

STATUS OF THE MARBLED MURRELET IN THE INNER  
NORTH COAST RANGES OF CALIFORNIA

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ABSTRACT—We sought to determine the presence or absence of marbled murrelets (*Brachyramphus marmoratus*) within the northern Inner North Coast Ranges of northwestern California. We conducted murrelet surveys and collected environmental data during 1995 and 1996 on national forest lands that were south of the Klamath Mountains Section and within *B. marmoratus* management Zone 2 as designated by the Forest Ecosystem Management Assessment Team. Using a stratified random sampling design, we surveyed for murrelets within the 2 coniferous forest habitat types most likely to be used by murrelets: late mature and old-growth Douglas-fir (*Pseudotsuga menziesii*) and late mature and old-growth tanoak (*Lithocarpus densiflora*). We used the generalized binomial model to determine sample sizes and to estimate the power of survey results for a range of assumed levels of murrelet occurrence ( $p$ ) and probabilities of detection ( $p'$ ). In 1995 and 1996, we conducted 1424 surveys at 178 Douglas-fir sampling units, surveying 30.8% of the total amount of this stratum within the study area. In 1995, we conducted 760 surveys at 95 tanoak sampling units, surveying 58.6% of this stratum. We did not detect *B. marmoratus* in either habitat type. When we assumed a  $p$  of 0.03, and a  $p'$  of 0.10, the power of our surveys to detect murrelets was 0.95 and 0.81 for the Douglas-fir and tanoak habitat types, respectively. Given the high power associated with our results and the large proportion of the total potential habitat surveyed, we concluded that our study area was not within the current range of *B. marmoratus*. Most habitat characteristics, including corvid abundance, were similar to murrelet nesting habitat in other areas. The relatively high elevation and far-land location, and the related characteristics of climate and habitat structure, may explain the apparent absence of *B. marmoratus* from our study area. Accordingly, we recommend that the Forest Ecosystem Management Assessment Team zone lines be adjusted so that the Inner North Coast Ranges are excluded from Zone 2.

Key words: *Brachyramphus marmoratus*, marbled murrelet, status, distribution, northwestern California, surveys

The marbled murrelet (*Brachyramphus marmoratus*) is a small seabird that spends most of its life in nearshore waters and nests primarily in late-successional and old-growth forests near the coast (Ralph and others 1995). Recent

declines in *B. marmoratus* populations are attributed to nesting habitat removal and possible increased at-sea mortality and predation at nest sites (Ralph 1994). Because of recent declines, *B. marmoratus* is federally listed as a "threat-

ened" species in Washington, Oregon, and California (USDI 1992). To fulfill their obligation under section 7(a)(1) of the Endangered Species Act, federal land managers are obligated to consult with the USDI Fish and Wildlife Service on any projects that "may affect" the murrelet. Consequently, land management agencies typically conduct surveys prior to management activities in or adjacent to potential murrelet nesting habitat to provide the best information possible for the consultation process.

The Forest Ecosystem Management Assessment Team (FEMAT) report provided a set of management options designed to resolve the ongoing crisis surrounding the management of forest resources in the Pacific Northwest (USDA and others 1993). Among other things, the report identified 2 *B. marmoratus* management zones within which it recommended that potential murrelet habitat be surveyed prior to implementation of any activity that may impact this species. Zone 1 included the majority of all known murrelet sites, whereas Zone 2 was characterized by few murrelet records. These management zones and survey recommendations were subsequently adopted by federal land managers under the Northwest Forest Plan (USDA and USDI 1994a, 1994b).

Far-inland records of *B. marmoratus* north of California, along with a lack of comprehensive inland surveys throughout its range, were the basis for the original delineation of Zone 2. Because of this paucity of survey data, however, the actual inland range and distribution of this species were unknown. Accordingly, we initiated this study to determine the presence or absence of murrelets within selected habitat types on national forest lands in the southern portion of Zone 2 in California. This information would increase the efficiency of the consultation and land management planning process. We selected this study area because the physiography and lack of murrelet records suggested that this portion of Zone 2 had an overall low probability of murrelet presence. We hypothesized that characteristics of habitat, climate, and predator abundance might influence the status and distribution of *B. marmoratus*.

#### STUDY AREA

The Mad River Study Area (MRSA; Fig. 1) consists of all national forest lands within Zone 2 that are south of the Klamath Mountains Sec-

tion (Miles and Goudey 1997). Physiographically, this area generally corresponds to the Northern California Coast Ranges Section of Miles and Goudey (1997) and the High and Inner North Coast Ranges Districts of Hickman (1993). This portion of Zone 2 has drier site conditions along with greater fire frequency and natural fragmentation than the Klamath Mountains portion of Zone 2 (USDA 1995). The MRSA encompasses the entire Mad River Ranger District of the Six Rivers National Forest and adjacent portions of the Shasta-Trinity and Mendocino National Forests.

The most extensive vegetation series within the MRSA is the Douglas-fir (*Pseudotsuga menziesii*) series, followed by the tanoak (*Lithocarpus densiflora*) series (USDA 1995). The Douglas-fir series is dominated by conifers, usually Douglas-fir, but white fir (*Abies concolor*), sugar pine (*Pinus lambertiana*), ponderosa pine (*P. ponderosa*), Pacific madrone (*Arbutus menziesii*), tanoak, and California black oak (*Quercus kelloggii*) are often significant components. The Douglas-fir series typically lacks a consistent hardwood midlayer. The tanoak series occurs on sites that are more mesic than the Douglas-fir series, and has an overstory dominated by conifers, usually Douglas-fir, and typically contains a tanoak regeneration or midlayer. Tanoak stands have a mean tree-layer cover of 85%, while Douglas-fir stands average 75%. This results in a more dense shrub layer and greater amounts of herbaceous cover in Douglas-fir stands. The white fir series becomes more dominant above 1525 m, with the red fir (*A. magnifica*) series appearing at the highest elevations. The white oak (*Q. garryana*), black oak, and grassland series dominate more xeric sites (USDA 1995; Jimerson and others 1996).

Natural conditions in combination with timber harvesting and other management have resulted in a mix of successional stages of the various vegetation series. Timber management has been the dominant land use in this area since the late 1940s. Late mature and old-growth stands generally have multiple tree layers and conifer overstory trees averaging  $\geq 76$  cm diameter at breast height (dbh) and 43.6 m tall (USDA 1995; Jimerson and others 1996).

Topography within the 164,300 ha MRSA is moderate to steep. In general, the MRSA is dominated by 3 ridge systems oriented NW to SE and 3 major drainages (Fig. 1). Elevation

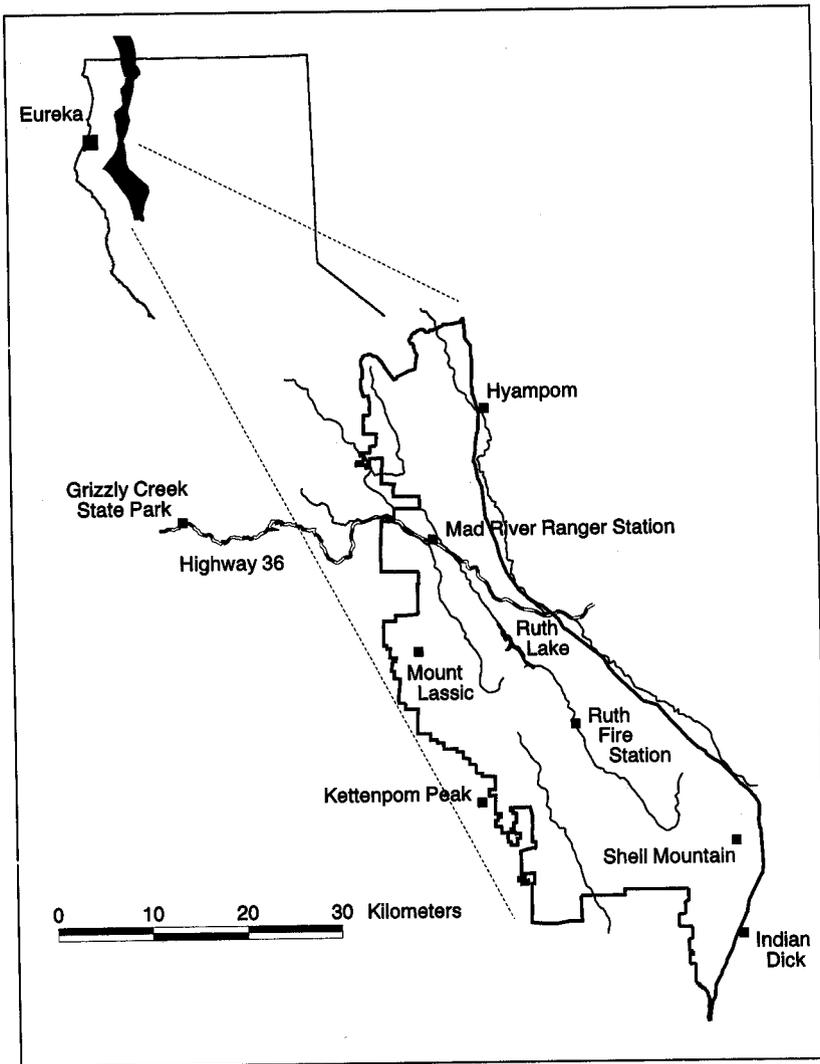


FIGURE 1. Location of the Mad River Study Area relative to Forest Ecosystem Management Assessment Team Zone 2 in northern California.

ranges from 380 to 2042 m, and distance from the ocean ranges from 45 to 72 km.

Generally, climate is characterized by hot and dry summers; summer drought is not moderated by coastal fog and summer showers are infrequent and short (Lewis 1982). Some drainages in the northwestern portion of the MRSA, however, occasionally experience late night and early morning fog in the summer. Winters are cold and wet; average annual precipitation varies from about 125 cm at the lower elevations to 200 cm at the higher elevations

(Miles and Roath 1993), with 75% of the annual precipitation recorded from November to March (Lewis 1982). Moderate to heavy snow can occur at elevations above 600 m and can persist well into spring above 1200 m.

We were unable to locate any historic murrelet records from within the MRSA. From 1992 through 1994, 623 murrelet surveys were conducted at 248 distinct survey points (hereafter known as murrelet survey stations) in or near timber sale areas within the study area. No murrelets were detected during these sur-

veys, which were conducted in the Douglas-fir, tanoak, and white fir series. These data were not included in our statistical analysis. No timber sale-related surveys were conducted in the MRSA during 1995 or 1996. The nearest known murrelet site was at Grizzly Creek Redwoods State Park, about 24 km west of the study area (Fig. 1). Grizzly Creek also was the farthest inland site in California with documented nesting and consistent observations of behaviors thought to indicate nesting (O'Donnell 1993).

## METHODS

### *Marbled Murrelet Sampling*

**Stratification.**—We used a stratified random sampling design to estimate presence or absence of *B. marmoratus* in specific habitat types (strata) that we considered homogeneous with respect to the probability of murrelet presence. We placed different vegetation series into separate strata due to distinct differences in floristics, vegetation structure, and site conditions (USDA 1995; Jimerson and others 1996). We were unable to find any confirmed records of murrelet occupancy in white fir stands and therefore did not include this series in our stratification. Of the remaining vegetation series in the study area, we considered only the Douglas-fir and tanoak series to contain potential murrelet habitat. With some exceptions, *B. marmoratus* only nests in older coniferous forests (Hamer and Nelson 1995). It was unclear if separation of the older successional stages into different strata was justified. Therefore, we included a combined late mature and old-growth successional stage in our stratification. As a result of these considerations, 2 distinct strata were defined and sampled: late mature and old-growth Douglas-fir (DFLMOG) and late mature and old-growth tanoak (TOLMOG). Within the MRSA there were an estimated 19,763 ha of DFLMOG and 5649 ha of TOLMOG.

**Sample Size and Power.**—We used the generalized binomial model (Shumway and Gurland 1960; Johnson and Kotz 1969:194) to determine sample sizes and the power of our survey results. In our analysis, power is the probability of detecting murrelets in a stratum if they are present, with the null hypothesis being that murrelets are absent. The generalized binomial model is a modification of the binomial distribution for presence-absence data, and accounts for the probability that murrelets may be present but not detected in sampling units (defined below). Results apply to the entire stratum sampled and not to individual sampling units. To use the generalized binomial model, 2 parameters must be assumed. First, the proportion of each stratum (or the proportion of sampling units) in which murrelets are actually pre-

sent ( $p$ ) must be assumed. Second, the conditional probability of any auditory or visual detection of a murrelet on a single survey visit to a single sampling unit, given that the birds are present at the sampling unit ( $p'$ ), must be assumed. To achieve a given power, lower assumed values of  $p$  or  $p'$  require larger sample sizes. While these values are assumed to be constant for a stratum, they will likely vary throughout the stratum. Computer simulations on the effects of variability of  $p$  and  $p'$  on the power of survey results have shown, however, that the generalized binomial model is robust with respect to these sources of variability (T. Matsumoto, Humboldt State University, Arcata, CA, pers. comm.).

To determine initial sample sizes we assumed that murrelets were present in  $\geq 3\%$  of each stratum ( $p = 0.03$ ) and that we had  $\geq 10\%$  chance of detecting them if they were present ( $p' = 0.10$ ). The value of  $p$  that we chose was a compromise between survey confidence and funding limitations. While sampling levels were intended to detect murrelets with high power if they were present in  $\geq 3\%$  of the stratum, lower power estimates were still attained if murrelets were actually present in  $< 3\%$  of the stratum. Previous estimates of  $p'$ , calculated with survey data from Washington, Oregon, and California, ranged from 0.554 to 0.606 (T. A. Max, USDA Forest Service, Portland, OR, pers. comm.) and were derived from a variety of murrelet sites including those with high abundance. We assumed that if murrelets were present in our study area, they would be in low abundance and harder to detect; thus, we selected a lower, more conservative  $p'$  for our area. The values of  $p$  and  $p'$  that we initially assumed should not be viewed as fixed absolutes; we calculated the power of our results for a range of values to account for a variety of possible conditions within the study area.

**Sampling Units and Surveys.**—Sampling units usually consisted of 40 contiguous hectares of the stratum around randomly distributed points. However, in cases where 40 contiguous hectares were not present around a point, smaller sampling units down to a minimum of 12 ha were used. Although murrelet nests have been found in stands as small as 3 ha (Hamer and Nelson 1995), we chose a minimum sampling unit size of 12 ha in order to reduce the variability in  $p'$  between sampling units. Very small stands may have a lower abundance of murrelets (and therefore, a lower  $p'$ ) due to an insufficient amount of habitat, rather than due to structural (Hamer 1995) or other environmental characteristics. The mean ( $\pm$  SD) size of DFLMOG and TOLMOG sampling units were  $34.2 \pm 8.9$  ha and  $34.9 \pm 2.8$  ha, respectively.

The generalized binomial model required that sampling units be independent. We assumed that if sampling units were at least as large as the area used by single pairs or groups of murrelets, then the

chance of the same birds being detected in  $>1$  sampling unit would be reduced and the probability of achieving independence would be improved. However, no data were available on the amount of area typically used by murrelets at inland nesting locations; for the purpose of this study we assumed that this area ranges from 12 to 40 ha. Sampling units of this size were similar to typical "survey sites" used for management-related murrelet surveys (Ralph and others 1994).

We used Six Rivers National Forest Ecology Program vegetation maps to locate random sampling units. These maps were produced by interpretation of aerial photographs using reference data collected in the field, followed by partial field verification (T. M. Jimerson, USDA Forest Service, Eureka, CA, pers. comm.).

Due to limitations imposed by topography and vegetation, the maximum effective area that could be surveyed in 1 visit was approximately 12 ha (Ralph and others 1994). Therefore, 4 murrelet survey stations were located within or adjacent to each sampling unit. Those sampling units that could not be completely surveyed with 4 survey stations were reduced in size to an area capable of being surveyed with 4 stations. Each DFLMOG station was surveyed once each year and each TOLMOG station was surveyed twice in 1995. This resulted in 4 surveys per year for each of 2 consecutive years (1995 and 1996) at each DFLMOG sampling unit and should account for within-season and among-year variability in presence at inland sites (O'Donnell 1993; Rodway and others 1993; Ralph and others 1994). There were a limited number of TOLMOG sampling units within the study area that met our criteria, and due to funding limitations TOLMOG sampling units were only sampled in 1995.

Murrelet surveys followed guidelines in Ralph and others (1994) for "intensive" surveys. Surveys were conducted from 45 min before to 75 min after local sunrise and were conducted between 19 April and 5 August, 1995, and between 14 May and 3 August, 1996. A minimum of 2 surveys were conducted at each sampling unit after 1 July, with  $\geq 1$  of these surveys during the last 3 weeks of July. Surveys at each sampling unit were between 6 and 30 days apart. All observers passed a murrelet surveyor evaluation as outlined by Ralph and others (1994).

#### *Environmental Data Collection*

Following each murrelet survey, observers established 4 vegetation and landbird sampling points adjacent to the survey station and within the sampling unit. If the station was  $\geq 50$  m inside the sampling unit, then the 1<sup>st</sup> point was at the station. If the station was at the edge of the sampling unit, observers proceeded 50 m

into the unit, in a direction perpendicular to its edge, and established the 1<sup>st</sup> point. The observer then established 3 additional points, each 125 m apart and  $\geq 50$  m from the edge of the sampling unit. The typical result of this layout procedure was an approximately diamond-shaped pattern of 4 points with the base of the diamond at the murrelet survey station. Some vegetation plots and point counts were not conducted due to weather or logistical constraints. As determined by topographic maps, we used the elevation at the random point used to locate each sampling unit as an estimate of the elevation at that sampling unit.

*Landbird Sampling.*—We conducted point counts for a limited number of landbird species to improve observer skills (Hunter and LeValley 1996) and to gather data on the occurrence of potential murrelet predators. Each point count was conducted for 10 min and included only those species known or suspected to be murrelet predators, or species that might be misidentified as murrelets. Otherwise, point count procedures followed guidelines in Ralph and others (1993). Point counts were conducted immediately following murrelet surveys and prior to collection of vegetation data. Eight point counts were typically conducted during 1995 and 1996 (4 counts per year) around each DFLMOG station. Because each TOLMOG station was surveyed twice, but only during 1995, 8 point counts also were typically conducted around each TOLMOG station. During 1995, we conducted 2808 point counts at DFLMOG sampling units and 2768 point counts at TOLMOG sampling units. During 1996, we conducted 2479 point counts at DFLMOG sampling units.

Using a similar methodology in 1993, Miller and Ralph (unpubl. data) conducted landbird point counts around murrelet survey stations in old-growth redwood (*Sequoia sempervirens*) at Prairie Creek and Humboldt Redwoods State Parks (Miller and Ralph 1995). We compared their unpublished data on corvids, which represented 2 areas of known murrelet occurrence in northwestern California, to our data on corvids in the MRSA. Using all point count data for each individual murrelet survey station, we calculated the mean number of individuals of each corvid species detected out to an unlimited distance. We considered this number an index of the abundance of corvids

around each survey station. To maintain consistency with the unpublished data of Miller and Ralph, we only used those data collected during the 1<sup>st</sup> 5 min of each point count. We also only used our 1995 data for this analysis because that year both DFLMOG and TOLMOG were sampled. We made statistical comparisons only for corvid species detected at >1 station in each of the 3 areas (MRSA, Prairie Creek, and Humboldt Redwoods). We also calculated the proportion of DFLMOG and TOLMOG sampling units within which potential predators were detected during 10-min point counts at the MRSA in 1995 and 1996.

*Potential Nest Tree Sampling.*—We gathered information on potential nest trees of *B. marmoratus* following the procedure of Hamer (1995). However, whereas Hamer (1995) used all dominant trees  $\geq 81$  cm within 25-m radius plots, time constraints limited us to using only the single largest living conifer tree visible from each point center. We assumed these trees would be most likely to have characteristics important for murrelet nesting. As a result, relative to Hamer's (1995) data, our data are biased toward larger trees. Because of these differences in methodology, unpublished data on potential nest trees collected by Hamer (Hamer Environmental, Mount Vernon, WA, pers. comm.) in Washington State are presented but not compared statistically. A total of 4 potential nest trees per station were typically sampled during 1995 and 1996 ( $n = 16$  trees per sampling unit) at the MRSA. We calculated mean potential nest tree values by sampling unit. In addition, we calculated mean potential nest tree values by tree species using all MRSA data for each species for which >10 trees were measured. During 1995 and 1996, potential nest tree data were collected at 2860 and 1526 points in DFLMOG and TOLMOG, respectively.

*Climate Data.*—We obtained daily maximum temperatures collected at weather stations at Grizzly Creek State Park, Mad River Ranger Station, and Ruth Fire Station (Fig. 1) for the 17-yr period from 1980 through 1996. Weather data were not collected prior to 1980 at Grizzly Creek. Elevations at these 3 locations are 125 m, 777 m, and 833 m, respectively. Data from these locations represent conditions at 1 site within the known range of the murrelet (Grizzly Creek), as well as 2 other sites within the MRSA. We compared daily maximum temper-

atures for June, July, and August at the 3 locations; data for April and May were not available for Mad River Ranger Station and Ruth Fire Station.

*Statistical Analysis of Environmental Data.*—All environmental data were analyzed with Mann-Whitney or Kruskal-Wallis tests using NCSS 6.0 (Hintze 1996). These nonparametric procedures were used because some data sets were nonnormal and/or heteroscedastic (Zar 1974). When Kruskal-Wallis tests indicated differences among groups, they were followed by Z-value multiple comparisons.

## RESULTS

### *Marbled Murrelet Surveys*

During 1995 and 1996, we conducted 1424 intensive murrelet surveys at 178 DFLMOG sampling units (712 surveys per year). A total of 6088 ha of this stratum was surveyed, which constituted 30.8% of the DFLMOG within the MRSA. During 1995, we conducted 760 intensive murrelet surveys at 95 TOLMOG sampling units. A total of 3313 ha of this stratum was surveyed, which constituted 58.6% of TOLMOG within the MRSA. We surveyed 37.0% of the combined DFLMOG and TOLMOG acreage. We did not detect marbled murrelets at any DFLMOG or TOLMOG sampling unit. The power associated with our surveys depended on the assumed values of  $p$  and  $p'$  (Table 1). When we assumed lower bounds of  $p = 0.03$ , and  $p' = 0.10$ , the power was 0.953 and 0.805 for DFLMOG and TOLMOG, respectively (Table 1).

### *Environmental Data*

*Landbird Data Analysis.*—Abundance of Steller's jays (*Cyanocitta stelleri*) was similar at DFLMOG and TOLMOG stations ( $Z = 0.04$ ,  $P = 0.968$ ; Table 2). At Prairie Creek they were less common than they were at DFLMOG and TOLMOG stations ( $Z > 7.44$ ,  $P < 0.001$ ; Table 2), and at Humboldt Redwoods they were more common than they were at DFLMOG ( $Z = 2.66$ ,  $P = 0.008$ ) and TOLMOG stations ( $Z = 2.61$ ,  $P = 0.009$ ; Table 2). Abundance of *C. stelleri* was higher at Humboldt Redwoods than at Prairie Creek ( $Z = 6.46$ ,  $P < 0.001$ ; Table 2). There were more than twice as many common ravens (*Corvus corax*) at DFLMOG than at TOLMOG ( $Z = 0.86$ ,  $P = 0.390$ ), and more than twice as many ravens at Humboldt Redwoods than at DFLMOG

TABLE 1. For a range of occurrence values ( $p$ ) and conditional probabilities of detection ( $p'$ ), the probability that *Brachyramphus marmoratus* would be detected in late mature and old-growth Douglas-fir (DFLMOG) and late mature and old-growth tanoak (TOLMOG), at the Mad River Study Area in northwestern California, 1995 and 1996. Each DFLMOG sampling unit was surveyed 4 times per year for 2 years and each TOLMOG sampling unit was surveyed 8 times in 1 year.

$p$	$p'$	DFLMOG ( $n = 178$ )	TOLMOG ( $n = 95$ )
0.01	0.10	0.638	0.419
0.01	0.25	0.800	0.576
0.01	0.50	0.832	0.614
0.02	0.10	0.870	0.663
0.02	0.25	0.961	0.822
0.02	0.50	0.972	0.852
0.03	0.10	0.953	0.805
0.03	0.25	0.992	0.926
0.03	0.50	0.995	0.944
0.04	0.10	0.983	0.888
0.04	0.25	0.999	0.969
0.04	0.50	0.999	0.979
0.05	0.10	0.994	0.936
0.05	0.25	1.000	0.987
0.05	0.50	1.000	0.992

stations ( $Z = 2.40$ ,  $P = 0.016$ ; Table 2). Abundance of ravens at TOLMOG stations was lower than at both Prairie Creek ( $Z = 1.97$ ,  $P = 0.049$ ) and Humboldt Redwoods ( $Z = 2.62$ ,  $P = 0.009$ ; Table 2). DFLMOG and Prairie Creek stations had similar abundances of ravens ( $Z = 0.63$ ,  $P = 0.529$ ; Table 2), while Humboldt Redwoods

had more ravens than Prairie Creek ( $Z = 2.43$ ,  $P = 0.015$ ; Table 2).

*C. stelleri* were widely distributed within the MRSA; jays were detected in all sampling units in 1995 and in all but 1 sampling unit in 1996 (Table 3). *C. corax* were less widely distributed, but were found at 68 to 75% of sampling units (Table 3). Douglas squirrels (*Tamiasciurus douglasii*), which are also possible predators of *B. marmoratus* nests (J. M. Marzluff, Sustainable Ecosystems Institute, Meridian, ID, pers. comm.), occurred at >81% of sampling units (Table 3). While other potential predators of murrelets were detected during point counts (Table 3), the sample sizes attained and the methodologies used at point counts were not amenable to statistical analysis for those species.

*Potential Nest Tree Analysis.*—Potential nest trees in DFLMOG and TOLMOG at the MRSA were similar in terms of potential nest platforms per tree and moss and lichen indices (Table 4). However, potential nest trees were larger in diameter in TOLMOG versus DFLMOG (Table 4). Tree dbh, platforms per tree, and lichen indices for potential nest trees at the MRSA appear to be similar to values for occupied stands in Washington (Table 4). Moss indices, however, appear to be greater for occupied stands in Washington than for the MRSA (Table 4) despite the fact that our data were biased toward larger, presumably older, trees.

TABLE 2. Comparisons of indices of abundance (mean number detected per station) for corvids during 5-min point counts around northwestern California *Brachyramphus marmoratus* survey stations in old-growth redwood stands, 1993, and at the Mad River Study Area, 1995.

Species <sup>f</sup>	Old-growth redwood <sup>a</sup>				Mad River Study Area				$P^g$
	HRSP <sup>b</sup> ( $n = 24$ )		PCSP <sup>c</sup> ( $n = 67$ )		DFLMOG <sup>d</sup> ( $n = 702$ )		TOLMOG <sup>e</sup> ( $n = 378$ )		
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	
Steller's jay	1.703A <sup>h</sup>	0.284	0.320B	0.060	0.920C	0.029	0.854C	0.029	<0.001
Gray jay	0.000	—	0.004	0.004	0.000	—	0.000	—	—
Scrub-jay	0.005	0.005	0.000	—	0.004	0.002	0.002	<0.001	—
Common raven	0.274A	0.087	0.122B	0.045	0.136BC	0.012	0.057C	0.006	0.062
American crow	0.014	0.011	0.007	0.007	<0.001	<0.001	0.003	0.001	—

<sup>a</sup> From Miller and Ralph, unpubl. data.

<sup>b</sup> HRSP = Humboldt Redwood State Park.

<sup>c</sup> PCSP = Prairie Creek State Park.

<sup>d</sup> DFLMOG = Late mature and old-growth Douglas-fir.

<sup>e</sup> TOLMOG = Late mature and old-growth tanoak.

<sup>f</sup> Common and scientific names of species not mentioned in text: gray jay (*Perisoreus canadensis*), western scrub-jay (*Aphelocoma californica*), American crow (*Corvus brachyrhynchos*).

<sup>g</sup> Kruskal-Wallis test results for all 4 groups; dashes indicate species too rare for meaningful statistical comparisons.

<sup>h</sup> Row means followed by different letters indicate indices were different ( $P \leq 0.05$ ) by  $Z$ -value multiple comparison test.

TABLE 3. The proportion of sampling units at the Mad River Study Area in northwestern California in which known or suspected *Brachyramphus marmoratus* predators were detected in late mature and old-growth Douglas-fir (DFLMOG) and late mature and old-growth tanoak (TOLMOG), 1995 and 1996.

Species	1995		1996
	DFLMOG (n = 178)	TOLMOG (n = 95)	DFLMOG (n = 178)
Sharp-shinned hawk ( <i>Accipiter striatus</i> )	0.00	0.03	0.02
Cooper's hawk ( <i>Accipiter cooperii</i> )	0.01	0.03	0.00
Northern goshawk ( <i>Accipiter gentilis</i> )	0.03	0.03	0.02
Red-shouldered hawk ( <i>Buteo lineatus</i> )	0.01	0.03	0.01
Red-tailed hawk ( <i>Buteo jamaicensis</i> )	0.16	0.15	0.10
Peregrine falcon ( <i>Falco peregrinus</i> )	0.00	0.01	0.01
Great horned owl ( <i>Bubo virginianus</i> )	0.01	0.02	0.01
Spotted owl ( <i>Strix occidentalis</i> )	0.01	0.04	0.00
Gray jay ( <i>Perisoreus canadensis</i> )	0.00	0.00	0.01
Steller's jay ( <i>Cyanocitta stelleri</i> )	1.00	1.00	0.99
Western scrub-jay ( <i>Aphelocoma californica</i> )	0.04	0.05	0.04
American crow ( <i>Corvus brachyrhynchos</i> )	0.02	0.08	0.01
Common raven ( <i>Corvus corax</i> )	0.68	0.75	0.70
Douglas squirrel ( <i>Tamiasciurus douglasii</i> )	0.82	0.85	0.91

Douglas-fir was the most abundant species of potential nest tree at the MRSA (Table 5). The presence of various pines (*Pinus* spp.) suggested somewhat xeric conditions. While white fir trees were not sampled within the white fir vegetation series, our data suggested that white fir trees provide relatively low numbers of potential nest platforms (Table 5).

Elevation at our sampling units ranged from 480 to 1798 m. Mean ( $\pm$  SD) elevation at DFLMOG and TOLMOG sampling units was  $1088.1 \pm 220.3$  m and  $911.2 \pm 190.0$  m, respectively. DFLMOG sampling units were higher ( $U = 12,187.5$ ,  $P < 0.001$ ) than TOLMOG sampling units. Greater than 95% of the DFLMOG in the MRSA was  $\geq 647$  m in elevation. About 84% of the TOLMOG in the MRSA was  $>722$  m in elevation.

*Climate Data Analysis.*—Daily maximum temperatures during June, July, and August were significantly higher ( $5.9$  to  $9.1^\circ\text{C}$  higher) at both locations within the MRSA than at Grizzly Creek ( $Z > 4.42$ ,  $P < 0.001$ ; Table 6). Temperatures at Mad River Ranger Station and Ruth Fire Station were similar in all 3 months ( $Z < 1.10$ ,  $P > 0.271$ ; Table 6).

#### DISCUSSION

Given the high power estimates associated with our survey results and the relatively large proportion of the total potential habitat surveyed, our results indicate with high confidence that the northern Inner North Coast Ranges of California are not within the current range of *B. marmoratus*. Several factors including habitat structure, elevation, abundance of

TABLE 4. Comparisons of potential *Brachyramphus marmoratus* nest tree characteristics measured in 141 occupied and unoccupied stands in Washington State, 1991 through 1993, and in 273 unoccupied sampling units at the Mad River Study Area in northwestern California, 1995 and 1996.

Variable	Washington <sup>a</sup>				Mad River Study Area				p <sup>d</sup>
	Occupied (n = 64)		Unoccupied (n = 77)		DFLMOG <sup>b</sup> (n = 178)		TOLMOG <sup>c</sup> (n = 95)		
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	
Tree dbh (cm)	124.4	2.3	112.6	2.2	126.9	1.3	133.1	1.7	0.006
Platforms/tree	1.7	0.2	1.1	0.1	2.0	0.1	1.9	0.1	0.436
Moss index	2.2	0.2	1.8	0.1	1.2	0.0	1.1	0.0	0.154
Lichen index	1.6	0.1	2.1	0.1	1.4	0.0	1.4	0.0	0.431

<sup>a</sup> From Hamer, pers. comm.

<sup>b</sup> DFLMOG = Late mature and old-growth Douglas-fir.

<sup>c</sup> TOLMOG = Late mature and old-growth tanoak.

<sup>d</sup> Mann-Whitney test results for Mad River Study Area.

TABLE 5. Characteristics of potential *Brachyramphus marmoratus* nest trees at 273 late mature and old-growth Douglas-fir and tanoak sampling units in the Mad River Study Area in northwestern California, 1995 and 1996.

Species <sup>a</sup>	n	Variable							
		Tree dbh (cm)		Platforms/ tree		Moss index		Lichen index	
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Incense cedar	24	120.0	36.3	2.2	4.5	1.3	0.7	1.8	1.2
White fir	30	87.8	23.2	0.1	0.4	1.0	0.0	1.0	0.0
Sugar pine	96	138.0	29.8	2.4	4.7	1.1	0.5	1.1	0.9
Ponderosa pine	212	119.2	30.0	1.9	2.9	1.2	0.5	1.3	0.7
Jeffrey pine	11	125.8	30.6	2.4	3.5	1.2	0.4	1.2	0.4
Douglas-fir	3,961	129.8	34.4	2.0	3.1	1.2	0.5	1.4	0.7

<sup>a</sup> Common and scientific names of species not mentioned in text: incense cedar (*Calocedrus decurrens*), Jeffrey pine (*Pinus jeffreyi*).

corvids, distance inland, and climate are potential explanations for this apparent absence.

With the exception of relatively low moss cover, our data on size of trees, number of potential platforms per tree, and amount of lichen cover suggest that habitats at the MRSA are structurally suitable for nesting of murrelets. While moss cover may be an important habitat characteristic for murrelets in some parts of its range (Hamer 1995; Hamer and Nelson 1995), we cannot completely attribute the absence of murrelets in this region to an absence of suitable habitat.

Hamer and Nelson (1995) reported that the average elevation at 45 murrelet nest sites in California, Oregon, Washington, and British Columbia was 332 m, with the highest nest at 1097 m in British Columbia. More than 95% of the DFLMOG and >85% of the TOLMOG in the MRSA are approximately twice as high as the mean elevation for the nest sites they reported. Approximately 50% of the DFLMOG and 32% of the TOLMOG at the MRSA are at higher elevations than the highest nest site they reported. It should be noted that the nest sites reported by Hamer and Nelson (1995) were not found in a random fashion and early research focused on lower elevation areas. However, the

contrast between elevation at known murrelet nest sites and the MRSA suggests that environmental conditions related to elevation such as climate, habitat structure, vegetation composition, and distance inland may influence murrelet distribution.

Potential murrelet predators were widely distributed within the MRSA. However, because abundance of corvids at the MRSA were intermediate to those at sites known to be occupied by murrelets, we conclude that corvids are not responsible for the apparent absence of this species from the Inner North Coast Ranges. Any relationship between predator abundance and long-term viability of murrelet subpopulations is unknown.

Limitations may be imposed on murrelets by the energetic demands of flying inland to incubate eggs and feed young (Hamer and Nelson 1995), as well as increased exposure to predation on long flights (Ralph and others 1995). However, the distance of the MRSA from the ocean cannot, in itself, explain the apparent lack of murrelets. Murrelets have been detected up to 100 km inland in British Columbia (Hamer and Nelson 1995). In northwestern Washington occupied stands have been found 84 km inland (Hamer 1995), and in southern Oregon

TABLE 6. Comparisons of mean daily maximum temperatures (°C), by month, at Grizzly Creek Redwoods State Park, and at 2 sites within the Mad River Study Area, 1980 through 1996.

Month	Grizzly Creek State Park		Mad River Ranger Station		Ruth Fire Station		P <sup>a</sup>
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	
June	20.6A <sup>b</sup>	0.3	26.5B	0.6	27.2B	0.7	<0.001
July	23.0A	0.3	31.0B	0.6	32.1B	0.6	<0.001
August	22.9A	0.2	31.5B	0.5	32.4B	0.4	<0.001

<sup>a</sup> Kruskal-Wallis test results for all 3 groups.

<sup>b</sup> Row means followed by different letters indicate temperatures were different ( $P \leq 0.05$ ) by Z-value multiple comparison test.

murrelets have been confirmed breeding at 51 km inland (J. Witt, Bureau of Land Management, Roseburg, OR, pers. comm.). While murrelet records for northern California from 1988 through 1992 indicate that 89% were within 10 km of the coast (Miller and Ralph 1995), murrelets have been confirmed breeding in California at 40 km inland at Grizzly Creek (O'Donnell 1993). There are also reports of murrelet detections about 59 km inland near Happy Camp, California (K. Nickell, USDA Forest Service, Happy Camp, CA, pers. comm.).

While no quantitative data exist which prove that there is a direct relationship between climate and murrelet distribution, the sharp contrast in daily maximum temperature between the MRSA and Grizzly Creek, suggests that climate may be an important factor. We only evaluated temperature, but summer temperature is often inversely correlated with humidity and cloud cover (Anthes and others 1975). The far-inland presence of murrelets in the North Cascades of Washington could be due to the lack of intervening mountains, which results in the maritime climate extending well inland (T. E. Hamer, Hamer Environmental, Mount Vernon, WA, pers. comm.). Dillingham and others (1995) also provided anecdotal evidence that the inland extent of the maritime influence is an important factor in southwestern Oregon. In California, where rugged topography limits the inland extent of the maritime influence, the majority of murrelet records are from redwood-dominated stands (Miller and Ralph 1995; E. E. Burkett, California Department of Fish and Game, Sacramento, CA, pers. comm.). The Grizzly Creek murrelet site consists of old-growth redwood (O'Donnell 1993) and typically has light fog on summer mornings (CDWR 1975). The historic inland extent of redwood forests in California closely matches the inland extent of the influence of marine air and summer fog (Barbour and Major 1977). Likewise, the eastern distribution boundary of the marbled murrelet in California may closely match the historic extent of redwood forests.

Other evidence suggests that there is a relationship between climate and the distribution of *B. marmoratus*. Moss, which favors mild and wet conditions, is a good indicator of murrelet habitat (Hamer 1995). Within the MRSA, moss cover was the only potential nest tree variable that appeared low relative to Hamer's unpub-

lished data for occupied stands in Washington State. Miller (1951:613) noted that abrupt changes in moisture regimes, such as the one near the western boundary of the MRSA, can have a dramatic influence on distribution of bird species. Cloud cover also may influence murrelet distribution; increased activity associated with cloudy weather may be a result of lower risk of predation due to reduced light levels (Rodway and others 1993). Because the marbled murrelet is a marine species that spends the majority of its time in cold Pacific waters, it seems plausible that some far-inland habitats, although otherwise suitable, may be too hot (Ralph and others 1995) and/or dry in the summer for nesting purposes.

Variability in occupancy of sites between years may have influenced our ability to detect murrelets at the MRSA, especially at TOLMOG sampling units. Factors that may affect year-to-year variation include unusual weather conditions and below normal breeding activity due to reduced availability of prey (Ralph 1995). While El Niño-Southern Oscillation events are often cited as a possible cause of reduced availability of prey (Burkett 1995), 1995 and 1996 apparently were not El Niño years in northern California (NOAA 1995, 1996). In addition, Ralph (1995) found no significant annual variability in detections of murrelets during 1989 through 1993 at 3 inland sites in California, and in 1995 and 1996 those sites were characterized by detection levels that were within the range of the previous 8 yr (C. J. Ralph and S. L. Miller, unpubl. data).

Our findings indicate, with high confidence, that marbled murrelets do not occur in our study area. If murrelets do use some portion of the Inner North Coast Ranges of California, numbers are probably exceedingly low and thus management activities in this area would not affect a large portion of the overall population. If small, far-inland subpopulations exist, their biological value relative to the larger population is unclear; they may act as population sinks (Pulliam 1988) or they may contain genetic diversity that would contribute to the capacity of this species to adapt to long-term environmental changes (Soulé 1987). Considering the relatively recent and rapid reduction in the number of murrelets and the elimination of 85 to 96% of the old-growth redwood in California (USDI 1992), it seems unlikely that this spe-

cies will begin to colonize our study area in the future if it has not already done so. Accordingly, we recommend that the FEMAT zone lines be adjusted so that the portion of the Inner North Coast Ranges that we studied be excluded from Zone 2. This would increase the efficiency of land use planning and allow managers to focus limited wildlife management resources on areas with a greater likelihood of being important to *B. marmoratus*. In addition, conservation efforts directed toward areas where murrelets are absent are counterproductive to species recovery.

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