have been observed taking off from the sea at dusk and heading inland, particularly toward shores supporting coniferous forests (Brooks 1926; Bent 1946; Jewett et al. 1953). In addition, some of these authors have specified that the forests were old-growth, or that murrelets tended to gather in greatest numbers during nesting season along shores near old-growth (Sowls et al. 1980; Nelson 1986; Paton et al. 1987; Varoujean and Williams 1987; McAllister, personal communication; Pacific Seabird Group, unpublished) Other observers (Guiguet 1956; Drent and Guiguet 1961; Savile 1972; Sealy 1975a) saw murrelets carrying fish as they headed inland. There is also a tendency in some areas for the birds to gather at the mouths of rivers before making their final nightly flight inland. On the Oregon and Washington coasts, they are seen flying up rivers, whereas in other cases they have been seen to gain altitude and head directly overland. They are also seen or heard flying inland or returning to sea before sunrise.

Some of the most descriptive writings come from McAllister (personal communication), who has observed marbled murrelets extensively in Alaska, Washington, and Oregon from both sea and land. Referring to flights inland, he wrote, "In the fading light of dusk, birds will suddenly take flight, as they approach land they will turn skyward, abruptly gaining altitude as rapidly as possible. I have observed birds climb at [what seems like] 90 degrees to an estimated 1,000 feet in about a minute before leveling out and disappearing overland. Most often birds level out and fly inland at 600–800 feet." Referring to flights back to sea half an hour after the first light until sunrise, he wrote, "From a boat, birds may be seen pulling out of steep dives from aloft at very high speed, leveling out only when they are again within a few feet of water."

McAllister (personal communication) further comments that "at all 30 inland areas in which he has observed marbled murrelets, the birds are associating with virgin stands of old-growth conifer—no tree species preference is apparent. These stands are on the steepest forested slopes often within the steeper feeder-stream drainages." However, as previously noted, the stands referred to by McAllister, while virgin, may not have reached old-growth conditions as defined by forest ecologists.

Several observers have recently documented observations of marbled murrelets in and around old-growth forests in California, Oregon, and Washington, often at considerable distance from the sea, as described by the following paragraph. Some of these people, notably Nelson (1986) and Paton et al. (1987), provided a definition of old-growth which is the same as that described by Franklin and Spies (1984) and Hall et al. (1985).

McAllister (personal communication), while working in Olympic National Park, WA, in 1979 and 1980, observed and heard marbled murrelets daily passing above old-growth at twilight between 1 June and 25 August, 10–15 km inland from the Strait of Juan de Fuca in the Elwha and Soleduck river valleys.

Paton et al. (1987) discussed numerous marbled murrelet records made in 1985 and 1986 during the course of censuses for other birds 2 km inland in Redwood Experimental Forest located between Crescent City and Eureka, CA. They made almost all detections aurally in that murrelets were "extremely difficult to observe." Murrelets were detected on 31 days in an old-growth plot throughout the year. They were detected 30 times in a shelterwood plot and once in a seed tree plot. The shelterwood plot adjoined a stand of old-growth. The authors commented, "Most actual observations were in the old-growth stand....Some individuals appear to circle the canopy calling constantly, while other individuals call once or twice while apparently flying out of the stand."

Marbled murrelets are regularly detected inland at several California State parks set aside to protect redwood groves. Big Basin Redwoods State Park is the best example, but others include Humboldt Redwoods, Jedediah Smith Redwoods, Portola and Prairie Creek Redwoods State parks, and San Mateo County Memorial Park (Becking 1987; Carter and Sealy 1987b; R. A. Erickson and T. G. Sander, personal communication). Remsen and Gaines (1973) reported the species 30–35 km inland at Grizzly Creek Redwoods State Park in Humboldt County, CA. Becking (1987) discovered them on 27 June 1987 at Cheatham Grove, Carlotta, which is near Grizzly Creek.

Nelson (1986) wrote of observations made during the course of circular plot censuses for forest birds as follows: "During the spring and early summer (28 April to 3 July) of 1985 and 1986, marbled murrelets were seen or heard in old-growth (200–400 yr) and mature (80–200 yr) forest stands in the Oregon Coast Range, up to 47 km (29 miles) from the ocean." This was in five of six old-growth stand plots, and in two of four mature forest stand plots distributed from Mary's Peak, Benton County to Cummins Creek, Lane County. Most sightings were near Rock Creek Reservoir of the Corvallis watershed. No murrelets were detected in three plots located in young forest stands, including one located 3 km inland. Murrelets were seen leaving forest stands on five separate occasions, and with one exception occurred in groups of two or more with the maximum being eight. Mattocks (1986) also reported the Mary's Peak observation.

In June 1986, D. Selby and E. Fisher of the Coos Bay Bureau of Land Management office observed marbled murrelets near Loon Lake in Douglas County, OR. Varoujean and Williams (1986) reported on this site in

detail. The site is located on a spotted owl habitat area in T23S, R9W, Sec 21–22 near Remmy Creek, 30 km southeast of Reedsport. The nearest salt water is 38 km distant, near the mouth of Tenmile Creek. They estimated that the nesting area, which is old-growth, supports 20 pairs of marbled murrelets. The best observations were made 6 August 1986 when four marbled murrelets were seen flying into stands of conifers dominated by old-growth Douglas-fir. Varoujean and Williams (1986) reported that the firs in the area have a mean dbh of 152 cm and are moss-covered on the upper surface of the limbs. They concluded, as have others, that marbled murrelets nest in aggregations when nesting areas are located in relatively large stands.

Still another recent inland observation comes from Alan Contreras, President of Oregon Field Ornithologists, and R. Hoyer (personal communication to S. K. Nelson). On 9 August 1987 they watched and heard four marbled murrelets in Lincoln County over Seits Ridge, 1.6 km west of Forest Service Road 32 on Forest Service Road 3220. The birds came from the west and flew northwest after circling. This location is about 19 km east of Yachats. Seits Ridge supports conifers that are probably older than 150 yr and have moss-covered limbs (my observation).

M. L. McAllister (personal communication) has been watching and hearing marbled murrelets fly up the Yachats River at various times in recent years. He watched two individuals circle trees with old-growth characteristics near the 1.6 km post above the river on 2 June 1985. However, most marbled murrelet sightings or aural detections have been farther upriver. On 22 November 1987, McAllister (personal communication) heard a number of marbled murrelets at a large old-growth or mature stand on the slopes of the School Fork of the Yachats River between Howell Ridge and Yachats Mountain. As is often the case, this was before dawn so it was impossible to visually observe these birds to determine numbers. This site is within the Siuslaw National Forest about 10 km inland from the town of Yachats.

Similar observations have been made of the Asiatic subspecies. Independently of American workers, Nechaev (1986) has written of inland observations. Referring to Sakhalin Island in Siberia, he reported that marbled murrelets nest in mountains in coniferous and mixed-stand forests near the coast and inland. The nest mentioned previously is his documentation (Nechaev 1986), as well as observations of adults that match sightings made from British Columbia to California. He noted the species by sight and sound as far inland as 30–40 km from the Okhotsk Sea and at elevations up to 600–700 m. Kishchinskii (1965) reported the Asiatic subspecies is associated with shorelines that are in taiga, whereas Kittlitz's murrelet associates with treeless alpine oceanfronts.

Marbled murrelets are seen over forests and on inland lakes during winter, as first reported by Willet (1926). Paton et al. (1987) referred to a Del Norte, CA, Christmas bird count in which 62 marbled murrelets were heard calling, although the reference he cites [Rubega and McCaskie (through Lester) 1984] does not give details. Census work in the Redwood Experimental Forest reported by Paton et al. (1987) detected these birds every month of the year. M. L. McAllister (personal communication) also reports winter flights inland in southeast Alaska and Oregon. H. R. Carter (personal communication) reported that T. G. Sander detected marbled murrelets on 66% of 53 d censused between 15 January and 11 March 1987 at Prairie Redwoods State Park, Humboldt County, CA. Carter and Sealy (1986) reported that 22.4% of 67 records of marbled murrelets at lakes were from the non-breeding season of October to March. They considered that their presence at lakes and inland sites in winter was related to visitation of nesting areas, possibly involving courtship, pair bond maintenance, and nest site prospecting.

The marbled murrelet's use of forests with old-growth characteristics is also recognized by others, including Sowls et al. (1980), the Pacific Seabird Group (1982, 1987), Sealy and Carter (1984), and Carter and Sealy (1987b). Presumption of the species' reliance on old-growth or trees nearing old-growth status is based on: (1) All nests found in coniferous forest biomes were in trees representing old-growth characteristics; (2) downy young have been found only in old-growth forests and fledglings in or near old-growth; (3) inland observations of adult marbled murrelets are associated with old-growth and mature forests; and (4) during the nesting season, marbled murrelets occur mainly offshore opposite old-growth or mature forest stands in the southern parts of their range. Additional factors include (1) the cryptic coloration of the bird (breeding plumage matches moss and wood); (2) the need for the bird to have elevation in order to gain flight; and (3) a leg structure not adapted to burrowing or walking.

The species is no longer found in significant numbers during the nesting season where old-growth forests have been cut, such as at Devil's Lake, OR, and at the mouth of the Columbia River. Gabrielson and Jewett (1940) mention the species as being a regular summer resident particularly of Lincoln, Tillamook, and Lane Counties in Oregon. This is no longer true of Tillamook County, where nearly all old-growth forest has been removed near the coast. However, the species still occurs in significant numbers in the other two counties where patches of old-growth and large sawtimber or mature forest stands remain. Similarly, Sowls et al. (1980) reported that marbled murrelets occur in two distinct areas in California – the section between the two areas has been extensively logged.

Whether the species could or would adapt to some other type of nesting habitat within the coniferous forest biome is a matter for conjecture. Such adaptations are rare, and when they do occur, develop over an extended period. The type of nesting site used is very specific—a moss-covered limb of adequate size for a nest that offers suitable ingress and egress for a bird with marbled murrelet flying characteristics. This does not occur in a young forest which lacks large moss-covered limbs, space between trees, and large openings in the canopy. The need for access to large, old conifer limbs could account for the preponderance of observations of murrelets along ridges and on steep slopes.

The humid forests of the Pacific Northwest where the marbled murrelet occurs are unique entities. According to Franklin (1979), "old-growth ecosystems in this region have the greatest biomass accumulations of any plant formations in the temperate zone and, probably, the world." They are dominated by coniferous trees which achieve long lives and large sizes. Dominant species near the coast include Douglas-fir, western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*) and Sitka spruce. In southern sections, coast redwood is dominant. Old-growth forests are comprised of many large trees, large snags, and numerous downed snags in all decay stages; they have a multilayered canopy composed of several tree species; the trees show signs of senescence. Forests begin exhibiting old-growth characteristics at about 175– 250 yr in Oregon, and, as described earlier, old-growth is preceeded by a forest stand described as being "mature" or of large sawtimber, a stage that begins at about 80 yr. There are no plans to regenerate mature or old-growth stands except in parks. For a complete description of these forests, the reader is referred to Franklin and Dyrness (1973); and Franklin et al. (1981).

Population Structure

Maximum production from a pair of marbled murrelets is only one young per year; in addition, the species delays sexual maturity (Sealy 1974, 1975b). Subadults, which occur as singles during the period the young are fed, made up 15% of the population off Langara Island, BC (Sealy 1975b). This kind of situation demands low mortality rates and long-lived adults that reproduce with a high degree of success, as is typical of Alcidae.

Population Numbers

Compared to colonial nesting alcids, the marbled murrelet is difficult to inventory. To date, at-sea inventory techniques have been the main method used. These have been conducted in different ways, according to logistical situations in the area being inventoried. All inventory work has been relatively recent; therefore, there has been no opportunity to record population changes. In addition to at-sea inventories, M. L. McAllister (personal communication) and S. K. Nelson (personal communication) have proposed inventories along inland flight corridors and at nesting sites by recording birds heard. S. Singer (personal communication) used such a method in breeding areas of Big Basin Redwoods State Park, CA, in 1976. A procedure for flight corridor inventories was field tested in Prairie Creek Redwoods State Park, CA and determined to be valid (Sander and Carter 1988).

Numerous counts of marbled murrelets have been reported. Most have been opportunistic in nature, but others were established specifically for marbled murrelets. Many of these are included in the following paragraphs. Variables in conducting marbled murrelet counts include sea conditions, weather, time, month, tidal conditions which relate to location of prey, daily movements, inventory technique (aerial, at-sea, or from shore), and any mathematical factors used to account for birds present but not seen, including incubating birds. While aerial censuses help overcome the problem of hourly or daily local movements during the census, Speich et al. (1988) found that the aerial observer overlooked birds actually present, and that sea and lighting conditions affected this bias. This makes establishment of a surface versus aerial visibility factor as used in other wildlife census work difficult.

Alaska. Based on miles of shoreline having food resources and appropriate nesting areas, Alaska is the major center of marbled murrelet population in North America. Using the same rationale, British Columbia populations are probably also sizeable. Johnsgard (1987) cited Forsell and Gould (1981) as reporting that as many as 13,000 marbled and Kittlitz's murrelets winter in the Kodiak area of Alaska, primarily the former. Islieb and Kessel (1973) are also cited as estimated the total marbled murrelet wintering population as being in the "several hundred thousands, possibly in millions, in the North Gulf Coast and Prince William Sound region of Alaska." Quinlan and Hughes (1984) cited a publication by Kessel and Gibson (1978) which reported 250,000 marbled murrelets in Prince William Sound and Nelson and Lehnhausen (1983) provided a figure of 250,000 for southeast Alaska. M. L. McAllister, during the course of an oral presentation on the current status of the species in Alaska (Mendenhall and McAllister 1988), provided much lower figures based on counts made from 1983 through 1987; during this period he was on fishing vessels that worked all the major marbled murrelet areas in Alaska. He pointed to three major breeding areas in Alaska with the following population estimates: Alaska Penninsula, 6,000–15,000 individuals; Prince William Sound, 15,000–20,000; and southeast Alaska, 50,000–75,000. The latter figures leave the "possibly in the millions" estimate open to question. An analysis of Christmas bird count data before 1980

from southeast Alaska by Trapp (1984) showed a decline in the late 1970's.

British Columbia. While no total figures are available for British Columbia, Sealy and Carter (1984) estimated a breeding population of 8,460 marbled murrelets in Clayoquot and Barkley sounds on the west coast of Vancouver Island in June 1982 using an at-sea quadrat census technique designed specifically for counting marbled murrelets. They counted 9,955 individuals on the water and 1,225 birds in flight. On the water they found marbled murrelet population densities to average 8.1 birds/km^2.

Washington. Speich et al. (1988) released a current estimate of marbled murrelet numbers at the 1987 meeting of the Pacific Seabird Group. The Washington data came from both aerial and boat censuses of seabirds. Depending on which set of assumptions were used, they estimated that the summer population of marbled murrelets stands between 4,400 and 8,300 individuals, or between 1,900 and 3,500 breeding pairs if 15% were assumed to be subadults. They split the State into two units, each consisting of subunits: The outer coast includes the Willapa Bay and Gray's Harbor region as one subunit and the outer coast of the Olympic Penninsula as another; the other unit covers the inland waters consisting of the Strait of Juan de Fuca, the San Juan Islands, and southern Puget Sound. The inland waters have about two-thirds of the birds. They estimated 1,000 to 2,000 additional birds occur during winter. This exceeds the 2,000 individuals estimated for the Straits of Juan de Fuca and the San Juan Islands in 1978 and 1979 as reported by Wahl et al. (1981).

Historically, Jewett et al. (1953) mention G. Cantwell's report of "no less than 1,000 individuals" opposite Port Townsend on 28 February 1920. Files of the Willapa National Wildlife Refuge contain a record of 200 seen by G. Cantwell at Dungeness Spit in the Strait of Juan de Fuca, 12–16 December 1917. The Washington Natural Heritage Data Base also includes numerous sightings from inland salt waters of Puget Sound including the Strait of Juan de Fuca, and San Juan Islands. Point Roberts, WA—a peninsula that extends south of Vancouver, BC—has particularly high counts in winter. A total of 450 marbled murrelets was recorded there 10 December 1972. The source of Point Roberts birds is probably British Columbia. —*American Birds* (formerly *Audubon Field Notes*) regularly reports sightings of marbled murrelets off the Washington coast and in inland salt water areas, but these are opportunistic sightings and not censuses. Examples of high counts are 265 birds on 21 June 1968 in Discovery Passage (Crowell and Nehls 1968b) and 73 off the coast of Point Roberts on 19 June 1983 (Mattocks et al. 1983).

Oregon. Varoujean and Williams (1987) ran at-sea transects along the Oregon coast in 1986 and 1987 between Yaquina and Coos bays. They found population densities ranging from 0 to 190 birds/km^2 with an overall mean of 12.9 birds/km^2. Applying their figures to the entire Oregon coast, they calculated 6,000 individuals (or about 2,500 breeding pairs) after removing 15% for nonbreeders. However, they pointed out that this central stretch of coast between the two bays, which accounts for roughly one-third of the Oregon coastline, is opposite most of the best remaining marbled murrelet breeding habitat in Oregon. Therefore, the 2,500 breeding pair figure is probably higher than actually occurs. Greatest population densities were found in and around the mouths of the larger bays and rivers, especially within 3 km north and south of Coos Bay, the Siuslaw River mouth, and Yaquina Bay. Data from a 1979 survey of seabird colonies off the Oregon coast (Varoujean and Pitman, unpublished manuscript) also suggests the 2,500-pair figure of Varoujean and Williams (1986) is an overestimate. While the 1979 survey tabulated marbled murrelets only opportunistically in connection with trips to offshore islands, it showed that out of 311 marbled murrelets sighted, 48% were seen in the central section of the coast; 33% of the 311 were between Alsea Bay and Hecata Head.

M. L. McAllister (personal communication), counting from shore with a 15-power telescope over a flat ocean, tabulated 260 marbled murrelets along a 21-km section of the coast between the Yachats River and Hecata Head in June, 1985. He considers this to represent some of the best habitat because it is adjacent to most of the remaining coastal old-growth stands in the Siuslaw National Forest. From McAllister's survey, and others off the Oregon coast, he estimates the State population to be less than 4,000 individuals, or less than 2,000 breeding pairs (Nelson et al. 1988).

American Birds and its predecessor, *Audubon Field Notes*, contain opportunistic sightings of marbled murrelets off the Oregon coast. Sightings involving young were mentioned earlier, but others include 7 at Boiler Bay on 15 August 1970 (Crowell and Nehls 1970) and 60 at the same site 26 January 1986 (Force and Mattocks 1986); in some numbers at the Columbia River mouth in July and along the north Oregon coast in June and August (Crowell and Nehls 1971); 30 at Florence, 27 December 1985; 35 on the Lincoln City, 28 December 1985, Christmas bird count (Leukering and Fis 1986); and more than 75 gathered 11 May 1983 just off the south jetty of the Siuslaw River (Mattocks 1983). Small numbers have repeatedly shown at Coos Bay and Tillamook Christmas bird counts. H. B. Nehls, regional sub-editor for *American Birds*, has the following additional records in his files (personal communication): 16 at Cape Arago, 23 August 1980; 100 at the mouth of Euchre Creek (Curry County), 10 September 1980; 20 off Cape Meares, 6 August 1983;

50 at Manzanita, 24 September 1983; 25 at the south jetty of the Columbia River, 20 July 1985; up to 60 at Boiler Bay, 18 January to mid-February, 1986; and 27 at Cape Meares, 18 September 1987. Notes kept by T. F. Love (personal communication) and Mark Smith (personal communication) include many sightings form the same locations plus records for Newport and Garibaldi.

While Cantwell (Taylor 1921) reported the marbled murrelet to be common at the mouth of the Columbia River, this is not the case today. The 25 seen from the south jetty as listed previously is the highest recent record. H. B. Nehls (personal communication), who has gone onto the jetty numerous times, reports he has never seen more than 10. T. F. Love's notes refer to more than 10 while crossing the Columbia River Bar. It is apparent the bird is no longer "common" there, but there is nothing else known to indicate population changes in Oregon except that the species is no longer prominent in Tillamook County as stated by Gabrielson and Jewett (1940).

California. Sowls et al. (1980) made 390 sightings of marbled murrelets during the course of seabird surveys conducted in 1980 off California shores. From their sample, they speculated the California summer population to be about 2,000 birds. Coastal waters from Eureka north to the Oregon border and from Santa Cruz north to Half Moon Bay accounted for 76% and 14%, respectively, of 185 sightings made during the 1979 breeding season. There is an over- 450 km section of the California coast between Eureka and Half Moon Bay which is nearly devoid of marbled murrelets. To all practical intents, the California birds are therefore split into two populations. No at-sea surveys have been made since 1980 (H. R. Carter, personal communication).

American Birds contains numerous opportunistic sightings of marbled murrelets off the California coast and a number of additional inland records. Observations of significant numbers from north to south for the past 10 yr include: at Crescent City, Del Norte County, 150 on 13 May 1980 (Laymon and Shuford 1980), 80 on 30 April 1985 (Bailey 1985), and 30 on 18 July 1979 (Laymon and Shuford 1979); Jedediah Smith State Park, Del Norte County, 8–9 pairs flying in and out of the park on 18 June 1979 (Laymon and Shuford 1979); Humboldt County coast, 50 on 28 October 1978 (Winter and Laymon 1979); Pigeon Point, San Mateo County, high count of 203 flew by 11 March 1970 (Laymon 1979); Año Nuevo Point, San Mateo County, 270+ on 20 June 1982 (LeValley and Evens 1982), 33 on 1 January 1984 (McCaskie 1984), and 61 on 25 August 1984 (Sterling and Campbell 1985). A large number of dead washed up on shore in Monterey Bay along with other seabirds, particularly from October 1980 to August 1981 (Evens et al. 1982). Elsewhere in California, few marbled murrelets were reported, usually less than 10; these records extend as far south as San Diego (McCaskie 1980). Overall, the distribution shown here corresponds to comments made in the previous paragraph concerning a gap in the distribution between northern and central California. H. R. Carter (personal communication) compiled nine citations from *American Birds* containing inland records from California between 1959 and 1979.

Big Basin Redwoods State Park, where the first North American nest of the species was found, is probably the best known inland site for seeing marbled murrelets in California. S. Singer (personal communication), using 12 observers at 6 sites on 10 July 1976, tabulated a combined total of 713 sightings in the park. However, considering many of these as repeats, he conservatively estimated the park population to be 100 pairs.

Asia. No population estimates have been obtained for the Asiatic subspecies.

Factors Affecting Continued Existence

Three threats to the species were identified by the Pacific Seabird Group (1987): old-growth habitat destruction, mortality from gill-net fisheries, and oil pollution. The Pacific Seabird Group Marbled Murrelet Workshop, held 9 December 1986, identified aquaculture facilities as a potential fourth threat (Pacific Seabird Group 1987). Habitat destruction and gill-net mortality, when combined with low reproductive rates of the marbled murrelet, are particular causes for concern, specifically in those portions of the bird's range where population numbers are already low and where remaining nesting habitat is threatened. Although our knowledge about these factors is less than optimal, the available evidence points to a strong possibility of extinction within major portions of the bird's range if conservation measures are not undertaken, including a concerted research program to better identify habitat requirements. Details on factors affecting continued existence follow.

Present and Threatened Habitat Destruction

Nearly all the terrestrial habitats of Washington, Oregon, and northern and central California within 55 km of the coast were originally in coniferous forest. Except for areas above timberline, the same situation occurred in British Columbia and southeastern Alaska. How much of this area was in old-growth forest will never be precisely known because of fires. However, historical evidence and descriptions show that at least half of the area was in old-growth. In 1987, a petition from the Seattle Audubon Society stated that Franklin and Spies (1984) considered 60%–70% of the Pacific Northwest's forest area was in old-growth before 1800. Carey (1985) stated that 6 million ha of old-growth (250–750 yr old) were present in the Pacific Northwest

in the 1880's. He estimated that one-third of this remains in Washington and Oregon, mostly at higher elevations in the Cascade Range, far outside the range of the marbled murrelet. Occupation of the land by European man resulted in an increase in fires, logging of old-growth, and its replacement by young forest stands.

The last remaining old-growth stands in Oregon's Coast Range Physiographic Province are largely in the Siuslaw National Forest, on O&C (Oregon and California Railroad Revested Lands and Coos Bay Wagon Road Reconveyed Lands) lands managed by the Bureau of Land Management and in State parks. Less than 800 ha of old-growth is within range of the marbled murrelet in Oregon State parks (Morrison 1987b), and most of that is in Oswald West State Park. In the Siuslaw National Forest, 12,600 ha of old-growth remain (Morrison 1987a). Old-growth remaining on O&C lands in western Oregon is estimated at 191,000 ha. An additional 174,200 ha is classified as being in mature forest (Morrison 1987b) Obviously, most of these acreages are too far from the coast to be useful to marbled murrelets.

The status of the spotted owl (*Strix occidentalis*), an old-growth obligate, resembles that of the marbled murrelet, although the owl's range extends much farther inland. Out of 254,222 ha of coastal forest in the Siuslaw National Forest, only 7,094 ha are judged suitable for the spotted owl (U.S. Forest Service 1986). On O&C lands in Oregon, 42 spotted owl pairs are all that could be supported, assuming no further cutting takes place. In Olympic National Park, Washington, 37 spotted owl pairs can be supported.

Under alternative F, the preferred alternative described in the Forest Service spotted owl guidelines (U.S. Forest Service 1986), spotted owl pairs that would remain in national forests along the coast of Washington and Oregon would be 24 in Olympic, 25 on the Siuslaw, and 22 on the Siskiyou national forests. Obviously some of the area in these national forests is too far from the sea for marbled murrelets, but some tracts of old-growth that are too small for spotted owls may be usable for marbled murrelet nesting. Spotted owl habitat on non-Federal lands within Oregon and Washington is described in the same document as having declined from 446,650 ha in 1961–62 to 88,579 ha in 1984–85. The greater part of this land is, of course, outside the range of the marbled murrelet, but it illustrates the decline in old-growth even within the last 25 yr. Old-growth within the range of the marbled murrelet in Oregon and Washington is subject to cutting, except the Drift Creek, Cummins Creek and Rock Creek wilderness areas in the Siuslaw National Forest, Olympic National Park, State parks, and what lands might be set aside for the spotted owl. The areas in the three wilderness areas total 9,078 ha, but only about one-third of this total is in old-growth. Old-growth trees in State parks, at least in Oregon, have been subject to logging in the past and are even now not exempt from it. Over the next 3 yr, the Bureau of Land Management expects to sell 20,963 ha of old-growth and 10,725 ha of mature forest in western Oregon. Subsequent harvest rates will be similar (Morrison 1987a). Spotted owl habitat in national forests in Oregon is being logged at a rate of 16,188 ha annually (Seattle Audubon Society, unpublished petition).

Referring to California, Sowls et al. (1980) stated, "The old-growth stands of the coast redwood alone have been reduced in area from an estimated 809,000 ha to 93,000 ha (Veirs, personal communication)." Thus, less than 10% of the original old-growth redwood forests remain. Approximately 28,300–30,400 ha have been preserved in parks, although no new parks have been created since 1978. More than 70% of park old-growth and over 40% of remaining commercial old-growth is located in Humboldt County (H. R. Carter, personal communication). Concern for the future of the marbled murrelet in Pacific Northwest forests – and specifically California – was also expressed by Carter (1987).

Sealy and Carter (1984) stated, with regard to British Columbia, that "If present policies are continued, probably more than 95 percent of the old-growth on productive forest land [on the west coast of Vancouver Island] will be gone within 50 years, and immature forest crops will then be rotated (B. Nyberg and N. Harrison in litt.)."

Currently, there is a controversy over how much old-growth is to be left in southeastern Alaska. Nearly all the coastal forests of southeast Alaska fall within the Tongass National Forest. Ninety-one percent of the old-growth in this forest is slated for harvest (Laycock 1987).

Inadequacy of Existing Regulatory Mechanisms

The marbled murrelet has not been placed in any special categories by State or Federal agencies except in California where it is considered a species of special concern by the California Department of Fish and Game. This is an administrative category which contains species that may face extirpation, but information is considered inadequate for listing or the listing process has not been completed. No management considerations are required for species in this category. Therefore, throughout its range, marbled murrelet habitat is not being afforded protection or special consideration by land management agencies, except that which might occur through decisions related to other species or factors. The U.S. Forest Service and the Bureau of Land Management recognize certain species as sensitive (an administrative category), but the species has not been designated sensitive by wildlife agencies, as recommended by the Pacific Seabird Group (1987). Even if it were, the Bureau of Land Management would not give it special consideration on O&C lands because of Director Burford's 1983

interpretation of the O&C Act of 1937, to the effect that O&C lands do not come under provisions of the Federal Land Policy and Management Act of 1976. As such, the primary management objective for these lands is for "high-level sustained yield output of wood products needed to contribute to economic stability of local communities and industries ..." (Burford policy statement entitled "O&C Forest Resources Policy").

The absence of protection for marbled murrelet nesting habitat contrasts with almost full nesting habitat protection provided other seabirds in Alaska, Washington, Oregon, and California through designation of their island nesting sites as National Wildlife Refuges or other protective categories.

Other Natural and Manmade Factors

Mortality from gill-net fisheries. Carter and Sealy (1984) first identified a salmon gill-net mortality problem during a study conducted in 1979 and 1980 in Barkley Sound off Vancouver Island, BC. They found that the marbled murrelet was the most frequently killed alcid during the course of a study involving fishermen who salvaged dead birds for inspection. Birds were also picked out of the water by a fisheries research vessel. All specimens were obtained between 11 June and 17 July. Marbled murrelets were killed almost exclusively at night and within 2 m of the surface. They estimated a total of 380 marbled murrelets were killed by gill-nets in 1980. This accounted for 7.8% of the potential fall population in the area or 6.2% of breeding birds in the Sound. Sealy and Carter (1984) also reported from 600 to more than 800 murrelets are killed annually in Prince William Sound, Alaska (Copper and Bering rivers, Coghill, Unakwik, and Eshamy fishing districts). Conservation measures recommended included changes in areas where the gill-net fishery takes place and prohibition of night fishing.

In minutes prepared on the marbled murrelet workshop held at the Pacific Seabird Group meeting on 9 December 1986 (Pacific Seabird Group 1987). M. L. McAllister also mentioned a potential for gill-net mortality in southeastern Alaska near Wrangel. H. R. Carter mentioned that 100 marbled murrelets washed ashore in Monterey Bay, CA, in 1980 were probably gill-net casualties. The extent of marbled murrelet casualties from gill-net fishing elsewhere is unknown except off the Oregon coast where gill-netting does not occur. Washington is a case in point: Speich et al. (1988) reported that there are 1,200 current gill-net permits issued for Puget Sound. Bird mortalities are not being monitored, but casual observations show losses of other alcids.

Oil pollution. Sealy and Carter (1984) noted that King and Sanger (1979) rated the marbled murrelet as having the highest oil : bird-vulnerability index of any seabird in southeastern Alaska. This is based in part on their feeding in local concentrations close to shore. They also mentioned that the bird has the highest oil index in the straits of Juan de Fuca and Georgia in Washington and British Columbia as described by Manuwal et al. (1979) and Wahl et al. (1981). Despite the high vulnerability, murrelets have only been reported oiled once each in British Columbia, Washington, and Japan, and sporadically in small numbers in California (H. R. Carter, personal communication). However, if an oil spill occurs in a marbled murrelet concentration area, losses could be significant. A proposed offshore oil development off northern California (Lease sale 91, February 1989) will be the first area where offshore oil production will potentially threaten a murrelet population (H.R. Carter, personal communication).

Aquaculture. K. Vermeer (Pacific Seabird Group, unpublished) identified aquaculture structures in protected bays and other marbled murrelet foraging areas as posing a potential threat.

Conclusion

The marbled murrelet has a declining nesting habitat base throughout most of its range where it nests in trees. Large populations remain in Alaska and British Columbia, where substantial old-growth forest stands, although threatened, remain; but continued logging operations there can be expected to cause a decline in marbled murrelet population numbers. Populations in these areas may already have declined, but there are no data available. The Washington population is estimated at between 1,900 and 3,500 breeding pairs and could be reaching a critical status because of low numbers and a limited nesting habitat base. With nearly all the remaining old-growth stands in the Siuslaw National Forest and Oregon Coast Range O&C lands slated for cutting, and considering that the Oregon population stands at less than 2,400 pairs, it is concluded the species is not secure in Oregon, either. The California population is also small (2,000 birds). Old-growth forests present in California's State and Federal parks provide limited protection to some habitat there, but the population is already broken into two segments, each of which is likely to become so small that it could be eliminated from other factors such as oil pollution and gill-net fishing. The insecure position of the species in Washington, Oregon, and California is also based on the fact that land management agencies are not making a specific effort to protect marbled murrelet nesting areas, except that which occurs incidental to other activities. Even when found, no effort is being made to protect these sites, nor are there any legal provisions to protect the sites on O&C lands in Oregon.

The role of gill-net mortality needs to be studied throughout the bird's range where gill-nets are used near the surface before this threat can be adequately assessed. However, this fishing method should be considered a threat, along with the potential for oil

pollution in combination with the bird's low reproductive rate. The marbled murrelet does not have the capability to sustain heavy losses. Like other species whose survival is based on long life rather than high reproductive rates, the marbled murrelet could undergo a population crash if recruitment rate does not keep up with mortality rate. Since 1980, another alcid, the common murre (*Uria aalge*), has (for example) declined by more than 59% in California due to gill-net mortalities, oil spills, and the effect of El Niño (Takekawa et al. 1988).

Research, Survey, and Protection Needs

There are many unanswered questions concerning the marbled murrelet. The magnitude of factors that pose threats to its continued existence has not been fully measured, and before it is possible to implement management measures, additional life history information and habitat data must be obtained. The Alaska Department of Fish and Game and the Oregon Department of Fish and Wildlife initiated marbled murrelet research in 1983 and 1985, respectively. In 1988, the U.S. Fish and Wildlife Service, U.S. Forest Service, Bureau of Land Management, Oregon Department of Fish and Wildlife, California Department of Fish and Game, Washington Department of Wildlife, the National Fish and Wildlife Foundation, and the National Council of the Paper Industry of Air and Stream Improvement, Inc., initiated cooperative research projects on the species. The lack of knowledge is, in itself, a threat to the species. By and large, resolutions sent to appropriate agencies by the Pacific Seabird Group in 1982 and 1986 – resolutions that called attention to threats to the species and requested that the bird be provided consideration in management decisions and research funds – have been ignored.

Standardized population monitoring procedures must be developed, implemented, and coordinated between cooperating agencies. Demographic characteristics of the marbled murrelet, especially in Washington, Oregon, and California, must be determined. This includes obtaining data on longevity, mortality rates, reproductive population, reproductive rates, and reproductive success necessary to sustain the population. Whether birds displaced by habitat loss use replacement habitat and what effect fragmentation of old-growth forests have on the population are both unanswered questions.

Nesting areas must be located, characterized, and protected. Inland habitat requirements must be better defined. Such actions will be expensive. The biology of the bird itself, and the fact that its nest is very difficult to locate and access, represents an avian research challenge which is unmatched in the Pacific Northwest. Attempts to locate nests in Alaska and Oregon through capture and radio-tagging at sea have been mostly unsuccessful, but hold promise if adequate funding becomes available (D. H. Varoujean, personal communication). Potential nesting areas can be identified through offshore observations and on-the-ground identification of flight corridors and utilized tree stands. All work in terrestrial habitats will be difficult, because peak activity occurs in poor light or in the dark.

As few as 10–50 yr remain before old-growth habitat will be all but eliminated along the coasts of Washington, Oregon, and California. Coupled with the difficulties of studying this species, there is not sufficient time to investigate all of the basic population variables needed to fully assess the status of the marbled murrelet. This situation dictates that protection should be afforded to the species in these States while further research is conducted. Based on this premise, the most important research projects to conduct in the immediate future are: (1) using at-sea censuses for annual monitoring of population numbers, and (2) locating all inland nesting areas. This information could be collected in a few years, and would provide the basis for making decisions about the forms of protection required. Two forms of protection should be considered: (1) setting aside the areas of mature and old-growth forests used by murrelets, and (2) providing special protection to at-sea concentration areas by restricting gill-net fishing and future oil development. However, at the same time, radio-tagging studies should continue to locate nests and develop needed demographic data and more detailed information on nesting habitat requirements information.

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The status of the marbled murrelet (Brachyramphus marmoratus) is summarized in terms of its conservation needs. The principal factor affecting the continued existence of the species over the southern portion of its North American range is destruction of old-growth and mature forests. Preservation of old-growth forest is needed to maintain populations of the marbled murrelet outside treeless areas in Alaska. A major research effort must be undertaken to identify other conservation needs, especially to locate and characterize forest habitat used by the species. Population monitoring is required to track population trends and to determine if future conservation measures are effective. Reproductive success, mortality rates, and longevity data are needed for determining acceptible mortality rates.

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