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STUDY AND BIOLOGY OF MARBLED MURRELETS IN SOUTHEAST ALASKA

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The marbled murrelet, (Brachyramphus marmoratus) a small diving seabird, occurs along the Pacific coast from central California to Prince William Sound, in the Aleutian Islands and in scattered locations along the Alaska Peninsula (A.O.U. 1957 Kessel and Gibson 1978). An Asiatic race, B. M. perdix occurs along the coast of Siberia (Dement'ev and Gladkov 1951, Vaurie 1965). Marbled murrelets are most abundant from British Columbia through Prince William Sound (A.O.U. 1957). An estimated 250,000 occur in Prince William Sound (Kessel and Gibson 1978), and 200,000 in southeast Alaska (Nelson and Lehnhausen 1983).

In contrast to most seabirds that nest colonially on oceanic islands, marbled murrelets appear to nest individually in scattered locations along the coast and sometimes far inland. Despite their abundance and intensive searching for their nests, few marbled murrelet nests have ever been documented. A review of the literature by Day et al. (1983) produced 8 definite and 1 probable nest site records. These included 7 ground nests in alpine and treeless areas and 2 nests in trees. In addition to these nest records, there are several records of eggs and young found in forested areas--two of these when large coniferous trees were felled by loggers (Guiquet 1956, Savile 1972, Harris 1971, Singer and Verado 1975). Further circumstantial evidence of tree-nesting are observations in California (Sowls et al. 1980) and British Columbia (Savile 1972) that marbled murrelets are most abundant adjacent to coastlines of mature coniferous forests.

Binford et al. (1975) suggested that habitat characteristics critical for murrelet tree nests may include: large trees with open crown structure (to allow easy access to nest sites), with moss-covered limbs large enough to support and camouflage a nest. Second growth forests in southeast Alaska generally consist of dense stands of relatively small, even-aged trees with dense crowns and little moss development on the branches (Franklin et al. 1981). In addition, the trees have smaller, more steeply sloped branches (Franklin et al. 1981). These characteristics suggest that second growth forest would not provide adequate tree-nest sites for marbled murrelets. Hundreds of years are required for a logged area to return to old-growth forest. Current logging schedules with 50-100 year rotations will replace old growth forests with a permanent mixture of clearcut and second growth stands. Hence, current and planned logging of forests of Oregon, Washington, British Columbia, and southeast Alaska poses a potentially serious threat to marbled murrelet nesting habitat throughout much of the species range.

The potential conflict between logging of old-growth forests and conservation of marbled murrelet populations has been recognized by several researchers (Sowls et al. 1980, McKnight and Knoder 1979, Carter and Sealy 1984) and has recently drawn the attention of professional conservation organizations. Resolutions calling for more research on marbled murrelet nesting biology, the potential impacts of logging on murrelets, and attention to conservation of the species have been recently passed by the International Council for Bird Preservation, Northwest Section of the Wildlife Society, and Pacific Seabird Group.

The immediacy of this potential conservation problem is underscored by what is known of the population dynamics of marbled murrelets. Sealy (1974) and other researchers concluded that marbled murrelets are restricted to a single egg clutch. Like other seabirds that lay a one-egg clutch, marbled murrelets likely have low reproductive rates, delayed maturation, high juvenile mortality, and low adult mortality (Drury 1979). Given these population characteristics, population declines caused by reduced fecundity (as would result from loss of nesting habitat) would not be apparent until after many years of reduced nesting success (Drury 1979). Current census techniques are inadequate for detecting any but catastrophic population changes (Manuwal and Campbell 1979). Hence, by the time a decline could be clearly identified, it might be difficult or impossible to stop or reverse, since 1) murrelet populations likely increase slowly even under optimum conditions and 2) if a decline is due to habitat loss as a result of logging of old growth forest, the nesting habitat could not be restored for hundreds of years. Clearly, waiting to find out whether or not murrelet populations decline as a result of logging is unwise.

The paucity of information on marbled murrelet nesting habitat requirements poses a difficult conservation problem. As noted by Carter and Sealy (1984): "Our present inability to find their widely scattered nests would make setting aside very large tracts of coastal forest the only effective solution to protect nesting habitat." This solution is both impractical and inconsistent with the current multiple-use management and timber harvest schedule that prevails throughout Alaska's Tongass National Forest. Clearly, more precise information on the nesting habitat requirements of marbled murrelets is needed to develop more precise and realistic conservation plans.

Our objectives for this project were 1) to find a way of locating additional marbled murrelet nests in southeast Alaska to determine 2) whether or not murrelets nest primarily in old growth forest in this region, and 3) if so, to characterize their habitat preferences so that wildlife managers will be able to develop realistic plans for protecting murrelet nesting habitat and mitigating habitat losses.

Radio telemetry appeared to be the only feasible means of locating murrelet nests (Sealy 1974). This technology, though routinely employed in many areas of wildlife management, is just beginning to be used in seabird research. Therefore, we began this project with the need to develop techniques for capturing, radio-tagging, and tracking these small, diving alcids.

We have not as yet been able to locate enough nests to characterize murrelet habitat preferences. We present here information on methods for capture and radio-tagging seabirds, notes on murrelet behavior, measurements of 21 murrelets, descriptions of an egg, and 1 new nest record. We hope this information will be of use to other workers who are attempting to locate murrelet nests or develop conservation plans.

Study Area

This study was conducted at Kelp Bay (57° 18' N, 134° 55'W), located on the northeast side of Baranof Island in southeast Alaska. The bay consists of 3 major arms and a bay, and is approximately 70 km^2. It is enclosed by steep mountains rising 610-1,280 m above sea level. The mountains are forested by Sitka spruce (*Picea sitchensis*), western and mountain hemlock (*Tsuga heterophylla*, *T. mertensiana*), and Alaska cedar (*Chamaecyparis nootkatensis*). Treeline is at 457-762 m but forests above 366 m are open and most trees are small and scrubby. About 4 km^2 of old growth forest in Kelp Bay was clearcut in 1976 and 1977. The coastal climate consists of moderate temperatures (mean annual temperature 40°F), frequent overcast, mists, fog, and an annual precipitation of 406-762 cm (Hartman and Johnson 1978).

Methods

Field work was conducted from 11 May-17 June 1983 and 4 May-13 June 1984. Fieldwork was timed to conincide with nest site establishment and incubation, based on chronology information from Sealy (1974). Fieldwork ended in both years when murrelet numbers and behavior prevented capturing additional birds, and searches for radio-tagged birds proved consistently unproductive. Techniques for capture and radio-tagging were developed and are described in detail under results. Captured birds were weighed using a 300g Pesola spring scale, and examined for brood patch development. Culmen length and depth, diagonal tarsus and extended wing were measured using Vernier Calipers. We used 10 gm radio-transmitter packages (transmitter, lithium battery, and antenna) developed by Advanced Telemetry Systems. In 1983, we tested transmitters with external whip antennae and with enclosed coiled antennae. We found no differences in range when placed on the bird externally. As birds appeared more tolerant of the coiled antennae model, we used only these in 1984. The entire package was protected from water and abrasion by an epoxy coating. Radio transmitters were attached to murrelets (with varying success) using backpack harnesses of polyethylene tubing, sutures, implantation, and epoxy glue. We implanted transmitters using techinques developed for diving ducks by Carl E. Korschgen (personal comm.) of the Northern Prairies Wildlife Research Station. This technique included anesthetizing the bird, making an abdominal incision, inserting the transmitter, then suturing the incision.

We attempted to follow radio-tagged birds for several hours after release, and then made daily efforts to relocate them. We searched for radio-tagged birds in Kelp Bay from an inflatable boat with 25hp motor using a Telonics TR-2 receiver with an H-antennae on an 8 foot pole. We stopped to listen for signals at 0.8-1.6 km intervals. In 1984, we also searched over and around Kelp Bay from a Cessna 185 using H antennae and a TR-2 receiver/scanner.

Three surveys were done at 152-304 m altitude in and around the three arms of Kelp Bay and around Catherine Island. Four surveys of the area were made at altitudes of 0.9-1.1 km, along transects spaced at 1.6 km intervals, on a 505 sq km grid. This grid stretched 21 km west from 1.6 km outside Kelp Bay, and from Cosmos Cove to 1 km offshore in Peril Strait. Additionally, a 194 sq km area over Hood Bay, Chaik Bay, and Whitewater Bay on

Admiralty Island, and a 194 sq km area from Cosmos Cove to Warm Springs Bay on Baranof Island were searched on 7 and 9 June, respectively, at an altitude of 0.9-1.1 km, along transects spaced 3.2 km apart. We also listened for radio signals along the air routes between Sitka and Kelp Bay, and our pilot, Jerry Carpenter, listened for signals along a transect from Red Bluff Bay to Hoonah. Figure 1 shows the areas covered by air surveys. In total, we conducted 20 hours of aerial surveys.

Developing capture and radiotelemetry techniques were our first priorities, but we made incidental observations of murrelet numbers, group sizes, behavior, and habitat use whenever possible. We conducted surveys of Kelp Bay by pneumatic boat on 11-12, 23, 26, 31 May and 7, 11 June 1983, and on 9, 19 May and 6 June 1984 to obtain estimates of the numbers of murrelets in the bay. On these surveys we followed a standardized route along the shores of the bay at low speed, and recorded all murrelets observed. Data from these censuses are likely affected by varying weather, tide stages, dates, and murrelet behavior. Thus, numbers derived from the surveys should be only considered as indications of the relative number of birds present, not as population estimates.

Results and Discussion

Population, Behavior, and Chronology. Marbled murrelets were the most abundant waterbird in Kelp Bay during May-June 1983 and May-June 1984. In 1983, estimated numbers increased from 104 on 11 May to 240 in late May, then declined to fewer than 50 by mid-June (Table 1). In 1984, less than 50 murrelets were present on 4 May, but we counted 104 on 9 May. Numbers appeared stable until early June, but we made only one other survey (19 May, 103 birds). Numbers again dropped off quickly in early June; only 53 birds were counted on a 6 June census. The decline in murrelet numbers observed in early June of both years likely reflects the absence of incubating birds and possibly a change in habitat use by nesting birds.

Murrelet group sizes varied from 1-28 in 1983 and 1-over 50 in 1984 (Table 1). Pairs were observed throughout the field season, but in both years made up a decreasing percentage of the groups observed as the seasons progressed. Observations of single birds and groups of 3 or more occurred throughout the field seasons, but were more frequent after mid-May in both years. In contrast, in British Columbia, Sealy (1974) did not observe groups of 4 or more murrelets until late June.

We observed a group of over 50 birds on 23 May at the head of South Arm. When we moved toward this group, we heard most of the birds repeatedly calling. We believe this group was aggregated around some kind of food concentration. We saw a dense concentration of jellyfish in the clear calm water in this area, suggesting that water currents may have created a concentration of organisms in that location. Guiquet (1950:39) observed large aggregations of murrelets which he related to chick fledging; Sealy (1975) reports a similar aggregation in late June and questions whether it was related to fledging or not. The aggregation we observed was clearly not related to fledging as it occurred during the egg-laying period.

Murrelets were observed at one time or another in almost every part of Kelp Bay. They were most numerous at the heads of South and Middle Arms and between Crow and Pond Islands in 1983. In 1984, few murrelets were seen at the head of Middle Arm, between Crow and Pond Islands. Rather, murrelets were most abundant at the head of South Arm and around Zubof Rocks in the Basin. In both years, murrelets were found most often in water less than 50 fathoms deep and along steep rocky coastlines (as opposed to shallow-sloped sand or mud beaches).

Displays between pairs were observed in both years, most frequently when a pair reunited after being separated by our chases. Separated pairs called back and forth to each other in high-pitched, plaintive, one-note whistles. The birds moved closer together by flying or diving; when they were within 1 m or less they became quiet and began a display. The display consisted of both birds extending their necks vertically and pointing their bills skyward while slowly swimming towards each other (Fig. 2). The birds, both maintaining this posture, then swam together for 15-30 seconds. Copulation by murrelets on the water was observed once on 16 May 1984.

Egg-laying apparently occurred primarily during late May. The first fully-feathered and vascularized brood patches were found on birds examined on 21 May 1983 and 19 May 1984 (Table 2); relatively few birds (21) were examined, however. In 1983, a female captured on 21 May laid a fully-shelled egg while recovering from anesthesia. The egg laid by the pair we followed to a nest in 1984, was likely laid on 21 or 22 May. We captured this bird on the water on 18 May while accompanied by its mate. We relocated it with its mate on 19 and 20 May. On 21 May, the tagged bird was found with 2 other birds; we were unable to determine if either was its mate. On 22 May, we relocated the transmitter signal inland; the signal was coming from land every other day thereafter, until 27 May. The decline in murrelet numbers in Kelp Bay in early June of both years also suggests that peak egg-laying occurred in late May.

Nesting chronology found in this study is similar to that reported for British Columbia by Sealy (1974); but 1-2 weeks earlier than reported for the western Gulf of Alaska (Simons

1980, Day et al. 1984). Additional evidence of egg-laying occurring from May to early June in southeast Alaska is provided by backdating from observations of fledglings at sea.

Gibson 1976 reported seeing fledged young on 18 and 20 July off southern southeast Alaska. Jack Hodges (pers. comm.) reports observing fledged young in various southeast locations in early to mid-July. Patton 1975 found a fledged marbled murrelet on Boussole Lake near Yakutat on 23 July 1974. These observations also indicated egg-laying from mid-May to early June in southeast Alaska, based on backdating 28 days for the nesting period and 30 days for incubation (Simons 1980).

Techniques for Capture and Radio-tagging. We attempted to capture murrelets using a gill net, dip nets, and night lights, but quickly determined that these were not viable capture methods for murrelets in Kelp Bay. Although we often were able to approach murrelets closely enough to make use of a dip net on a 3 m (10 foot) pole appear feasible, birds were able to dive more quickly than we could maneuver the net. We attempted dip-netting with a night-light on 2 nights, using a 250,000 candlepower light from an inflatable boat equipped with a 25 hp outboard motor. Although we visited areas where murrelets were abundant during the day, no birds were seen during the 5 hours (total) that we searched at night. A lightly weighted gill net that birds might dive into and then surface when entangled also seemed feasible.

However, when we placed a 30 m section of gill net out in the smallest cove frequented by murrelets, it was clearly apparent that to be at all successful, we would need several hundred meters of net.

We captured 17 murrelets (8 in 1983 and 9 in 1984, Table 3) using a capture net gun we made based on a design by the Northern Prairies Waterfowl Research Station. The capture gun used blank charges to propel 3 floats attached to the corners of a triangular-shaped mesh net. The net was 2 m on each side and had 7.5 cm mesh openings. We modified the gun so that the base of the triangle formed by the floats was parallel to the water, and we added a forearm handle. These modifications improved our ability to handle the gun which increased our capture success rate. Only flying birds can be captured with this gun.

Capture teams consisted of the boat operator, the shooter, and in 1983, a spotter. Murrelets were spotted, then approached in a Zodiac with a 25 hp motor. Generally, murrelets dive to escape, so it was necessary to approach the birds in a manner that provoked takeoffs rather than dives. The successful angle and speed of approaches varied depending on wind and water conditions and the position of the birds relative to our boat. We had best success when we approached obliquely from an upwind direction. We stayed wide of the birds, until we were within 7-10 m, then turned sharply to push the birds into the wind. We were often able to flush birds with this approach, enabling us to get a shot immediately. More often the murrelets dove when approached. After many hours of practice, we were able to roughly predict the direction and distance the birds would swim, and maneuver the boat fairly close to where they surfaced. In calm water, bubble trails left by diving murrelets were of great value in accurately predicting their movements. When the bird surfaced, we approached rapidly to within 5-6 m then slowed to low speed. This slow final approach seemed to allow the birds adequate time and distance to takeoff rather than diving. It also allowed the shooter to take more careful aim. Hitting and entangling flying murrelets with the net proved quite difficult. As murrelets rarely flew higher than 15-46 cm above the water surface, the gun had to be aimed so that the 2 lower floats were level and traveled just above the water surface. If either float struck the water, the net tumbled, resulting in a missed shot.

With heavy load charges (red blanks) the net traveled 15-20 m but its effective distance was 5-10 m. At shorter distances, the net was not fully opened, plus the bird was so close as to often cause the shooter to aim low and miss when floats hit the water. At longer ranges murrelets were sometimes able to dodge the net by changing flight direction or by diving from mid-air, into the water. We were able to catch 1 bird/3-4 days effort our first field season. In 1984, with an experienced boat operator and experienced shooter, we were able to catch about 1 bird/day of effort. Teams of unexperienced workers, or of one experienced individual with an unexperienced individual had much less success in getting shots. We averaged 4-8 shots/day depending on weather. Weather conditions consisting of a 5-10 kt wind to produce a small chop on the water were best for flushing birds into flight and acceptable for aiming accurately from the bouncing boat. We were most successful in approaching and flushing murrelet pairs. Usually one bird in each pair preferred to fly away, while the other (which we believed to be the female) had difficulty taking off and preferred to dive. Once separated, pairs called to each other, which helped us spot them. The bird that flew away usually returned to rejoin its mate. Single birds were almost impossible to follow and groups of 3 or more murrelets generally caused both gunner and driver to become confused about the direction the birds dove. We increased our capture success in 1984 by concentrating our capture efforts on pairs. We found that capturing murrelets became much more difficult from early June on, when increasing numbers of murrelets were alone or in large groups rather than in pairs.

Murrelets were sensitive to handling after capture. We noticed this problem when birds with polyethylene tubing backpacks and implanted transmitters got wet soon after release. Feather-wetting was most conspicuous on the bird's wings, which they repeatedly shook, but the back and head also appeared wet. These birds ultimately died within 12 h after release, most likely of hypothermia. This loss of feather water repellency was apparently caused by residues of oil or WD-40 on our hands, as we solved the problem by wearing surgical gloves when disentangling birds from the net, taking measurements, and attaching the transmitter.

Radio transmitters were surgically implanted, or mounted externally as "backpacks". We tried several methods of backpack attachment including polyethylene tubing harnesses, sutures, and epoxy glue. Seven of eight birds captured in 1983 were fitted with radio transmitters. Four were fitted with backpacks (two with polyethylene tubing and two with sutures); transmitters were implanted in three birds. Transmitter backpacks were glued to the feathers of all 9 birds captured in 1984.

Although backpacks attached with harnesses of polyethylene tubing have been used successfully on a variety of birds, (Cochran 1980) the wing anatomy of murrelets was inappropriate for this technique. Murrelets with this type of backpack could swim and dive normally, but were unable to fly. Murrelets with sutured backpacks were able to fly and dive. One bird with a sutured backpack survived 3 days; we then traced the radio signals to a bald eagle (Haliaeetus leucocephalus) nest. The other bird appeared to behave normally for 6 days, then it disappeared and we were unable to relocate it.

Abdominal implantation of transmitters with coiled antennae required anesthesia and 30 minute surgery. Murrelets responded poorly to the anesthetic, Ketamin. High doses (40 mg) were required to attain anesthesia adequate for surgery, and several hours (8-14) of recovery were necessary for drugged murrelets to visibly recover from the drug's effects. Restraint of the bird during this recovery period was necessary to prevent injury. Two birds with implants died in part due to feather-wetting problems; the third bird survived 2 days but was unable to fly due to a wing injury suffered during capture or recovery from the drug.

In addition to other problems, most birds radiotagged in 1983 behaved abnormally upon release. They tended to set low in the water, flopped their wings frequently, and rolled on their sides to preen. This behavior seemed to provoke bald eagle attacks; 4 of the 8 birds were stooped on by bald eagles. The remains of 1 bird were radiotracked to an eagle nest.

Attaching radio transmitters with waterproof epoxy glue (Devcon 2-ton epoxy) proved to be the best method. Glue was spread on the transmitter and on the feathers of the bird's back over an area equivalent to the size of the radio package. The glue was allowed to dry slightly, then the transmitter was placed on the bird's back. Drying the glue in the wet, cool environment required 1 hour with a 300 watt hair dryer. Surgical gloves were worn at all times when handling birds. Captured birds were measured, weighed, and transmitters attached in the boat where the bird was caught. This was important as it allowed separated mates to call back and forth (even after capture) and promoted prompt reunions upon release. Seven of 8 paired birds with glue attached transmitters rejoined their mates within 5 minutes to 1 hour after release. All birds with glued transmitters were able to fly and dive, and appeared to behave normally. No eagle attacks were observed in 1984, however, remains of 1 radiotagged bird were found below an eagle perch. We observed a merlin (Falco columbarius) stoop unsuccessfully, on a radiotagged murrelet right after it was released.

Backpack transmitters (both whip and coiled antennae) had a maximum range of 4.8 km air and ground to ground. However, low temperatures and humidity strongly affected the transmitter range; under average weather conditions the range was 1.2 km. Heavy mist or rain reduced the range to 0.4 km. We could not pick up any signal from a transmitter implanted antennae end last, when the tagged murrelet was on the water. With the transmitter implanted antennae end first, the maximum range of an implanted transmitter was 1.2 km; 0.4-0.8 km was normal. We could not pick up a signal from any of the transmitters when murrelets dove under water. Transmitters were estimated to have a life of 37-42 days; however the signals from radiotags on murrelets for 20 and 22 days, had highly variable pulse rates, suggesting the transmitters were not functioning properly and would soon die out.

Movements of Radio-tagged Birds. In 1983, 7 radio-tagged birds were known to have survived 8 hours to 6 days (Table 2). The 2 birds capable of flight (sutured backpacks) moved 9.6 km from the capture site. Birds not capable of flight moved up to 3.2 km from the capture site by swimming and diving. Five of the 8 birds radio-tagged in 1983 are known to have died. Causes of mortality included feather-wetting (3), and wing injury (1), bald eagle predation (1). A fifth bird was either killed or scavenged by a bald eagle. The fate of the other 3 is unknown.

Movements of radio-tagged birds in 1984 are more likely representative of movements of undisturbed birds; all birds were able to fly and 7 of the 8 paired birds rejoined their mates soon after release. We relocated 7 of 9 birds 1 or more times after release. The longest period between release and last relocation was 22 days; other birds were relocated 20, 15, 9, 2, and 1 day after release. Remains of 1 bird and its glued backpack were found beneath a raptor perch 4 days after release; a bald eagle was the most likely predator. Four of the 7 birds we relocated returned to their capture site on 1 or more days after release. All relocations of tagged birds were within Kelp Bay, possibly in part reflecting greater search effort in this area. Maximum distances that tagged birds were known to have moved were 9.6, 7.2, 6.4, 6.4, 4.8, 3.2, and 1.6 km. These distances were measured assuming the birds did not travel over land; straight line distances moved were 6.4, 4.8, 4.8, 4.8, 3.2, 3.2, 1.6 km.

The absence of most of the radio-tagged birds from the 505 sq km area searched by air (as indicated by the absence of signals) indicates that murrelets may have moved greater distances. In order to have been missed by these surveys, murrelets would have had to move 9.6-14.5 km from their capture sites. Moving these or greater distances inland would have required flying over mountain passes of 762-1066 m. Relocation records of murrelets #5 and #6, in particular, suggest that murrelets did move greater distances to feed and nest. Murrelet #5 was on its nest on 22, 24, 26 May and 7 June. We located it on the water, 1.5 and 2 miles (straight line distance) from its nest site on 23 May (found at the end of South Arm) and on 27 May (found on the central Basin). Murrelet #5 was apparently absent from Kelp Bay and adjacent areas on 2, 8, and 9 June when we searched by air, and on 6 June when we searched the bay by boat. Murrelet #6 was located in a cove on the north end of Pond Island on 23, 27, 29, 31 May and 2, 6, and 8 June. On alternate days (when it was presumably on its nest), we were unable to locate it. On 7 June we searched Kelp Bay, and Chaik Bay, Whitewater Bay, and Wilson Cove on Admiralty Island; on 9 June, we searched Kelp Bay again and a 8 km wide strip south along Baranof Island to Warm Springs Bay--we did not find it in any of these areas.

Bird and Egg Measurements. Measurements of 21 murrelets examined in this study are presented in Table 3. Average weight was 220.5 g (5 = 18.26, h = 20). The 2 known females were heavier (236 and 252 g) than the 5 known males (m = 209.2, s = 12.5), however the 252 g female had a fully shelled egg in her oviduct when weighed. Average body measurements were: were exposed culmen 16.9 mm (s = 16.9, n = 20); culmen deph- 6.1 (s = 0.28, n = 18); diagonal tarsus- 17.5 mm (s = 2.68, n=21). These measurements are similar to average measurements reported by Sealy (1975).

An egg was laid by murrelet #7, in 1983, when it was recovering from the anesthetic. The egg was ____________green (   ), weighed 38 g, and measured 34.5 X 59.0 mm. This bird later died; an examination of its reproductive tract revealed an ovary 15.7 X 8.2 mm with 1 ruptured follicle 7.7 mm in diameter; the next largest follicle was 3.2 mm. The reproductive tract thus supports Sealy's (1974) contention that marbled murrelets lay a single egg clutch.

Nest Site Characteristics. We found the nest of one ratio-tagged marbled murrelet in 1984 (Fig. 4,5, and 6). The nest was 15.5 m up and 1.24 m out on an 18 cm diameter (at the base), moss-covered branch of a mountain hemlock (Tsuga mertensiana). No nest material or construction was apparent; the olive-green bed of moss (Antitrichia curtipendula) beneath the nest was about 10 cm thick. The nest was on the downhill, east side of the tree and sheltered by overhanging branches 46 cm above the nest. The nest limb sloped steeply downward from the trunk but leveled out near the nest site. The nest tree was 3.9 m circumference, 1.2 m~~m~~ diameter and approximately 25 m tall. The top 3 m of the tree was dead.

The nest tree was located on a southeast facing, 25° slope, approximately 18 vertical meters below a 366 m elevation ridge. About 90 m below the tree, the slope increased to 80%. The tree was in an open, uneven-aged stand of mountain hemlock. There were 11 trees and 2 stumps of large fallen trees within 20 m radius of the nest tree. Average diameter of these trees was 0.6 m (s = 0.6, n = 11, range = 0.06 - 1.6 m). All live trees were mountain hemlock except for 1 western hemlock. ~~A few large Stika spruce were in the general area, but were farther than 20 m away.~~ We ~~were unable to measure these trees, but~~ estimated the~~ir~~ ~~heights~~ heights of these trees at 6-30 m.

According to U.S. Forest Service timber type maps, the stand was __________ volume, old growth forest. Snowline had receded to 10 m below the nest tree by June 4; 0.5 - 1 m or more of snow covered all ground at higher elevations on the mountain. Huckleberry (Vaccinium ovalifolium) was the main ground cover. A rivulet of water from melting snow formed the beginning of a stream about 50 m from the nest tree. However, this was not likely to provide a travel route for adult or fledging murrelets due to the small amount of water in the stream headwaters, and the torrential descent of the water as the stream proceeded to the bay. The nest tree was 1.2 km from the nearest saltwater and 3.2 km (straightline distance) from where we captured the murrelet.

After the nest tree was found, the nest was located and photographed by climbing the tree. The murrelet did not flush from its nest during the 2 hours it took to climb the tree and 1½ hours that we photographed the nest and took measurements around the tree. From the time the bird was spotted until we left, the murrelet remained perfectly motionless. The murrelet was not camouflaged by the green moss around the nest. The overhanging branches likely concealed the nest from overhead, however.

Conclusions

The nest found in this study is similar to the only other North American tree-nest record, in Big Basin State Park, California, (Binford et al. 1975) in that it was high up on a moss-covered branch of an old coniferous tree, at a high elevation, and in a location allowing access to the exterior of the forest. The nest tree in Kelp Bay was smaller (only 25 m versus Big Basin 61 m) and the nest was at a lower height (only 15.5 m versus 45 m), but the trees were similar diameter (1.24 and 1.67 m). Both trees were among the largest, but not the largest trees, in the vicinity of the nests. As indicated by the dead crown and rotten core of the Kelp Bay tree, and dead branches of the Big Basin tree, both trees were decadent. In contrast to the Big Basin nest, the Kelp Bay nest was located away from, rather than next to the red-brown tree trunk, so the adult did not blend in with its immediate surroundings. The bird's coloring may still have provided camouflage from above, however, as it's feathers did resemble a piece of exposed limb or bark. The Kelp Bay nest was much closer (0.81 km) to the coast than the Big Basin nest (10 km).

The Kelp Bay nest was dissimilar to the "average" marbled murrelet nest site characterized by Day et al. (1983) in that it was on a southfacing rather than northfacing slope, at a lower elevation (366 m versus 570 m), was closer to the coast (0.81 km versus 6.0 km), and it was in a tree (unlike 7 of the 9 nests they summarize). As Day et al. note, ground nest records are likely more numerous because of the relative ease of finding ground nests as compared to tree nests.

We think it is unlikely that murrelets nest on the ground in alpine areas in Kelp Bay because there were few, if any snow-free alpine areas around Kelp Bay during mid- to late May when murrelets were laying eggs. Interestingly, nest and egg records of marbled murrelets are generally earlier (mid May-early July) than those of Kittlitz's murrelets, (mid June-late July); Kittlitz murrelets are apparently restricted to ground nests in alpine areas (see summary in Day et al. 1983). Marbled murrelet use of trees for nesting may reflect in part the scarcity of snow-free alpine areas during the time they are selecting nest sites and laying eggs. If this is so, one might expect marbled murrelets to nest in trees in areas of heavy snowfall and late snowmelt. More information on precipitation and murrelet nest records are needed to test this hypothesis.

Other researchers have speculated that use of inland nest sites might be a predator avoidance tactic (Simons 1980). Our observations of bald eagle attacks and predation, and merlin attacks on radio-tagged adult marbled murrelets indicate that murrelets are susceptible to avian predators. We regularly observed bald eagles and ravens circling above the ridges surrounding Kelp Bay, and observed a goshawk at 243 m (800 ft) elevation, so murrelets do not entirely avoid these predators by nesting inland at high elevations. Northwestern crows and Steller's jays, both conspicuous birds along the coast and often indicated as egg and nestling predators, were never seen or heard inland or at high elevations, however. We suspect marbled murrelets may nest inland to avoid these potential nest predators.

The discovery of another marbled murrelet nest in a tree in old growth forest lends additional weight to the concerns that this species may depend on old-growth forest in parts of its range. Although the nest located in this study was in a location where the steep slope and high elevation will likely prevent logging operations, the stand of trees was old-growth forest, and the nest was on a limb covered by heavy moss. British Columbia records of an adult with an egg and murrelet chicks found after trees were felled by loggers (Drent and Guiquet 1961, Harris 1971) clearly indicate that murrelets use old growth forest in areas accessible for logging. Use of moss-covered limbs may restrict tree-nesting murrelets to old-growth forests, as lush moss growth does not occur in second-growth forests (Franklin et al. 1981). Continued work is needed to identify the nest site preferences of marbled murrelets. The techniques developed in this study will allow researchers to locate additional marbled murrelet nests. However, identification of many nests will likely require the efforts of many people and a considerable amount of financial support for radio-telemetry equipment and extensive air surveys.

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