Surveys for Marbled Murrelets in Potential Habitat in the Oregon Coast Range

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Draft Final Report 2005

Prepared for the: The Trustees Council of the *New Carissa* Oil Spill and the U.S. Fish and Wildlife Service

Suggested Citation: Nelson, S.K. 2005. Surveys for Marbled Murrelets in Potential Habitat in the Oregon Coast Range. Oregon Cooperative Fish and Wildlife Research Unit, Oregon State University, Department of Fisheries and Wildlife, Corvallis, OR. 26 pp.

ABSTRACT

To mitigate for the injury and scale restoration for Marbled Murrelets *(Brachyramphus marmoratus)* from the *New Carissa* oil spill, information on murrelet habitat use, nest density and site characteristics was needed. We conducted intensive surveys for Marbled Murrelets in 10 sites along the Oregon Coast between 17 May and 3 August 2001. We also established vegetation plots within each site to describe the habitat features known to be important to murrelets. The specific objectives of this project were to: (1) determine the status (presence, absence or occupancy) of murrelets in each site by conducting dawn surveys; (2) characterize the quality of nesting habitat within each site by estimating the number of platform trees and the abundance moss or other substrate on each platform; and (3) estimate nest density within each site.

We detected murrelets in 100% of the sites surveyed, with occupied behavior observed in seven sites and presence documented in the remaining three sites. The number of total and occupied detections was correlated with the number of platforms. The mean density of platform trees (55.5-66.0 trees/ha) and total number of platforms (926-1078) was highest at Cook's Ridge, Darkey Creek and Oswald West. These sites also had the highest total number of murrelet detections, ranging from 73 to 246. The remaining seven sites had lower mean densities of platform trees (15.5-49.5 trees/ha), total number of platforms (173-744), and total number of detections (1-74). Moss abundance ranged from 36-77% and was highest (66%) in four of the mature sites (80-200 yrs).

Based on our intensive surveys using multiple observers in radio communication, the highest number of birds we observed on any single survey day over the survey season ranged

from 0 to 5 birds. Using our best professional judgment based on our detection data, we concluded that between 0 and 8 birds could be using our sites (see methods). We estimate that the potential density of nests among the eight sites ranged from 0.03 to 0.11 nests/ha ($\bar{x}$ = 0.07 nests/ha). This is comparable to nest density estimates from some studies conducted in California, Oregon, Washington, and British Columbia.

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INTRODUCTION

On 4 February 1999, the *M/V New Carissa* cargo ship ran aground just north of the entrance of Coos Bay, Oregon. On or about February 8, the stranded vessel began leaking oil, an *in situ* burn was conducted, the vessel split in two, and additional oil was released. The bow section was refloated and towed offshore, only to break its tow, release some oil and re-ground approximately 110 km to the north at Waldport, Oregon, where additional oil was released. The bow section was again refloated, towed to sea, and sunk. The stern section remains stranded near the entrance to Coos Bay.

An estimated 25,000 to 70,000 gallons or more of oil were leased into the waters off the coast of Oregon, killing several thousand seabirds, including 262 Marbled Murrelets *(Brachyramphus marmoratus;* hereafter murrelet) (Ford et al. 2001). The murrelet was classified as federally threatened in California, Oregon and Washington in 1992 (U.S. Fish and Wildlife Service 1992), and was state listed as threatened in Oregon in 1995 (Oregon Administrative Rule 635-100-125, 1995). Because the spill resulted in the loss of a significant number of murrelets (Ford et al. 2001), a team of agency and contract biologists was convened to develop projects that would restore the number of murrelets killed during this incident. One important option being considered is the acquisition of additional nesting habitat, a known limiting factor that is contributing to the decline of murrelet populations on the Oregon coast and elsewhere (U.S. Fish and Wildlife Service 1997, McShane et al. 2004).

The purpose of this study was to: (1) identify several parcels of land (both public and

private) containing potential murrelet nesting habitat; (2) quantify the amount of nesting habitat within each parcel; (3) estimate of the number of murrelets using each parcel for nesting and; (4) estimate the density of nests within each parcel.

STUDY AREA AND METHODS

We systematically selected ten study sites along the central Oregon coast containing murrelet nesting habitat that in our best professional judgment were representative of known nesting habitat (Table 1). These sites were located within 56 km (35 mi) of the coast, from Tillamook County in the north to Coos County in the South, and ranged in size from 9 to 104 hectares. Five of the sites contained mature forest (80-200 years), four were older-aged (>200 years), and one contained a mixture of young (60-80 years) and mature forest habitat**.**

Surveys and Estimated Number of Birds

As murrelets return to inland nesting sites during the early morning hours, they can be detected by sight and sound using the Pacific Seabird Group survey protocol (Evans et al. 2000). Under this protocol, murrelet activity at a survey station is classified as either absent, present (flying over the forest) or occupied (flying below the canopy or circling - both an indication of nesting). However, this protocol was not designed to determine relative abundance or the number of nesting pairs in a forest stand or site (Paton 1995; but see Stauffer et al. 2004). To determine how many murrelets could be occupying a given site, we created a more intensive survey protocol, employing multiple observers within a site. We conducted surveys in each site

from 17 May until 3 August 2001, during the murrelet breeding season (see Evans et al. 2000 for detailed methods). To maximize our ability to determine the number of murrelets using each site, we: (1) established at least one survey station for every 10 acres of suitable nesting habitat to ensure adequate coverage of the suitable habitat in each site[1]; (2) positioned a minimum of two surveyors in each site; and (3) surveyed each site a minimum of 10 times (even if occupancy was determined early in the survey season). Surveyors were trained to conduct protocol murrelet surveys using the standardized training methods outlined in Evans et al. (2000). In addition, early in the season, surveyors repeatedly practiced estimating the number of birds and comparing their results with other surveyors in the same site. Surveyors used VHF radios allowing them to communicate with each other during surveys and track individual murrelets or groups of murrelets flying together. Stations were placed in suitable habitat based on visual surveys for suitable platforms, therefore the number of stations established in each site depended on the amount of suitable habitat. In most cases surveyors were positioned at different stations on each survey.

By using an intensive survey method, with multiple observers in radio communication, we were able to estimate the highest number of birds observed on any single survey and the minimum number of birds consistently using the site. The highest number of birds observed on any single survey was determined by totaling the number of individual murrelets observed in or near the survey area (the suitable habitat surveyed within each site) by a single observer on a

[1] All survey stations established in each site were surveyed. On occasion additional stations were added during the survey season to allow for better determination of murrelet numbers.

single survey day; the numbers presented in the results for each survey area are the highest number recorded on any single survey day over the survey season. In estimating the minimum number of birds consistently using the suitable habitat in each site, we took into account all the observations that the crew recorded during their surveys over the survey season, including audio and visual detections, and especially those indicating occupied behaviors. A key to estimating this number was the communication between observers doing simultaneous surveys. During detections on all surveys, observers identified individual birds or groups of birds and tracked their movements from one observer to the other as the murrelets moved through the site. This allowed the observers to more accurately attribute detections to individual birds or groups of birds using the site. At the end of the season, we used the detailed detection data and the site-specific knowledge of each observer to estimate the number of birds that appeared to be consistently using the suitable habitat in the site during the season. Note that the minimum number of birds consistently using a site over the survey season can be a larger number than the highest recorded on a single survey day.

The density of birds (birds/ha) was determined by dividing the minimum number of birds consistently using the suitable habitat over the survey season by the amount of suitable habitat surveyed. Potential nest density (nests/ha) was estimated by dividing the density of birds by two, assuming two birds per nest[2].

[2] This is a minimum estimate given that both birds in a pair may not have been present during our surveys.

Habitat Characterization

We assessed the quality of each site by collecting detailed information on several key habitat structural components (see below). To do this, we overlaid each site with a grid and randomly selected 10 points on which to locate our vegetation plots. At each 25-m radius plot we collected the following data: platform abundance (limbs >10cm in diameter and >10 m in height above ground), platform tree diameter and abundance, and percent moss or substrate on each platform tree. We classified platforms into categories based on diameter and height: (1) those with diameters of 10-15 cm or > 15 cm; and (2) those that were 10-15 m and >15 m above the ground (modified from Hamer and Meekins 1999). The highest quality sites were assumed to be those with murrelet occupancy, high platform and platform tree density, and an abundance of nesting substrate (Nelson and Wilson 2002).

For sites on federal and state land, the amount of suitable nesting habitat within the site was provided to us by the managing agency. These agencies determined the amount of suitable nesting habitat through stand exams, and aerial photo and GIS interpretation (based on tree size). For the two private land sites, we determined the amount of suitable nesting habitat based on aerial photo interpretation (based on tree size) and descriptive information provided to us by the land owner. The size of each site ranged from 9-104 ha and included both suitable and unsuitable habitat (Table 2). The amount of suitable habitat estimated in each parcel ranged from 1-69 ha. A majority of the suitable habitat within each parcel was covered by placement of our survey stations (Table 2).

Relationship Between Habitat and Murrelet Detections

We used a Spearman Rank correlation[3] to compare the relationship between murrelet detections and the habitat features measured in our survey sites (SAS Institute Inc. 1990). In this analysis, the number of total and occupied detections, the number of birds consistently using the sites, and the ratio of occupied detections to all visual detections were compared to all of the habitat variables. The ratio of occupied detections to all visual detections was used as an additional measure to compensate for the differences in visibility at the survey stations and to account for the presence of potential flight corridors near some survey stations (Rodway and Regehr 1999, Burger et al. 2000).

RESULTS

Surveys

Murrelets were detected at all 10 of the sites surveyed (Table 3). Occupied behaviors were observed in seven of the sites and presence was recorded in the remaining three. The total number of detections and the number of occupied detections per day ranged from 1-246 and 0-40, respectively. The site with the most detections over the season was Oswald West (n = 246). Cook's Ridge had the most below canopy behaviors (n = 40). Activity levels increased over the season with peak detections occurring in July at most sites.

Habitat Characteristics

The characteristics of the study sites are summarized in Tables 2 and 4. The density of platform trees (55.5-66.0 trees/ha) and the total number of platforms (926-1078) was highest and fairly uniform in the older-aged forest sites: Cook's Ridge, Darkey Creek and Oswald West (Table 4). These sites also had the highest total number of detections (73-246; Table 3). The other sites, which were primarily mature forests, had much lower densities of platform trees (15.5-49.5 trees/ha) and number of platforms (173-744) and yielded fewer total detections (1-74). Platform trees in all sites had fairly uniform diameters, although Baker Creek had the largest trees and Oswald West the smallest trees. Platforms at the two height and diameter classes were common on most platform trees in these all study sites. However, lower platforms were more abundant than high platforms and most platforms were >15 cm in diameter except at the Hall Property. Moss abundance ranged from 36-77% and was highest (>66%) in four of the mature sites.

Relationship Between Habitat Characteristics and Detections

We ran correlations between all habitat variables measured and murrelet detections (total number, occupied detections, highest number observed on a single survey day, and minimum number consistently using the site). Significant positive correlations with the number of total

[3] Spearman Rank correlations are nonparametric measures of linear association between two variables. We considered the correlations significant if they had an r-value $\geq$ 0.70 and a P-value $\leq$ 0.05.

detections and the number of birds consistently using each site were found only for the number of platforms and density of platform trees ($r > 0.70$, $P < 0.05$). Occupied detections were only correlated with the number of platforms ($r = 0.74$, $P = 0.04$). The ratio of occupied detections to all visual detections was not correlated with these habitat characteristics.

Estimated Number of Birds and Nests

Based on our intensive surveys, with multiple observers in radio communication, the highest number of birds observed at one time on a single survey ranged from 0-5 (Table 2). This number included birds flying over the site that may be traveling to other areas, so it is not necessarily an indication of site use. Using the number of occupied behaviors and highest number of birds seen on any one survey, we estimated that each site contained a minimum of between 0 and 8 nesting birds during the survey season (Table 2). The estimated number of birds consistently using each site did not vary greatly from the highest number of murrelets recorded on any single survey day over the survey season.

Based on the above numbers, the estimated density of birds varied from 0.05 to 0.22 birds/ha ($\bar{x}$ = 0.13 birds/ha; Table 2). The highest density of birds was in Oswald West and the lowest density in Darkey Creek and Sixes River. The density of potential nests ranged from 0.03 to 0.11/ha ($\bar{x}$ = 0.07 nests/ha; Table 2). The sites with the highest and lowest nest density were the same as for bird density[4].

[4] The estimated potential nest density was based on the density of birds.

DISCUSSION

Surveys and Habitat Characteristics

Murrelets were detected in all of our survey sites. Few detections were recorded at Crane Creek, Hall Property and Johnson Ridge because they were small, isolated parcels with limited nesting sites compared to other areas. Howell 709 also had a low number of detections but was not an isolated site. The explanation for this is unknown. Additional surveys would undoubtedly increase the likelihood of detecting occupied behavior on sites where presence was documented. All of our survey sites contained suitable murrelet habitat and were similar in characteristics to other known occupied or nest sites (Hamer and Nelson 1995, Nelson and Wilson 2002). Our surveys and analysis of vegetation characteristics revealed that the highest quality sites, based on density of platform trees, number of platforms, high total detections and occupied behavior, were Cook's Ridge, Darkey Creek, and Oswald West. In addition to being the oldest-aged sites in our sample, Cook's Ridge and Oswald West were also located adjacent to a wilderness area and a state park, respectively, further increasing the site's quality as murrelet nesting habitat. Other studies corroborated our findings on murrelet habitat associations by demonstrating: (1) a positive relationship between the number of detections and platform or abundance of platform tree; and (2) that platforms and moss substrate are key characteristics at nests and occupied sites (e.g., Burger 1995, 2001, Grenier and Nelson 1995, Hamer 1995, Kuletz et al. 1995, Manley 1999, Miller and Ralph 1995, Naslund et al. 1995, Nelson and Wilson 2002, Rodway et al. 1993). Any parcel of land considered for acquisition should either contain these key habitat features, or act as a buffer to sites with these key habitat features, or have the ability

to develop into habitat with these characteristics in the short term (within 25-50 years).

Estimated Number of Birds and Nests

In this study, we estimated the number of birds consistently using our sites based on intensive dawn surveys to create an estimate of nest density. Because the murrelet survey protocol (Evans et al. 2000) was not designed for determining abundance, our estimates should be considered rough approximations of the numbers of murrelets in each site. Our bird densities (0.05-0.22 birds/ha, $\bar{x}$ = 0.13) and potential nest densities (0.03-0.11 nests/ha, $\bar{x}$ = 0.07; one nest per 14.3 ha or 35.3 ac) should therefore also be considered rough estimates.

Alternative, although more costly and labor-intensive, techniques for determining occupancy rates or nest densities are radar and tree climbing. Radar has been used as a tool to estimate the number of birds in select watersheds in British Columbia and Washington (Schroeder et al. 1999, Manley 2000, Burger 2001, Cullen and Manley 2001, Raphael et al. 2002b). In these studies, the counts of murrelets flying into and out of these watersheds were used to determine the density of birds based on the number of hectares surveyed. Based on their results, the mean density of birds ranged from 0.005 to 0.083 birds/ha (Table 5). From these numbers we estimated the mean density of nests by dividing each bird density number by 0.50 (assuming 2 birds per nest). The density of nests, therefore, ranged from 0.003 to 0.042 nests/ha (one nest per 24-333 ha or 59-824 ac; Table 5). In general, the estimates of bird and nest densities from our study are higher than those from these radar studies, although they overlapped with estimates from two studies in British Columbia (Manley 2000, Burger 2001).

Tree climbing has been used in a variety of studies in British Columbia, Washington and Oregon to locate murrelet nests, describe habitat associations and estimate nest density, generally in occupied older-aged forests (Hamer and Meekins 1999, Manley 1999, Rodway and Regehr 1999, Conroy et al. 2002, Nelson and Wilson 2002). In most of these studies, climbers climbed potential nest trees (with platforms) in randomly located plots. Mean estimates of nest density from these studies based on all visible nests found (old and active nests) ranged from 0.50-1.42 nests/ha (one nest per 0.7-2.0 ha or 1.7-4.9 ac; Table 5). Because these and other studies did not distinguish between active and inactive nests, the estimated nest density is likely higher than the true density (see the home range discussion below). Our estimates of nest density using multiple ground observers are much lower than those based on all visible nests from these tree climbing studies.

Counting the number of active nests would provide the most accurate estimate of nest density. However, the only estimate of nest density from active nests was 0.11 nests/ha (one nest per 9 ha or 22 ac) comes from a rigorous study by Conroy et al. (2002) in Clayoquot Sound, British Columbia. Their estimate of active nest density (0.11 nests/ha) is identical to the higher end of the range of nest densities from our study (0.03-0.11 nests/ha).

When examining the relationship between number of birds or nests and actual productivity, it is important to consider several aspects of murrelet biology, including home range and nesting success. Unlike most other alcids, Marbled Murrelets are solitary nesters and pairs generally nest distant from one another within a forest stand or site. The closest documented simultaneous active nests were 30 m in Oregon, 38 m in British Columbia, 100 m in

Washington, and 1 km in Alaska (Nelson 1997, Manley 1999). It has been hypothesized that each nesting pair of murrelets has a home range and within this area they alternate between nests among years (Nelson 1997, unpubl. data). Recent data from a radioed bird in British Columbia demonstrates this theory, with the bird returning to an adjacent tree (within 75 m) to nest in the subsequent year (F. Cooke, pers. comm.). It is possible that a single pair of birds could have up to a dozen or more nest platforms or trees within their home range, which are used on an alternating basis. This hypothesis is based on the discovery of clusters of old nests in forest stands or sites, birds (assumed to be the same individuals) returning to nest in the same or nearby trees in subsequent years, and the need for murrelets to avoid predation (Singer et al. 1995, Nelson and Hamer 1995a, 1995b, Nelson and Peck 1995, Nelson 1997, Manley 1999, Nelson and Wilson 2002).

Murrelet nesting success has been documented through observations of active nests and artificial nest studies. Most active murrelet nests have failed (43-85%), and most failures resulted from predation (78%; Nelson and Hamer 1995, Hamer and Meekins 1999, unpubl., Manley 1999, Manley and Nelson 1999, Bradley 2002; summarized in McShane et al. 2004). Recent radio telemetry research found failure rates of 54% in British Columbia (Bradley 2002), 68-86% in northern California (Hebert and Golightly 2003), and 84-100% in central California (Peery et al. in prep). In a study of artificial nests in Washington and Oregon, 81-86% were disturbed or depredated (Luginbuhl et al. 2001, Raphael et al. 2002a). Predation rates are thought to be influenced by the amount of forest edge and composition of the surrounding forest (Nelson and Hamer 1995b, Marzluff et al. 2000, Raphael et al. 2002a, Ripple et al. 2003).

Therefore, the quality of murrelet nesting habitat (factors such as the amount of interior forest and edge habitat) will influence nesting success and should be considered, in addition to key nesting characteristics, when determining the value of a particular site as nesting habitat.

ACKNOWLEDGMENTS

I greatly appreciated the assistance of Karen Cradler, Ross Hubbard and Jim Rogers in collecting the field data. Thanks to Mandy Wilson for supervising the crew, and compiling and entering the data. This project was funded by the U.S. Fish and Wildlife Service, Portland State Office. Thanks to Larry Mangan, Lee Folliard, Mike Szumski, and Sarah Madsen for providing input on the study plan and making this study possible.

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Table 1. Study sites, Oregon Coast Range.

Site Name	Ownership	Site Size (ha) [a]	Habitat Type [b]
Baker Creek	Coos Bay BLM	104	mature forest
Cook's Ridge	Siuslaw National Forest	69	older-aged forest
Crane Creek	Coos Bay BLM	19	mature forest
Darkey Creek	Siuslaw National Forest	58	older-aged forest
Hall Property	Private Ownership	9	mixed mature and young
Howell 709	Siuslaw National Forest	23	mature forest
Johnson Ridge	Coos Bay BLM	17	mature forest
Oswald West	Oregon Department of Forestry	45	older-aged forest
Radtke Property	Private Ownership	33	mature forest
Sixes River	Coos Bay BLM	63	older-aged forest

[a] For private properties this includes parcel size, not site size.
[b] Older-aged forest (>200 years), mature forest (80-100 years), young forest (60-80 years).

Table 2. Estimated number of Marbled Murrelets, amount of suitable habitat, and potential density of nests at each site, Oregon Coast Range.

Site Name	Site Size (ha) [a]	Suitable Habitat (ha)	Surveyed Suitable Habitat (ha)	# Platform Trees	Highest # Observed [b]	Minimum # Birds in Surveyed Area [c]	# Birds/ha	# Potential nests/ha
Baker Creek	104	53	38	99	4	4	0.11	0.06
Cook's Ridge	69	69	51	111	4	7	0.14	0.07
Crane Creek	19	19	19	33	0	0	0	0
Darkey Creek	58	58	56	121	2	3	0.05	0.03
Hall Property	9	1	1	32	0	0	0	0
Howell 709	23	23	23	53	2	2	0.09	0.05
Johnson Ridge	17	17	17	31	3	3	0.18	0.09
Oswald West	45	36	36	132	5	8	0.22	0.11
Radtke Property	33	10	10	46	2	2	0.20	0.10
Sixes River	63	62	55	61	2	3	0.05	0.03

[a] For private properties this includes parcel size not site size.
[b] Highest number of murrelets observed on a single survey day over the survey season.
[c] Estimated minimum number of murrelets (not necessarily pairs) consistently using each site over the season based on simultaneous surveys on each survey day.

Table 3. Detections and status, by date and station number, of Marbled Murrelets at each site, Oregon Coast Range.

Visits	1	2	3	4	5	6	7	8	9	10	11	STATUS
Site (# Survey Stations)[a]	Date of Survey Number of Detections (Number of Below Canopy Detections)											
Baker Creek (11)	30 May 2 (2)	31 May 0 (0)	17 June 1 (1)	18 June 0 (0)	9 July 0 (0)	10 July 0 (0)	16 July 11 (1)	17 July 1 (0)	27 July 10 (0)	28 July 1 (0)	29 July 1 (0)	Occupied
Cook's Ridge (9)	17 May 0 (0)	17 May 4 (0)	24 May 5 (0)	24 May 4 (0)	20 June 0 (0)	20 June 4 (1)	5 July 0 (0)	5 July 11 (10)	23 July 73 (27)	23 July 23 (2)	-------	Occupied
Crane Creek (4)	29 May 0(0)	5 June 0 (0)	12 June 0 (0)	19 June 0 (0)	20 June 0 (0)	3 July 0 (0)	10 July 0 (0)	17 July 0 (0)	24 July 1 (0)	31 July 0 (0)	-------	Presence
Darkey Creek (8)	21 May 4 (0)	21 May 4 (0)	4 June 3 (0)	4 June 4 (0)	25 June 0 (0)	25 June 0 (0)	9 July 0 (0)	9 July 0 (0)	19 July 18 (0)	19 July 40 (1)	-------	Occupied
Hall Property (7)	22 May 0 (0)	30 May 0 (0)	7 June 0 (0)	14 June 0 (0)	22 June 2 (0)	2 July 0 (0)	11 July 3 (0)	18 July 0 (0)	27 July 2 (0)	2 Aug 5 (0)	-------	Presence
Howell 709 (6)	31 May 0 (0)	31 May 0 (0)	8 June 0 (0)	8 June 0 (0)	27 June 0 (0)	27 June 0 (0)	6 July 3 (0)	6 July 3 (0)	16 July 1 (0)	16 July 1 (0)	-------	Presence
Johnson Ridge (4)	29 May 0 (0)	29 May 0 (0)	5 June 0 (0)	12 June 0 (0)	19 June 1 (0)	26 June 0 (0)	3 July 0 (0)	10 July 1 (1)	17 July 0 (0)	24 July 0 (0)	31 July 1 (0)	Occupied

Table 3 cont. Detections and status, by date, of Marbled Murrelets at each study site, Oregon Coast Range.

Visits	1	2	3	4	5	6	7	8	9	10	11	STATUS
Site (# Survey Stations)[a]	Date of Survey Number of Detections (Number of Below Canopy Detections)											
Oswald West (6)	25 May 5 (0)	25 May 1 (0)	15 June 1 (0)	15 June 3 (0)	12 July 82 (17)	12 July 91 (6)	20 July 22 (0)	20 July 31 (0)	3 Aug 7 (0)	3 Aug 3 (0)	-------	Occupied
Radtke Property (7)	22 May 0 (0)	30 May 0 (0)	7 June 0 (0)	14 June 3 (1)	22 June 1 (0)	2 July 0 (0)	11 July 1 (0)	18 July 6 (0)	27 July 21 (0)	2 Aug 7 (0)	-------	Occupied
Sixes River (9)	19 May 0 (0)	3 June 1 (0)	11 June 1 (0)	19 June 0 (0)	1 July 0 (0)	7 July 15 (0)	13 July 0 (0)	20 July 23 (3)	26 July 16 (1)	23 July 18 (2)	-------	Occupied

[a] All survey stations established in each site were surveyed. On occasion additional stations were added to allow for better determination of murrelet numbers.

Table 4. Characteristics (number or mean ± SE [range]) of each site, Oregon Coast Range.

Site Name	# Plots	# Platform Trees (Platforms)	Mean # Platforms	Mean Platform Tree Diameter (cm)	Density of Platform Trees/ha	Percent Moss	# (%) of Platforms			
							Height		Diameter	
							10-15 m	>15 m	10-15 cm	>15 cm
Baker Creek	10	99 (744)	7.5 ± 0.5 (1-24)	136.1 ± 4.0 (40.9-240.3)	49.5 ± 5.2 (15-75)	67.5 ± 2.5 (20-100)	618 (83)	126 (17)	93 (13)	648 (87)
Cook's Ridge	10	111 (1078)	9.7 ± 1.0 (1-65)	101.1 ± 3.9 (39.0-268.5)	55.5 ± 6.1 (25-85)	47.7 ± 1.6 (5-85)	821 (76)	257 (24)	200 (19)	878 (81)
Crane Creek	10	33 (284)	8.6 ± 1.2 (1-25)	106.6 ± 7.7 (44.4-191.2)	16.5 ± 5.1 (5-55)	76.9 ± 3.3 (25-100)	182 (64)	102 (36)	60 (21)	224 (79)
Darkey Creek	10	121 (972)	8.0 ± 0.6 (1-51)	101.6 ± 2.8 (26.4-235.4)	60.5 ± 7.0 (25-100)	41.9 ± 2.0 (5-90)	710 (73)	262 (27)	30 (3)	942 (97)
Hall Property	9	32 (173)	5.4 ± 0.7 (1-14)	114.7 ± 5.7 (44.0-197.3)	17.8 ± 4.6 (5-50)	36.4 ± 3.5 (0-75)	153 (88)	20 (12)	88 (51)	85 (49)
Howell 709	10	53 (384)	7.2 ± 0.7 (1-27)	114.0 ± 3.1 (64.3-155.3)	26.5 ± 4.5 (5-50)	43.0 ± 2.4 (10-80)	309 (80)	75 (20)	52 (14)	332 (86)
Johnson Ridge	10	31 (248)	8.0 ± 1.0 (1-23)	115.3 ± 7.8 (60.0-231.8)	15.5 ± 2.4 (5-30)	66.0 ± 3.2 (30-90)	160 (65)	88 (35)	101 (41)	147 (59)
Oswald West	10	132 (926)	7.0 ± 0.6 (1-38)	75.6 ± 2.2 (29.4-221.8)	66.0 ± 9.9 (25-130)	46.2 ± 1.2 (10-80)	627 (68)	298 (32)	199 (21)	727 (79)

Table 4 cont. Characteristics (number or mean ± SE [range]) of each site, Oregon Coast Range.

Site Name	# Plots	# Platform Trees (Platforms)	Mean # Platforms	Mean Platform Tree Diameter (cm)	Density of Platform Trees/ha	Percent Moss	# (%) of Platforms			
							Height		Diameter	
							10-15 m	>15 m	10-15 cm	>15 cm
Radtke Property	10	46 (519)	11.3 ± 1.5 (1-39)	100.0 ± 5.4 (47.0-212.2)	23.0 ± 6.3 (5-55)	71.2 ± 3.4 (25-99)	336 (65)	183 (35)	186 (36)	333 (64)
Sixes River	10	61 (417)	6.8 ± 0.8 (1-28)	92.9 ± 5.7 (33.1-231.2)	30.5 ± 4.8 (10-55)	55.7 ± 4.0 (0-100)	291 (70)	126 (30)	122 (29)	295 (71)

Table 5. Estimated Marbled Murrelet and nest densities from radar and tree climbing studies.

Location	Method	Mean Birds/ha	Mean Nests/ha[1]	Reference
Central Coast, BC	Radar	0.042	0.021	Schroeder et al. 1999
NW Vancouver Island, BC	Radar	0.083	0.042	Manley 2000
Clayoquot Sound, BC	Radar	0.067	0.034	Burger 2001
Sunshine Coast, BC	Radar	0.021	0.011	Cullen and Manley 2001
Olympic Peninsula, WA	Radar	0.005	0.003	Raphael et al. 2002b
Olympic Peninsula, WA	Tree climbing	---	0.90	Hamer and Meekins 1999
Sunshine Coast, BC	Tree climbing	---	0.50	Manley 1999
Clayoquot Sound, BC	Tree climbing	---	1.42 [2]	Rodway and Regehr 1999
Clayoquot Sound, BC	Tree climbing	---	0.86 [3]	Rodway and Regehr 1999
SW Vancouver Island, BC	Tree climbing	---	0.60	Bahn and Burger, Unpubl. data
Clayoquot Sound, BC	Tree climbing	---	0.53 [4]	Conroy et al. 2002
Clayoquot Sound, BC	Tree climbing	---	0.66 [5]	Conroy et al. 2002
Clayoquot Sound, BC	Tree climbing	---	0.11 [6]	Conroy et al. 2002
Coast Range, OR	Tree climbing	---	0.92	Nelson and Wilson 2002

Coast Range, OR	Surveys	0.13	0.07	This study

[1] Nests/ha for radar studies was determined by multiplying birds/ha by 0.50.
[2] Based on valley bottom forested area only.
[3] Based on entire study area.
[4] All nests.
[5] Pooled nests from Conroy et al. 2002 and Rodway and Regehr 1999.
[6] Active nests only.