

USE OF AN INLAND SITE IN NORTHWESTERN CALIFORNIA BY MARBLED MURRELETS

PETER W. C. PATON,¹ C. JOHN RALPH, AND RICHARD A. ERICKSON²
*U.S.D.A. Forest Service, Pacific Southwest Forest and Range Experiment Station
1700 Bayview Drive, Arcata, California 95521*

Abstract. We investigated Marbled Murrelet (*Brachyramphus marmoratus*) habitat-use patterns by censusing a variety of forest stands at Redwood Experimental Forest in northwestern California. Murrelet activity levels were greatest 30 minutes before to 30 minutes after sunrise in May, June, and July. Surveys at fixed stations showed that during the breeding season, murrelets were present more often in old-growth redwood (*Sequoia sempervirens*) stands than adjacent clearcuts and partially harvested stands ($P < 0.01$). Although no nests were found, observations of murrelets landing in trees and flying low through the forest were confined to old-growth stands. Problems associated with surveying murrelets at inland sites are discussed.

Key words: *Brachyramphus marmoratus; California; Marbled Murrelet; survey.*

INTRODUCTION

On the west coast of North America, from southcentral Alaska to central California, the Marbled Murrelet (*Brachyramphus marmoratus*) is thought to nest primarily in old-growth coniferous forests (Sealy and Carter 1984, Marshall 1988, Paton and Ralph 1990). The old-growth forests of the region have been reduced by at least 90% due to logging since the mid-1800s and much of the remaining old-growth habitat is still being harvested (Morrison 1988, Fox 1989). Yet despite this threat to murrelet habitat, little is known about the habitat characteristics of nest stands.

Information on murrelet use of old-growth forests in California has accumulated rapidly in recent years. The first nest was discovered in 1974 at Big Basin Redwoods State Park, Santa Cruz County (Binford et al. 1975). Three more nests have since been found in the same park: two in 1989 (Singer et al. 1991) and one in 1991 (S. W. Singer, pers. comm.). Inland sightings of downy young and fledglings, use of inland sites by adult birds, and at-sea distributions have all been associated with old-growth forests (Sowls et al. 1980, Carter and Sealy 1987, Carter and Erickson 1988). Surveys conducted at inland sites in California in 1988 and 1989 showed murrelet activity levels were greatest in old-growth forest stands in Humboldt, Del Norte, San Mateo, and

Santa Cruz counties (Paton and Ralph 1990, Ralph et al. 1990).

Our objectives are to: (1) describe daily activity patterns of murrelets at Redwood Experimental Forest (hereafter, the Forest), and (2) to assess their habitat relationships based on two types of surveys at the Forest. Surveys conducted in 1985-86 were designed to determine the habitat association patterns of all diurnal birds (Ralph et al. 1991), whereas surveys in 1988 exclusively assessed Marbled Murrelet behavior and further quantified their habitat associations at the Forest. This study was one of the first attempts to systematically determine habitat use patterns of murrelets at an inland site. Previously, they had been studied only at sea (Sealy 1974, 1975; Carter 1984).

STUDY AREA AND METHODS

The Forest was located 8 km north of the Klamath River and 2 km east of the Pacific Ocean in northwestern California. The area was managed by the U.S. Forest Service for investigations and experiments for the benefit of landowners with similar forests. The Forest was 376 ha in size, with 226 ha (60%) harvested from 1958-89 using various shelterwood and clear-cutting techniques. Old-growth redwood (*Sequoia sempervirens*) and riparian corridors occupied approximately 150 ha, including 61 ha in a designated Research Natural Area. The Natural Area was not harvested and will not be logged in the future, but all the other areas of the Forest were available for harvesting.

During 1985 and 1986, we censused all diurnal birds at 12 stations on each of three stands using

¹ Present address: Department of Fisheries and Wildlife, Utah Cooperative Fish and Wildlife Research Unit, Utah State University, Logan, Utah 84322.

² Present address: LSA Associates, 1 Park Plaza, Suite 500, Irvine, California 92714.

the variable circular plot method (Ralph et al. 1991). The three stands consisted of three structural classes: (1) closed-canopy old-growth; (2) a partially harvested shelterwood stand; and (3) a partially harvested seedtree stand. Census stations were located 150 m apart and > 50 m from another habitat type. Censuses were conducted at least once monthly at the Old-Growth and Seedtree stands from April 1985 to May 1986, whereas the Shelterwood stand was only censused six times during the 1985 breeding season. Birds were counted for 8 minutes at each station; a complete census took approximately 3.5 hours and began within 20 minutes of official sunrise to maximize the probability of all diurnal birds being active during the census. Because censuses started after sunrise, the peak of murrelet activity was often missed (see Paton et al. [1990]). Therefore, data collected in 1985-86 were only used to determine murrelet presence.

In 1988, two road transects (11 stations each) were established to survey murrelets at the Forest on existing roads using census protocols developed by Paton et al. (1990). These two transects, High Prairie Creek and Overlook, were surveyed five and four times, respectively. In contrast to 1985-86, murrelets were the only species counted during 1988 surveys. The observation unit used to record murrelets was a "detection," defined as the sighting and/or hearing of a single bird or a flock of birds acting in a similar manner. Transects were initiated 45 minutes before official sunrise and continued until 90 minutes after sunrise. Each station was censused for 10 minutes and station order was varied between visits. Intensive inventories, where murrelets were counted from one location throughout the dawn activity period (Paton et al. 1990), were also conducted during 1988 in areas where birds were landing in trees. We categorized each road transect station into one of three habitat types, based on the closest habitat type to the east of the station. We felt murrelets detected at a station were generally coming from or headed to a point farther east. We used three habitat types for this analysis: old-growth (High Prairie Creek station nos. 1, 2, 3, 4, 5, 11), partially harvested (High Prairie Creek station nos. 6, 8 and Overlook station nos. 3, 4, 6, 8), and clearcut (High Prairie Creek station nos. 7, 9, 10 and Overlook station nos. 1, 2, 7). We only used the first six stations visited each morning, as few murrelets were detected after the sixth station. Therefore, Overlook station nos. 9-11 were dropped from the

road transect habitat analysis, as they were never visited early enough to be included. We analyzed habitat selection from road transect data using a chi-square contingency test.

In 1985, vegetation was quantified with circular plots at each of the 1985-86 stations. Tree stems 1-50 cm in diameter at breast height (dbh) were counted within a 13-m radius of the station, whereas tree stems >50 cm dbh were counted within a 25-m radius.

RESULTS

Vegetation

Redwood was the dominant tree species at the Forest, with Douglas-fir and red alder (*Alnus rubra*) comprising the majority of the other tree species present (Table 1). Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*) occurred in low densities in creek drainages away from vegetation plots, but still on the study site. Based on ring counts of stumps in the Forest, tree ages ranged up to 1200 years (B. Bingham, Redwood Sciences Laboratory, Arcata, Calif., pers. comm.).

The Old-Growth stand was located within the boundaries of the Research Natural Area, and had a dense canopy of redwoods >1 m dbh, a sparse mid-canopy of red alders (compared to the other two stands), and a dense fern understory (Table 1). About 75% of the old-growth trees at both the Shelterwood and Seedtree stands were harvested in 1970 and 1983, resulting in a sparse canopy of redwoods >1 m dbh, averaging approximately 10 trees/ha. Both these partially logged stands had an extremely dense mid-canopy of red alder, with some bigleaf maple (*Acer macrophyllum*) and Pacific Dogwood (*Cornus nuttallii*) (Table 1).

Murrelet seasonal and daily behavior

Variable circular plot censuses.—Marbled Murrelets were detected at the three stands from April-July and October-November in 1985 and again in May 1986 (Table 2). Activity levels were greatest from May to July (Table 2). All observations were auditory detections, as murrelets were extremely difficult for observers to see when censusing from within the stands. Although surveys were initiated past the early dawn period of peak murrelet activity, birds were detected an average of 26.3 minutes/census (SD = 32.9; range = 4-101; $n = 10$) at the Old-Growth stand, 41.0 minutes/census (SD = 23.7; range = 11-69; $n =$

TABLE 1. Dominant tree cover at three stands at the Redwood Experimental Forest, California.

Tree species	Dbh (cm)	Stand types ^a					
		Old-growth		Shelterwood		Seedtree	
		\bar{x}	SD	\bar{x}	SD	\bar{x}	SD
Redwood	1-10	11.5 ^b	12.5	77.9	83.0	24.4	21.3
	10-49	21.3	20.4	31.6	25.9	6.1	6.6
	50-99	19.1	13.7	9.7	4.1	4.1	2.0
	>100	41.7	17.8	11.7	16.3	8.9	3.1
Douglas-fir	1-10	1.3	3.2	1.5	4.6	8.7	11.2
	10-50	2.0	6.1			2.0	
	50-99	5.6	8.7			4.1	13.2
	>100	4.6	5.6			9.1	3.1
Red alder	1-10	2.5	6.1	202.2	193.0	108.0	182.3
	10-50	0.5	1.5	57.0	42.2	37.8	19.3
	50-99			2.0	2.5		
Bigleaf maple	1-10			2.0	5.1		
	10-50			5.0	5.8		
	50-99			2.5	8.7		
Pacific dogwood	1-10	5.1	11.7	1.0	5.1		

^a Blanks = no data available or did not occur.

^b Number of tree stems/ha.

4) at the Seedtree stand, and single birds were heard 24 minutes apart on 27 June 1985 at the Shelterwood stand.

Road transects/stationary counts.—In 1988, we combined data from road transects and stationary counts to determine the overall daily activity pattern of murrelets at the Forest (Fig. 1). Most detections, 74% (398 of 538), occurred before sunrise. The latest detection occurred 89 min after sunrise on a foggy morning on 21 July. Murrelets were detected a mean of 40.5 minutes/transect (SD = 26.9; range = 1-91; $n = 9$) during road transects. Only 4% (8 of 206) of the detections occurred after the sixth station visited (Table 3).

We noted a high degree of daily variation in detection rates at individual stations and overall on the two road transects (Table 3). There was no significant difference between mean daily activity levels on the Overlook transect ($\bar{x} = 17.5$; SD = 17.3; $n = 4$) and the High Prairie Creek transect ($\bar{x} = 27.2$; SD = 22.6; $n = 5$) (t -test; $P = 0.51$). Activity levels on Overlook transect increased from late May to late July, whereas detections were more numerous in mid-May and mid-July on the High Prairie Creek transect (Table 3). All stations were visited at least once during the peak activity period.

In contrast to our variable circular plot surveys, 31% (64 of 206) of the detections along the road transects were visual sightings. Birds were usually detected within 100 m of the observer (\bar{x}

= 102.1 m; SD = 83.1; range = 0-350 m; $n = 188$). Visible flock sizes and flight behavior determined from transect data were similar to those elsewhere (Paton and Ralph 1988). Flocks of 1, 2, 3, and 4 murrelets, accounted for 49%, 44%, 5%, and 2%, respectively, of all detections. Most detections (60%, 124 of 206) were birds whose flight behavior could not be determined. The most commonly observed activity was flying in a straight path over the forest canopy (29%), although circling over the canopy (5%), flying in a

TABLE 2. Percent of survey days when Marbled Murrelets were detected using the variable circular plot census method in 1985-86 at Redwood Experimental Forest, California.

Month	Forest stand type		
	Old-growth	Seedtree	Shelter wood
Jan	0 (3)	0 (2)	
Feb	0 (3)	0 (3)	
Mar	0 (4)	0 (4)	
Apr	20 (5)	0 (4)	
May	100 (3)	33 (3)	0 (3)
Jun	100 (3)	50 (4)	33 (3)
Jul	100 (1)	50 (2)	
Aug	0 (2)	0 (2)	
Sep	0 (2)	0 (2)	
Oct	100 (1)	0 (1)	
Nov	100 (1)	0 (2)	
Dec	0 (1)	0 (1)	

^a Percent of days detected (number of survey days).

^b Blanks = no surveys conducted.

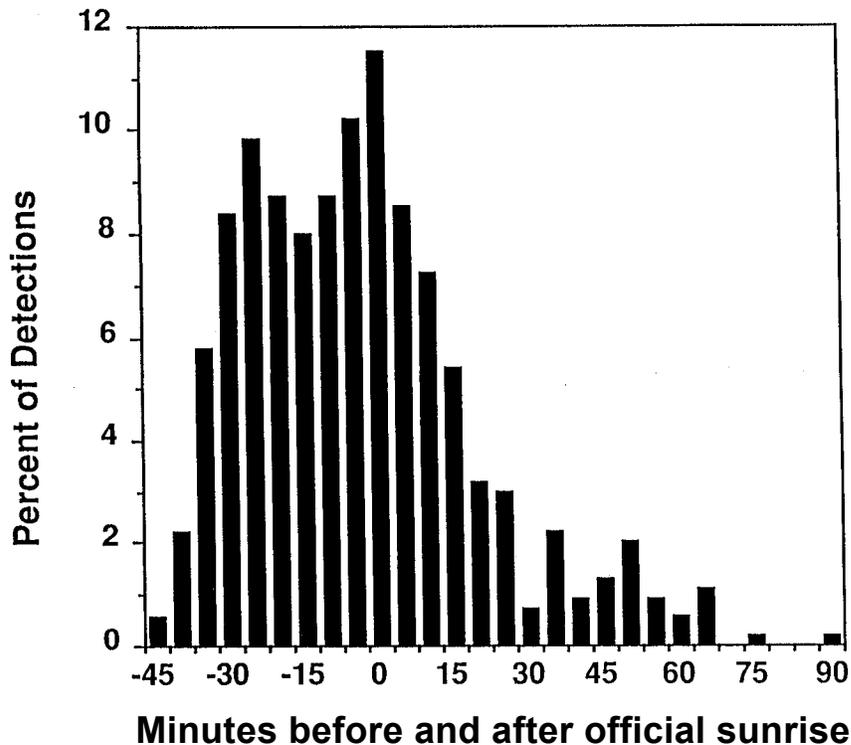


FIG. 1. Timing of Marbled Murrelet detections during morning surveys in 1988 at Redwood Experimental Forest, California. The census period extended from 45 minutes before to 90 minutes after sunrise ($n = 538$ detections).

straight path below the canopy (2%), circling below the canopy (2%), and landing in trees (2%) were also seen.

Patterns of habitat use

Variable circular plot censuses.—There was no difference between the two stands in the number of days murrelets were present throughout the year: Old-Growth stand (10 of 29 days or 34%); Seedtree stand (4 of 30 days or 13%) ($\chi^2 = 3.6$, $P = 0.052$) (Table 2). However, we did find a significant difference in presence rates when we compared May and June data between the three stands ($\chi^2 = 8.8$, $P = 0.012$) (Table 2). Murrelets were heard 100% of the survey days at the Old-Growth stand ($n = 6$) during May and June, while birds were heard 57% of the days at the Seedtree stand ($n = 7$) and only 17% of the days at the Shelterwood stand ($n = 6$) (Table 2).

Since variable circular plot surveys usually started after sunrise, the presence of murrelets at individual stations was biased towards those censused first. No birds were heard after the fourth station of the morning (Table 4). To reduce this

bias, we compared only the first four stations censused each morning for data collected in May and June. Murrelets were heard most often at stations in the Old-Growth stand (54% or 13 of 24 stations surveyed), less frequently at the Seedtree stand (29% of 7 of 24 stations surveyed), and rarely at the Shelterwood stand (8% or 2 of 24). This variation in presence rates was significant ($\chi^2 = 11.9$, $P = 0.003$) (Table 4), again indicating that murrelets were associated with old-growth stands during the breeding season.

Road transects.—During 1988, birds were present more often at old-growth stations (87% or 13 of 15 stations), than clearcuts (53% or 8 of 15 stations) and partially harvested areas (38% or 9 of 24 stations) ($\chi^2 = 9.1$, $P = 0.01$) (Table 3). The stations on the High Prairie Creek transect (stations 2, 3, 4, 10) with relatively high levels of murrelet activity were adjacent to or within the old-growth Research Natural Area (Table 3). However, not all stations located in old-growth had high activity levels (e.g., High Prairie Creek station 1, surveyed twice during peak activity periods). The highest detection rate

TABLE 3. Total number of Marbled Murrelet detections for each station on two road transects at Redwood Experimental Forest, California.

Station number	Overlook transect					High Prairie Creek transect					
	Survey dates					Survey dates					
	5/20	5/31	7/6	7/24	Total	5/18	5/31	6/5	7/6	7/15	Total
1	1 (1) ^a	0 (1)	0 (8)	0 (1)	1	0 (1)	0 (11)	0 (7)	0 (1)	1 (5)	1
2	0 (2)	0 (2)	0 (7)	0 (2)	0	0 (11)	0 (10)	1 (8)	5 (2)	18 (4)	24
3	0 (3)	0 (3)	0 (6)	5 (3)	5	6 (1)	0 (9)	0 (9)	7 (3)	14 (3)	27
4	0 (4)	0 (4)	0 (5)	0 (4)	0	16 (2)	0 (8)	0 (10)	3 (4)	5 (6)	24
5	0 (5)	8 (5)	6 (4)	22 (5)	36	2 (3)	0 (7)	0 (11)	0 (5)	0 (7)	2
6	0 (6)	1 (6)	3 (3)	7 (6)	11	8 (4)	0 (6)	0 (1)	0 (6)	0 (8)	8
7	0 (7)	0 (7)	10 (2)	4 (7)	14	1 (5)	0 (5)	2 (2)	0 (7)	0 (9)	3
8	0 (8)	0 (8)	0 (1)	3 (8)	3	1 (6)	0 (4)	0 (3)	0 (8)	0 (10)	1
9	0 (9)	0 (9)	^b		0	0 (7)	1 (3)	0 (4)	0 (9)	0 (11)	1
10	0 (10)	0 (10)			0	0 (8)	9 (2)	7 (5)	0 (10)	7 (1)	23
11	0 (11)	0 (11)			0	0 (9)	2 (1)	1 (6)	0 (11)	19 (2)	22
Total	1	9	19	41	70	34	12	11	15	64	136

^a Number of detections (daily order station was surveyed).

^b Blanks = no data collected.

for any station (22 detections/10 minutes) occurred in a shelterwood stand (Overlook station 5, Table 3), which coincided with the junction of the two main stream drainages in the area. Based on our observations of birds leaving the Forest, it appeared that birds tended to head south from the Forest along this drainage to return to the ocean.

The northern stations on the High Prairie Creek transect (6-9) had relatively few detections, except station 6 early in the breeding season (Table 3). These four stations were located in an area that was selectively logged. Birds were observed flying high over the canopy and did not appear to use any areas near these four stations. The only stations with no detections (Overlook stations 2 and 4) were located in the center of a large clearcut and shelterwood stand, respectively.

Landing in trees.—We felt that observations of birds flying low below the canopy or landing in trees were among the most useful clues to help identify potential murrelet nest sites (Singer et al. 1991). We only observed this behavior in old-growth stands. We observed birds landing in trees near two road transect stations in 1988. One bird landed for 1 second on a redwood limb on 1 July at 0447 (PST) near station 4 on the High Prairie Creek transect. Extensive landing behavior was noted between 15-21 July near High Prairie Creek station 2 (Table 5).

On 15 July, two birds landed together on a broken top snag, a 34-m high, 4-m dbh redwood (Table 5). The next morning, two birds again perched once on top of the same snag. On 18,

20, and 21 July, stationary counts were conducted at the base of the snag. On 18 July, we recorded 95 detections within 150 m of the snag, with peak landing activity from 3 minutes before to 4 minutes after sunrise (0500 PST). During this period, murrelets were observed landing in three trees within 25 m of the snag. One murrelet was seen leaving the snag platform, although none were observed landing on the platform. On 19 July, birds landed on limbs in trees adjacent to the snag, but none went to the broken top snag.

TABLE 4. The number of days when murrelets were detected during six surveys in May and June 1985 at three stands. Each stand was surveyed in ascending and descending order three times each.

Station number	Forest stand type ^a					
	Old-growth		Seedtree		Shelterwood	
	1-12	12-1	1-12	12-1	1-12	12-1
1	3	0	3	0	0	0
2	2	0	2	0	0	0
3	1	0	1	0	0	0
4	2	0	1	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	1
11	0	2	0	0	0	0
12	0	3	0	0	0	1

^a Station order: the Old-growth stand was censused on 11, 19, 26 May and 23, 26, 28 June. The Seedtree stand was censused on 12, 25 May and 2, 22, 25, 27 June and the Shelterwood stand was visited on 14, 18, 27 May and 24, 27, and 29 June.

TABLE 5. Observations of Marbled Murrelets landing in trees at Redwood Experimental Forest, California, in 1988.

Date	Time (PST)	Number of murrelets	Seconds on perch	Tree species	Tree height (m)	Landing height (m)
15 Jul	0449	2	30	redwood	34	32
16 Jul	-	2	2	redwood	34	32
18 Jul ^a	0457	2	10	redwood	95	20
18 Jul	0458	1	3	redwood	90	20
18 Jul	0503	2	1	Sitka spr.	80	30
18 Jul	0504	1	1	Sitka spr.	80	30
19 Jul ^b	0455	2	2	redwood	- ^c	-
19 Jul	0500	1	1	redwood	-	-
21 Jul ^d	0458	1	1	Sitka spr.	80	30
21 Jul	0503	1	1	redwood	90	35
21 Jul	0505	2	210	Sitka spr.	85	40

^a Stationary count: birds detected in area from 0413-0524.

^b Stationary count: birds detected in area from 0415-0515.

^c No data taken.

^d Stationary count: birds detected in area from 0426-0629.

On 21 July, 147 detections were recorded near the snag over a 123-minute period, with landings observed from 5 minutes before to 2 minutes after sunrise (0503 PST). No birds landed on the platform, but two murrelets perched together 40-m high on a branch in a nearby Sitka spruce where they remained for 3.5 minutes. All landing activity was centered around a short 10-minute interval near sunrise. We could not determine how many birds landed in the area near the snag, but only two birds were seen in the area at any one moment.

Birds flew silently and relatively slowly through the stand before and after landing. Murrelets that landed were not heard calling closer than 75 m from where they perched. Many murrelets flying near the snag used a flight path formed by the road swath cut through the old-growth canopy. Birds flew at a height of 15-30 m down the road before flying into the forest to land in trees.

The snag was ascended by a tree climber on 21 July. The 1-m by 3-m platform the murrelets perched on was 2 m from the top of the snag and had a 1-m tall huckleberry (*Vaccinium ovatum*) growing in the center. In addition, several large cracks in the rotten wood adjacent to the platform appeared to provide other potential nest and/or roost sites. However, no evidence of a nest, egg, or droppings were found.

DISCUSSION

Daily activity patterns of murrelets at the Forest were similar to those reported from other parts of California (Carter and Erickson 1988, Paton and Ralph 1988). The detection period

generally extended from 45 minutes before to 60 minutes after sunrise, with most detections heard before sunrise. The lack of murrelet detections from December 1985 to May 1986 was probably due in part to our not starting surveys before sunrise. In nearby Prairie Creek Redwood State Park, murrelets used stands during winter months in 1981 and 1982, with birds first heard 40 minutes before sunrise for a mean of 14.8 minutes (SD = 13.2; range = 1-46; $n = 25$) (Carter and Erickson 1988).

Observations of birds landing in trees, flight path directions, and the distribution of detections within the Forest all suggested that birds were nesting (or possibly roosting) within the old-growth forest in the Research Natural Area boundaries (Singer et al. 1991). Unfortunately, most murrelet detections did not provide clues for finding nests. Observations of birds flying silently through the forest prior to landing in trees suggested that murrelets reduce their detectability in the vicinity of nests, something that has been reported from active nests (Singer et al. 1991). When nests are found, more information on behavioral cues that might help researchers find nests needs to be collected.

Our data showed that murrelets were associated with old-growth redwood during the breeding season. However, the relationship was difficult to discern due to the nature of murrelet behavior. Generally, avian habitat selection studies deal with stationary birds on their breeding territories, while this investigation described birds on their way to (or from) their nest. Therefore, the placement of survey stations was crit-

ical. Habitat selection patterns might have been clearer if we could have obtained permission to survey private lands to the east of the Forest. The 150 ha of old-growth at the Forest was the only major stand of old-growth in the area (Fox 1989). The absence of murrelets in young forests east of the Forest might have helped clarify habitat relationships in lieu of finding nests.

Based on our field work in 1985-86, we learned that the placement of survey stations and the selection of an earlier census period were critical to maximizing visual and auditory detections (Paton et al. 1990). The lack of visual detections in 1985-86 was because survey stations were placed in the center of the forest where the sky was obstructed from view by a dense canopy of 100-m tall redwoods. A dense, mid-canopy of layers also hindered observers from seeing the sky in the Shelterwood and Seedtree stands. In contrast, we placed survey stations in 1988 in wide openings, where it was possible to watch murrelet silhouettes directly overhead. Standing on a ridge attempting to see silent murrelets flying below us was virtually impossible. We found that murrelets were generally detected within 100 m of census points, so stations were located close to the stands of interest. In addition, when murrelet behavior suggested there was a nest in the vicinity, we used stationary counts to maximize the probability of seeing a murrelet heading to a nest. Stationary counts were also useful in determining the entire daily activity period (Paton and Ralph 1988, Paton et al. 1990).

We were not able to estimate how many birds used or flew over the Forest. The relationship between murrelet abundance and numbers of detections could not be calculated and will be extremely difficult to determine. Murrelets can circle over stands for long periods, resulting in multiple detections of the same individual if the observer does not have a constant view of the bird. We observed murrelets circling over the Forest for 10 minutes and S. K. Nelson (pers. comm.) observed a pair flying in a 500-m diameter circle over a stand in Oregon for 45 minutes. Therefore, we only used detection rates as a measure of relative activity levels.

Finally, the only way to verify habitat use patterns of murrelets at inland sites was to find a nest. Behavioral cues give some insights into their forest habitat requirements, but the quantification of vegetation and physical characteristics of nests should be the goal of Marbled Murrelets researchers in the future.

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