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DISCOVERY AND OBSERVATIONS OF TWO TREE NESTS OF THE MARBLED MURRELET[1]

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Abstract. Two nests of the Marbled Murrelet (*Brachyramphus marmoratus*) were found in old-growth (300 + years) Douglas-fir (*Pseudotsuga menziesii*) trees in Big Basin Redwoods State Park, Santa Cruz County, California. These were the third and fourth known North American tree nests, and the first to be found by searching from the ground without the use of radio-telemetry. Ground-search techniques for finding nests are presented. Both nests were in the incubation stage when found. Each was observed from a distance for 15 days and 34 days, respectively. Incubation shifts lasted 24 hr with the adults exchanging duties at dawn. Flight behavior near the nest is described. Corvid predation caused both nests to fail, and may be a problem where murrelets nest in areas of high human usage. After nest failure, each tree was climbed. Both nests were located in the inner canopy, mid-crown portion of the trees. Nest branches were large, moss-covered, horizontal branches that were well shaded. One nest was a previously undescribed type of constructed nest made up of small Douglas-fir twigs and foliose lichens. The other nest was a natural depression in a moss-covered limb. Eggshell fragments were similar to previously described eggs. Nest site characteristics are compared to characteristics of the other known Marbled Murrelet tree nests.

Key words: *Marbled Murrelet;* Brachyramphus marmoratus; *tree nests; old-growth forest; California.*

INTRODUCTION

The nest sites of the Marbled Murrelet (*Brachyramphus marmoratus*) are barely known, with only thirteen nests confirmed to date (Marshall 1988, Rodway 1990). Nests have been found in Alaska, California, Siberia and Japan. Day et al. (1983) and some subsequent authors report an additional nest that we question—an egg found in the office of a Washington logging camp (Anonymous 1927) with few details. Two subspecies of the Marbled Murrelet are recognized—in North America, *B. m. marmoratus,* and in Asia, *B. m. perdix.* The North American form is found in summer from the Aleutian Islands and Gulf of Alaska south to Santa Cruz County, California (AOU 1983). Asiatic birds range in summer from the Bering Sea and the Kamchatka Peninsula south along the coast of Siberia, the Sea of Okhotsk and Sakhalin Island, to northern Japan (Sealy et al. 1982).

This paper is confined to the North American subspecies' use of tree nests, which, from southeastern Alaska southward, is the only type of nest known. The southern portion of the range of *B. m. marmoratus* is coincident with the Pacific Forest Province Ecoregion (Bailey 1980), noted for large, long-lived coniferous trees. Old-growth forests in this ecoregion typically have a canopy height of 50 to 75 m (Franklin and Dyrness 1973) which is much higher than the forests in which *B. m. perdix* is known to nest.

Evidence is mounting that nests are restricted to old-growth forests. This includes the location of eggshells and grounded flightless young, the intensity of overland flight activity and vocalizations, and the summer distribution of birds at sea, which is primarily off-shore of old-growth forest (Carter and Sealy 1987; Rodway 1990; Pa-

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ton and Ralph, in press). Although murrelets commonly use coastal old-growth forests during the breeding season, they are secretive near the nest. Only four tree nests have been found in North America. The first tree nest was found accidentally in an old-growth Douglas-fir (*Pseudotsuga menziesii*) in Big Basin Redwoods State Park, Santa Cruz County, California, in 1974 (Binford et al. 1975). The second tree nest was found in an old-growth mountain hemlock (*Tsuga mertensiana*) near Kelp Bay, Baranof Island, southeastern Alaska in 1984 (Quinlan and Hughes 1990). The latter nest was found by radio-tagging birds captured at sea. We report here the discovery of the third and fourth North American tree nests in old-growth Douglas-fir in Big Basin Redwoods State Park, California. Each nest was found by ground-search techniques without using radio-telemetry.

STUDY AREA

Big Basin Redwoods State Park (37°10′N, 122°13′W) is approximately 30 km northwest of Santa Cruz, California in the Santa Cruz Mountains. Most of the range's original old-growth redwood forest was logged around 1900. However some stands remain, primarily in state or county parks, and many have breeding murrelets (Paton and Ralph, in press).

Approximately 1,000 ha of Big Basin Redwoods State Park are old-growth redwood forest (Hill and Hill 1927). Park headquarters, at 300 m elevation, is located in the center of this area approximately 8.5 km from the ocean. Both 1989 nests, as well as the 1974 nest (Binford et al. 1975) were less than one km from park headquarters.

Big Basin is located in the southern part of the Redwood Forest Section of the Pacific Forest Province Ecoregion (Bailey 1980), where the dominant tree species are coast redwood (*Sequoia sempervirens*) and Douglas-fir. Understory species include tan oak (*Lithocarpus densiflora*), California wax myrtle (*Myrica californica*), and a shrub layer primarily of evergreen huckleberry (*Vaccinium ovatum*) (Thomas 1961).

The region has a cool Mediterranean climate with high humidity, low average summer temperatures, and mild winters. The summers have morning and evening coastal fog or low clouds. Annual precipitation of 125–150 cm is almost entirely rain, with 90% occurring between November and May (Donley et al. 1979).

METHODS

We looked for nests in the old-growth redwood forest using ground-search techniques. We concentrated on areas where birds had been seen flying silently below the canopy around dawn, when murrelets are most active in the forest (Paton et al. 1989). Location of the first nest took seven days. First, a tree in the Opal Creek Picnic Area was closely observed because it had characteristics of the 1974 nest tree described by Binford et al. (1975). It was an old-growth Douglas-fir with large diameter, nearly horizontal branches and natural platforms within the live crown. On 3 June 1989, a few minutes before sunrise (at 04:41 PST), one murrelet was seen flying out of the tree. On 8 June at 04:50, a murrelet was observed landing on a branch. A few seconds of soft low vocalizations were heard, then a murrelet left the same branch. Finally, on 10 June, an adult murrelet was seen sitting on the nest. A second nest, 1.25 km southwest of the first, was found near the park sewage treatment plant bordering Waddell Creek on 28 June using similar procedures.

Observation points were located 40 m or more from each nest and partially screened by trees. Equipment used to make observations consisted of a video camera and recorder on a 25.4-cm Meade telescope for daytime activity, and a Javelin night-viewing device with a 500-mm telephoto lens and a 2× tele-extender mounted on a video camera with recorder for twilight and nocturnal activity. Observations were generally carried out from 45 min before dawn to 45 min after sunset on the Opal Creek nest between 10 June and 24 June, and on the Waddell Creek nest between 28 June and 31 July. Additionally, a few 24-hr observations were made on the Waddell Creek nest. In both nesting pairs, the adults differed in plumage, one being much darker than the other, so that incubation shifts could be accurately determined.

After the nests failed, the Opal Creek and Waddell Creek trees were climbed on 1 and 6 August, respectively. The climber photographed and measured the nests, and collected samples of nest materials, generally conforming to the protocol of Varoujean and Carter (1989). Each nest was left substantially intact.

Tree stand composition was assayed in a 25-m radius circular plot, centered on the nest tree, following Varoujean and Carter (1989). One ex-

TABLE 1. Characteristics of North American tree nests of the Marbled Murrelet.

	"J" Camp Big Basin, California[a]	Kelp Bay Baranof Is., Alaska[b]	Opal Creek Big Basin, California[c]	Waddell Creek Big Basin, California[c]
Tree species	Douglas-fir	Mountain Hemlock	Douglas-fir	Douglas-fir
Dbh (cm)	167	120	210	196
Height (m)	61.0	ca. 25	61.2	76.2
Stage of vigor	Declining (several dead branches)	Declining (top 3 m dead)	Declining (broken top; several dead branches)	Declining (several dead branches)
Vertical extent of live crown (m)	27	—	30	50
Canopy closure (%)	Open canopy	Open canopy	40	25
Nest branch diameter (cm)	41.0	38.0 (18 cm wood + 20 cm moss)	47.7	36.3
Nest branch height (m)	45.0	15.5	43.7	38.5
Direction of branch projection	South	East	North-northwest	Southeast
Branch position within live crown	Middle	Lower ⅓	Middle	Middle ⅓
Branch condition	Long branch with distal ⅓ dying	Long healthy limb	Broken stub just distal of nest with several upright projecting limbs	Woody knob just distal of nest with several upright projecting limbs
Nest distance from trunk (cm)	6.8	124.0	122.0	61.0
Nest substrate	Moss-covered branch	Moss-covered branch	Natural platform with moss, twigs, dead needles, and lichens	Moss-covered branch
Nest materials	None	None	Douglas-fir twigs with attached lichens	None[d]
Nest dimensions (cm)	9.5 × 6.5	—	16.5 × 14	11.5 × 7.5
Depth of nest bowl (cm)	1.0–3.0	—	8.0 (3.0 cm due to depression in branch)	2.0
Departure of nest orientation from branch orientation	30°	—	28°	46°

[a] Binford et al. 1975.
[b] Quinlan and Hughes 1990.
[c] This study.
[d] At time of collection (see text).

ception was that plot dimensions were determined by measurement on the ground surface instead of on a horizontal plane in order to allow comparison of quantitative data between plots (Mueller-Dombois and Ellenberg 1974). Height of the nest trees was determined by triangulation using a Lietz optical transit. Age was estimated from growth ring counts on ten Douglas-fir stumps of similar diameter found within 1.5 km.

RESULTS

ACTIVITIES AT THE OPAL CREEK NEST

The Opal Creek nest was observed for 15 days. At discovery, the bird was incubating an egg. Incubation duties were shared by both adults, each for 24 hr, confirming Simons (1980). The exchanges took place between 04:26 and 04:41 (PST) each day, with official sunrise between 04:

47 and 04:49. On 24 June, at about 06:30, a Common Raven (*Corvus corax*) landed on the branch and displaced the adult murrelet. Both birds disappeared from the nest branch. Approximately 15 min later, a raven was seen flying from the direction of the tree carrying what seemed to be a carcass in its bill. The size of the carcass indicated that it was either the embryo or part of the adult. Steller's Jays (*Cyanocitta stelleri*) were observed picking at eggshell fragments in the nest that same day. On the morning of 25 June, an adult murrelet returned to the nest but did not stay. On 26 June, a large murrelet eggshell fragment was found on the ground below the nest. Periodic observations over the next few weeks showed that no re-nesting occurred.

DESCRIPTION OF THE OPAL CREEK NEST SITE AND TREE

Nest site characteristics are given below and in Table 1.

Location. The tree was located 300 m north of park headquarters in the picnic area east of Opal Creek. An electric power line and a foot trail passed within 10 m of the tree. The nest-tree stand (Table 2) occupied the toe of a hillslope and the adjoining alluvial terrace. Slopes ranged from 46% on the hillside to 18% on the terrace. Near the nest tree, the slope averaged 41% towards the west. The closest old-growth trees were two coast redwoods to the northwest, a 200 cm dbh (diameter at breast height) tree at 6.3 m, and a 167 cm dbh tree at 7.5 m.

The nest tree. The main trunk of the nest tree was broken off at about 52 m, and several once-horizontal branches had turned vertical to take the place of the leader (Fig. 1). The tree, estimated to be 300 to 600 years old, had a pronounced lean to the southwest. The nest limb was about 1.5 m long, and extended nearly level to a broken end. Several smaller branches originated from a protuberance at the limb end, including one large branch that immediately turned upwards. A widened platform had formed at this junction. Shading from nearby branches and adjoining trees kept direct sunlight off the nest for all but short periods of time.

The nest. The nest was located on the platform. It was an oval cup with sides and bottom of small Douglas-fir twigs and dead filaments of the epiphytic fruticose lichen, *Usnea* sp. (Fig. 1). The twigs were approximately 1–4 mm diameter, similar to twigs accumulating naturally on the branch. Attached to many of the twigs were species of foliose lichen, including *Hypogymnia enteromorphia.* Some dried Douglas-fir needles and cone scales were also in the nest. A layer of *Antitrichia californica* moss, approximately 1.0 cm deep, covered the branch under the nest. Neither droppings nor a ring of excrement, like that described by Binford et al. (1975), were in the nest. This difference is probably due to the presence of a large young in the 1974 nest.

TABLE 2. Tree density and coverage in a 25 m radius circular plot in the Opal Creek nest stand, Big Basin Redwoods State Park.

Species	Density (no./ha)	Relative density (%)	Coverage (basal area m^2/ha)	Relative coverage (%)
Coast redwood	71.3	23.7	103.5	71.3
Douglas-fir	20.4	6.8	31.3	21.6
Tan oak	208.8	69.5	10.3	7.1
Other hardwoods	0	0	0	0
Total	300.5	100.0	145.1	100.0

ACTIVITIES AT THE WADDELL CREEK NEST

The Waddell Creek nest was observed nearly continuously during daylight hours and intermittently at night for 34 days. At discovery, the bird was incubating an egg. Incubation and brooding duties were shared by both adults, in 24-hr shifts, with the exchange taking place between 6 and 37 min before sunrise. A chick was first observed on 29 July.

At about 09:00 on the morning of 31 July, while the chick was unattended, a Steller's Jay landed on the nest and removed the chick, apparently killing it. Forty-five minutes later, an adult murrelet returned with a fish, but left shortly after. The nest was observed periodically for the rest of the season, but re-nesting did not occur.

DESCRIPTION OF THE WADDELL CREEK NEST SITE AND TREE

Nest site characteristics are given below and in Table 1.

Location. The tree was located 1.0 km southwest of park headquarters near the east fork of Waddell Creek and within 34 m of a sewage treatment plant. An unofficial hiking trail and a ser-

FIGURE 1. The Opal Creek nest. a. Nest tree with arrow showing nest location. b. Close-up of nest branch with arrow showing nest location. c. The constructed nest as viewed from the trunk looking along the branch to the natural platform. Arrows indicate outside edges of the nest.

vice road passed within 25 and 28 m, respectively, of the nest tree. The area immediately southwest of the tree appeared to have been disturbed 20 to 50 years ago as evidenced by a clump of pole-sized young redwoods, an overgrown dirt road, and the remains of an old wooden bridge.

The nest tree stand (Table 3) occupied the alluvial bench north of the creek and the toe of the adjoining hillside. Slopes varied from 14% to 23% to the south, and 12% to 18% to the east. The slope near the nest tree averaged 24% to the southeast. The closest old-growth trees were two coast redwoods, a 103 cm dbh tree 18.1 m west, and a 137 cm dbh tree 18.4 m southwest.

The nest tree. The trunk of the nest tree was straight and the top intact, although some broken branches occurred near the top (Fig. 2). The nest limb was a live branch with a damaged end. About 12 cm beyond the nest, a large knob projected up from the branch, creating a 27 cm high vertical wall. Branches on the nest tree and nearby trees kept the nest in shade for all but short periods each day. Estimated tree age was 300–600 years.

The nest. The nest was in a mossy depression on the branch, lacking the built-up sides of the other nest (Fig. 2). Underlying most of the nest was a 0.8–1.0 cm layer of moss (*Antitrichia californica*) with dried Douglas-fir needles, small pieces of bark (2–10 mm across), Douglas-fir cone fragments and seeds mixed in. On the branch surrounding the nest was more moss, the epiphytic fruticose lichen, *Usnea* sp., and other lichens, including *Evernia* sp. and *Parmelia* sp. As in the Opal Creek nest, a ring of excrement was lacking. However, five intact droppings were present inside the lip.

TABLE 3. Tree density and coverage in a 25 m radius circular plot in the Waddell Creek nest stand, Big Basin Redwoods State Park.

Species	Density (no./ha)	Relative density (%)	Coverage (basal area m^2/ha)	Relative coverage (%)
Coast redwood	443.1[a]	57.2[a]	54.4	58.9
Douglas-fir	61.1	7.9	20.6	22.2
Tan oak	208.8	27.0	15.6	16.8
Other hardwoods[b]	61.2	7.9	2.1	2.1
Total	774.2	100.0	92.8	100.0

[a] High density due to a pole-sized stand of young trees in a portion of plot that had been disturbed in the past.
[b] Species included in this category are California wax myrtle, California bay (*Umbellularia californica*), blueblossom ceanothus (*Ceanothus thyrsiflorus*), and coast live oak (*Quercus agrifolia*).

DESCRIPTION OF EGGSHELL FRAGMENTS FROM BOTH NESTS

One large eggshell fragment (approximately 18 × 25 mm) and numerous small fragments (mostly less than 3 mm) were collected from the nests (WFVZ 161963 and 161964). Colors and markings were generally similar to those described by other workers (Kiff 1981; Atkinson and Manlow, in press; Reed and Wood, in press). Exceptions are the partially *pale turtle green* background color of the Waddell Creek egg and *pale dull green-yellow* background color of both eggs (italicized colors from Ridgway 1912). Colors of spots and splotches not previously described include *chestnut brown, aniline black, light seal brown,* and *olive-gray.*

DESCRIPTION OF FLIGHT BEHAVIOR NEAR BOTH NESTS

We observed several distinctive types of flight behavior occurring below the canopy near both nests. This behavior occurred during the morning period of activity, especially in the half hour before dawn. These included:

Tail-chasing. One murrelet flies closely behind another through the canopy at moderate-to-high speed. On one morning three weeks before the discovery of the Opal Creek nest, this behavior was observed six times near the nest tree. On those occasions, another or the same pair was seen flying in the opposite direction along the same course within 15 sec after the first pair flew out of sight.

Buzzing. A single bird flies at a height of 10–30 m through the forest, making a continuous low-pitched buzzing wing sound.

Stall-flight. A low-flying bird or pair hovers over a branch, or lands momentarily, before flying on. This behavior is sometimes associated with tail-chasing.

Fly-bys. A single bird flies silently by the nest tree just outside or through the crown and at approximately the same height as the nest. This was observed frequently at both nests, often occurring 1–2 min prior to and up to several minutes after the dawn exchange.

Both nesting pairs were quite predictable in their flight direction to and from the nest. They used the most direct and least obstructed flight path available. The birds showed a high degree


a
b
c

of maneuverability in take-offs and landings. On one occasion a murrelet was seen flying directly up through the crown of the Opal Creek nest tree from a lower to a higher branch.

At the Opal Creek nest, 19 incubation exchanges were recorded. Most birds arrived from the west and departed to the west, flying over the tops of some younger redwoods on the edge of the clearing. Generally, the murrelets landed on the nest branch near its junction with the trunk and walked towards the nest. Similarly, on departing, birds usually walked towards the trunk before flying from the tree. However, on a few occasions, a murrelet simply dropped off the east side of the nest.

Of the 32 incubation and brooding exchanges recorded at the Waddell Creek nest, all of the arrivals and 94% of the departures were from the south or southwest. Usually, murrelets flew directly up or down Waddell Creek Canyon. Several times departing murrelets flew directly over the sewage treatment plant. At this nest the murrelets typically landed and departed from a point on the limb halfway between the nest and the trunk.

DISCUSSION

The Opal Creek nest is a new type of nest for the North American subspecies, being a cup constructed of twigs and lichens. The three other tree nests were depressions on moss-covered branches. The Asiatic subspecies uses constructed nests, but has not been observed constructing them. A nest found on Sakhalin Island, Siberia, U.S.S.R. (Nechaev 1986), was composed of twigs and small pieces of lichen. It was in the broken top of a larch about 5 m above the ground. The inside dimensions of the nest were 5.5 cm × 3.5 cm, considerably smaller than the Opal Creek nest. We do not know if the Opal Creek nest was constructed by the nesting adults or if it was an abandoned nest of another species. The Band-tailed Pigeon (*Columba fasciata*), which breeds in Big Basin, constructs nests of similar materials and similar dimensions. However, the incubating murrelet was observed, on at least one occasion, to break off a twig and add it to the nest, and on several occasions, to adjust the positions of existing twigs. At the Waddell Creek nest, the incubating bird also placed twigs, needles, moss, and lichen from the surrounding branch around the nest, although no evidence of nest construction was in place when the tree was climbed. The North American subspecies has now been shown to nest in depressions on the ground surface (Simons 1980, Hirsch et al. 1981), in rock cavities on the ground (Day et al. 1983, Johnston and Carter 1985), on moss-covered branches of old-growth conifers (Binford et al. 1975; Quinlan and Hughes, 1990), and in constructed nests on the branches of old-growth trees (this study).

The four known North American tree nests (Table 1) shared the following characteristics: (1) the tree was in an open canopy stand; (2) the tree was >120 cm dbh (old-growth); (3) the tree was in a declining state of vigor; (4) the nest was within the middle to lower part of the live crown; (5) moss grew on the nest branch; (6) the nest branch was partially shaded; and (7) the nest branch was approximately horizontal with a diameter (including associated moss) of at least 36 cm.

The three Big Basin nest trees were 300–600 years old and had nest limbs greater than 36 cm in diameter. The time required to grow a horizontal branch of this thickness may determine the minimum age at which a tree is suitable for nesting. Conifers in the Pacific Northwest can acquire some old-growth characteristics at 175 years (Franklin et al. 1981). However, the large branches or horizontal platforms that murrelets in the Santa Cruz Mountains apparently need may not be acquired until trees are much older.

Recreational facilities, such as picnic areas and visitor service facilities, may interfere with the nesting success of Marbled Murrelets. Both 1989 nests were in such areas. Although incubating birds only rarely showed behavior suggesting agitation from human presence or noise, they may have been indirectly affected by supplemental

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FIGURE 2. The Waddell Creek nest. a. The nest tree with arrow showing nest location. b. The nest, a mossy depression in the branch, as viewed from the trunk looking outward toward the vertical "wall" at the distal end of the branch. Arrows indicate the outside edges of the nest. White flecks are pieces of eggshell or egg membrane. c. Close-up of nest branch with arrow showing nest location.

food items (table scraps and garbage) made available to potential nest predators. Both Steller's Jays and Common Ravens have been observed feeding from garbage cans in the Opal Creek picnic area. Ravens, which did not nest in the park prior to 1987 (D. Suddjian, pers. comm.) nested successfully near the picnic area in 1989. Elsewhere, unusually large corvid populations have been noted in picnic areas and campgrounds where garbage is available (Gaines 1977, Beedy and Granholm 1985). Work done in Big Basin by Orr (1942) found a correlation between the higher numbers of Steller's Jays in campgrounds and the reduced number of passerine birds there. Now that Steller's Jays and Common Ravens are known to prey on Marbled Murrelet eggs and nestlings (this study), visitor activities that favor corvid populations should be minimized. The discovery of additional nests is needed to elucidate the problem and propose a solution.

To aid researchers in locating nests, we summarize here our ground-search techniques:

1. Survey old-growth stands in the breeding season, during the two hour period around sunrise, for murrelets flying below the canopy. Special attention should be paid to those birds flying silently or making the "buzzing" wing sound.

2. Within a suitable stand, select a large tree for detailed surveillance. Suitable trees have large live horizontal branches or platforms in the inner canopy. The presence of a knob or vertically-projecting limb on the potential nest branch may also be important. All three of the Big Basin nests were located close to a vertical projection formed by either the trunk or a vertical limb.

3. Find an observation point with a view of the live crown with as much sky as possible in the background. Closely observe the tree, and the air space surrounding it, for the two hour period centered around sunrise. Look for murrelets flying to or from the tree. In the two nests that we discovered, the exchange of incubation duties occurred in the period from 1–37 min before sunrise.

4. Once a murrelet has been seen flying into or from a tree with suitable branches, a nest is possible. Landings or take-offs are difficult to observe in the pre-dawn light, so repeated observations and/or multiple observers may be needed to pinpoint the specific branch the birds are using.

5. Once the branch has been found, look for a nearby vantage point, such as a steep slope, from which to view the top of the suspected nest branch. Observation of an adult murrelet or nestling on the branch during the day will confirm the nest.

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