FINAL REPORT

MARBLED MURRELET HABITAT CHARACTERISTICS ON STATE LANDS IN WESTERN OREGON

by

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IN MEMORIAM

This report is dedicated with much respect, admiration, and appreciation to David B. Buchholz. His unflagging interest and curiosity about the Marbled Murrelet proved to be an inspiration to us all. We had the privilege of working with him on the Tillamook State Forest. Dave's knowledge of the area and the bird was an invaluable tool that we utilized often throughout the years. He was always available to us whether we needed assistance in the field, in the office, during his work day or during his personal time. On several occasions Dave directed us to an area where we found an active nest, an old nest or time permitting, he simply found the nest himself and told us about it. His interest in the bird's behavior produced a profusion of notes that contain the minutest details, down to whether or not the murrelet carried the fish into the nest with the belly in or belly out.

Dave's assistance was not limited to the field season. His many helpful comments, suggestions and insights to the contents of this final report were invaluable. No one could find a discrepancy better than Dave, and he certainly wasn't going to let it pass without comment. For that we are very grateful.

We miss you Dave, you were a great friend and colleague. Thank you for your genuine interest and tireless enthusiasm for this project and the Marbled Murrelet.

Mandy Wilson and S. Kim Nelson

PREFACE

This is the final report from our five year study on the characteristics of Marbled Murrelet nesting habitat on the Clatsop, Tillamook and Elliott State Forests in western Oregon. Interim summaries of this research were provided in Nelson and Wilson (1996, 1997, 1999). The Oregon Cooperative Fish and Wildlife Research Unit (OCFWRU) at Oregon State University, in conjunction with its cooperators (U.S. Geological Survey, Oregon Department of Fish and Wildlife, Oregon State University, Wildlife Management Institute), reserves the rights to publish the data contained in this report and to play an active role in their interpretation. These data are not to be used or published without the written consent of the OCFWRU. However, this report is available through the OCFWRU and may be cited as:

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EXECUTIVE SUMMARY

The Marbled Murrelet (*Brachyramphus marmoratus*) is a small seabird most notable for its unusual habit of nesting in trees in forests up to 101 km inland. This species was once common along the eastern Pacific from Alaska to central California, but has apparently undergone population declines throughout much of its range (USFWS 1992, 1997). Loss of murrelet nesting habitat to timber harvest was determined to be the most critical threat to their survival (USFWS 1992, 1997). To provide for the persistence and recovery of this species, forest managers need accurate information on the characteristics of their nests and nesting stands.

Comprehensive studies on murrelet nest-site characteristics have previously or simultaneously been conducted in Alaska (Naslund et al. 1995), British Columbia (Manley 1999) and Washington (Meekins and Hamer 1999), however no information on murrelet nest-site characteristics and nest-site selection has been presented for western Oregon. Therefore, we designed this study to describe and provide quantitative information on the nest platform, nest tree and nest-site characteristics of Marbled Murrelet nesting habitat on state lands in western Oregon. Through this study, we hope to better understand murrelet nest-site selection and the influence of habitat variables at three scales (platform, tree and site) on the apparent suitability of sites for nesting murrelets.

Our study area was located on Oregon Department of Forestry (ODF) lands in western Oregon, including the Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*) zones of the Clatsop, Tillamook, and Elliott State forests. We used four climbing plot sampling methods (intensive, paired-plot, grid and cluster) and dawn surveys to locate active and old murrelet nests in 34 study sites between 1995 and 1999. Climbing plots (40 m radius; n = 149) were located in randomly selected sites with previous murrelet below-canopy activity (occupied sites). We conducted dawn surveys in occupied sites and near trees with previous landing behavior. We measured the characteristics of nest and random platforms, nest and non-nest trees, and the vegetation within 25 m radius plots centered on nest trees or climbing plots without nests. The 25 m radius plots described nest and non-nest sites. We then summarized these habitat data and developed a set of *a priori* hypotheses to explore the potential relationship between the probability of murrelet nesting and each of the selected explanatory variables at the platform, tree and nest-site scales.

We located a total of 37 nests (27 old and 10 active) after climbing or observing 1,890 trees, searching 31,778 potential nesting platforms, and conducting 402 dawn and 35 evening surveys. Twenty-one old nests were located in 18 climbing plots in nine sites, six old nests were discovered in four sites during other climbing, and 10 active nests were found in five sites during dawn surveys or tree climbing.

Murrelets were nesting in large (primarily old-growth and mature), tall conifer trees with numerous broad, moss-covered platforms and extensive horizontal and vertical cover. Murrelets were selecting nest platforms that were larger in diameter or width and had more cover (horizontal and close vertical) than non-nest platform trees available in nesting sites. At the tree scale, the most important characteristics were abundance of large (>15 cm) platforms, moss or substrate, and dwarf mistletoe (*Arceuthobium sp.*); non-nest trees had fewer platforms, less moss or substrate, and less mistletoe. In general, platforms and nest trees on the north coast (Clatsop and Tillamook State Forests) and Elliott State Forests were similar, although trees were taller, larger in diameter and contained more lichen and moss or substrate on the Elliott compared with the north coast.

Marbled Murrelet nest trees were located in areas of the forest that included an abundance of large trees with numerous platforms and generally more than two canopy layers. Murrelets were selecting nest-sites with significantly more platform trees and platforms, and sites on gentler slopes than non-nest sites. These results indicate that nest trees on the Clatsop, Tillamook and Elliott State Forests were located in habitat patches or areas that were unique from the surrounding forest, suggesting the distribution of suitable murrelet habitat was not uniform. Nest sites on the north coast and the Elliott State Forest differed with respect to tree species composition, tree size (diameter and height) and tree density. The Elliott had larger platform trees, taller trees (canopy and midstory), and a lower density of medium-sized trees than the north coast.

Despite some differences in the characteristics of nest sites on the north coast and Elliott State Forests due to forest type, micro-climate, historic fires and management, and variation in growing conditions, the overall key characteristics of murrelet nest sites at the platform (large platforms with substrate and cover), tree (trees with numerous substrate-covered platforms), and site (high densities of platform trees) scales remain the most important components for nesting on State Lands in western Oregon. These should be the components that ODF attempts to maintain and create when managing for Marbled Murrelets and their habitat.

Based on the results of our study, we recommend that forest managers consider platform tree abundance and abundance of platforms (including dwarf mistletoe) with adequate cover and moss when attempting to provide suitable habitat for this threatened seabird. In addition, access variables, such as canopy layers and distance to edge (or other measures of flight space) should be addressed when managing habitat for murrelets. Several means for providing these characteristics include: (1) creating or maintaining groups of large trees with numerous platforms, in areas that provide a suitable microclimate for the development of moss or other substrates; (2) using a variety of silvicultural or other methods that promote rapid limb growth; and (3) lightly thinning dense younger stands that have some platform development. In addition, because our data indicated that murrelet nest densities appear to be very low, many or larger stands of suitable habitat will be required for providing for viable breeding populations of murrelets.

Ultimately, nest success will effect the suitability of sites for murrelet use. Unfortunately because of small sample sizes we were not able to provide information on the characteristics of successful and failed nests. However, the potential effects of habitat management on the risk of predation should be considered in any management projects.

Finally, we believe the habitat management recommendations listed in the Marbled Murrelet Recovery Plan (USFWS 1997) should be considered when managing for murrelets, including maintaining all occupied sites and other older-aged forests for recruitment habitat, and creating new habitat in areas adjacent to existing murrelet nesting habitat. This would not only allow for the creation of larger blocks of murrelet habitat but also provide buffers to existing nesting areas and potentially allow murrelets to expand into the newly created habitat.

This study focused on the within-stand characteristics of Marbled Murrelet nest sites. Additional murrelet research in Oregon and elsewhere should be conducted to explore murrelet habitat relationships at the landscape and geographic scales. We also recommend that any timber harvest or habitat modification projects in habitat buffers or near occupied sites be completed as part of a long-term research project that explores the trade-off between creating suitable murrelet habitat and increasing the risks of predation.

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MARBLED MURRELET HABITAT CHARACTERISTICS ON STATE LANDS IN WESTERN OREGON

INTRODUCTION

Marbled Murrelets (*Brachyramphus marmoratus*) are unique among seabirds in their nesting habits, using arboreal nests within mature and old-growth forests, and choosing nest sites on relatively large limbs or deformations primarily within upper portions of the canopy (Hamer and Nelson 1995, Nelson 1997). This species was once common along the eastern Pacific from Alaska to central California, but has apparently undergone population declines throughout much of its range and is now federally listed as threatened (USFWS 1992, 1997). Loss of murrelet nesting habitat to timber harvest was determined to be the most critical threat to their survival (USFWS 1997, USFS and BLM 1994). To aid in maintaining and developing habitat for this species, and providing for its recovery, accurate information is needed on their nesting habitat associations. Knowledge of their specific habitat and nest site preferences will be critical for helping land managers develop Habitat Conservation Plans and make informed decisions regarding forest management.

Information on the characteristics of Marbled Murrelet nest platforms and nest trees have been described throughout their range, based on small samples of nests discovered accidentally or through dawn surveys, tree climbing, and searches for eggshell fragments (*e.g.*, Binford et al. 1975, Day et al. 1983, Singer et al. 1991, papers in Nelson and Sealy 1995, papers in Ralph et al. 1995, Nelson 1997). In addition, murrelet nesting habitat has been characterized based on associating inland activity patterns with forest or landscape structural characteristics (*e.g.*, Rodway et al. 1993, papers in Ralph et al. 1995, papers in Nelson and Sealy 1995, Meyer 1999, Burger and Bahn, in press; Rodway and Regehr, in press). From these studies, details on general murrelet habitat relationships and associations are known, however little information is available on murrelet nest-site selection at the stand or landscape level based on large samples of nests.

Recently, and concurrent with our research, comprehensive studies on murrelet nest-site selection using telemetry and tree climbing have been initiated in British Columbia (Manley 1999; Cooke et al. unpubl. data), Washington (Meekins and Hamer 1999), and California (Beissinger et al. unpubl. data). In Oregon, Ripple et al. (in press) conducted a landscape-level habitat selection study, however no stand-level studies on murrelet nest-site selection are known from western Oregon. Therefore, we designed this study to describe and provide quantitative information on the nest platform, nest tree and nest-site characteristics of Marbled Murrelet nesting habitat on state lands in western Oregon. Through this study, we hope to better understand murrelet nest-site selection and the influence of habitat variables at three scales (platform, tree and site) on the apparent suitability of sites for nesting murrelets.

This study incorporated intensive tree climbing (Nelson et a. 1994, Nelson 1995, Nelson and Peck 1995) with traditional methods (ground-based dawn watches and eggshell searches) to find nests and study the nesting biology of murrelets. Our goals were to determine Marbled Murrelet nesting habitat characteristics and nest-site selection in western Oregon, and determine those characteristics associated with successful nesting. Specifically, our objectives were to: (1) locate murrelet tree nests; (2) describe nest platform and nest tree characteristics and selection;

(3) compare vegetative structures of nest and non-nest plots, and describe key habitat features of murrelet nest sites; (4) monitor active nests for murrelet behavior and reproductive success (fledging of young); and (5) compare nest and site characteristics between successful and unsuccessful nests to determine suitable and preferred habitat, and develop an understanding of what factors influence habitat quality. From these data we planned to develop models of murrelet nest-site selection and key characteristics that maximized habitat suitability and reproductive success. In addition, because we used different methods to locate murrelet nests, we assessed the efficiency and success of our different climbing techniques.

STUDY AREA

Our study was conducted on Oregon Department of Forestry (ODF) lands in western Oregon, including the Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*) zones of the Clatsop (62,323 ha), Tillamook (147,309 ha), and Elliott (37, 637 ha) State Forests (Figure 1). In general, the Oregon Coast Range is characterized by rugged, mountainous terrain, with steep slopes and deeply cut river and creek drainages. Elevations range from sea level to 1100 m. The climate consists of cool, wet winters (150 to 300 cm of rain) and warm, dry summers. Mean temperatures range from 0° C in the winter to 24° C in the summer (Franklin and Dyrness 1973). The landscape consists of a mosaic of young (<80 yrs), mature (80-200 yrs), and old-growth (>200 yrs) mixed Douglas-fir (*Pseudotsuga menziesii*), Sitka spruce, and western hemlock stands. The distribution and abundance of old-growth trees and stands are limited

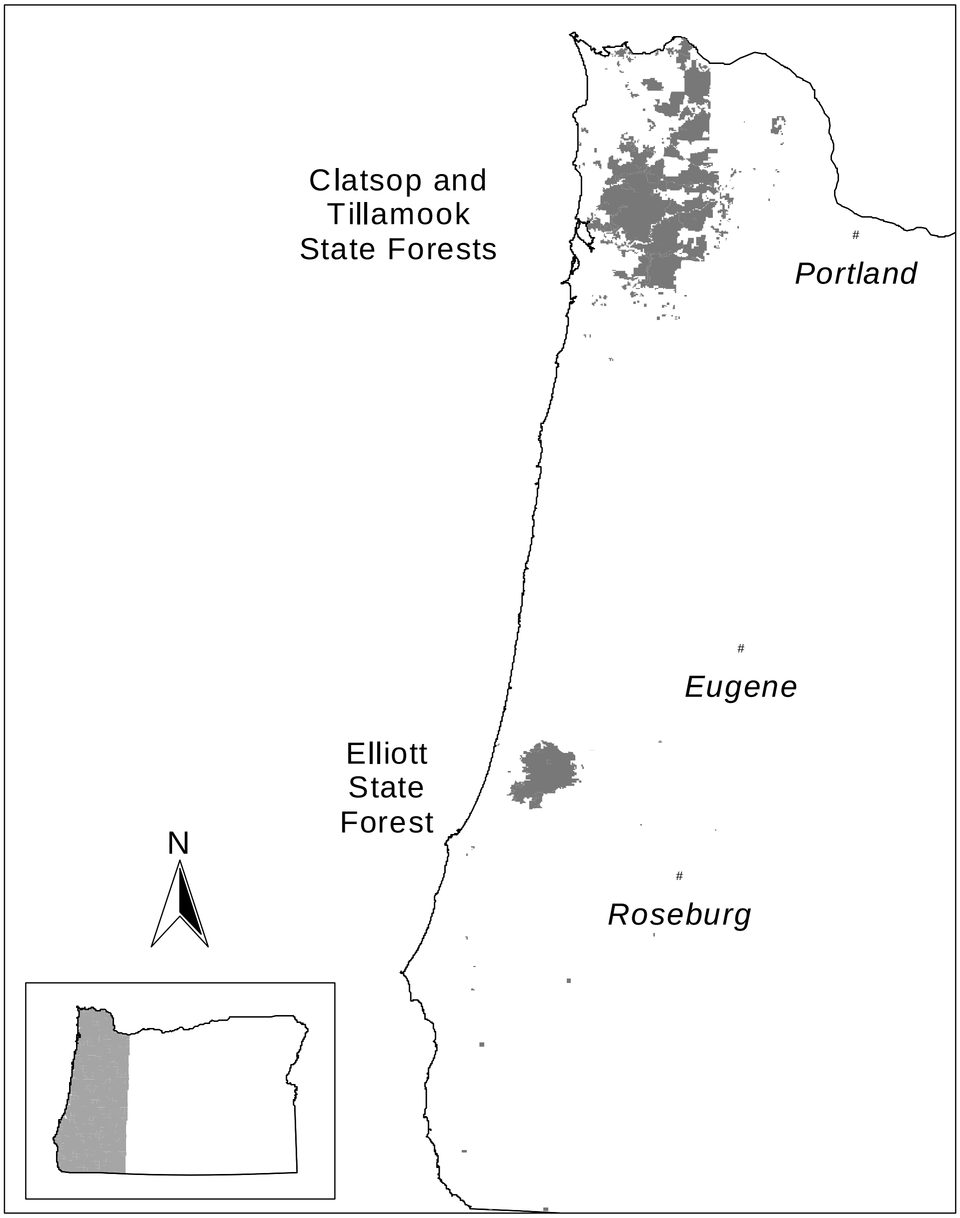

Figure 1. Study area in western Oregon, including the Clatsop, Tillamook and Elliott State Forests.

because of extensive wildfires and intensive timber management.

The structure and characteristics of the Clatsop, Tillamook and Elliott State Forests have been created by a variety of factors including fire, windthrow, early logging, and modern forest management. The Clatsop State Forest consists primarily of second-growth conifer stands in the 30-70 year old age class. Extensive logging between the late 1800's and 1940 shaped the age structure of this forest. Our survey sites on the Clatsop were characterized by Sitka spruce/western hemlock forests with dominant trees ranging in age from 50-90+ years (Appendix 1). These sites were clearcut in the 1930's and left to naturally regenerate. However, some trees, including western hemlock and other defective trees, which had no market value, were left behind during these logging events. Because of the more open growing conditions (compared with plantations) and high site classification[1] on the north coast, the trees left behind are now larger in size (generally >80 cm in diameter) than would be expected under other growing conditions. Although most stands on the forest are homogeneous, the presence of these older and larger trees, along with dwarf mistletoe (*Arceuthobium tsugense* subsp. *tsugense*) infected western hemlock, created a heterogeneous nature in portions of our study sites and provided murrelets with large nesting platforms.

The Tillamook State Forest has had numerous fires over the last century, from the late 1800's through 1951. The most devastating fires occurred in the 1930's and 1940's; these human caused fires were catastrophic and burned more than 98,500 ha. In addition, some habitat was

[1] Fast growing trees on the deep, nutrient rich, well-drained soils.

lost during windthrow events. Because of these recent events, suitable murrelet habitat only occurred outside of the burn and windthrow areas. Our study sites in this forest were primarily comprised of Sitka spruce and western hemlock trees with dominants ranging in age from 45 to >200 years (Appendix 2). In some sites, Douglas-fir and red alder (*Alnus rubra*) were also present. Many of the sites were railroad logged, high graded or partially logged between 1900 and 1978. During these events, some trees (mostly western hemlocks) were left behind during logging operations. In addition, some remnant old-growth trees (>200 years in age) remained after fire and logging. The combination of fires, partial harvesting, natural regeneration, high site classification, and the presence of mistletoe in these sites created either heterogeneous stands or portions of stands with a variety of tree ages and limb structures for nesting. For example, Big and Bearly Rackheap were predominately homogeneous 90-120 year old stands, however they contained individual and scattered patches of older-aged remnants creating areas of heterogeneity.

The Elliott State Forest experienced many fires throughout the last two centuries, the most catastrophic occurring in 1770 and 1868. Most of our study sites were located in the eastern and southeastern portion of the forest where the two fires overlapped. Some of our sites were old-growth forests (>200 years in age) that were not burned in 1868, others were mature forests (115-200 years in age) with and without patches of older-aged remnants. These sites all naturally regenerated after fire, and management was limited to thinning and mortality salvage from the Columbus Day storm of 1962. Therefore, our study sites were characterized by both mixed-aged (a mix of tree ages) and even-aged (tree of similar ages), Douglas-fir and western hemlock stands with trees ranging in age from 115 to >230 years (Appendix 3). Most of the even-aged sites included individual and scattered patches of older-aged residual trees. Big-leaf maple (*Acer macrophyllum*) was common in the understory of many of these sites.

METHODS

Locating Nests

We used two general approaches to locate Marbled Murrelet nests: tree climbing and surveys.

Tree Climbing

During the course of this study, we implemented four climbing plot sampling methods: paired-plot, intensive, grid and cluster. The methods changed over the years to meet changing objectives of the Oregon Department of Forestry and in an attempt to locate more murrelet nest sites. After the first year, we decided we wanted to conduct the climbing in a more unbiased manner than the paired-plot design, so we implemented the grid climbing, which was used from 1996 to 1998. In 1998, we also introduced the cluster sampling method to take advantage of the niche-like availability of potential murrelet nest trees. The intensive climbing was conducted only in 1995 in one site as an experiment to look at murrelet nesting with respect to habitat edges.

We implemented the paired-plot sampling design in three sites on the Tillamook and 18 sites on the Elliott State Forest (Appendix 4). Under this method, two climbing plots were located in a single site. A site was defined as contiguous forest stand or an area delineated by ODF as a stand based on forest type and age. We located one 40-m radius climbing plot at a non-random, previously established vegetation sampling station thought to include some of the most suitable nest trees in the site; the second 40-m radius plot was located randomly. We determined the location of random plots in each site prior to entering the field by one of two methods: (1) placing a numbered grid over aerial photos of the study site (contiguous stand) and using a random number table to choose a grid point, or (2) randomly locating a plot on an aerial photo by randomly dropping a pencil on the aerial photo until a point was selected within the boundaries of the study site. Once a spot was marked on the aerial photo, we went to that location to establish our plot. If a plot was located within 80 m of an existing plot or if it did not contain at least one potential nest tree (a tree with at least one potential nest platform, defined as any limb or structure ≥ 10 cm in diameter and ≥ 10 m in height; Hamer and Nelson 1995) a new plot center was selected. This was accomplished by searching the immediate area and moving to the first tree found with a suitable nest platform. No maximum distance was set, but the furthest we moved from the original aerial photo locations was approximately 75 m.

For the intensive tree climbing technique, one site (Big Rackheap) was divided into two zones relative to the mature-managed forest interface (edge and interior), with the objective of looking at nest density and distribution in each zone (Appendix 4). Four edge and seven interior 40-m radius (0.5 ha) plots were established (Appendix 5N). Edge was defined as habitat within 125 m of the stand perimeter. The stand perimeter was defined by clearcut edges (including recent cuts or pole stands) or areas where gaps in the canopy exceed 50 m and were > 1.2 ha (3 ac) in size. Interior plots were located ≥150 m from the stand edge. The area between 125 m and 150 m provided a separation between the interior and exterior plots.

The grid sampling method was implemented in two sites on the Clatsop, six sites on the Tillamook, and five sites on the Elliott State Forest, which were randomly selected from a pool of known occupied sites (Appendix 4). This method was used for the purpose of randomly locating murrelet nests so inferences about murrelet nesting habitat could be made about the entire ODF ownership. We randomly selected sites from the pool of occupied sites in each study area. We overlaid a grid pattern (80 m by 80 m) on an aerial photo of each site, and randomly selected at least four grid numbers. Each grid number selected was visited on the ground to assess the abundance of platforms. If no platforms were available in the grid, then another grid number was selected using a random numbers table. This process was continued until four non-adjacent grids with at least one suitable murrelet platform were selected in each site. One 40-m radius plot was located in each grid for conducting tree climbing.

In 1996 on the Elliott State Forest, we used a slightly different method for conducting the grid climbing. In this case we used information available on the density of platforms per grid (from Hamer 1996) to stratify the grids in each site into 5 groups: 0, 1-3, 4-9, 10-19, and ≥20 platforms per grid. The lowest (not 0) and highest groups were selected for study (groups: "low", 1-3 platforms and "high", ≥20 platforms)[2]. A minimum of four non-adjacent plots were

[2] These groupings were not used in any data analyses because of small sample sizes.

selected in each platform abundance group (if available) in each site by randomly selecting grids from the available pool of grids in each platform abundance group. We attempted to avoid overlap of the 40-m radius plots (0.5 ha, 1.2 acres) placed in each grid, but this was not always possible. Two plots overlapped in the Silver Beaver site, where both plots shared one platform tree.

We used cluster plot sampling on all three forests, including one site on the Clatsop, three sites on the Tillamook, and two sites on the Elliott State Forest (Appendix 4). Suitable murrelet nesting habitat was not distributed evenly within the forest stand in our study area. Past disturbance, both natural and anthropogenic, and dwarf mistletoe distribution (on the north coast), has created a clumped distribution of suitable nesting structure, which often occurs in small niches. Therefore, we decided to use an adaptive cluster sampling technique (Thompson 1992) to establish the tree climbing plots during the last two years of the study. We hypothesized that the cluster sampling technique would yield more nests and allow us to determine the distribution or density of nests in nest-sites. We determined the locations for cluster sampling by randomly selecting a nest from the pool of known nests, and to minimize bias, choosing only between those nests that were found in randomly located plots in randomly selected sites between 1995 and 1998. Once the nests were selected, climbing was conducted in 40-m radius climbing plots in all grids, with at least one suitable platform, adjacent to the nest tree.

In all five years, conifer trees with potential platforms within each plot were accessed via ropes and ascenders (Perry 1978). Trees that were difficult to see from the ground were viewed from adjacent trees to see if they had potential platforms. If the trees had potential platforms they were climbed in most cases (93% of trees with potential limbs climbed). Some trees were not climbed because of limb placement (too high for setting a rope), inadequate limb structure, the presence of a bee or wasp nest, or logistics. In these cases the number of platforms, and moss and mistletoe abundance were determined by the climber from an adjacent tree, and all limbs were searched for nests using binoculars. Recently active nests were identified by the presence of fecal rings, eggshell fragments, and/or feathers. Old nests (which can remain evident for 10 years or more; SKN, unpublished data[3]) were identified by the presence of a nest cup and landing pad (for summary of this technique see Nelson 1995). All climbers were intensively trained in nest-search protocol. Extreme caution was exercised to minimize disturbance to the canopy community while climbing trees. Nests located during tree climbing were marked, mapped, and photographed. Small diameter, camouflaged cord was left in nest trees to facilitate future climbing.

Surveys

We used dawn surveys to locate active nests and to augment our tree climbing methods. We conducted these surveys from 22 June through 19 August 1995 (Elliott and Tillamook only), 1 July through 6 August 1996 (Elliott only), 12 May to 31 August 1997, 1 May to 31 August 1998, and 6 May to 23 August 1999 (Clatsop and Tillamook only). The surveys were conducted

[3] We have reclimbed some our nest trees in subsequent years and found the nest cup and landing pad still evident after 10 years.

adjacent to trees with known nest cups or in sites with nesting behavior (*e.g.*, birds landing in trees). In 1998, we also conducted protocol surveys (Ralph et al. 1994) at four new sites on the west side of the Elliott State Forest. The objective of these surveys was to: (1) determine or verify occupancy, and (2) add any occupied sites to the pool of potential climbing sites in 1999.

Monitoring Active Nests

We intensively monitored active nests located during dawn surveys or tree climbing. We observed activity and behavior patterns at these nests from the ground, from a platform in an adjacent tree (Elk Creek 1995, Low Simmons 1998) and with a camouflaged remote camera set up in the same tree as the active nest (Big Rackheap 1997). Video and still photos were taken when weather and conditions allowed.

We determined the fate of a nest through active monitoring and signs left at the nest site. We determined a nest to be successful if fledging was observed or the chick was of fledging age (4-5 weeks) and a fecal ring and down were present at the site. Unsuccessful nests were identified by finding a dead chick or un-faded eggshells in the nest cup or below the nest tree. Nests were assumed to have been depredated if either the predation event was observed, puncture marks or albumen were seen on eggs, or the remains (plucked feathers or body parts) of adults or chicks were found. To minimize the potential for predation or disturbance, observers did not remain at nests any longer than necessary (primarily 2 hrs at dawn and 90 minutes at dusk), kept noise to a minimum, wore dark clothing, and remained still or moved off the platform when predators were in the vicinity.

Determining Habitat Characteristics

In all five years, we measured the characteristics of active and inactive nests, nest trees, and random trees along with the characteristics of nest and non-nest sites. We collected the data for describing these habitat characteristics at three spatial scales: platform, tree and site.

We measured the tree and platform characteristics listed in Table 1. Our tree climbers collected information describing features of the nest and nest platform or random platform, while most of the nest or random tree characteristics were collected from the ground. To create a comparison between the platforms selected for nesting and those available in the climbing plot, we randomly selected three platform trees[4] from the pool of platform trees in each climbing plot, and measured detailed platform characteristics (similar to that measured at each nest) for one randomly-selected platform in each of these trees (1997-1999). In addition, from the ground, we measured the characteristics of five randomly-selected platforms (number was fewer if tree had <5 platforms) on each tree with potential platforms in each 25-m radius plot.

The nest site or micro-site characteristics, including the area in the immediate vicinity of the nest or within non-nest plots, were taken from the ground unless noted otherwise (Table 1). We determined these site structure and vegetation composition characteristics by measuring a variety of variables within a 25-m radius plot (0.2 ha) centered on the 40-m radius climbing plot.

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[4] Unless there were 3 or less platform trees or only one platform in a selected tree.

For nests located outside the climbing plot[5] or further than 10 m from the climbing plot center

[5] We located these nests by occasionally climbing trees just outside the climbing plot or where murrelet landing was seen during surveys. We did not include these nests in analyses at the site scale.

Table 1. Habitat variables measured at the platform, tree and site scales at nest and random sites.

Platform	Tree	Site
Limb height (m)	Species	Slope (%)
Limb length (m)	Diameter (dbh, cm)	Aspect (°)
Limb diameter at trunk and nest (cm)	Diameter at nest limb (cm)	Forest zone [a]
Limb aspect (°)	Height (m)	Plant associations [b]
Aspect at nest (°)	Substrate cover (%)	Position on slope [c]
Platform slope (°)	Moss cover (%)	Canopy closure (%) (upper, mid, and total)
Type of limb (e.g., primary)	Lichen cover (%)	Diameter of all trees and snags ($\geq$10 cm dbh)
Accessibility to platform (%cover)	Mistletoe (%)	Tree and snag species
Vertical and horizontal cover (%) [d]	Number of platforms	Snag decay class and height (m)
Distance from trunk (cm)		Number of canopy layers
Landing pad(s) distance from the nest (cm)		Canopy height (m)
Nest cup, platform, and landing pad(s) dimensions (cm)		Distance (m) to nearest water source
Substrate abundance (%)		Distance (m) to manmade edge
Type of substrate		Distance (m) to natural opening
Moss cover (%)		
Lichen cover (%)		
Substrate depth (cm)		
Moss depth (cm)		

[a] Franklin and Dyrness 1973.
[b] Hemstrom and Logan 1986.
[c] canyon bottom, lower 1\3, middle 1\3, upper 1\3, ridgetop.
[d] above limb and nest. Also measured distance (cm) to cover.

(*n* = 24 of 35 nests), the 25-m radius plot was centered instead on the nest tree. The distance to nearest water source (stream, lake, river, seep), manmade edge (clearcut [0-15 years, 16-30 years] and roads), and natural opening (river corridor or gap >10 m^2 in size) were estimated or measured with a meter tape (if in close proximity to the plot), or determined from topographic maps or aerial photographs. Closest distance to a road included only roads within forests (>30 years); those along clearcuts were considered part of the clearcut. We determined canopy height for five random dominant trees and five midstory trees (1997-1999) in each plot using a clinometer. Calculations made from these data included density of trees (#/ha; overall and by dbh class), snag density, mean tree diameter (dbh, cm), mean tree height (m), mean midstory tree height, and tree species composition.

Within both the 25-m and 40-m radius plots, we mapped the location of all trees with potential platforms and calculated mean platform tree diameter (cm) and species composition. The number of potential platforms on each tree with platforms was counted by both climbers in trees and observers on the ground to determine differences between these methods. The number of platforms per tree and platform density (#/ha) were then calculated. On each tree with a potential platform, tree climbers estimated the percent cover of epiphytes (moss and lichens) and determined the abundance of dwarf mistletoe (*Arceuthobium sp.*) using the Hawksworth Index (Hawksworth 1977).

We determined nest tree age by coring trees with an increment borer. For trees larger than 50 cm, the age was estimated by counting the number of rings in the last 2.5 cm, extrapolating to the center, and adding seven years. We determined distance inland (km), latitude, longitude, elevation (m) and stand size (ha) from topographic maps (1:250,000) and aerial photos (1:1,000).

Data Analyses

Univariate Statistics

We summarized all habitat variables (mean, SE, range) by plot type (nest and non-nest sites), area (Clatsop/Tillamook vs. Elliott), platform type (nest and random), nest status (active and old), and nest success (successful and failed). In cases where sample sizes were adequate, we separated data from the north coast (Clatsop and Tillamook forests) and the Elliott because of known differences in vegetation structure and characteristics between the regions. For other analyses, we pooled data from all the forests knowing that we could be biasing the results towards not finding differences that really occur. We conducted all statistical tests using SAS System Software (SAS Institute Inc., 1998). All tests were 2-tailed and considered significant at $\propto \leq 0.05$.

For paired comparisons, we divided the data into two groups (plot type, area, platform type, and nest status; sample sizes for nest success were too small for analysis) and tested for normality using the Shapiro-Wilk test (Proc UNIVARIATE). In general, the independent variables in one or both groups were not normally distributed even after transformation and removal of outliers. Therefore we used non-parametric statistics in most analyses. We summarized the characteristics of nest trees and compared them between the north coast and the

Elliott State Forest using a non-parametric Wilcoxon rank-sum statistic. We also compared the characteristics of active and old nests using a non-parametric Wilcoxon rank-sum statistic pooled across study sites. To look at habitat selection, we tested for differences in characteristics between nest and non-nest plots, and nest and random platforms using the Wilcoxon rank-sum statistic, pooled across study sites. In addition, we compared characteristics of nest trees to other platform trees in the nest plot and nest site (to look at selection) by pooling data across forests and using a Kruskal-Wallis non-parametric analysis of variance for an unbalanced design (Proc GLM on ranked data with a Student-Newman-Keuls test for comparison among means). The relationship between tree diameter, platform size, tree age, tree height, and number of platforms for each study area and pooled across study areas, was explored with Pearson correlation (Proc CORR) analyses. In addition, the relationship between tree density, platform density, percent moss and distance to stand edge (natural, clearcut and road) was assessed for each study area and pooled across study areas using Pearson correlation analyses.

Model Development

We used an information-theoretic approach to analyze our habitat data on murrelet nest and non-nest sites (approach summarized in Burnham and Anderson 1992, 1998). This approach provides a consistent way for dealing with model formation, model selection, estimation of model parameters, and their uncertainty. It involves developing a set of *a priori* hypotheses, expressing those hypotheses as models (in this case Logistic Regression models), ranking the models according to their ability to approximate the data using Akaike's Information Criterion

(AIC), and calculating parameter estimates weighted by model rank. This approach has recently been used for a variety of habitat related wildlife studies (e.g., Franklin et al. 2000, 2001).

Variable Selection – Fifty-five habitat variables were collected in the 25- and 40-m radius plots around nest and non-nest sites. Twenty-six of these variables either had missing information or were not available at all sites and could not be used for model building, therefore they were excluded from the multivariate analyses. Of the remaining 29 variables, we selected 15 variables for developing a set of *a priori* hypotheses for distinguishing between murrelet nest and non-nest sites at the platform, tree and site scales (see results). We selected these variables based on our understanding of murrelet ecology and results from other modeling or habitat selection efforts (Burger 1995a, Grenier and Nelson 1995, Hamer 1995, Kuletz et al. 1995, Miller and Ralph 1995, Meekins and Hamer 1999).

Hypotheses – Prior to data analysis, we developed a set of hypotheses to explore the potential relationship between the probability of murrelet nesting and each of the selected explanatory variables at the platform, tree and nest-site scales. We constructed 24 (10 platform, 7 tree, 7 site) models that we thought were the most likely factors or combinations of factors for distinguishing between nest and non-nest sites (see results). Logarithmic and quadratic forms of variables were used to express non-linear relationships.

Multivariate Statistics – We used logistic regression (Proc GENMOD)[6] to model the habitat variables that best distinguished Marbled Murrelet nest sites from non-nest sites at the

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[6] Logistic regression is a non-linear regression that allows analysis of binary and categorical variables, is extremely flexible (mathematically), and lends itself to biologically meaningful interpretation. Our data met the requirements for using this modeling technique.

platform, tree and site scales (SAS Institute 1995). This procedure is the best for describing the relationship between a binary response variable (nest=1; non-nest=0) and a set of continuous or categorical explanatory habitat variables. The logistic regression model [Logit(π)] describes the probability of a cell being a nest site as a function of a set of explanatory variables, where π is the maximum likelihood estimate of the probability that, in a specific cell, a murrelet nest was located during the sampling process. The assigned predicted probability for each nest site analyzed can then be used to predict the probability of any site, within the scope of the sample, being a nest site.

We used a Hosmer and Lemeshow (1989) goodness-of fit test (SAS Institute 1995) and deviance divided by the degrees of freedom to test for lack of fit of a global model (including all the variables considered for each scale), and examined correlations between variables using Pearson correlation (Proc CORR) coefficients. The adequacy of the models was determined by comparing a series of reduced models to the global model using the small-sample variant of Akaike's information criterion (AIC_c; Burnham and Anderson 1998: 51). AIC_c is an adjusted -2LogL score based on the number of explanatory variables in the model and the number of observations used with a built in correction term for small sample sizes. It is a goodness-of-fit measure for comparing one model to another, with lower values indicating a better model (SAS Institute, Inc. 1995). We considered the best models to be those with the lowest AICc. Models with AIC_c values <2 units from the best approximating model were considered competing models, and given equal importance, while those with AIC_c values >4 units were considered a marginal fit to the data (Burnham and Anderson 1998: 123).

The models were ranked according to the difference in the AIC_c values (ΔAIC_c) from the best approximating model. Akaike weights (*w*) were also used to compare models using Equation 4.2 from Burnham and Anderson (1988:124). These weights were then used to calculate weighted parameter estimates for the variables in the best model(s), using the sums of the products of the estimate and weight from each model that included a particular variable. Weighted parameter estimates incorporate information from all models containing a given variable and appear to have better precision and lower bias than estimates from a single model (Burnham and Anderson 1998). Finally, we computed unconditional standard errors that incorporated the uncertainty associated with both the estimation of a parameter and with model selection (Equation 4.7; Burnham and Anderson 1998: 134) and used these to construct 95% confidence intervals (estimate * 1.96[SE_{uncond}]) for the variables included in the best model(s).

RESULTS

Number of Nests Found and Nest Status

We located a total of 37 Marbled Murrelet tree nests, three on the Clatsop State Forest, 23 on the Tillamook State Forest and 11 on the Elliott State Forest, between 1994 and 1999 (Tables 2 and 3). Ten of the nests were active, and were located during surveys (n = 9) and tree climbing (n = 1). The remaining 27 nests were old, and were located after climbing or observing 1,890 trees and searching 31,778 potential nesting platforms. Twenty-three of these old nests were found while climbing in established plots and four were located while conducting other

Table 2. Marbled Murrelet nests located by tree climbing and surveys on the Clatsop, Tillamook and Elliott State Forests, 1994-1999.

Site	Year	Number of Nests	Status	Method Used
Clatsop State Forest				
Ebsen Road 70.0	1997	2	old	grid climbing plots
Ebsen Road 70.0	1998	1	old	cluster climbing plots
Tillamook State Forest				
Bearly Rackheap 101.0	1995	2	old	paired climbing plots
Bearly Rackheap 101.0	1998	1	active	forest surveys
Big Rackheap 100.0	1995	1	old	intensive climbing
Big Rackheap 100.0	1997	2	active	forest surveys
Big Rackheap 100.0	1998	1	active	forest surveys
Big Rackheap 100.0	1998	4	old	cluster climbing plots
Big Rackheap 100.0	1999	2	old	cluster climbing plots
Coal Creek 10.0	1995	1	old	climbing tree where birds observed landing
Low Simmons 105.0	1996	1	old	grid climbing plots
Low Simmons 105.0	1998	1	active	climbing tree where birds observed landing
North Rector 9.0	1994	2	active	forest surveys
North Rector 9.0	1995	2	old	climbing during training
North Rector 9.0	1997	1	old	climbing tree where birds observed landing
North Rector 9.0	1997	1	active	forest surveys

North Rector 9.0	1998	1	active	forest surveys

Table 2 cont. Marbled Murrelet nests located by tree climbing and surveys on the Clatsop, Tillamook and Elliott State Forests, 1994-1999.

Site	Year	Number of Nests	Status	Method Used
Elliott State Forest				
Elk Creek 5.1	1995	1	active	forest surveys
Joe Buck 20.1	1995	1	old	grid climbing plots
Knife Otter 173.0	1996	2	old	grid climbing plots
Knife Otter 173.0	1998	1	old	cluster climbing plots
Lower Fish 81.1	1995	1	old	paired climbing plots
Panther Elk 41.2	1995	1	old	paired climbing plots
Silver Beaver 6.1	1996	1	old	grid climbing plots
Silver Creek 22.2	1995	3	old	paired climbing plots

Table 3. Number of nests by forest, year, and discovery method, 1994-1999.

Totals	Number
Forest	
Clatsop	3
Tillamook	23
Elliott	11
Year	
1994	2
1995	13
1996	4
1997	6
1998	10
1999	2
Method	
Paired plots	7
Grid plots	7
Intensive	1
Cluster	8
Other climbing	5
Forest surveys	9

climbing (two during training and two while climbing trees where birds were observed landing).

Nest Density

We estimated the density of nests at the plot level for each of our study sites based on the area sampled in our climbing plots and the number of nests found. Nest density ranged from 0.1 to 3.0 nests per hectare (Table 4). Because of the clumped nature of habitat patches in our study areas, densities are probably much lower at the stand level.

Characteristics of Nests and Nest Trees

Our 37 nests were located in large ($\geq$ 49 cm dbh [92% $\geq$76 cm], > 33 m in height) western hemlock (n = 25), Douglas-fir (n = 9), Sitka spruce (n = 2) and western redcedar (*Thuja plicata*) (n = 1) trees (Table 5, Appendices 5-9). The location of one of the nests in a western redcedar tree was a first for Oregon. These nest trees were generally moss covered (all but three $\geq$50%), and some contained lichen and mistletoe. All nest trees had four or more potential nest platforms

Nests were on broad ($\geq$ 11.5 cm in diameter at nest), moss-covered (all but one $\geq$40%) primary (70%; two dead) or secondary (5%) limbs, limb forks (11%), or platforms created by mistletoe infections or deformations (14%; Table 6, Appendices 10-14). Nest limbs were located above 9 m in height and throughout the live crown. Nests were within 350 cm of the tree bole, generally in areas with high vertical and horizontal cover. On average nest cups were small ($\bar{x}$ =

Table 4. Study plot nest density, 1995-1999.

Site	# Plots climbed	Area sampled (ha)	# Nests found	Nest density (#/ha)
Clatsop State Forest				
Ebsen Road (70.0)	10	5.0	3	0.6
Lost Creek Headwaters (1.0)	4	2.0	0	0
Tillamook State Forest				
Bearly Rackheap (101.0)	3	1.5	2	2.0
Big Rackheap (100.0)	19	9.5	7	0.7
Coal Creek (10.0)	3	1.5	0	0
County Line (8.0)	5	2.5	0	0
Crystal Barn (108.0)	4	2.0	0	0
Helloff Creek (18.0)	4	2.0	0	0
Jacoby Patterson (103.0)	4	2.0	0	0
Low Simmons (105.0)	9	4.5	1	0.2
North Rector (9.0)	3	1.5	0	0
Stuart Creek (106.0)	4	2.0	0	0
Elliott State Forest				
Elk Creek (5.1)	2	1.0	0	0
Elk Pass (31.1)	2	1.0	0	0
Elk Pass (31.2)	2	1.0	0	0
Elk Pass (39.1)	2	1.0	0	0
Goody Ridge (231.0)	4	2.0	0	0
Joe Buck (16.2)	2	1.0	0	0

Table 4, cont. Study plot nest density, 1995-1999.

Site	# Plots climbed	Area sampled (ha)	# Nests found	Nest density (#/ha)
Elliott State Forest cont.				
Joe Buck (20.1)	2	1.0	0	0
Joe Buck (20.2)	2	1.0	0	0
Knife Bend (27.1)	2	1.0	0	0
Knife Otter (173.0)	17	8.5	3	0.4
Lower Fish (26.1)	2	1.0	0	0
Lower Fish (26.2)	2	1.0	0	0
Lower Fish (81.1)	2	1.0	1	1.0
Lower Fish (81.2)	2	1.0	0	0
No Name (70.1)	2	1.0	0	0
Panther Elk (41.2)	2	1.0	1	1.0
Salander Headwaters (282.0)	4	2.0	0	0
Schumacher Creek (29.1)	2	1.0	0	0
Silver Beaver (6.1)	16	8.0	1	0.1
Silver Creek (22.1)	2	1.0	3	3.0
South Panther (703.0)	4	2.0	0	0
South Umpcoos (15.3)	2	1.0	0	0

Table 5. Characteristics (mean, SE, range) [a] of Marbled Murrelet nest trees on the Clatsop, Tillamook and Elliott State Forests, 1994 - 1999.

Characteristic	Clatsop and Tillamook (n = 22 [b])	Elliott (n = 11)	Overall (n = 33 [b])	Z [c]	P
Tree species [d]	WH, WRC, SS	DF, WH	WH, DF, WRC,SS	-----	------
Diameter(dbh,cm)	**104.2 (6.9) (49-177)**	**139.9 (11.2) (94.0-212.5)**	116.1 (6.5) (49.0-212.5)	**2.7**	**0.0123**
Height (m)	**43.8 (1.2) (33.5-55.7)**	**64.3 (3.8) (46.2-85.1)**	50.6 (2.3) (33.5-85.1)	**4.0**	**0.0004**
# Platforms / tree	21.3 (3.1) (4-71)	35.0 (8.1) (8-92)	25.8 (3.5) (4-92)	1.2	0.2371
%Moss on tree	76.0 (4.7) (5-100)	67.7 (6.0) (30-100)	73.3 (3.7) (5-100)	-1.5	0.1441
%Lichens on tree	**10.2 (2.2) (0-35)**	**23.6 (4.5) (0-40)**	14.7 (2.4) (0-40)	**2.3**	**0.0285**
Mistletoe presence	yes (n = 17) no (n = 5)	yes (n = 0) no (n = 11)	yes (n = 17) no (n = 16)	-----	------

[a] bold type indicates significant differences ($P \leq 0.05$).
[b] the North Rector tree with 5 nests is only included once in these analyses.
[c] Wilcoxon rank-sum test; associated P value is the significance level for an approximate T-test.
[d] WH = western hemlock, WRC = western redcedar, SS = Sitka spruce, DF = Douglas-fir.

Table 6. Characteristics (mean, SE, range) [a] of Marbled Murrelet nest limbs on the Clatsop, Tillamook and Elliott State Forests, 1994 - 1999.

Characteristic	Clatsop and Tillamook (*n* = 26)	Elliott (*n* = 11)	Overall (*n* = 37)	Z [b]	P
Limb diameter at bole (cm)	16.7 (1.5) (6.8-36.6)	17.4 (1.1) (13.0-23.0)	16.9 (1.1) (6.8-36.6	1.2	0.2523
Limb diameter at nest (cm) [c]	20.0 (1.2) (11.5-36.0)	21.5 (1.7) (13.0-30.0)	20.4 (1.0) (11.5-36.0)	0.8	0.4208
Limb height (m)	**24.8 (1.5) (9.9-38.7)**	**36.5 (4.8) (17.0-74.8)**	28.3 (2.0) (9.9-74.8)	**2.4**	**0.0196**
Limb length (m)	4.3 (0.3) (0.6-8.0)	5.1 (0.4) (3.5-8.0)	4.6 (0.3) (0.6-8.0)	1.4	0.1789
Limb aspect (°)	30-349	40-280	30-349	------	------
Distance from trunk (cm)	92.9 (17.1) (0-350)	100.9 (21.4) (0-214)	95.3 (13.4) (0-350)	0.7	0.4694
% Horizontal cover	**61.0 (3.7) (18-85)**	**41.7 (4.7) (15-63)**	55.3 (3.3) (15-85)	**- 2.7**	**0.0094**
% Vertical cover	89.9 (3.0) (40-100)	74.0 (8.6) (25-100)	85.2 (3.5) (25-100)	1.3	0.1876
Distance to vertical cover above nest (cm)	41.5 (13.9) (0.1-270)	36.2 (8.1) (4.5-82)	39.9 (10.0) (0.1-270.0)	1.5	0.1521
Cup dimensions: Length (mm)	108.2 (3.8) (70-140)	103.9 (11.5) (70-180)	106.9(4.3) (70-180)	- 1.0	0.3390
Width	101.5 (3.2) (70-130)	97.3 (8.5) (65-150)	100.2 (3.3) (65-150)	- 0.9	0.3797
Depth	39.3 (4.0) (18-130)	41.5 (5.0) (20-80)	40.0 (3.2) (18-130)	0.9	0.3811
% Moss on platform	78.0 (5.0) (0-100)	83.9 (4.9) (50-100)	79.8 (3.8) (0-100)	0.2	0.8286
% Lichens on platform	**2.4 (0.9) (0-20)**	**7.2 (1.9) (0-20)**	3.8 (0.9) (0-20)	**2.6**	**0.0147**
Moss depth (mm) [d]	37.5 (4.7) (0-90)	54.9 (8.9) (20-110)	42.7 (4.4) (0-110)	1.2	0.2026

[a] bold type indicates significant differences ($P \leq 0.05$).
[b] Wilcoxon rank-sum test; associated P value is the significance level for an approximate T-test.
[c] proximal to nest.
[d] adjacent to nest.

106.9 x 100.2 x 40.0 mm) in size, circular or oval in shape. Moss measurements adjacent to the nests were over 9 mm in depth at all but two nests (Appendices 10-14). All nests, except four (Elk Creek, North Rector 9.6, Ebsen Road 70.1 and 70.3), had at least one landing pad within 2 m of the nest cup. In general, our correlation analyses showed no relationship between these tree and platform characteristics for all nests (Table 7), and for the north coast ($r<0.546$, $p>0.0127$) and Elliott State Forest ($r<0.555$, $p>0.0717$) separately. However, there was a significant relationship between tree diameter and tree height for all nests (Table 7) and for the Elliott State Forest ($r = 0.740$, $p = 0.0092$).

North Coast vs. Elliott Nests

Nests on the Clatsop and Tillamook State Forests were in mature western hemlock or Sitka spruce trees with large limbs or mistletoe deformations that provided platforms for nesting, with the exception of the old-growth western redcedar in Bearly Rackheap and the young western hemlock in Low Simmons. On the Clatsop State Forest, these nests were in trees that were older than the most abundant cohort (Appendix 1). On the Tillamook Forest, nests were located in

trees that ranged in age from approximately 66 to > 400 years; 57% (13 of 23) were in remnant trees or the oldest cohort in the site, while the others were the same age as the most abundant cohort (Appendix 2). On the Elliott State Forest, the nests were in old-growth Douglas-fir or western hemlock trees >200 years in age, with the exception of those in the Joe Buck and Knife Otter sites, which were in trees the same age as the most abundant cohort (Appendix 3).

The characteristics of the 37 nests were generally similar between the north coast

Table 7. Correlations[a] between nest tree and platform characteristics, Clatsop, Tillamook, and Elliott State Forests, 1994-1999.

	r and P Values				
Characteristic	Tree Diameter (dbh, cm)	Tree Height (m)	Tree Age	Platform Diameter (cm)	Number of Platforms
Tree diameter (dbh, cm)	1.000	**0.724 (0.0001)**	0.529 (0.0026)	0.035 (0.8538)	0.193 (0.2978)
Tree height (m)	**0.724 (0.0001)**	1.000	0.492 (0.0058)	-0.040 (0.8327)	0.163 (0.3800)
Tree age	0.529 (0.0026)	0.492 (0.0058)	1.000	0.034 (0.8595)	-0.120 (0.5389)
Platform diameter (cm)	0.035 (0.8538)	-0.040 (0.8327)	0.034 (0.8595)	1.000	-0.021 (0.9097)
Number of platforms	0.193 (0.2978)	0.163 (0.3800)	-0.120 (0.5389)	-0.021 (0.9097)	1.000

[a] Pearson correlation coefficients (r values < 0.60 not considered significant).

(Clatsop and Tillamook forests) and the Elliott State Forest. However, nests on the Elliott were in taller, larger diameter trees with more lichens on the tree and nest platform (Tables 5 and 6). Nests were also higher in trees on the Elliott compared to the north coast. On the north coast, nest trees had more horizontal cover on nest platforms compared to the Elliott, and mistletoe was common on nest trees on the north coast but absent on nest trees in the Elliott. No Douglas-fir nest trees were located on the north coast as our study sites were located in forests primarily composed of western hemlock.

Active vs. Old Nests

In a comparison of active (n = 10) and old (n = 27) nests, we found the characteristics to be extremely similar (Tables 8 and 9). Only tree diameter, limb diameter at the bole, limb height, and percent lichens varied between active and old nests. Old nests were in larger trees with larger limbs, more lichens and at higher heights than active nests. The ages of the old nests could not be precisely determined, however five of the nests were thought to have been used within the last two to three years based on recent observations of murrelets landing in trees, eggshell fragments found in the nest cup, or limited re-growth of moss in the nest cup.

Successful vs. Failed Nests

Of the 10 active nests we located, four were successful and six failed. Because of small sample sizes we were not able to conduct statistical analyses. Based on looking at the means and standard errors, it appears that successful nests may be in larger trees, higher in the tree, and in

Table 8. Characteristics (mean, SE, range) [a] of active and old Marbled Murrelet nest trees, 1994 - 1999.

Characteristic	Active Nests (*n*=9)[b]	Old Nests (*n*=24)[b]	Overall (*n* = 33)[b]	Z [c]	P
Tree species [d]	WH, SS	WH, DF, SS, RC	WH, DF, SS, RC	-----	-----
Diameter(dbh,cm)	**95.9 + 3.8 (79.4-115.9)**	**123.7 + 8.4 (49.0-212.5)**	**116.1 + 6.5 (49.0-212.5)**	**-2.0**	**0.0539**
Height (m)	44.4 + 1.5 (36.3-50.0)	52.9 + 2.9 (33.5-85.1)	50.6 + 2.3 (33.5-85.1)	-1.4	0.1610
# Platforms	17.4 + 3.3 (4-32)	29.0 + 4.6 (8-92)	25.9 + 3.5 (4-92)	-3.3	0.2114
% Moss on tree	74.4 + 9.8 (5-100)	72.8 + 3.7 (30-100)	73.3 + 3.7 (5-100)	0.8	0.4109
% Lichens on tree	8.4 + 3.9 (0-35)	17.0 + 2.8 (0-40)	14.7 + 2.4 (0-40)	-1.9	0.0641
Mistletoe presence	yes (*n* = 7) no (*n* = 2)	yes (*n* = 10) no (*n* = 14)	yes (*n* = 17) no (*n* = 16)	-----	-----

[a] bold type indicates significant differences ($P \leq 0.05$).
[b] Trees with more than one nest only counted once in analyses.
[c] Wilcoxon rank-sum test; associated P value is the significance level for an approximate T-test.
[d] WH = western hemlock, DF= Douglas-fir, SS = Sitka spruce, RC = western redcedar

Table 9. Characteristics (mean, SE, range) [a] of active and old Marbled Murrelet nest limbs, 1994 - 1999.

Characteristic	Active Nests (n = 10)	Old Nests (n = 27)	Overall (n = 37)	Z [b]	P
Limb diameter at bole (cm)	**12.9 ± 1.3 (6.8-20.0)**	**18.4 ± 1.3 (8.9-36.6)**	**16.9 ± 1.1 (6.8-36.6)**	**-2.3**	**0.0301**
Limb diameter at nest (cm) [c]	20.9 ± 1.4 (11.5-26.0)	20.2 ± 1.2 (13-36)	20.4 ± 1.0 (11.5-36.0)	0.9	0.3618
Limb height (m)	**21.9 ± 2.5 (9.9-33.3)**	**30.7 ± 2.4 (13.2-74.8)**	**28.3 ± 2.0 (9.9-74.8)**	**-2.2**	**0.0365**
Limb length (m)	4.3 ± 0.6 (0.6-8.0)	4.7 ± 0.3 (2-8)	4.6 ± 0.3 (0.6-8.0)	-0.6	0.5745
Distance from trunk (cm)	141.7 ± 33.1 (18-350)	78.1 ± 12.7 (0-214)	95.3 ± 13.4 (0-350)	1.8	0.0730
% Horizontal cover	56.4 ± 5.3 (21-83)	54.9 ± 4.1 (15-85)	55.3 ± 3.3 (15-85)	0.09	0.9323
% Vertical cover	94.7 ± 3.1 (70-100)	81.6 ± 4.5 (25-100)	85.2 ± 3.5 (25-100)	1.9	0.0693
Distance of vertical cover above nest (cm)	65.5 ± 30.8 (0.7-270.0)	30.5 ± 7.4 (0.1-175.0)	39.9 ± 10.0 (0.1-270.0)	0.0	1.0000
Cup dimensions (mm): Length	107.5 ± 5.2 (87-140)	106.7 ± 5.6 (70-180)	106.9 ± 4.3 (70-180)	0.2	0.8644
Width	102.3 ± 5.4 (70-130)	99.4 ± 4.1 (65-150)	100.2 ± 3.3 (65-150)	0.6	0.5839
Depth	37.1 ± 2.5 (25-50)	41.0 ± 4.2 (18-130)	40.0 ± 3.2 (18-130)	0.1	0.9183
% Moss on platform	67.8 ± 10.4 (0-100)	84.2 ± 3.3 (4-100)	79.8 ± 3.8 (0-100)	-1.3	0.2035
% Lichens on platform	**1.1 ± 0.5 (0-5)**	**4.9 ± 1.2 (0-20)**	**3.8 ± 0.9 (0-20)**	**-2.0**	**0.0530**
Moss depth (mm) [d]	29.8 ± 7.9 (0-76)	47.4 ± 5.0 (8.5-110.0)	42.7 ± 4.4 (0-110)	-1.7	0.0892

[a] bold type indicates significant differences ($P \leq 0.05$).
[b] Wilcoxon rank-sum test; associated P value is the significance level for an approximate T-test.
[c] proximal to nest.
[d] adjacent to nest.

trees with more lichens than failed nests (Tables 10 and 11). In addition, failed nests may have larger limb diameters (at the nest) and be further from the trunk than successful nests (Table 11). However, these results need verification using a larger sample of successful and failed nests.

Nest Platform and Tree Selection

In the results so far, we have presented the characteristics of murrelet nests and nest trees according to location, age (active *vs* old), and success. In this section, we look at murrelet preferences for nest platforms, platform trees, and tree species by comparing the characteristics of nests and nest trees used by murrelets to those available in nesting sites using both univariate and multivariate methods.

Univariate Analyses

Nest Platform Selection **–** To determine nest platform selection, we compared the characteristics of nest platforms used by murrelets to those selected at random within randomly selected platform trees in each climbing plot. Murrelets were nesting on platforms that were significantly higher in trees, and on larger diameter and longer limbs than platforms available within the nesting sites (Table 12). Small platforms (10-19.9 cm) were larger on nest trees, but large platforms ($\geq$20 cm) did not vary between nest and random platforms. In addition, nest limbs included more horizontal cover and had closer vertical cover than available platforms. Random platforms were closer to the bole and included deeper substrate at the "nest" than nest platforms. The significance of distance from the trunk in our comparison of nest and random platforms may have been biased somewhat by the climbers platform sampling method. Climbers

Table 10. Characteristics (mean, SE, range) of failed and successful Marbled Murrelet nest trees, 1994 - 1999.

Characteristic	Failed Nests (*n* = 6)	Successful Nests (*n* = 4)	Overall (*n* = 10)
Tree species [a]	WH, SS	WH	WH, SS
Diameter(dbh,cm)	91.6 (3.9) (79.4-108.0)	105.5 (4.5) (94-115)	97.1 (3.6) (79.4-115.9)
Height (m)	44.0 (2.3) (36.3-50.0)	45.9 (0.9) (43.4-47.7)	44.8 (1.4) (36.3-50.0)
# Platforms	16.8 (4.5) (4-29)	18.3 (5.5) (7-32)	17.4 (3.3) (4-32)
% Moss on tree	72.5 (14.8) (5-100)	83.8 (7.5) (65-100)	77.0 (9.1) (5-100)
% Lichens on tree	7.7 (5.5) (0-35)	8.5 (3.8) (4-20)	8.0 (3.5) (0-35)
Mistletoe presence	yes (*n* = 5) no (*n* = 1)	yes (*n* = 3) no (*n* = 1)	yes (*n* = 8) no (*n* = 2)

[a] WH = western hemlock, SS = Sitka spruce

Table 11. Characteristics (mean, SE, range) of failed and successful Marbled Murrelet nest limbs, 1994 - 1999.

Characteristic	Failed Nests (n = 6)	Successful Nests (n = 4)	Overall (n = 10)
Limb diameter at bole (cm)	12.5 (2.0) (6.8-20.0)	13.6 (1.5) (10.7-17.5)	12.9 (1.3) (6.8-20.0)
Limb diameter at nest (cm) [a]	23.1 (1.2) (19-26)	17.7 (2.2) (11.5-21.6)	20.9 (1.4) (11.5-26.0)
Limb height (m)	19.1 (3.5) (9.9-32.7)	26.0 (2.9) (21.0-33.3)	21.9 (2.5) (9.9-33.3)
Limb length (m)	4.4 (1.0) (0.6-8.0)	4.1 (0.6) (3.0-5.5)	4.3 (0.6) (0.6-8.0)
Distance from trunk (cm)	180.1 (47.9) (40-350)	84.0 (25.1) (18-125)	141.7 (33.1) (18-350)
% Horizontal cover	50.3 (7.2) (21-71)	65.5 (6.2) (55-83)	56.4 (5.3) (21-83)
% Vertical cover	96.5 (2.4) (85-100)	92.0 (7.3) (70-100)	94.7 (3.1) (70-100)
Distance of vertical cover above nest (cm)	72.9 (41.7) (0.7-270)	54.4 (51.9) (0.8-210.0)	65.5 (30.8) (0.7-270.0)
Cup dimensions (mm): Length	115.7 (6.6) (90-140)	95.3 (3.1) (87-100)	107.5 (5.2) (87-140)
Width	107.0 (8.5) (70-130)	95.3 (3.5) (85-100)	102.3 (5.4) (70-130)
Depth	38.7 (3.8) (25-50)	34.8 (2.7) (28-41)	37.1 (2.5) (25-50)
% Moss on platform	60.8 (16.1) (0-100)	78.3 (10.2) (50-98)	67.8 (10.4) (0-100)
% Lichens on platform	0.3 (0.2) (0-1)	2.3 (0.9) (1-5)	1.1 (0.5) (0-5)
Moss depth (mm) [b]	35.7 (11.5) (0-76)	21.0 (9.9) (0-44)	29.8 (7.9) (0-76)

[a] proximal to nest.
[b] adjacent to nest.

Table 12. Characteristics (mean, SE, range) [a] of nest (1994-1999) and random (1997-1999) platforms.

Characteristic	Nest Platforms (*n* = 37)	Random Platforms (*n* = 154)	Z [b]	P
Limb height (m)	**28.3 (2.0) (9.9-74.8)**	**23.2 (0.7) (10-50)**	**2.6**	**0.0091**
Limb length (m)	**4.6 (0.3) (0.6-8.0)**	**3.7 (0.2) (0.4-12.0)**	**2.9**	**0.0037**
Moss on limb (%)	79.8 (3.8) (0-100)	78.3 (2.0) (0-100)	- 0.01	0.9973
Platform diameter (cm)	**21.0 (1.0) (11.7-39.0)**	**17.2 (0.6) (10-56)**	**4.4**	**< 0.0001**
Diameter Small Platforms (10-19.9 cm)	**16.4 (0.5) (11.7-19.8)**	**14.4 (0.2) (10-19.7)**	**3.4**	**0.0009**
Diameter Large Platforms ($\geq$20 cm)	25.9 (1.0) (21.1-39.0)	27.2 (1.5) (20-56)	0.31	0.7594
Platform distance from bole (cm)	**98.0 (13.5) (0-350)**	**44.7 (4.1) (0-253)**	**4.2**	**< 0.0001**
Platform length (cm)	**79.0(14.5) (7.5-450.0)**	**48.3 (3.7) (5-320)**	**2.4**	**0.0189**
Platform width (cm)	**22.1 (1.3) (7-44)**	**16.0 (0.5) (4-40)**	**4.9**	**< 0.0001**
Platform slope (°)	11.9 (1.7) (0-42)	8.3 (0.7) (0-25)	1.5	0.1407
Moss on platform (%)	81.3 (4.3) (0-100)	83.9 (1.9) (1-100)	0.3	0.7527
Lichen on platform (%)	2.8 (0.8) (0-20)	1.9 (0.2) (0-20)	0.05	0.9604
Substrate depth on platform (cm)	**1.7 (0.2) (0.0-6.0)**	**4.6 (0.2) (0.0-21.5)**	**- 6.3**	**< 0.0001**
Vertical cover (%)	85.2 (3.5) (25-100)	88.2 (1.5) (0-100)	- 0.5	0.6388
Distance to vertical cover (cm)	**115.9 (22.0) (6-700)**	**161.3 (11.9) (1.2-850.0)**	**- 2.6**	**0.0100**
Horizontal cover (%)	**55.3 (3.3) (15.0-88.0)**	**37.7 (1.6) (0-100)**	**4.6**	**< 0.0001**

[a] bold type indicates significant differences ($P \leq 0.05$); [b] Wilcoxon rank-sum test; P value is the significance level for an approximate T-test.

often selected the area closest to the bole when selecting a potential nest site (usually the largest, best looking place for a nest). Changes in the sampling method and more sampling will be needed to determine if murrelets are truly selecting to nest further from the tree bole than available platforms.

To determine the type of platform preferred for nesting, we compared platform types used for nesting to those available in each study area (north coast vs. Elliott). We found that murrelets used primary limbs in proportion to their availability on the north coast, but preferred (used in greater proportion than available) to use forks and mistletoe or witches brooms for nesting (Figure 2). They did not use non-mistletoe deformities, secondary leaders, or other platforms in this area. On the Elliott State Forest, murrelets used primary platforms less than what was available in the forest, and preferred to nest on forks. They did not use other platform types, although some mistletoe, witches brooms and other platform types were available in this area.

Nest Tree Selection – To determine nest tree selection, we compared the characteristics of nest trees to other platform trees in the nest plot (plot trees) and nest site (platform trees in non-nest plots). We separated out the available trees in nest plots from non-nest plots because of the clumped nature of habitat patches, and to see if murrelets were selecting habitat at the tree or site scale. We found that nest trees were structurally unique compared with plot trees and other platform trees in the same site (Tables 13 and 14). Nest trees were larger in size, and had significantly more platforms, larger platforms, more moss, and more horizontal cover on platforms than plot and other platform trees. Vertical cover and percent mistletoe were similar at nest and plot trees, while percent moss on platforms, moss depth, and percent lichen were

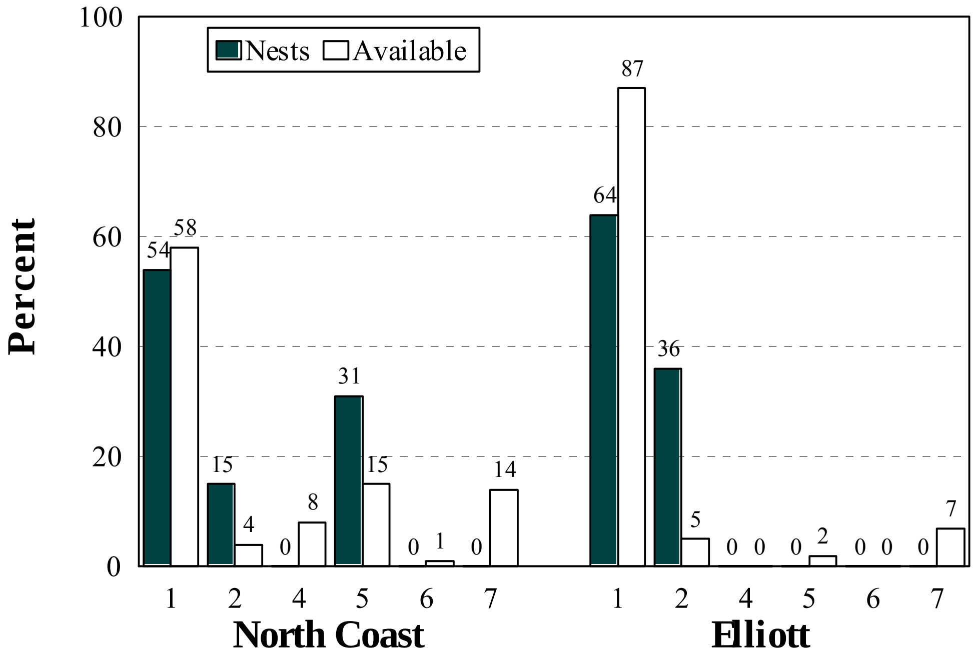

Figure 2. Marbled Murrelet preferences for platform types on the north coast and Elliott State Forests. The blue bars indicate the percent of each platform type used for nesting, while the green bars indicate the percent of each platform type available, in each study area. 1 = primary limb, 2 = fork, 3 = secondary limb (not used or available so left off figure), 4 = non-mistletoe deformity, 5 = mistletoe or witches broom, 6 = secondary leader, and 7 = other.

Table 13. Characteristics (mean, SE, range) [a] of platform trees: nest trees compared with other trees in the nest plot and other site plots, 1995 - 1999.

Characteristic	Nest Trees (n = 23) [b]	Platform Trees in Nest Plot (n = 446) [c]	Platform Trees in Other Site Plots (n = 833) [c]	F [d]	P
Diameter (dbh, cm)	**120.2 ± 8.6 (49.0 - 212.5) A**	**83.4 ± 1.6 (29.8 - 246.0) B**	**94.2 ± 1.1 (23.8 - 217.5) C**	**25.6**	**< 0.0001**
# Total platforms (climber count)	**29.6 ± 4.7 (6 - 92) A**	**14.7 ± 0.7 (0 - 103) B**	**17.4 ± 0.5 (0 - 120) C**	**10.5**	**< 0.0001**
# Small (10-15 cm) [e] platforms (climber count)	16.3 ± 3.9 (0 - 49)	10.2 ± 0.4 (0 - 67)	10.2 ± 0.4 (0 - 66)	1.1	0.3444
# Large (≥15 cm) [f] platforms (climber count)	**21.1 ± 5.0 (0 - 60) A**	**4.6 ± 0.5 (0 - 64) B**	**6.3 ± 0.4 (0 - 84) B**	**11.6**	**< 0.0001**
# Total platforms (ground count)	**22.0 ± 3.2 (7 - 58) A**	**11.3 ± 0.5 (1 - 72) B**	**12.3 ± 0.4 (0 - 59) B**	**9.6**	**< 0.0001**
% Moss on tree	**74.1 ± 4.2 (20 - 100) A**	**62.0 ± 1.4 (0 - 100) B**	**62.1 ± 1.0 (0 - 100) B**	**3.2**	**0.0524**
Substrate Depth (cm) [g]	**5.3 ± 0.8 (2.1 - 11.0) A**	**3.0 ± 0.1 (0 - 11.5) B**	**3.6 ± 0.1 (0 - 11.7) A**	**11.9**	**< 0.0001**
% Lichen on tree	**17.2 ± 4.2 (0 - 65) A**	**8.5 ± 0.5 (0 - 65) B**	**11.4 ± 0.5 (0 - 90) A**	**6.5**	**0.0015**
% Mistletoe on tree	**49.5 ± 11.4 (0 - 100) AB**	**52.6 ± 2.2 (0 - 100) A**	**34.4 ± 1.4 (0 - 100) B**	**28.8**	**< 0.0001**

[a] bold type indicates significant differences among groups (P ≤ 0.05).
[b] only nests located by climbing are included.
[c] n represents the number of trees climbed in 40-m radius plots in each category.
[d] df = 2; 1299.
[e] data from 1995 was not included as platforms were not divided into categories; in 1998 and 1999 small platforms were defined as 10-19 cm.
[f] data from 1995 was not included, as above; in 1998 and 1999 large platforms were defined as ≥20 cm.
[g] includes primarily moss.

Table 14. Characteristics (mean, SE, range) [a] of platforms: nest trees compared with other trees in the nest plot and other site plots, 1994 - 1999.

Characteristic	Nest Trees (n = 164) [b]	Platform Trees in Nest Plot (n = 1563) [b]	Platform Trees in Other Site Plot (n = 1859) [b]	F [c]	P
Platform diameter (≥10 cm)	**16.8 ± 0.5 (10 - 50) A**	**14.8 ± 0.1 (10 - 60) B**	**14.3 ± 0.1 (10 - 65) C**	**27.3**	**< 0.0001**
Diameter small platforms (10-19.9 cm)	**14.2 + 0.2 (10-19) A**	**13.0 + 0.07 (10-19) B**	**12.7 + 0.6 (10-19) C**	**22.0[d]**	**<0.0001**
Diameter large platforms (≥20 cm)	24.8 + 1.0 (20-50)	25.7 + 0.5 (20-60)	25.4 + 0.4 (20-65)	0.5[e]	0.6396
Platform height (m)	19.5 ± 0.7 (10 - 42)	18.1 ± 0.2 (10 - 42)	18.7 ± 0.2 (10 - 48)	2.2 [f]	0.1128
Height lowest platform (m)	15.4 ± 0.6 (10 - 25)	14.2 ± 0.1 (9.5 - 33.0)	14.5 ± 0.2 (7 - 45)	2.4	0.0917
% Moss on platforms	**83.1 ± 1.9 (0 - 100) A**	**78.3 ± 0.6 (0 - 100) B**	**79.0 ± 0.6 (0 - 100) A**	**12.7 [g]**	**< 0.0001**
Moss depth on platforms (index)	**2.7 ± 0.1 (0 - 4) A**	**2.5 ± 0.02 (0 - 4) B**	**2.6 ± 0.02 (0 - 4) A**	**6.5 [h]**	**0.0016**
Horizontal cover (index)	**1.8 ± 0.1 (0 - 3) A**	**1.5 ± 0.02 (0 - 3) B**	**1.5 ± 0.01 (0 - 3) B**	**10.5**	**< 0.0001**
Vertical cover (index)	**2.1 ± 0.1 (0 - 3) A**	**2.0 ± 0.02 (0 - 3) A**	**1.7 ± 0.02 (0 - 3) B**	**52.0 [i]**	**< 0.0001**

[a] bold type indicates significant differences among groups ($P \leq 0.05$).
[b] data are from $n \leq 5$ randomly selected platforms per tree depending on number available on each tree (does not necessarily include the nest platform). Joe Buck 20.1 plot1, Big Rackheap 100.0 plots E2, E2S, E2SE, 2W and 2SW, Panther Elk 41.2 plot 1, Knife Otter 173.0 plots 8, 9 and 8SW, Silver Beaver 6.1 plot 59, Silver Creek 22.1 plot 2, and Ebsen Road 70.0 plots 43 and 53E, are not included because of overlap with nest plots.
[c] df = 2; 3583. [d] df = 2; 3092. [e] df = 2; 494. [f] df = 2; 2672. [g] df = 2; 3541. [h] df = 2; 3426.
[i] df = 2; 3578.

different between nest and plot trees. However, plot trees were more similar to nest trees than to other platform trees in the nest site. Tree diameter, platform diameter, number of platforms, vertical cover, and percent mistletoe were different between plot and other platform trees.

In a comparison of the characteristics of platform trees in nest plots, we found that the Elliott had larger and higher platforms, with more and deeper moss compared to those on the north coast (Table 15). In addition, mistletoe was more abundant on platform trees on the north coast than on the Elliott[7].

Tree Species Characteristics and Selection – The characteristics of available platform trees varied by species. Sitka spruce trees had significantly more platforms (both small and large) than other conifer tree species (Table 16). Western redcedar trees had the largest platforms and Sitka spruce the smallest. Douglas-fir trees had more large platforms than western hemlock trees. Horizontal cover was greatest on Douglas-fir and western redcedar trees, and vertical cover lowest on Sitka spruce trees. Percent moss on platforms was greatest on Sitka spruce trees and lowest on western hemlock trees. Moss depth did not vary among species.

To look at tree species selection, we compared the percent of tree species used to the available trees with platforms in each study area (north coast vs. Elliott). On the north coast, murrelets preferred to nest in western hemlock trees and used this species in greater proportion than available in this area (Figure 3). However, they used western redcedar and Sitka spruce in proportion to their availability and did not use Douglas-fir or other tree species (bigleaf maple,

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[7] mistletoe occurred in low abundance on platform trees in some plots on the Elliott, but did not occur on any nest trees or in nest plots.

Table 15. Characteristics (mean, SE, range) [a] of platform trees and platforms in nest plots on the north coast (Clatsop/ Tillamook) and Elliott State Forests, 1994 - 1999.

Characteristic	Clatsop and Tillamook Plots (n = 22) [b]	Elliott Plots (n = 10) [c]	Z [d]	P
Moss on tree (%)	76.6 (5.3) [e] (52.1-98.8)	85.9 (4.2) [f] (81.7-90.0)	0.1	0.8872
Lichens on tree (%)	7.7 (0.9) [e] (4.5-10.4)	10.9 (0.9) [f] (10.0-11.7)	1.6	0.1460
Mistletoe on tree (%)	26.5 (11.4) [e] (2.2-61.9)	0 [f]		
Mean platform diameter (cm)	**14.9 (0.3) (12.3-17.5)**	**17.0 (1.0) (12.6-24.6)**	**2.1**	**0.0443**
Mean platform height (m)	**16.5 (0.8) [g] (12.8-20.4)**	**22.8 (1.4) [h] (19.2-25.8)**	**2.8**	**0.0135**
Height of the lowest platform (m)	13.7 (0.14) [i] (10.3-16.4)	17.9 (2.3) [j] (13.6-21.4)	1.6	0.1257
Moss on platforms (%)	**77.2 (3.5) (55.8-100.0)**	**88.3 (3.3) (73.7-100.0)**	**2.0**	**0.0575**
Moss depth (cm; index)	**2.3 (0.1) (1.2-3.1)**	**2.9 (0.2) (2.0-3.5)**	**2.5**	**0.0168**
Horizontal cover (index)	1.7 (0.1) (0.8-2.5)	1.8 (0.1) (1.3-2.5)	0.8	0.4560
Vertical cover (index)	2.1 (0.1) (1.0-2.8)	2.2 (0.2) (1.3-2.9)	0.3	0.7311

[a] bold type indicates significant differences between groups ($P \leq 0.05$).
[b] n = 22 because 5 nests are in the same tree and plot.
[c] n = 10 because 2 nests are in the same plot.
[d] Wilcoxon rank-sum test; associated P value is the significance level for an approximate T-test.
[e] n = 7; [f] n = 2
[g] n = 4; [h] n = 13
[i] n = 11; [j] n = 3

Table 16. Characteristics (mean, SE, range) [a] of available platform trees by species [b].

Characteristic	Western Hemlock (*n* = 3122)	Douglas-fir (*n* = 1546)	Western Redcedar (*n* = 55)	Sitka Spruce (*n* = 550)	F [c]	P
Number of platforms (10-19.9 cm)	**11.6 ± 0.2 (1-52) B**	**12.0 ± 0.3 (1-75) B**	**10.7 ± 1.1 (3-29) B**	**14.5 ± 0.6 (1-103) A**	**7.36**	**<0.0001**
Number of platforms (≥ 20 cm)	**13.0 ± 0.5 (1-52) C**	**17.9 ± 0.9 (2-75) B**	**13.0 ± 2.2 (1-29) BC**	**30.5 ± 3.8 (1-103) A**	**16.72**	**<0.0001**
Platform size (cm)	**14.5 + 0.09 (10-65) B**	**14.5 + 0.1 (10-60) B**	**17.2 + 1.0 (10-50) A**	**13.7 + 0.2 (10-35) C**	**6.92**	**0.0001**
Horizontal cover (index)	**1.5 ± 0.02 (0-3) B**	**1.7 ± 0.02 (0-3) A**	**1.7 ± 0.1 (0-3) A**	**1.4 ± 0.03 (0-3) C**	**26.69**	**< 0.0001**
Vertical cover (index)	**1.9 ± 0.01 (0-3) A**	**1.9 ± 0.02 (0-3) A**	**2.1 ± 0.1 (1-3) A**	**1.7 ±0.04 (0-3) B**	**8.81**	**< 0.0001**
Moss on platforms (%)	**77.6 ± 0.4 (0-100) C**	**79.1 ± 0.8 (0-100) B**	**78.4 ± 3.8 (0-100) BC**	**89.9 ± 0.8 (0-100) A**	**91.57**	**<0.0001**
Moss depth (cm)	2.5 ± 0.02 (0-4)	2.5 ± 0.03 (0-4)	2.6 ± 0.1 (0-4)	2.6 ± 0.03 (1-4)	0.73	0.5333

[a] Bold indicates significant differences among groups ($P \leq 0.05$).
[b] Data taken from ground counts of random platforms.
[c] Wilcoxon rank-sum test; associated P value is the significance level for an approximate T-test.

red alder). On the Elliott, murrelets preferred to nest in Douglas-fir and used this species in greater proportion than available in this area (Figure 3). They used western hemlock less than available and did not use western redcedar, Sitka spruce or other tree species.

Multivariate Model Selection

We developed a set of hypotheses to explore the potential relationship between the probability of murrelet nesting and each of the 10 selected explanatory variables at the platform and tree scales (Table 17). Logarithmic and quadratic forms of variables were used to express non-linear relationships. We constructed 17 (10 platform, 7 tree) models that we thought were the most likely factors or combinations of factors contributing to the probability of murrelet nesting (Tables 18-19).

At the platform scale, all models included platform width, reflecting the assumption that wide platforms are necessary for nesting as murrelets do not construct an actual nest (Table 18). Models 2-4 included an additional variable (substrate, vertical cover or substrate depth) that we thought was potentially important for assuring murrelet selection of a nest platform. Models 5-8 included platform width and substrate in addition to one or two variables (substrate depth, vertical cover and platform diameter), under the assumption that multiple characteristics are required at the platform scale in order for a platform to be selected as a nest site. In adding platform diameter we assumed that both the size of the limb and platform were important in platform selection. Model 9 was the global model using the simplest structure of all the variables, and Model 10 reflected the null hypothesis that no variables distinguished murrelet

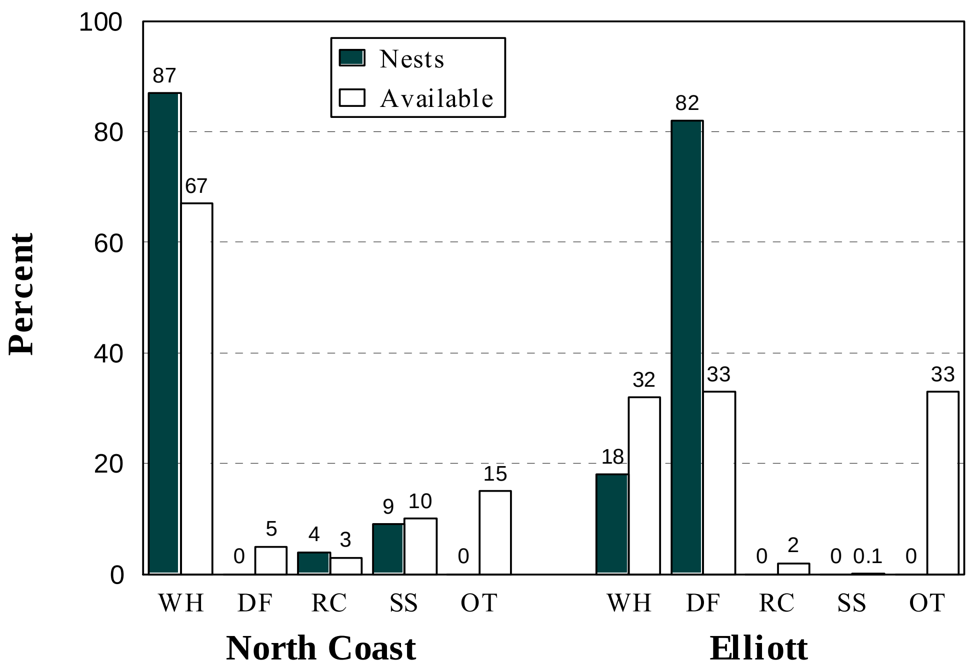

Figure 3. Marbled Murrelet preferences for nest tree species on the north coast and Elliott State Forests. The blue bars indicate the percent of each species used for nesting, while the green bars indicate the percent of each platform tree species available, in each study area. WH = western hemlock, DF = Douglas-fir, RC = western redcedar, SS = Sitka spruce, OT = bigleaf maple and red alder.

Table 17. Descriptions of explanatory variables used in models to estimate the probability of murrelet nesting in western Oregon.

Variable	Abbreviation	Units	Transformation [a]
Platform Scale			
Platform width	PW	cm	ln(PW)
Platform diameter	PD	cm	ln(PD)
Vertical cover	VC	%	ln(VC)
Substrate	S	%	ln(S)
Substrate depth	SD	cm	ln(SD)
Tree Scale			
Tree species	SP		SP
Platforms	PL	#	ln(PL)
Platforms * Tree species	PLSP		ln(PL)*SP
Substrate	SB	%	ln(SB)
Mistletoe	MS	%	ln(MS)
Site Scale			
Density of trees	DT	#/ha	$DT + DT^2$
Density of platforms	DP	#/ha	ln(DP)
Canopy layers	CL	#	CL
Distance to closest edge	DE	m	ln(DE)
Slope	SL	%	SL

[a] ln = logarithmic; $x + x^2$ = quadratic.

Table 18. Description of *a priori* models concerning the effects of platform characteristics on the probability of murrelet nesting in western Oregon.

	Hypotheses	Model Structure	Expected Results [a]
	Platform Scale		
1	Positive effect of platform width	$\beta_0 + \beta_1(PW)$	$\beta_1 > 0$
2	Positive effects of platform width and substrate	$\beta_0 + \beta_1(PW) + \beta_2(S)$	$\beta_1 > 0, \beta_2 > 0$
3	Positive effects of platform width and vertical cover	$\beta_0 + \beta_1(PW) + \beta_2(VC)$	$\beta_1 > 0, \beta_2 > 0$
4	Positive effects of platform width and substrate depth	$\beta_0 + \beta_1(PW) + \beta_2(SD)$	$\beta_1 > 0, \beta_2 > 0$
5	Positive effects of platform width, substrate, and substrate depth	$\beta_0 + \beta_1(PW) + \beta_2(S) + \beta_3(SD)$	$\beta_1 >0, \beta_2 > 0, \beta_3 > 0$
6	Positive effects of platform width, substrate, and vertical cover	$\beta_0 + \beta_1(PW) + \beta_2(S) + \beta_3(VC)$	$\beta_1 > 0, \beta_2 > 0, \beta_3> 0$
7	Positive effects of platform width, substrate, substrate depth, and vertical cover	$\beta_0 + \beta_1(PW) + \beta_2(S) + \beta_3(SD) + \beta_4(VC)$	$\beta_1 > 0, \beta_2 > 0, \beta_3 > 0, \beta_4 > 0$
8	Positive effects of platform width, substrate, and platform diameter	$\beta_0 + \beta_1(PW) + \beta_2(S) + \beta_3(PD)$	$\beta_1 > 0, \beta_2 > 0, \beta_3 > 0$
9	Positive effects of platform width, substrate, substrate depth, vertical cover, and platform diameter	$\beta_0 + \beta_1(PW) + \beta_2(S) + \beta_3(SD) + \beta_4(VC) + \beta_5(PD)$	$\beta_1 > 0, \beta_2 > 0, \beta_3 > 0, \beta_4 > 0, \beta_5 > 0$
10	No effects (null model)	β_0	

[a] Expected direction of the regression coefficients, given that the model is correct to use.

Table 19. Description of *a priori* models concerning the effects of tree characteristics on the probability of murrelet nesting in western Oregon.

	Hypotheses	Model Structure	Expected Results [a]
	Tree Scale		
1	Positive effect of number of platforms	$\beta_0 + \beta_1(PL)$	$\beta_1 > 0$
2	Positive effects of number of platforms and substrate	$\beta_0 + \beta_1(PL) + \beta_2(SB)$	$\beta_1 > 0, \beta_2 > 0$
3	Positive effects of number of platforms and mistletoe	$\beta_0 + \beta_1(PL) + \beta_2(MS)$	$\beta_1 > 0, \beta_2 > 0$
4	Positive effects of number of platforms, substrate, and mistletoe	$\beta_0 + \beta_1(PL) + \beta_2(SB) + \beta_3(MS)$	$\beta_1 > 0, \beta_2 > 0, \beta_3 > 0$
5	Positive effects of number of platforms, tree species, and the interaction of tree species and number of platforms	$\beta_0 + \beta_1(PL) + \beta_2(SP) + \beta_3(PLSP)$	$\beta_1 >0, \beta_2 > 0, \beta_3 > 0$
6	Positive effects of number of platforms, substrate, mistletoe, tree species, and the interaction of tree species and number of platforms	$\beta_0 + \beta_1(PL) + \beta_2(SB) + \beta_3(MS) + \beta_4(SP) + \beta_5(PLSP)$	$\beta_1 > 0, \beta_2 > 0, \beta_3 > 0, \beta_4 > 0, \beta_5 > 0$
7	No effects (null model)	β_0	

[a] Expected direction of the regression coefficients, given that the model is correct to use.

nests from non-nests.

At the tree scale, number of platforms was present in all the models reflecting the assumption that (multiple) platforms are required in each tree to provide suitable sites for nesting (Table 19). Models 2-3 included an additional variable (substrate, mistletoe) that we thought was potentially important for assuring murrelet selection of a nest tree. Models 4-5 included number of platforms and two or more variables (substrate, mistletoe, tree species, interaction of tree species and number of platforms), under the assumption that multiple characteristics are required at the tree scale in order for a tree to be selected for a nest site. Model 5 was used to test the effect of tree species and the associated number of platforms (or forest type) on selection. Model 6 was the global model using the simplest structure of all the variables, and Model 7 reflected the null hypothesis that the probability of murrelet nesting is not related to any variables.

At the platform scale, the model with platform width, percent substrate and substrate depth (Model 5) was ranked first with an AIC_c of 100.142 and an Akaike *w* of 46% (Table 20). Models 4 (without substrate) and 7 (with vertical cover) had a ΔAIC_c value ≤ 2 and were considered competing models. These three models captured 94% of the Akaike *w*, suggesting that, given the data, these models have a 94% chance of being the best models. The shapes of the relationships in these models were consistent with the *a priori* hypotheses (Table 18), except for substrate depth, which had a negative rather than positive relationship with the probability of murrelet nesting. The probability of murrelet nesting was most closely associated with platform width and substrate depth; the odds of a platform being selected as a nest site increased 230.9

Table 20. Ranking of the *a priori* models to estimate the probability of murrelet nesting at the platform and tree scales.

Model Parameters (model#; from tables 18-20)	K[a]	AIC_c[b]	Δ AIC_c[c]	AIC_c weight[d]	Sum of AIC_c weights
Platform Scale					
Platform width, substrate, substrate depth (5)	4	100.142	0.000	0.459	0.459
Platform width, substrate depth (4)	3	100.910	0.768	0.313	0.772
Platform width, substrate, substrate depth, vertical cover (7)	5	102.161	2.019	0.167	0.939
Platform width, substrate, substrate depth, vertical cover, platform diameter (9)	6	104.174	4.032	0.061	1.000
Platform width (1)	2	167.193	67.051	0.000	1.000
Platform width, substrate (2)	3	168.679	68.537	0.000	1.000
Platform width, substrate, platform diameter (8)	4	168.818	68.676	0.000	1.000
Platform width, vertical cover (3)	3	169.257	69.115	0.000	1.000
Platform width, substrate, vertical cover (6)	4	170.759	70.617	0.000	1.000
Null model (10)	1	189.800	89.658	0.000	1.000
Tree Scale					
#Platforms, substrate, dwarf mistletoe (4)	4	236.528	0.000	0.612	0.612
#Platforms, substrate (2)	3	237.629	1.102	0.353	0.965
#Platforms, substrate, dwarf mistletoe, tree species, #platforms x tree species (6)	8	244.176	7.649	0.013	0.978
#Platforms (1)	2	244.559	8.031	0.011	0.989
#Platforms, dwarf mistletoe (3)	3	244.579	8.051	0.011	1.000
#Platforms, tree species, #platforms x tree species (5)	6	251.292	14.764	0.000	1.000
Null model (7)	1	258.087	21.560	0.000	1.000

[a] K = number of estimable parameters + intercept.
[b] AIC_c is the small sample variant of Akaike's Information Criterion.
[c] ΔAIC_c indicates differences in AIC_c values between each model and the top-ranked model. Lower ΔAIC_c values indiciate more competitive models and better model fit to the data.
[d] Weights sum to 1 and are suggested by Burnham and Anderson (1998: p129) to represent the probability that the model is the actual Kullback-Leibler best model.

times for each increase in platform width of 1 ln(cm) and decreased 16.1 times for every increase in substrate depth of 1 ln(cm; Table 21). Percent substrate on the platform and percent vertical cover above the platform explained less of the variation in the probability of murrelet nesting, however the odds of a site being selected as a nest site will increase by a factor of 1.7 and 1.1, respectively, for each added percent in ln(%substrate) and ln(%vertical cover).

At the tree scale, the model with number of platforms, percent substrate and percent dwarf mistletoe (Model 4) had the lowest AIC_c value (236.5) and captured 61% of the Akaike *w* (Table 20). Model 2 (without dwarf mistletoe) had a ΔAIC_c value < 2 and was considered a competing model. These two models together had a 97% chance of being the best models, given the data.

The shapes of the relationships were consistent with the *a priori* hypotheses (Table 19). Substrate was most closely associated with the probability of murrelet nesting; the odds of a tree being selected for a nest site increased 27.8 times for each increase in percent substrate of 1 ln(%; Table 21). The parameter estimates further suggested that the odds of a tree being selected as a nest site will increase by a factor of 2.0 for each added (platform) and 1.2 for each added ln(%dwarf mistletoe).

Nest-Site Characteristics

In the results so far, we have described the characteristics of murrelet nests and nest trees, and evaluated preferences with respect to platforms, platform trees and tree species. In this section, we describe the characteristics of nest sites or the vegetation characteristics in the area

Table 21. Weighted parameter estimates, unconditional standard errors, and odds ratios for

variables in the best approximating models (top two to three) at the platform and tree scales to estimate the probability of murrelet nesting in western Oregon.

Variable	Form[a]	Estimate[b]	SE[c]	Odds ratio (95% CI)[d]
Platform Scale				
Platform width	ln	5.442	1.052	230.904 (29.371-1815.144)
Substrate	ln	0.516	0.309	1.675 (1.094-3.070)
Substrate depth	ln	-2.777	0.488	16.071 (6.175-41.824)
Vertical cover	ln	0.113	0.380	1.120 (0.532-2.358)
Tree Scale				
#Platforms	ln	0.715	0.280	2.044 (1.181-3.539)
Substrate	ln	3.326	1.492	27.827 (1.494-518.179)
Dwarf mistletoe	ln	0.147	0.086	1.158 (0.979-1.371)

[a] ln = logarithmic transformation.
[b] Model-averaged parameter estimates.
[c] Unconditional standard errors of the parameter estimates.
[d] Odds ratio calculated as e^{β}; 95% confidence interval calculated as $e\{\beta_1 \pm 1.96(SE[\beta_1]\}$ (Hosmer and Lemeshow 1989: 40-44).

surrounding our nest trees. Murrelet preferences for nest-site structure are presented in the nest-site selection section (see below).

Our nests were located in areas in the forest with large (>24.3 cm dbh), tall (>35.6 m) trees and numerous platforms (>12 per plot; Table 22). At least two platform trees occurred in each nest plot, with platform and platform tree densities ranging from 56 to 808/ha and 10 to 195/ha, respectively. Nests were located in areas with >38% canopy cover and generally in areas with at least two canopy layers. There was no relationship between tree density (all trees and platform trees) or platform abundance with respect to distance to stand edge (road, clearcut or natural opening; $r < 0.50$, $p > 0.0037$ and $r = .67$, $p = 0.1463$, respectively), however percent moss on trees moss increased with increasing distances from 0-15 year old clearcuts ($r = 0.78$, $p = 0.0126$).

North Coast vs. Elliott Sites

In a comparison of nest plot vegetation characteristics on the north coast and the Elliott, we found that the Elliott nest plots had taller trees (canopy and midstory) and larger diameter platform trees than the north coast sites (Table 22). In contrast, nest plots on the north coast had a higher density of trees 46.0-80.9 cm than on the Elliott. In terms of tree species composition, the Elliott had a significantly higher proportion of Douglas-fir platform trees, while the north coast nest plots had a higher (but not significant) proportion of western hemlock platform trees. In addition, the Elliott did not have any Sitka spruce or western redcedar platform trees.

Table 22. Characteristics (mean, SE, range) [a] of north coast (Clatsop/Tillamook) and Elliott nest plots, 1994-1999.

Characteristic	Clatsop and Tillamook Plots (*n* = 22) [b]	Elliott Plots (*n* = 10) [c]	Z [d]	P
Trees/ha	230.5 (18.0) (120-445)	239.0 (37.5) (140-475)	- 0.2	0.8086
Trees 46-80.9 cm/ha	**61.6 (6.5) (5-120)**	**32.5 (5.4) (5-60)**	**- 2.6**	**0.0145**
Trees $\geq$ 81 cm/ha	37.3 (2.4) (15-60)	40.0 (7.9) (15-100)	- 0.5	0.6240
Mean tree diameter (cm)	49.5 (2.6) (24.3-66.5)	50.4 (6.5) (26.1-94.0)	- 0.1	0.9197
Mean platform tree diameter (cm)	**92.4 (5.1) (60.3-140.6)**	**130.3 (7.7) (104.9-181.2)**	**3.3**	**0.0026**
Mean tree height (m)	**43.8 (0.8) (35.6-49.9)**	**62.0 (2.2) (52.6-76.2)**	**4.5**	**0.0001**
Mean midstory tree height (m)	**28.2 (1.5) [e] (16.1-38.3)**	**37.3 (3.5) [f] (27.0-56.3)**	**2.3**	**0.0323**
# Trees with platforms	12.6 (2.2) (2-39)	7.4 (1.5) (2-19)	- 1.3	0.1949
Platform trees/ha	63.2 (10.8) (10-195)	37.0 (7.4) (10-95)	-1.3	0.1949
# Platforms	125.5 (18.7) (12-348)	84.9 (13.3) (23-162)	- 1.0	0.3367
# Platforms/ha (climber)	439.0 (168.5) [g] (56-808)	184.0 (0.0) [h] (184)	- 0.7	0.5126
Mean # platforms/tree (climber count)	18.4 (4.7) [g] (9.3-31.1)	15.8 (2.7) [h] (13.1-18.4)	- 0.2	0.8261
Mean # of platforms/tree (ground count)	12.3 (1.1) [i] (6.0-16.8)	9.3 (1.1) [h] (8.2-10.4)	- 1.0	0.3336

Table 22 cont. Characteristics (mean, SE, range) [a] of north coast (Clatsop/Tillamook) and Elliott nest plots, 1994-1999.

Characteristic	Clatsop and Tillamook Plots (*n* = 22) [b]	Elliott Plots (*n* = 10) [c]	Z [d]	P
Douglas-fir with platforms (%)	**1.4 (1.4) [i] (0-10)**	**83.4 (16.7) [h] (67-100)**	**2.3**	**0.0536**
Western hemlock with platforms (%)	86.7 (5.7) [i] (66.7-100)	16.7 (16.7) [h] (0-33)	- 1.9	0.0890
Canopy cover (%)	68.6 (3.1) (44.5-95.0)	66.2 (5.5) (38.8-95.3)	- 0.5	0.5868
# Canopy layers	2.3 (0.1) (1-3)	2.7 (0.2) (2-3)	1.6	0.1251
Slope (%)	38.6 (3.7) (10.5-82.5)	38.6 (6.2) (10.0-69.6)	- 0.2	0.8559
Distance to stream (m)	125.6 (40.8) (8-650)	46.1 (11.9) (6-110)	- 1.1	0.2718
Distance to nearest 0-15 year old clearcut (m)	326.2 (66.1) (36-1322)	329.6 (84.4) (25-793)	0.04	0.9678
Distance to nearest 16-30 year old clearcut (m)	248.9 (54.1) (30-847)	167.6 (67.2) (28-751)	-1.0	0.3365
Distance to nearest road (m)	169.4 (25.4) (6.5-396.0)	140.6 (32.6) (31-335)	-0.5	0.6290
Distance to nearest natural opening (m)	103.8 (42.0) (2-650)	31.6 (10.9) (5-110)	- 0.6	0.5729

[a] bold type indicates significant differences between groups ($p \leq 0.05$).
[b] *n* = 22 because 5 nests are in the same tree (thus the same plot).
[c] *n* = 10 because 2 nests are in the same plot.
[d] Wilcoxon rank-sum test; associated P value is the significance level for an approximate T-test.
[e] *n* = 17; [f] *n* = 8; [g] *n* = 4; [h] *n* = 2; [i] *n* = 7.

Active vs. Old Nests

In a comparison of characteristics of plots surrounding active (n = 9) and old (n = 23) nests, we found no differences except with respect to distance to edges. Old nests were significantly closer to natural openings than active nests ($\bar{x}$ = 53.0 vs. 153.4 m, Z = 2.2, P = 0.0321), but active nests were closer to roads than old nests ($\bar{x}$ = 75.1 vs. 193.7, Z = -3.1, P =0.0045). We consider the latter to be an artifact of how we located active nests; most (90%, n = 9 of 10) of our active nests were found using dawn surveys, which were generally conducted from large openings such as roads and clearcut edges, rather than tree climbing.

Successful vs. Failed Sites

A small sample size of active nests prevented an analysis of the differences between successful and failed nest sites. Based on looking at the means and standard errors, it appears that successful nests may be located in areas with taller trees (50.4 $\pm$ 4.7 m vs. 43.0 $\pm$ 1.6 m), lower snag density (7.5 $\pm$ 3.2/ha vs. 35.0 $\pm$ 12.0/ha), and less canopy cover (52.6 $\pm$ 7.5% vs. 68.5 $\pm$ 5.7%) than failed nests. However, these results are speculative without information from additional active nests.

Nest-Site Selection

In the previous sections, we have described the characteristics of murrelet nests, nest trees, and nest sites, and evaluated preferences with respect to platforms, platform trees and tree species. In this section, we describe murrelet preferences for nest-site structure by comparing nest and non-nest plots.

Univariate Analysis

In a comparison of nest and non-nest plot characteristics, we found that nest plots had more platform trees, platforms, western hemlock trees with platforms, and canopy layers than non-nest plots (Table 23). Non-nest plots had more Douglas-fir trees with platforms and were located on steeper slopes than nest plots.

North Coast vs. Elliott Sites – We further divided the data to look at the characteristics of nest and non-nest plots on each forest (north coast vs. Elliott; Table 24). The number of trees with platforms, density of platform trees, and number of platforms differed between nest and non-nest plots on both forests. The relationships were the same for each forest, with nest plots having more platforms, more trees with platforms, and a higher density of platform trees than non-nest plots. In addition, on the Elliott, trees were taller, the slope was less steep, and more canopy layers occurred at nest versus non-nest plots.

Multivariate Model Selection

We developed a set of hypotheses to explore the potential relationship between the probability of murrelet nesting and each of the 5 selected explanatory variables at the site scale (Table 17). Logarithmic and quadratic forms of variables were used to express non-linear relationships. We constructed 7 site models that we thought were the most likely factors or combinations of factors contributing to the probability of murrelet nesting (Table 25). The

Table 23. Characteristics (mean, SE, range) [a] of nest and non-nest plots, 1994-1999.

Habitat Variable	Nest Plots (*n* = 32) [b]	Non-nest Plots (*n* = 130)	Z	P [c]
Trees/ha	233.1 (16.7) (120-475)	228.3 (9.4) (50-695)	0.4	0.6882
Trees 46-80.9 cm dbh/ha	52.5 (5.3) (5-120)	58.3 (3.3) (0-190)	- 0.4	0.6848
Trees ≥ 81 cm dbh/ha	38.1 (2.9) (15-100)	33.5 (1.7) (2-100)	1.3	0.1797
Mean tree diameter (cm)	49.7 (2.6) (24.3-94)	50.2 (1.1) (25.3-83.4)	- 0.1	0.8947
Mean platform tree diameter (cm)	104.3 (5.3) (60.3-181.2)	110.8 (2.8) (60.7-313.0)	- 1.0	0.3102
Mean tree height (m)	49.5 (1.7) (35.6-76.2)	49.1 (0.9) (29.5-71.8)	0.02	0.9866
Mean midstory tree height (m)	31.1 (1.7) [d] (16.1-56.3)	28.2 (1.2) [e] (13.2-63.6)	1.2	0.2211
# Trees with platforms	**11.0 (1.6) (2-39)**	**5.3 (0.5) (0-37)**	**4.4**	**<0.0001**
Platform trees/ha	**55.0 (8.0) (10-195)**	**27.1 (2.5) (2-185)**	**4.3**	**<0.0001**
# Platforms	**112.8 (13.8) (12-348)**	**61.7 (6.0) (0-394)**	**4.1**	**<0.0001**
# Platforms/ha (climber)	354.0 (119.4) [f] (56-808)	382.0 (31.0) (10-1856)	0.05	0.9620
Mean # platforms/tree (climber count)	17.5 (3.1) [f] (9.3-31.1)	18.4 (0.9) (1.7-60.3)	0.01	0.9958
Mean # platforms/tree (ground count)	11.6 (1.1) [g] (6.0-16.8)	12.2 (0.5) (1.7-29.3)	- 0.08	0.9358

Table 23 cont. Characteristics (mean, SE, range) [a] of nest and non-nest plots, 1994-1999.

Habitat Variable	Nest Plots (n = 32) [b]	Non-nest Plots (n = 130)	Z [c]	P
Douglas-fir with platforms (%)	**19.6 (12.4) [g] (0-100)**	**52.0 (4.0) (0-100)**	**- 2.1**	**0.0402**
Western hemlock with platforms (%)	**71.2 (11.5) [g] (0-100)**	**35.9 (3.3) (0-100)**	**2.5**	**0.0122**
Canopy cover (%)	67.9 (2.7) (38.8-95.3)	66.0 (1.5) (11.8-100.0)	0.5	0.6025
# Canopy layers	**2.4 (0.1) (1-3)**	**2.2 (0.05) (1-3)**	**2.5**	**0.0137**
Slope (%)	**38.6 (3.1) (10.0-82.5)**	**48.7 (2.0) (2.8-89.8)**	**- 2.4**	**0.0171**
Distance to stream (m)	100.8 (28.9) (6-650)	100.5 (12.2) (0-850)	- 0.5	0.6231
Distance to nearest 0-15 year old clearcut (m)	327.3 (51.8) (25-1322)	361.0 (19.4) (32-915)	- 1.3	0.1984
Distance to nearest 16-30 year old clearcut (m)	223.5 (42.6) (28-847)	266.9 (24.9) (0-1315)	- 1.3	0.1991
Distance to nearest road (m)	160.4 (20.1) (6.5-396)	168.4 (13.5) (0-758)	0.3	0.7385
Distance to nearest natural opening (m)	81.2 (29.5) (2-650)	88.1 (12.0) (0-850)	- 1.5	0.1416

[a] bold type indicates significant differences between groups ($p \leq 0.05$).
[b] n = 32 because 5 nests are in one plot and 2 nests in another.
[c] Wilcoxon rank-sum test; associated P value is the significance level for an approximate T-test.
[d] n = 25.
[e] n = 58.
[f] n = 6.
[g] n = 9.

Table 24. Characteristics (mean, SE, range) [a] of nest and non-nest plots on the north coast (Clatsop/Tillamook) and Elliott State Forests, 1994-1999.

Habitat Variable	Clatsop/Tillamook		Elliott		Z [c]	P
	Nest (n = 22) [b]	Non-nest (n = 60) [b]	Nest (n = 10)	Non-nest (n = 70)	North Elliott	North Elliott
Trees/ha	230.5 (18.0) (120-445)	266.0 (16.3) (80-695)	239.0 (37.5) (140-475)	197.0 (8.9) (50-425)	-1.0 0.8	0.3305 0.4428
Trees 46-80.9 cm dbh/ha	61.6 (6.5) (5-120)	76.7 (5.2) (10-190)	32.5 (5.4) (5-60)	42.5 (3.2) (0-120)	-1.3 -0.9	0.2101 0.3529
Trees ≥ 81 cm dbh/ha	37.3 (2.4) (15-60)	32.9 (2.5) (2-75)	40.0 (7.9) (15-100)	34.0 (2.2) (4-100)	1.1 0.5	0.2618 0.6050
Mean tree diameter (cm)	49.5 (2.6) (24.3-66.5)	50.4 (1.8) (26.7-75.3)	50.4 (6.5) (26.1-94.0)	50.0 (1.4) (25.3-83.4)	-0.3 -0.02	0.8023 0.9826
Mean platform tree diameter (cm)	92.4 (5.1) (60.3-140.6)	95.5 (2.8) (60.7-168.2)	130.3 (7.7) (104.9-181.2)	124.0 (4.1) (78-313)	-0.8 0.9	0.4409 0.3814
Mean tree height (m)	43.8 (0.8) (35.6-49.9)	41.6 (0.7) (29.5-53.0)	**62.0 (2.2)** **(52.6-76.2)**	**55.6 (1.0)** **(30.1-71.8)**	1.8 **2.2**	0.0739 **0.0299**
# Trees with platforms	**12.6 (2.2)** **(2-39)**	**6.9 (0.9)** **(0-37)**	**7.4 (1.5)** **(2-19)**	**4.0 (0.4)** **(0-18)**	**2.8** **3.1**	**0.0062** **0.0028**
Platform trees/ha	**63.2 (10.8)** **(10-195)**	**35.1 (4.7)** **(2-185)**	**37.0 (7.4)** **(10-95)**	**20.3 (2.0)** **(4-90)**	**2.7** **3.1**	**0.0082** **0.0029**
# Platforms	**125.5 (18.7)** **(12-348)**	**80.4 (10.2)** **(0-394)**	**84.9 (13.3)** **(23-162)**	**45.7 (6.4)** **(0-322)**	**2.3** **3.1**	**0.0199** **0.0024**
# Platforms/ha (climber)	439.0 (168.5) (56-808)	446.4 (52.9) (10-1856)	184.0 (0.0) (184)	326.8 (34.5) (16-1268)	0.2 -0.5	0.8792 0.6208
Mean # platforms/tree (climber count)	18.4 (4.7) (9.3-31.1)	17.1 (1.1) (1.7-38.1)	15.8 (2.7) (13.1-18.4)	19.5 (1.3) (3.8-60.3)	0.3 -0.2	0.7930 0.8644
Mean # of platforms/tree (ground count)	12.3 (1.3) (6.0-16.8)	12.5 (0.7) (1.7-27.0)	9.3 (1.1) (8.2-10.4)	11.9 (0.7) (2.4-29.3)	-0.04 -0.5	0.9674 0.6208

Table 24 cont. Characteristics (mean, SE, range) [a] of nest and non-nest plots on the north coast (Clatsop/Tillamook) and Elliott State Forests, 1994-1999.

Habitat Variable	Clatsop/Tillamook		Elliott		Z [c]	P
	Nest (n = 22) [b]	Non-nest (n = 60) [b]	Nest (n = 10)	Non-nest (n = 70)	North Elliott	North Elliott
Douglas-fir with platforms (%)	1.4 (1.4) (0-10)	8.6 (2.5) (0-93.3)	83.4 (16.7) (66.7-100)	89.3 (2.5) (0-100)	-0.9 -0.6	0.3891 0.5471
Western hemlock with platforms (%)	86.7 (5.7) (66.7-100.0)	65.5 (3.9) (0-100)	16.7 (16.7) (0-33)	10.7 (2.5) (0-100)	1.8 0.6	0.0753 0.5471
Canopy cover (%)	68.7 (3.1) (44.5-95.0)	71.0 (2.1) (11.8-100.0)	66.2 (5.5) (38.8-95.3)	61.8 (2.0) (20.0-92.5)	-0.5 0.7	0.5840 0.4735
# Canopy layers	2.3 (0.1) (1-3)	2.2 (0.08) (1-3)	**2.7 (0.2) (2-3)**	**2.1 (0.05) (1-3)**	0.6 **3.6**	0.5217 **0.0006**
Slope (%)	38.6 (3.7) (10.5-82.5)	41.3 (2.8) (8.2-89.0)	**38.6 (6.2) (10.0-69.6)**	**55.1 (2.6) (2.8-89.8)**	-0.4 **-2.3**	0.7112 **0.0242**
Distance to stream (m)	125.6 (40.8) (8-650)	129.4 (22.7) (2-850)	46.1 (11.9) (6-110)	75.8 (11.0) (0-500)	-0.3 -0.8	0.7821 0.4175
Distance to 0-15 year old clearcut (m)	326.2 (66.1) (36-1322)	308.1 (26.9) (40-915)	329.6 (84.4) (25-793)	406.4 (26.8) (32-783)	-0.4 -1.2	0.7190 0.2480
Distance to 16-30 year old clearcut (m)	248.9 (54.1) (30-847)	389.7 (47.2) (20-1315)	167.6 (67.2) (28-751)	161.7 (13.4) (0-513)	-1.7 -0.9	0.0843 0.3472
Distance to road (m)	169.4 (25.4) (6.5-396)	217.6 (24.0) (14-758)	140.6 (32.6) (31-335)	126.3 (12.3) (12.3)	-0.5 0.5	0.6315 0.5918
Distance to natural opening (m)	103.8 (42.0) (2-650)	116.4 (23.1) (0-850)	31.6 (10.9) (5-110)	63.9 (9.5) (0-350)	-1.1 -1.1	0.2658 0.2566

[a] bold type indicates significant differences between groups ($p \leq 0.05$).
[b] n = 32 because 5 nests are in one plot and 2 nests in another.
[c] Wilcoxon rank-sum test; associated P value is the significance level for an approximate T-test.

Table 25. Description of *a priori* models concerning the effects of nest-site characteristics on the probability of murrelet nesting in western Oregon.

	Hypotheses	Model Structure	Expected Results [a]
	Site Scale		
1	Positive effect of density of platforms	$\beta_0 + \beta_1(DP)$	$\beta_1 > 0$
2	Positive effects of density of platforms and canopy layers	$\beta_0 + \beta_1(DP) + \beta_2(CL)$	$\beta_1 > 0, \beta_2 > 0$
3	Positive effects of density of platforms and distance to closest edge	$\beta_0 + \beta_1(DP) + \beta_2(DE)$	$\beta_1 > 0, \beta_2 > 0$
4	Positive effect of density of platforms; negative effect of high and low tree densities	$\beta_0 + \beta_1(DP) + \beta_2(DT) + \beta_3(DT^2)$	$\beta_1 > 0, \beta_2 > 0, \beta_3 < 0$
5	Positive effects of density of platforms, canopy layers, distance to closest edge, and slope	$\beta_0 + \beta_1(DP) + \beta_2(CL) + \beta_3(DE) + \beta_4(SL)$	$\beta_1 >0, \beta_2 > 0, \beta_3 > 0, \beta_4 > 0$
6	Positive effects of density of platforms, canopy layers, distance to closest edge, and slope; negative effect of high and low tree densities	$\beta_0 + \beta_1(DP) + \beta_2(CL) + \beta_3(DE) + \beta_4(SL) + \beta_5(DT) + \beta_6(DT^2)$	$\beta_1 >0, \beta_2 > 0, \beta_3 > 0, \beta_4 > 0, \beta_5 > 0, \beta_6 < 0$
7	No effects (null model)	β_0	

[a] Expected direction of the regression coefficients, given that the model is correct to use.

density of platforms was included in each model under the assumption that platforms (and in some cases groups of platforms trees) are required for murrelet selection of a nest site. Models 2-4 included an additional variable (canopy layers, distance to closest edge, tree densities) that we thought was potentially important for assuring murrelet selection of a nest site. Canopy layers and tree density represented both cover for the nest tree (protection from predation) and a measure of access to nest sites, with medium levels of tree density and high canopy cover assumed to be preferred. Distance to closest edge included the closest distance to either natural(streams, gaps) or man-made edges, and was intended as a measure of access to nest sites. Because access is important for murrelets when flying into and out of their nest tree and nesting area, Model 5 was created as an overall measure of access to nest sites. Model 6 was the global model using the simplest structure of all the variables, and Model 7 reflected the null hypothesis that no variables distinguished murrelet nests from non-nests.

At the site scale, the model with platforms/ha (Model 1) was ranked first with an AIC_c of 53.3 and an Akaike *w* of 48% (Table 26). Models 2 (with canopy layers) and 3 (with distance to closest edge) had a ΔAIC_c value ≤ 2 and were considered competing models. These three models captured 90% of the Akaike *w*, suggesting that, given the data, these models have a 90% chance of being the best models. The shapes of the relationships in these models were consistent with the *a priori* hypotheses (Table 25), except for canopy layers, which had a negative rather than positive relationship with the probability of murrelet nesting (Table 27). The probability of murrelet nesting was most closely associated with canopy layers; the odds of a site being selected as a nest site decreased 2.0 times for each increase in the number of canopy layers

(Table 27).

Table 26. Ranking of the *a priori* models to estimate the probability of murrelet nesting at the nest-site scale.

Model Parameters (model#; from tables 18-20)	K[a]	AIC_c[b]	ΔAIC_c[c]	AIC_c weight[d]	Sum of AIC_c weights
Site Scale					
Platforms/ha (1)	2	53.265	0.000	0.483	0.483
Platforms/ha, canopy layers (2)	3	54.667	1.401	0.240	0.723
Platforms/ha, distance to closest edge (3)	4	55.321	2.056	0.173	0.896
Platforms/ha, density of trees (4)	4	57.427	4.162	0.060	0.956
Platforms/ha, canopy layers, distance to closest edge, slope (5)	5	58.681	5.416	0.032	0.988
Platforms/ha, canopy layers, distance to closest edge, slope, density of trees (6)	6	60.767	7.502	0.011	0.999
Null model (7)	1	163.040	109.775	0.000	0.999

[a] K = number of estimable parameters + intercept.
[b] AIC_c is the small sample variant of Akaike's Information Criterion.
[c] ΔAIC_c indicates differences in AIC_c values between each model and the top-ranked model. Lower ΔAIC_c values indiciate more competitive models and better model fit to the data.
[d] Weights sum to 1 and are suggested by Burnham and Anderson (1998: p129) to represent the probability that the model is the actual Kullback-Leibler best model.

Table 27. Weighted parameter estimates, unconditional standard errors, and odds ratios for variables in the best approximating models (top three) at the nest-site scale to estimate the probability of murrelet nesting in western Oregon.

Variable	Form	Estimate[a]	SE[b]	Odds ratio (95% CI)[c]
Site Scale				
Density of platforms	ln	0.060	0.418	1.062 (0.468-2.409)
Canopy layers		-0.690	0.834	1.994 (0.389-10.223)
Distance to closest edge	ln	0.064	0.338	1.066 (0.550-1.940)

[a] Model-averaged parameter estimates.
[b] Unconditional standard errors of the parameter estimates.
[c] Odds ratio calculated as e^{β}; 95% confidence interval calculated as $e\{\beta_1 \pm 1.96(SE[\beta_1]\}$ (Hosmer and Lemeshow 1989: 40-44).

The parameter estimates further suggested that the odds of a site being selected as a nest site will increase by a factor of 1.1 for each added ln(density of platforms) and 1.1 for each added meter in ln(distance to closest edge).

Tree Climbing and Platform Counting Methods

In this section we evaluate the success of our different climbing methods and methods of counting platforms.

Comparison of Climbing Methods

The most successful climbing methods were the paired-plot design and the cluster sampling method, with 8 nests being found using each method (Table 28). The success per plot, however, was greatest in the cluster sampling method (0.25 nests found per plot climbed). The paired-plot design was biased by the fact that ODF personnel selected the location for one of the plots based on the presence of suitable nesting habitat or murrelet below-canopy activity. Many of the nests found during the paired-plot design were located in the biased plots (these biased plots were not used in most of the analyses). The success of the cluster sampling method was based on locating climbing plots adjacent to known nest trees. Given that habitat in our study area generally occurred in patches or niches, climbing within these niches would be expected to improve our success rate. In areas where nests are not known, the grid method will be the most unbiased way to search for nests and will likely be quite successful in locating nests, especially with larger sample sizes of plots in each study site. Sample sizes were not large enough to assess the success of the intensive tree climbing method.

Table 28. Number of plots and nests found by sampling method, year and forest,1995-1999.

Year	Forest	Number of Plots				Nests Found
		Paired	Intensive	Grid	Cluster	
1995	Tillamook	6	11	0	0	3 [a]
	Elliott	36	0	0	0	6
1996	Tillamook	0	0	8	0	1
	Elliott	0	0	19	0	3
1997	Clatsop	0	0	8	0	2
	Tillamook	0	0	9	0	0 [b]
	Elliott	0	0	9	0	0
1998	Clatsop	0	0	0	6	1
	Tillamook	0	0	8	4	4 [c]
	Elliott	0	0	3	12	1 [c]
1999	Tillamook	0	0	0	10	2
Total # of plots		42	11	64	32	---
Total # of nests found		8	1	6	8	23
# of nests/plot		0.19	0.09	0.09	0.25	---

[a] two found using paired sampling and one found using intensive plot sampling. Two additional nests were located in trees just outside plots where birds were observed landing.
[b] two old nests were found in the same tree during climber training.
[c] nests found using cluster sampling.

Climber vs. Ground Counts of Platforms

The number of platforms counted by climbers and ground crews was correlated (r = 0.72653, P < 0.0001, *n* = 1294). However, observers on the ground counted an average of only 73.2% (29.5-157.1%, SE = 1.9) of the platforms counted by tree climbers. Most ground counts of platforms were underestimates because visibility was often limited to the lower one-half to two-thirds of the live crown. Ground counts were lower than climber counts on large trees with many platforms, but greater than climber counts on trees with few platforms. Classification of trees as potential nest trees (containing platforms) by the ground crews was accurate in most cases (97%; 1,806 of 1,861 trees). In the cases of misidentification, platforms identified from the ground were either less then 10 cm in diameter, sloping at >45 degrees or to round (*n* = 36 trees). There were also trees (*n*=19) in which the ground crew saw no platforms but climbers counted from 1 to 19.

Murrelet Nesting Behavior

This section details the behaviors observed at each of the ten active nests, listed by forest and site.

Tillamook State Forest

North Rector – In 1994, the behavior at two nests were monitored from 28 June until 19 July. Surveys were conducted from stations on the road (approximately 15 and 30 m from the nest trees). The two nest trees were separated by about 30 m and were active at the same time, although the chicks were not at the same stage of development.

The first nest found (9.1) was monitored from 28 June - 6 July (Table 29). Six morning and six evening surveys were conducted over a period of eight days. Dawn feeding visits occurred between 0508 and 0909 hrs (22 minutes before to 3 hours and 38 minutes after sunrise) and dusk feedings occurred between 2015 and 2123 hrs (51 minutes before and 17 minutes after sunset). Of the observed feeding visits, three, two, and one adult arrivals were observed on two, four, and four of the surveys, respectively. No adults were recorded on 2 of the surveys. On 30 June, the adults were observed carrying two fish in their bills on two of the three morning feeding visits. Live fish were seen being fed to the chick on three occasions. Vocalizations were heard from both of the adults while on the nest and when leaving. Chick vocalizations were also heard. Although fledging was not observed, the chick was assumed to have fledged on 6 July. This was based on the observation of the chick in juvenile plumage during the evening survey of July 6 (they generally pluck off their down within 8 to 16 hours of fledging). The chick was gone from the nest the morning of 7 July. We took measurements of the nest platform and contents of the nest on 25 August.

Activity at the second 1994 nest (9.2) was monitored from 28 June (nest location verified on 30 June) until 19 July. There were 9 morning visits and 8 evening visits recorded over a period of 13 days (Table 29). We observed only one adult visit on seven of the surveys, but two and three adult visits were seen on eight and one of the surveys, respectively. No adults were observed on one survey. Dawn feeding visits occurred between 0507 and 0902 hrs (24 minutes before and 3 hours 22 minutes after sunrise) and dusk feeding visits occurred between 1900 and 2141 hrs (2 hours 6 minutes before and 33 minutes after sunset). On the evenings of 30 June and

Table 29. Timing of nest visits by adult Marbled Murrelets monitored on the Tillamook and Elliott State Forests, 1994-1995 and 1997-1998.

Nest Site	Site Number	Date	Time Arrive [a]	Time Depart [a]	Length of Visit (minutes) [b]	Type of Visit [c]
Tillamook State Forest-1994						
North Rector	9.1	6/28	2106	2118	12	F
		6/29	0605	0623	18	F
			0623	0656	33	F
			2053	2112	19	F
		6/30	0508	0535	17	F
			0638	0656	18	F
			0656	0718	22	F
			2041	2048	7	F
		7/1	0526	0534	8	F
			0534	0606	32	F
			0625	0646	21	F
			0647	0718	31	F
			0847	0909	22	F
		7/5	0552	0604	12	F
			0604	?	?	F
		7/6	?	0545	55+	F
			2015	2016	1.5	F
			2123	2123	1	F
North Rector	9.2	6/28	2112	2128	26	?
		6/29	0530	0608	38	?
			2110	?	?	?
		6/30	0509	?	?	?
			0548	0609	21	F
			2107	2123	16	F
			2123	2141	18	F
		7/1	0538	0604	26	F
			2008	2020	12	F
		7/2	0507	0543	36	F
			0546	0601	15	F
		7/5	0557	0559	2	F
			0559	0613	14	F
		7/6	0634	0657	23	F
			0708	0738	30	F
			1900	1930	30	F
			2114	2133	19	F
		7/7	0627	0648	21	F
		7/11	0644	0651	7	F
		7/13	2042	2058	16	F
			2058	2130	32	F

Table 29 cont. Timing of nest visits by adult Marbled Murrelets monitored on the Elliott and Tillamook

State Forests, 1994-1995 and 1997-1998.

Nest Site	Site Number	Date	Time Arrive [a]	Time Depart [a]	Length of Visit (minutes) [b]	Type of Visit [c]
Tillamook State Forest-1994, cont.						
North Rector	9.2	7/14	0541	0607	26	F
			0835	0902	27	F
Elliott State Forest-1995						
Elk Creek	5.1	8/7	0608	0608	~ 3 sec	?
			0609	0609	~ 3 sec	?
			?	0638	?	?
		8/8	0601	?	?	?
			0618	?	?	?
			2025	2037	12	F
			2052	2105	13	F
		8/9	0608	0617	9	F
			0617	0643	26	F
		8/10	?	0629	?	F
		8/11	0606	0623	17	F
		8/12	2044	?	?	F
		8/13	0602	0634	12	F
		8/14	?	0605	?	F
		8/16	0602	0618	16	F
			0618	0648	30	F
			1957	2001	4	F
			2022	2028	6	F
		8/17	0519	0636	17	F
			0704	0727	23	F
			2013	2019	6	F
		8/18	0557	0558	1	?
			0610	0625	15	F
			0625	0627	2	F
Tillamook State Forest-1997						
Big Rackheap [d]	100.2	5/26	0528	0529	1	P
			0528	0543	15	P
		6/10	0504	0517	13	P
		6/11	0516	0545	29	P
		6/12	?	?	22+	P
		6/28	0517	0517	<1	E
		7/1	?	?	8 sec	E
		7/3	?	?	7 sec	E
		7/9	0525	0525	10 sec	E
		7/11	0511	0511	9 sec	E
		7/14	0517	0517	20 sec	E

Table 29 cont. Timing of nest visits by adult Marbled Murrelets monitored on the Elliott and Tillamook State Forests, 1994-1995 and 1997-1998.

Nest Site	Site Number	Date	Time Arrive [a]	Time Depart [a]	Length of Visit (minutes) [b]	Type of Visit [c]
Tillamook State Forest-1997, cont.						
Big Rackheap [d] cont.	100.2	7/15	0517	0518	8 sec	E
		7/17	?	?	9 sec	E
		7/21	0526	0526	23 sec	E
		7/24	0521	0526	5 min 26 sec	E
		7/27	0528	0541	13	F
		7/28	0613	0624	10 min 45 sec	F
		7/30	0618	0619	1	F [f]
			0637	0642	5	F [f]
North Rector	9.6	7/10	2059	?	?	?
		7/11	0641	0701	20	F
		7/14	2003	2015	12	F
		7/17	0609	0620	11	F [g]
			0741	0756	15	F
			2102	2118	16	F
		7/21	0653	0702	9	F
		7/23	0518	0527	9	F
Big Rackheap [e]	100.3	7/22	?	0527	?	F
			0529	0551	22	F
		7/24	0523	0524	1	F
		8/6	2058	2103	5	F
		8/7	0614	0625	11	F
			0743	0752	9	F
			2049	2059	10	F
			2101	2108	7	F
		8/8	0653	0705	12	F
		8/12	0601	?	?	F
			0702	0711	8	F
		8/13	0614	0636	22	F
			0639	0655	16	F
		8/14	0606	0612	6	F [f]
			0618	0621	3	F [f]
Tillamook State Forest-1998 [h]						
Big Rackheap [i]	100.8	7/21	?	0636	?	?
		7/22	1958	2017	20	?
		7/23	0550	0603	13	F
		7/23	0613	0633	20	F
		7/27	?	0527	?	F
			0546	0602	16	F

Table 29 cont. Timing of nest visits by adult Marbled Murrelets monitored on the Elliott and Tillamook State Forests, 1994-1995 and 1997-1998.

Nest Site	Site	Date	Time	Time	Length of	Type of

	Number		Arrive [a]	Depart [a]	Visit (minutes) [b]	Visit [c]
Tillamook State Forest-1998 [h], cont.						
Big Rackheap [i]	100.8, cont.	7/28	2007	2017	10	F
			2016	2022	6	F
		7/29	2010	2017	7	F
Low Simmons	105.2	8/11	2000	2006	6	F
		8/13	0755	0809	14	F
		8/14	2022	2033	11	F
		8/15	2000	2011	11	F
		8/16	2014	2022	8	F
		8/18	1955	2000	5	F
		8/19	2009	2012	3	F
		8/20	0602	0603	1	F
			2015	2016	1	F
		8/21	0557	0558	1	F
		8/22	0619	0619	8 sec	F [f]

[a] Recorded in 24 hour time.
[b] Unless otherwise noted.
[c] P = pre-egg laying visit, E = nest exchange, F = feeding visit, ? = type of visit not determined.
[d] Also known as Little Rackheap, 1997
[e] Also known as Gods Valley West.
[f] Adult arrived at the nest with fish, but the chick was gone.
[g] Aborted feeding because of human disturbance.
[h] Not enough conclusive data recorded by observers to include the nests North Rector 9.8 and Bearly Rackheap 101.3.
[i] Also known as Little Rackheap, 1998.

14 July, an adult arrived with two fish to feed the chick. Vocalizations from the chick and the adults were heard occasionally at this nest. On 6 July at 1947, we observed a Sharp-shinned hawk (*Accipiter striatus)* flying between the two nests with a small bird in its talons. The hawk flew within 15 m of the second nest. The chick was observed in the nest on the evening of 18 July, but was missing the following morning (19 July). During the ground search around the nest tree, feathers and the head of the chick were found. A climber found additional feathers on the nest platform. We believe the chick may have been preyed upon by the Sharp-shinned hawk that had been observed previously in the area. We took measurements of the nest platform and contents of the nest on 20 July.

In 1997, we discovered an additional nest at the North Rector site. The nest was discovered on July 10th after the official dawn survey had ended; while the ground crew was establishing new survey stations in the North Rector site, they saw an adult murrelet fly by with a fish in its bill. The nest was confirmed with a survey that evening. We monitored the nest during eight morning and seven evening surveys between 10 - 25 July (Appendix 17). We conducted surveys approximately 40 m to the south of the nest tree, across a road and upslope. Video footage of the nest was taken from this camouflaged location on the ground; Dave Buchholz also took a few still photos from a nearby location. These pictures captured similar behaviors as described in 1995. We observed only one adult at the nest on five of the eight morning feedings and five of the seven evening visits and no adults on two of the morning and evening surveys (Table 29). On 17 July, there were two morning feeding events. The first occurred between 0609 and 0620. This adult may have been startled off the nest by observers, as it dropped the fish and departed after an observer ran down a nearby embankment. A second feeding was recorded between 0741 and 0756. Two adults were never seen at this nest at the same time, and it was suspected that only one adult was feeding the chick. Dawn feeding visits occurred between 0518-0741 hrs (31 min before to 118 min after official sunrise) and dusk feeding visits occurred between 2003 and 2110 hrs (52 min before to 18 min after official sunset). The chick was fed a single fish by the adult at each feeding. On one occasion it was believed a fish carried by the adult was still alive, as observers noticed the gills opening and closing.

On the morning of 25 July, we confirmed the chick dead on the nest limb. It was probably dead during the evening survey of 24 July but was not noted as so. No adults came to feed during either of these surveys. A necropsy was performed on the retrieved carcass and it was determined the chick died of renal failure (dehydration), possibly due to being tended by one adult and not getting enough food/hydration. Photos of the nest platform and of the dead chick were taken on 25 July. We documented the nest on 23 September. Predators, including Steller's Jays, Common Ravens and a Red-tailed Hawk (*Buteo jamaicensis*) were recorded in the vicinity of the nest during the surveys. Distances for the Stellar's Jays and Common Ravens ranged from 25 m to over 200 m from the nest. The Red-tailed Hawk was circling above the nest at 1.2 canopies.

In 1998, a fourth active nest was found at the North Rector site (9.7). We conducted 12 morning and one evening survey at this nest between 14 May and 11 June (Appendix 18). This nest was found in the same tree, but a different limb, as the 1994 North Rector (9.1) nest. We conducted surveys from the road approximately 10 m north of the nest tree and in the stand approximately 15 m south of the nest tree. Dawn landings occurred between 0503 and 0524 hrs (28 minutes before to 19 minutes before official sunrise; Table 29). Incubation exchanges were probably initiated on 25 May and continued through 10 June (n = 5). Video footage of an adult sitting on the egg was taken from an adjacent tree on 3 June.

On two mornings (May 29 and 30), the observers heard wingbeats which indicated two takeoffs and two landings in the tree; multiple landings do not usually occur during incubation. On 10 June, a normal incubation exchange was observed at 0520, but at 0530 the adult who had just arrived at the nest, left. An observer stayed for four hours but no adult returned. An evening survey was conducted on 10 June and no adults were observed; as well, no entries or exits were observed on the morning of 11 June. Later this day, a climber confirmed the nest had failed. Eggshell fragments were found on the nest platform and at the base of the tree. Eggshell fragments were also found around the base of a tree approximately 36.5 m to the south of the nest tree. This adjacent tree was climbed, but no evidence of a nest was found, suggesting the eggshell fragments may have been from the depredated nest. Predators noted in the area included Common Ravens and Stellar's Jays. We documented the nest on 9 July.

A disturbance was created at this nest on 29 May at 1100 hrs. Because of inconsistent murrelet activity at this tree, a climber prepared to climb the tree to determine the status of the suspected nest. A climbing rope was attached to the parachute cord which was already in the tree from previous climbing. While pulling the climbing rope into the tree a murrelet flushed. The rope was quickly lowered and removed. The crew then left the site immediately, therefore, it was not noted when or if the adult returned to the nest on 29 May. We observed birds returning on the morning of 30 May (multiple landings as above), and documented a normal incubation exchange on the morning of 31 May.

Big Rackheap – In 1997, we found two nests at the Big Rackheap site. The Big Rackheap 100.2 nest, also known as Little Rackheap, was monitored from 23 May until 31 July 1997 (Appendix 17). We conducted surveys (*n* = 14 dawn surveys) from across the road, approximately 15 m northwest of the nest tree. A remote video camera was installed in the nest tree on 11 June, approximately five meters from the nest limb. The camera was wrapped in camouflage to limit disturbance. The camera was turned on in the morning before sunrise and left running until the tape ran out (approximately 2 hours). Seventeen dawn surveys were recorded by the remote camera during the months of June and July. One pre-egg laying visit, eight nest exchanges and one feeding visit were filmed.

We observed pre-egg laying activity at this site 23 May through 12 June with probable copulation on the nest branch 27 May. Activity during this period included both adults landing simultaneously on the nest branch and remaining for up to 33 min. The first confirmed nest exchange between the two adults occurred 28 June. The first feeding visit was observed on 27 July (Table 29). Nest exchanges (*n* = 9) took place between 0511 and 0526 hrs (27 min before to 22 min before official sunrise). Feeding visits (*n* = 4) took place between 0528 and 0637 (26 min before and 40 min after official sunrise). The nest was thought to be empty on 30 July due to the short (1 minute) feeding visits exhibited by each adult. After the morning survey on 31 July, in which no adults arrived at the nest, a climber was sent up the tree to determine its fate.

The nest cup was empty; all that remained was a pile of chick down on a branch adjacent to the nest limb. Near the down was a half eaten carcass of a deer mouse. A small owl could be a possible predator. However, Steller's Jays were the only predator observed in the vicinity of the nest (heard vocalizing on 30 July). We documented the nest on 31 July.

The Big Rackheap 100.3 nest, also known as God's Valley West, was monitored from 6-14 August 1997 (Appendix 17). We conducted six morning and two evening surveys from a downed tree approximately 20 meters south of the nest tree. Video footage of the nest was taken from the downed tree during five of the six morning surveys. Dave Buchholz also took some still photos of the chick from this location on one morning. The videos documented landings, take-offs, chick feedings, interactions between the chick and adults, and behaviors of the chick while alone on the nest. Two adults were observed at the nest on four of the six morning surveys and one of the two evening surveys; the other visits included only one confirmed adult (Table 29). Each adult carried a single fish for the chick during the feeding visits. One fish seemed to be alive in the adult's bill, as its gill plates were moving and it was observed arching its body before being passed to the chick. Morning feeding visits occurred between 0543 and 0743 hrs (21 min before and 38 min after official sunrise) and evening feeding visits occurred between 2050 and 2102 hrs (up to 32 minutes after official sunset.).

The chick was thought to have been depredated on the evening of 13 August. This was based on the fact that the chick was in the nest on the morning of 13 August and both adults came to the nest with a fish for morning feeding visits. On the morning of 14 August the nest cup was empty (both adults arrived with fish expecting to feed the chick; behavior of one adult at finding an empty nest was captured on video). A thorough ground search for the chick was conducted but nothing was found. A climber climbed and documented the nest on 14 August and found no remains of the chick on the nest platform or in the nest tree. Other trees in the area were investigated by the climber, using binoculars, but again nothing was found. Estimated age of the chick when it disappeared (2 ½ weeks) and lack of down on the nest limb, were additional indications that the nest probably failed. Predators recorded in the area during surveys were Common Ravens, Steller's Jays, and on one occasion a Northern Pygmy Owl (*Glaucidium ghoma)* over 200 m away. The jays and ravens ranged from 25 m to over 200 m from the nest.

In 1998, we monitored the Big Rackheap 100.8 nest, also known as Little Rackheap, from 21 July until 4 August (Appendix 18). We surveyed the nest from two stations, approximately 11 m south and 33 m northwest of the nest tree. The dense crown made viewing this nest from the ground impossible. We conducted six morning and eight evening surveys. Because the nest was found after the chick had hatched, only feeding visits (n = 15) were observed (Table 29). Dawn feedings occurred between 0516 and 0613 (32 minutes before and 24 minutes after official sunrise), and evening feedings occurred between 1951 and 2044 (50 minutes before and 6 minutes after sunset). We observed two adults at the nest on three of the six morning surveys and four of the eight evening surveys. Each adult was observed carrying one fish during each visit. Fledging was observed on 1 August at 2108 (30 minutes after official sunset). No detections were recorded in the area on one morning (2 August) and two evening (3 and 4 August) surveys performed after fledging. We documented the nest on 10 August.

Predators noted near the nest tree were Common Ravens, Stellar's Jays and Great Horned

Owls. An owl (suspected to be a Great Horned Owl) landed in a dead western hemlock near the nest tree (approximately 137 m away) on 1 August at 2106, 2 minutes before the chick fledged. The chick flew a route approximately 55 m south of this tree when it fledged. It was not noted whether the owl remained in the snag after the chick left.

Bearly Backheap – Bearly Rackheap (101.3) was monitored from 9 - 28 July 1998 (Appendix 18). We conducted surveys from approximately 21 m to the northwest of the nest tree. During ten morning surveys, we observed landings by pairs and single murrelets between 0512 and 0629 hrs (30 minutes before and 45 minutes after official sunrise). Multiple landings in the nest tree on a single morning occurred on four of the ten surveys (Table 29). These landings occurred at two different heights in the tree (at 0.8 and 0.9 canopy). During two surveys (24 and 25 July), potential nest exchanges (one entry and exit by single murrelets) were recorded at the 0.8 location; these occurred between 13 minutes before and 20 minutes after official sunrise. However, no entries or exits from the tree occurred on 26, 27, and 28 July, suggesting that the nest had failed or incubation was never initiated. The tree was climbed on 10 August to document the nest. It appeared that the cup may have been used two to three seasons ago. This nest may have been found in the pre-egg laying stage or the nest was depredated very early in the incubation stage. No eggshell fragments were found in or around the tree, but fresh claw marks were observed on the landing pad. Predators noted in the vicinity of this nest were Common Ravens and Steller's Jays. Common Raven feathers were found at the base of the tree and on a limb above the nest. An owl pellet was also found at the base of the tree.

Low Simmons – We discovered the Low Simmons nest (105.2) on 11 August and monitored it until 22 August 1998 (Appendix 18). The nest was found by a tree climber sent up a suspected nest tree, where consistent below canopy flights were observed for numerous days in June. However, because of subsequent inconsistent activity in the area, the nest was thought to have failed. The climber instead found an active nest with a chick that was thought to be approximately 2 ½ weeks old.

We established monitoring stations 20 m north and 25 m west-southwest of the nest tree. Four morning surveys were performed, with one adult arriving to feed the chick during each of these surveys. These feeding visits occurred between 0557 and 0755 (25 minutes before to 43 minutes after official sunrise; Table 29). During eight of the 10 evening surveys, one adult arrived to feed the chick. Arrival times were between 1955 and 2022 hrs (26 minutes before and 4 minutes after official sunset). Adults arrived with a single fish during each visit. On 17 August at 2007, an adult approached the nest limb but did not land and no feeding visits were recorded that evening. A second bird (species unknown), flying past the nest at the time the adult was approaching the platform, may have scared the murrelet. The chick fledged on 21 August at 2031 (22 minutes after official sunset). During a morning survey performed on 22 August, one adult arrived but left immediately (8 seconds) when it found no chick in the nest. No detections were recorded in the area that evening. Video footage was shot from the ground from both survey stations; the footage included feeding visits by adults and chick behavior (preening and wing flapping) while alone on the nest. We also took still photos from a platform in an adjacent tree. Predators noted in the area (none came closer than 50 m to the nest) during nest surveys were Common Ravens, Stellar's Jays, Western Screech Owls (*Otus kennicottii*) and an unidentified hawk. We documented the nest on 29 August.

Elliott State Forest

Elk Creek – In 1995, we monitored behavior of the adults and chick at the Elk Creek nest from 7-19 August. We conducted surveys at the base of the nest tree or from a platform in an adjacent tree (30 m from the nest tree) at dawn on most (n = 10) days and dusk on four days (Appendix 15). Video and still photographs were taken from the platform on most visits to the nest site. These pictures captured landings, take-offs, feeding of the chick, and adult and chick behavior. We observed adults at the nest on all visits, except after the chick fledged. Two adults were observed at the nest or feeding the chick on seven of 10 dawn surveys and three of four dusk surveys; the other visits included only one confirmed adult (Table 29). The chick was fed a single fish by each adult during each visit. Dawn feeding visits occurred between 0519 and 0727 hrs (58 min before to 70 min after official sunrise) and dusk feeding visits occurred between 1957 and 2105 hrs (22 min before to 36 min after official sunset). The chick was assumed to have fledged on the evening of 18 August. The actual fledging was not seen, but based on the development of the chicks' plumage, experience with other nests, the fact that chick appeared healthy on the morning of 18 August, and the lack of evidence to prove otherwise, we assume the chick fledged successfully. On the morning of 19 August, the observation tree was climbed and we confirmed that the chick was gone. We collected measurements of the nest platform and contents of the nest on 20 August.

We recorded predators, including Steller's Jays (*Cyanocitta stelleri*), Common Ravens

(*Corvus corax*) and Great Horned Owls (*Bubo virginianus*), in the vicinity of the nest during most (71.4%) visits. We observed Great Horned Owls and Steller's Jays within 50 m of the nest tree on numerous occasions, but they were not observed in the nest tree or at the nest limb. During these close encounters, climbers and observers were extremely cautious and quiet, and in some cases observations from the platform were suspended. On several occasions no one climbed to the platform because of the presence of predators in the area.

Forest Surveys

This section summarizes the results of the forest surveys we conducted for locating and monitoring nest sites during this study. The sites surveyed, survey effort and site status are recorded for each year in the Tables 30-34. The actual dates, number of detections, and outcomes of each survey are presented in Appendices 15-19.

Murrelet activity and detection rates varied among years, forests, and sites. Murrelet activity appeared to be the lowest between 1996 and 1998 and the highest in 1995 (Tables 30-34, Appendices15-19). We believe that warm ocean water temperatures and a change in the currents along the Pacific Coast between 1996 and 1998 may have affected the distribution and abundance of small schooling fish, thus affecting murrelet nesting attempts and inland flights. Detections were also fairly low in 1999; despite the waning of 1997 El Niño, warm waters continued to be found off the eastern Pacific in 1999 because of changes in water flow (decadal oscillation).

On the north coast, the average number of detections per survey was greatest in 1995 and

Table 30. Survey effort, number of nests, and site status, Tillamook and Elliott State Forests, 1995.

Study Site	Site #	# Nests found in 1995	# Survey Days	1995 Status	Previous Status
Tillamook State Forest					
North Rector	9.0	1 [a]	3	occupied	occupied
Coal Creek	10.0	1 [a]	2	presence [b]	occupied
Big Rackheap	100.0	1 [a]	8	occupied	occupied
Bearly Rackheap	101.0	2 [a]	5	occupied	occupied
Elliott State Forest					
Elk Creek	5.1	1	12	occupied	occupied
Silver Beaver	6.1	0 [c]	1	no detections [b]	occupied
Joe Buck	16.2	0	0	no surveys	occupied
Joe Buck	20.1	1 [a]	1	presence [d]	occupied
Joe Buck	20.2	0	0	no surveys	presence
Silver Creek	22.2	3 [a]	1	occupied	no [e]
Lower Fish	26.1	0 [c]	1	presence	occupied
Lower Fish	26.2	0	0	no surveys	occupied
Schumacher Creek	29.1	0	0	no surveys	occupied
Elk Pass	31.1	0	0	no surveys	occupied
Elk Pass	31.2	0 [c]	1	no detections	occupied
Elk Pass	39.1	0	0	no surveys	occupied
Panther Elk	41.2	1 [a]	1	no detections [b]	no
Lower Fish	81.1	1 [a]	1	no detections [b]	occupied
Lower Fish	81.2	0	0	no surveys	occupied

[a] nests found by tree climbing not surveys.
[b] occupied behavior was noted on surveys conducted by B. Fields, D. Buchholz and others in 1995.
[c] although no nests were located, surveys were conducted because the sites were occupied.
[d] occupied behavior was observed within 100 m of the nest site.
[e] site not surveyed to protocol.

Table 31. Survey effort, number of nests, and site status, Tillamook and Elliott State Forests, 1996.

Study Site	Site #	# Nests found in 1996	# Survey Days	1996 Status	Previous Status
Tillamook State Forest					
Crystal Barn	108.0	0	0	no surveys [a]	occupied
Low Simmons	105.0	1 [b]	0	no surveys [a]	occupied
Elliott State Forest					
Silver Beaver	6.1	1 [b]	3	no detections	occupied
Knife Otter	173.0	2 [b]	3	no detections	occupied
Elk Creek	5.1	0	10	occupied	occupied
Silver Creek	22.2	0	1	no detections	occupied
Lower Fish	26.1	0	5	occupied	occupied
Lower Fish	81.1	0	2	no detections	occupied
Joe Buck	20.1	0	1	no detections	occupied
No Name	70.1	0	1	no detections	no surveys

[a] these sites were not visited until after the survey season in 1996.
[b] nests found by tree climbing not surveys.

Table 32. Survey effort, number of nests, and site status on the Clatsop, Tillamook and Elliott State Forests, 1997.

Study Site	Site #	# Nests found in 1997	# Survey Days	1997 Status	Previous Status
Clatsop State Forest					
Ebsen Road	70.0	2 [a]	4	no detections	occupied
Tillamook State Forest					
North Rector	9.0	3	18	occupied	occupied
Big Rackheap	100.0	2	28 [b]	occupied	occupied
Bearly Rackheap	101.0	0	15	occupied	occupied
Coal Creek	10.0	0	3	no detections [d]	occupied
County Line [c]	8.0	0	1	presence	occupied
Low Simmons	105.0	0	5	occupied	occupied
Elliott State Forest					
Elk Creek	5.1	0	5	occupied	occupied
Elk Pass	31.1	0	1	no detections	occupied
Joe Buck	16.2	0	1	no detections	occupied
Joe Buck	20.1	0	1	no detections	occupied
Knife Otter	173.0	0	4	occupied	occupied
Lower Fish	81.1	0	3	no detections	occupied
Panther Elk	41.2	0	2	no detections	no detections [e]
Silver Beaver	6.1	0	3	no detections	occupied
Silver Creek	22.2	0	3	no detections	occupied

[a] nests found by tree climbing not surveys.
[b] Big Rackheap survey days include Little Rackheap and Gods Valley West nest observations.
[c] survey done to follow up on previous survey with suspected nesting behavior.
[d] one occupied behavior and 23 detections recorded at this site by other surveyors in 1997.
[e] occupied behavior was noted on surveys conducted by B. Fields in 1995.

Table 33. Survey effort, number of nests, and site status on the Clatsop, Tillamook and Elliott State Forests, 1998.

Study Site	Site #	# Nests found in 1998	# Survey Days	1998 Status	Previous Status
Clatsop State Forest					
Ebsen Road	70.0	1 [a]	2	no detections	occupied
Tillamook State Forest					
North Rector	9.0	1	19	occupied	occupied
Big Rackheap	100.0	5	26	occupied	occupied
Bearly Rackheap	101.0	1	22	occupied	occupied
Coal Creek	10.0	0	5	occupied	occupied
Low Simmons	105.0	1	8	occupied	occupied
Elliott State Forest					
Elk Creek	5.1	0	16	occupied	occupied
Joe Buck	20.1	0	5	no detections	occupied
Knife Otter	173.0	1 [a]	5	no detections	occupied
Lower Fish	81.1	0	7	presence	occupied
Panther Elk	41.2	0	5	no detections	no detections
Silver Beaver	6.1	0	7	occupied	occupied
Silver Creek	22.2	0	5	no detections	occupied
Roberts Creek [b]	2.0	0 [c]	15	presence	no surveys
Alder Fork [b]	42.0	0 [c]	25	presence	no surveys
Larson Creek [b]	66.0	0 [c]	20	presence	no surveys
Palouse Creek [b]	99.0	0 [c]	11	occupied	no surveys

[a] nests found by tree climbing not surveys.
[b] these sites were surveyed to the 1998 Pacific Seabird Group inland survey protocol.
[c] no nest searches were conducted.

Table 34. Survey effort, number of nests, and site status on the Clatsop and Tillamook State Forests, 1999.

Study Site	Site #	# Nests found in 1999	# Survey Days	1999 Status	Previous Status
Clatsop State Forest					
Ebsen Road	70.0	0	6	no detections	occupied
Tillamook State Forest					
North Rector	9.0	0	9	occupied	occupied
Big Rackheap	100.0	2 [a]	49	occupied	occupied
Bearly Rackheap	101.0	0	28	occupied	occupied
Coal Creek	10.0	0	12	occupied	occupied
Low Simmons	105.0	0	10	occupied	occupied

[a] nests found by tree climbing not surveys.

lowest in 1999 (except at Coal Creek and Low Simmons; Table 35). Most sites on the Tillamook had consistent below canopy detections in each year. No detections were recorded at the Ebsen Road site on the Clatsop State Forest despite occupied behavior being observed there in previous years. Overall detections and below canopy detections were low at all sites on the Elliott except Elk Creek.

Murrelet status changed with year at seven survey sites (Table 35, Appendices 15-19). We recorded occupancy at Joe Buck and Silver Creek in 1995, but no detections during subsequent surveys between 1996 and 1998. Silver Beaver had occupancy in 1995 and 1998 but no detections in 1996 and 1997. Coal Creek had no detections in 1997 but we recorded presence in 1995 and occupancy in 1998 and 1999. We did not record any detections at Knife Otter in 1996 and 1998, but observed occupancy in 1997. And finally, no detections were recorded at Lower Fish (81.1) and Panther Elk between 1995 and 1997, but we observed birds flying over the canopy in 1998.

We located two nests in 1995 on the Elliott State Forest in portions of their respective sites that had no detections during surveys conducted prior to this study (Table 30, Appendix 15). At the Panther Elk site, no detections were recorded at any station within 0.4 km of the nest after two years of protocol surveys. We also had no detections at this site after one survey. However, occupied and presence behaviors were observed on the opposite side of the ridge from the nest in the same large, contiguous stand. At the Silver Creek site, no detections were recorded from a station located within 200 m of the three nest trees during surveys conducted prior to this study[8]. After finding the nests in 1995, we noted occupied behavior in the nest area after one survey.

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[8] Protocol surveys were not conducted (*i.e.*, one station per 12 ha). This site is a reserve area and was surveyed only because it was within 0.4 km of a timber sale area.

Table 35. Comparison of Marbled Murrelet detections in sites surveyed more than one year, 1995-1999.

Year	Presence (# Visual)	Circling	Below Canopy	Total # Detections	Total # Survey Days (Peak) [a]	Total # of Surveys [b]	Average # of Detections/ Survey
				Clatsop State Forest			
Ebsen Road-70.0 (3 nests)							
1997	0	0	0	0	4 (2)	8	0
1998	0	0	0	0	2 (0)	6	0
1999	0	0	0	0	6 (0)	12	0
				Tillamook State Forest			
North Rector-9.0 (7 nests)							
1995	67 (7)	0	49	116	3 (3)	6	19.3
1997	588 (10)	5	152	745	18 (11)	49	15.2
1998	607 (24)	5	153	765	19 (2)	55	13.9
1999	5 (0)	0	1	6	9 (2)	22	0.3
Coal Creek-10.0 (1 nest)							
1995	291 (7)	2	0 [c]	293	2 (1)	4	73.3
1997	0	0	0	0	3 (0)	5	0
1998	82 (4)	0	57	139	5 (1)	16	8.7
1999	36 (13)	12	97	145	12 (6)	32	4.5
Big Rackheap-100.0 (10 nests)							
1995	1019 (33)	5	24	1048	8 (4)	17	61.6
1997	422 (37)	9	118	549	28 (8)	58	9.5
1998	488 (53)	7	162	657	26 (12)	82	8.0
1999	428 (52)	28	125	581	49 (14)	136	4.3
Bearly Rackheap-101.0 (3 nests)							
1995	236 (10)	1	29	266	5 (4)	10	26.6
1997	381 (18)	2	93	476	15 (6)	43	11.1
1998	1165 (61)	7	133	1305	22 (13)	58	22.5
1999	401 (23)	21	67	489	28 (11)	94	5.2

Table 35 cont. Comparison of Marbled Murrelet detections in sites surveyed more than one year, 1995-

1999.

Year	Presence (# Visual)	Circling	Below Canopy	Total # Detections	Total # Survey Days (Peak) [a]	Total # of Surveys [b]	Average # of Detections/ Survey
Tillamook State Forest cont.							
Low Simmons-105.0 (2 nests)							
1997	2 (1)	0	6	8	5 (3)	10	0.8
1998 [d]	2 (2)	0	10	12	8 (2)	13	0.9
1999	12 (1)	3	6	21	10 (3)	18	1.2
Elliott State Forest							
Elk Creek- 5.1 (1 nest)							
1995 [e]	15 (1)	0	57	72	12 (0)	20	3.6
1996	42 (0)	0	131	173	10 (6)	17	10.2
1997	6 (0)	0	28	34	5 (2)	12	2.8
1998	92 (17)	9	118	219	16 (6)	37	5.9
Silver Beaver-6.1 (1 nest)							
1995	0	0	0 [f]	0	1 (0)	2	0
1996	0	0	0	0	3 (2)	6	0
1997	0	0	0	0	3 (1)	5	0
1998	5 (0)	0	5	10	7 (3)	10	1.0
Joe Buck-16.1, 16.2, 20.1, 20.2 (1 nest)							
1995	2 (0)	1	2	5	1 (1)	2	2.5
1996	0	0	0	0	1 (1)	1	0
1997	0	0	1	1	2 (0)	3	0.3
1998	0	0	0	0	5 (3)	8	0
Silver Creek-22.2 (3 nests)							
1995	3 (3)	0	6	9	1 (1)	2	4.5
1996	0	0	0	0	1 (1)	2	0
1997	0	0	0	0	3 (1)	6	0
1998	0	0	0	0	5 (1)	9	0

Table 35 cont. Comparison of Marbled Murrelet detections in sites surveyed more than one year, 1995-1999.

Year	Presence (# Visual)	Circling	Below Canopy	Total # Detections	Total # Survey Days (Peak) [a]	Total # of Surveys [b]	Average # of Detections/ Survey
				Elliott State Forest cont.			
Lower Fish 26.1 (0 nests)							
1995	4 (0)	0	0	4	1 (1)	2	2.0
1996	2 (0)	0	6	8	5 (5)	10	0.8
Lower Fish 81.1 (1 nest)							
1995	0	0	0 [f]	0	1 (0)	2	0
1996	0	0	0	0	2 (2)	3	0
1997	0	0	0	0	3 (0)	5	0
1998	3 (0)	0	0	3	7 (4)	10	0.3
Panther Elk 41.2 (1 nest)							
1995	0	0	0 [f]	0	1 (0)	2	0
1997	0	0	0	0	2 (0)	3	0
1998	1 (0)	0	0	1	5 (2)	8	0.1
Knife Otter 173.0 (3 nests)							
1996	0	0	0	0	3 (3)	5	0
1997	3 (1)	0	1	4	4 (1)	8	0.5
1998	0	0	0	0	5 (2)	8	0

[a] Surveys done in the month of July were counted in the peak activity period.
[b] Total number of surveys done at each site. Numbers vary due to number of surveyors per day at each site.
[c] Occupied behaviors recorded during surveys by Dave Buchholz.
[d] Does not include 9 days of surveys done at the active nest due to modified method of data recording.
[e] Surveys done at active nest only.
[f] Occupied behaviors recorded during surveys by Bob Fields.

DISCUSSION

Characteristics of Nest Platforms and Nest Trees

The 37 Marbled Murrelet nests we located on state lands between 1994 and 1999 were in large, tall conifer trees with broad, moss-covered platforms and extensive horizontal and vertical cover. In general, the characteristics of these nests were similar to those previously described in Oregon and elsewhere south of Alaska (papers in Ralph et al. 1995, papers in Nelson and Sealy 1995, Manley 1999). However, in this study, seven nests were located in smaller diameter trees (minimum 49 cm) and seven at lower heights (minimum 9.9 m) than previously known; the former published minimums for tree diameter and nest height were 88 cm and 18 m, respectively (Hamer and Nelson 1995). In addition, two firsts for Oregon include the discovery of a nest in a western redcedar tree (Bearly Rackheap 101.1) and one on a debris platform with no moss or substrate (North Rector 9.6). Four nests (Elk Creek, North Rector 9.6, Ebsen Road 53-70.1 and 53E-70.3) also did not have distinctive landing pads; although on close inspection of the Elk Creek nest limb, the moss was observed to be slightly matted down. In most cases the landing pad is more obvious, often including large areas of matted, dead or missing moss. Perhaps the level of wear of landing pads on moss-covered limbs was an indication of the number of years a nest limb has been used for nesting.

Active and Old Nests

Despite our different methods in locating nests, active nests, which were located primarily by conducting dawn surveys, were very similar to old nests, which were found only through tree climbing. Differences occurred at the platform and tree scale; old nests were in larger trees, had larger limbs and were higher in trees than active nests. Old nests also had more lichen on platforms than active nests. The only difference at the site scale was related to distance to edge; active nests were located closer to roads and old nests were located closer to natural openings. The differences in height and distance to edge between active and old nests can be explained by the fact that lower nests and nests located closer to large edges are easier to find while observing birds flying into the forest. We do not have an explanation for the other minor differences. Given the limited differences however, locating nests through watching birds may not be as biased as previously assumed.

Nest Platform and Tree Selection

Based on both the univariate and multivariate analyses of nest platform and tree selection, murrelets were selecting nest platforms that were larger in diameter or width and had more cover (horizontal and close vertical) than available platforms in the nesting sites. Platform width was most strongly associated with the probability that a platform will be selected as a nest site. Similar results are presented by Manley (1999) and Meekins and Hamer (1999). The size of platforms may be key in protecting the egg and chick from falling out of the nest, although chicks have been observed falling out of nests even when platforms are large in size ($\bar{x}$ = 37.5 cm, n = 3 nests where chicks fell out; S. K. Nelson, unpubl. data). Cover, both horizontal and vertical, is vital for providing protection for the chick and adults from predators (Nelson and

Hamer 1995b; Nelson and Manley, in prep.). Most murrelet nests are located in areas of extensive vertical cover (Hamer and Nelson 1995, papers in Nelson and Sealy 1995, Manley 1999), but our results also indicated that the close distance of vertical cover above the nest and the large amount of horizontal cover around the nest platform were important nesting platform features.

Murrelets were also selecting nest limbs in platform trees with more substrate (primarily moss) than in other nearby platform trees. Ninety-two percent (n = 34) of the nest limbs had at least 7 mm of moss or substrate at or adjacent to the nest cup. The North Rector 9.6 nest was the only nest that contained no moss, and it was unique in that the nest was located on a mistletoe platform of cris-crossing small limbs (this was a mistletoe infestation in the "witches broom" stage, rather than a more well-developed platform that had grown around the initial infestation). In general, broad platforms with substrate create a place for murrelets to lay their single egg and provide a soft, insulating area for protection of the egg and chick. Furthermore, moss or substrate can increase the size of platforms and protect chicks, which are typically left alone on the nest, and eggs from falling from the nest platform or being discovered by a predator. Moss or substrate also provides insulation from cold temperatures, but this may be less important in Oregon than in Alaska (Naslund et al. 1995). It is interesting to note, however, that nest platforms had thinner substrate than random platforms; this could be an artifact of our sampling design rather than selection by murrelets, or murrelet avoidance of mice (*Peromyscus sp.*), a potential predator, that we observed using platforms with deep moss during our climbing efforts. Additional research will be needed to determine the importance of moss depth at the platform scale.

At the tree scale, the most important characteristics were abundance of large (>15 cm) platforms and moss or substrate. While nests were also in trees larger than other platform trees, tree diameter was only weakly correlated with platform size and abundance, therefore the abundance of large platforms was a more vital characteristic of nesting trees than tree size. Murrelets were selecting trees with many large platforms, whereas other platform trees in nest and non-nest plots sometimes had only one or two platforms. Nest trees with many large platforms were also identified as important in British Columbia (Manley 1999) and Washington (Meekins and Hamer 1999). The presence of moss or substrate was significant on nesting platforms, as discussed above, and it was also important on the tree as a whole; murrelets were selecting trees that had more moss or substrate than other platform trees in their nest sites. This variable was most strongly associated with the probability of a tree being selected as a nest site. This may be related to the fact that multiple suitable platforms were present in every nest tree, each covered with extensive moss or substrate. Moss or substrate has been identified as an important nest platform and nest tree component (Meekins and Hamer 1999), but the amount varies with tree species (or forest type); many nests in California, which have primarily been located in coast redwood (*Sequoia sempervirens*) trees, have only limited piles of duff or needles (rarely moss) or no substrate at all (Singer et al. 1991, 1995). Perhaps the large size of platforms in some of these trees compensates for the lack of substrate in terms of providing a safe location for the egg and chick to reside.

Dwarf mistletoe was present in the model with the lowest AICc at the tree scale. While its association with the probability of a nest being selected as a nest site was less than percent substrate and number of platforms, the odds of selection as a nest site increase 1.2 times with each added percent mistletoe. We believe the importance of mistletoe is related to the murrelet's preference for nesting in western hemlock trees on the north coast, many of which were heavily infected with this parasite. This tree characteristic has not been identified as important in other studies of murrelet nest characteristics.

North Coast and Elliott Nest Platforms and Nest Trees

In general, platforms and nest trees on the north coast and Elliott State Forests were similar, although trees were taller, larger in diameter and contained more lichen and moss or substrate on the Elliott compared with the north coast. In addition, nest platforms were located higher in the tree on the Elliott. In contrast, nest limbs on the north coast contained more extensive horizontal cover than those on the Elliott. Additionally, murrelets preferred to nest on forks or mistletoe deformations in western hemlock trees on the north coast, while those on the Elliott preferred to nest on forked limbs in Douglas-fir trees and avoided western hemlock trees.

These differences in nest platform and tree characteristics between the north coast and the Elliott State Forests appeared primarily related to differences in tree species composition (Sitka spruce/western hemlock vs. Douglas-fir), stand age, and microclimate in our study areas. On the north coast, murrelets were nesting in old-growth remnant trees, or young or mature western hemlock trees with large limbs, deformations or mistletoe platforms. Most of these trees were younger in age or a different species than on the Elliott, thus they were smaller in diameter and height (stand density and site class can also be a factor here). It was the abundance of mistletoe (and associated limb deformations) in the Sitka spruce/western hemlock forests of the north coast, however, that provided opportunities for murrelet nesting at younger forest ages compared with the Douglas-fir forests of the Elliott and other areas of the Coast Range. Nesting in young Douglas-fir trees and stands in the Coast Range will be limited as they generally lack mistletoe, thus these trees generally lack the appropriate limb structure for murrelet nesting. Therefore, providing either older-aged Douglas-fir forests (mature and old-growth) or Sitka spruce/western hemlock forests (>60 years in age) with patches of mistletoe will be important for providing suitable murrelet habitat on the Clatsop and Tillamook State Forests. If possible, promoting growth of platforms on young and mature Douglas-fir trees may also be helpful for providing habitat.

On the Elliott State Forest, murrelet nests were found primarily in old-growth trees (based on core samples); exceptions include the open-grown tree at Joe Buck and the mature nest trees at Knife Otter. In general, the climate on the Elliott is drier (average annual precipitation 100-120 cm) and the distribution of moss is less uniform compared with the north coast. However, many of the nests on the Elliott were located near streams; the wetter microclimate in these areas allowed for greater moss growth. Because moss is more limited in other areas of the Elliott (away from streams), however, suitable nest sites may be limited to stream corridors especially in mature forests. The combination of the restricted distribution of moss and the limited availability of large ($\geq$15 cm) diameter limbs on Douglas-fir trees <200 years in age (except in cases of disease, damage, and unique growing situations, e.g., Joe Buck), likely reduces opportunities for murrelets to nest in young and mature stands on the Elliott. Management for old-growth stands and characteristics or somehow promoting the growth of larger platforms in young and mature Douglas-fir trees will be important for providing suitable murrelet habitat on the Elliott State Forest. In addition, while murrelets appeared to avoid western hemlock on the Elliott (used in less proportion to availability), 10% (2 of 11) of the nests on this forest were in western hemlock trees. Providing more suitable hemlock nest trees may be important for increasing the availability of nesting habitat for the murrelet on the Elliott.

Nest-Site Characteristics

Marbled Murrelet nest trees were located in areas of the forest that included an abundance of large trees with numerous platforms and generally more than two canopy layers.

Nest-Site Selection

Marbled Murrelets were selecting nest-sites with significantly more platform trees and platforms than non-nest sites. In addition, nest sites were generally on gentler slopes and had more canopy layers than non-nest sites. The most important nest-site attributes were the density of platforms (#/ha), number of canopy layers, and distance to closest edge (providing access to nests). Manley (1999) and Meekins and Hamer (1999) found similar results. These results indicate that nest trees on the Clatsop, Tillamook and Elliott State Forests were located in areas that were unique from the surrounding forest, suggesting the distribution of suitable murrelet habitat was not uniform. These nest sites (or portions thereof) were generally heterogenous and included specific site characteristics, such as clumps of large trees with numerous platforms. For example, at the Silver Creek site, the mid-ridge portions of the site (adjacent to Plot 1) had large trees, but in general only small diameter limbs. In contrast, the lower portion of the site (adjacent to Plot 2 which was 150 m from Plot 1) was located along a stream, and had an abundance of large (>15 cm) limbs. Although this site was a minimum of 200 years in age and had many large trees, only portions of the stand appeared to provide suitable nesting habitat for Marbled Murrelets. It is also important to note that Marbled Murrelets will use small patches of habitat (< 2 ha) surrounded by larger patches of unsuitable habitat (*e.g.*, Coal Creek), but additional information on nest success in relation to patch size is needed before determining the quality of these areas for nesting.

Unfortunately, the univariate and multivariate results conflicted with respect to the relationship with canopy layers and distance to closest edge. The modeling analyses indicated that fewer canopy layers were preferred while other analyses suggested that nest sites had more canopy layers than non-nest sites. In addition, the modeling indicated that the probability of a site being a nest site increased with increasing distance to an edge (stream, gap, road, clearcut), while the univariate analysis showed nest sites were closer (although not significantly) to edges than non-nest sites. Both of these variables are potentially associated with murrelet access to their nest site and levels of predation. Access is important for murrelets when flying into and out of their nest tree and nesting area, and nests are generally located adjacent to an opening to allow access (pers. obs.). We believe that providing suitable habitat adjacent to natural openings and streams will enhance use of a site, however some openings could potentially increase predation rates depending on the openings size and context (e.g., road next to a clearcut vs. road within a contiguous forest). Manley and Nelson (1999) found a survival rate of 38% when murrelet nests were located within 50 m of edges verses a 62% survival rate for nests greater than 50 m from edges. In addition, lower nest success was documented at artificial murrelet nests located within 50 m of edges, but only when the matrix around the nests contained human settlements, recreation areas, or clearcuts (Raphael et al. in press). There was no difference in nest success when the nest stand was adjacent to regenerating forest. Ultimately, nest success will factor into the suitability of a site for murrelet nesting. Additional research on the platform, tree, site and landscape features that contribute to successful nesting should be conducted to address the importance of canopy cover, distance to edge, and other factors.

North Coast and Elliott Nest Sites

Nest sites on the north coast and the Elliott State Forest differed with respect to tree species composition, tree size (diameter and height) and tree density (medium-sized; 46-80.9 cm dbh). The Elliott had larger platform trees, taller trees (canopy and midstory), and a lower density of medium-sized trees than the north coast. Additionally, the percent of Douglas-fir trees with platforms was significantly higher on the Elliott. These differences in nest site characteristics between the north coast and Elliott are related to differences in forest type, stand age, and the distribution of platform trees, as discussed above (pages 98-100). Additionally, differences in historic fires and management of these stands, in addition to variation in growing conditions, could explain some of the variation between study areas.

Nest Success and Habitat Characteristics

Small sample sizes of active nests precluded the development of models or a discussion of habitat suitability (tree and site characteristics) based on nest success. Previous studies have shown that successful nests were located close to tree bole in areas of extensive vertical cover (Nelson and Hamer 1995b, Manley 1999). We believe that vertical cover contributes to nest camouflage, while the location of nests close to the tree trunk limits avian (and perhaps mammalian) predator access from one side of the nest cup. Although murrelets have evolved with predation and have developed a variety of morphological characteristics and secretive behaviors to avoid predation (Nelson 1997), their nests are subject to high rates of predation (>56% of nests; Nelson and Hamer 1995b, Manley 1999, Manley and Nelson 1999, Nelson and Manley in prep.). The availability of high quality nest trees and sites, including camouflage and protection from predator access, are probably important to the murrelets long-term survival. Additional research at the tree and site scales are needed to adequately address this question.

Characteristics at the stand and landscape scales, as well as abundance of predators, may also influence murrelet nest success. Studies on active and artificial murrelet nests and those of other forest nesting species have shown that predator abundance, proximity to human activity, stand size, distance to edge, and amount of interior habitat affected nest success (Marzluff and Restani 1999, Nelson and Manley in prep., Paton 1994, Rochelle et al. 1999, Raphael et al. in press, Ripple et al. in press.). Further research at these scales, and year to year conditions in the marine environment, are needed to understand the role of these factors in Marbled Murrelet nest success.

Nest Density and Surveys

In contrast to other alcids, nest densities of the nesting Marbled Murrelets are very low. The density of murrelet nests in our study sites ranged from 0.1 to 3.0 per hectare. Given that murrelets in our study were nesting in patches of suitable habitat, the density of nests at the stand level is likely lower. Marbled Murrelets are solitary nesters despite occurring in groups in forest stands (Nelson 1997, Nelson and Peck 1995). Their nests are generally spaced far apart (although they have occurred as close as 30 m; North Rector 1994 nests) and tremendous effort is required to locate them through climbing and surveys. Because detection rates (average number of detections per survey) and populations of murrelets are relatively low in Oregon (2,500-22,500 birds) compared to British Columbia (45-50,000 birds) and Alaska (280,000 birds; Rodway et al. 1992, Burger 1995b, Piatt and Naslund 1995, Strong et al. 1995), one might expect nest densities in Oregon to be lower than other areas. Conversely, one might expect nest densities to be higher in Oregon compared the BC and Alaska because of more fragmented habitat. However, nest densities from random plot tree climbing in British Columbia and Alaska appeared to be equally as low, even in areas of contiguous old-growth and high detection rates (0.11-4.2/ha; Manely 1999, Rodway and Regehr 1999, Conroy et al. in press, K. Kuletz pers. comm.). Besides requiring tremendous effort for locating nests, low nesting densities indicate that many or larger stands of suitable habitat will be necessary for providing for viable breeding populations of murrelets.

Since the 1982-83 El Niño along the eastern Pacific, surface water temperatures have been above normal off the coast of Oregon (http://www.ncdc.noaa.gov). These increased temperatures have resulted not only from the El Niño events, but also from changes in ocean currents and interdecadal climate oscillations in the eastern Pacific (Mantua et al. 1997). Warmer waters are known to affect productive upwelling (Brosnan and Becker 1997) and probably the distribution and abundance of murrelet prey species (small schooling fish; Strong et al. 1995). These ocean conditions may have also affected nesting attempts, as depleted food resources are known to affect seabird breeding, survival and distribution (Hodder and Graybill 1985, Bayer 1986, Furness and Monaghan 1987, Sydeman and Eddy 1995, Brosnan and Becker 1997). It is likely that these ocean conditions may have affected both the detection rates (especially in 1999) and nest density within our study area. Further research in cold water years is needed to determine if ocean conditions significantly affect murrelet nest density and detection rates.

To accurately assess the effect of ocean conditions on nesting success, inland activity patterns, and the distribution of murrelets in any given year, a long-term research project using radio telemetry would need to be implemented.

Nest Behaviors

All behaviors and interactions of the adult and chick were similar to that recorded at other murrelet nests in Oregon and elsewhere (Nelson and Hamer 1995a, Nelson and Peck 1995). The only difference we noted was the timing of the down preening by the Elk Creek chick in relation to its time of fledging. On the morning of 18 August, the day the chick fledged, the chick was missing some down from small areas around the mandibles and eyes, but otherwise appeared fully feathered. The chick then preened off all its down in an estimated 8 to 10 hr period before fledging on the evening of 18 August. Other bouts of preening, where chicks removed their remaining down feathers prior to fledging, have lasted 12-48 hrs (Nelson and Hamer 1995a).

We also think it important to note some of the interesting behaviors we observed at nests prior to egg laying. At three nests in Oregon, including the 1997 Little Rackheap and the 1998 North Rector nests, landings were observed in the nest tree prior to actual egg laying. At these nests, two adults generally arrived together and spent <1 to 33 min together on the nest limb copulating or preparing the nest for egg laying. The adults could often be heard softly vocalizing during these nests visits, and they sometimes gave one to two loud "keer" calls as they left the nest limb. After a period of up to about 5 days of dawn landings at the nest tree, the birds disappeared for up to 18 days before laying the egg (nests were not observed consistently and behavior varied among nest sites). Similar pre-egg laying behavior has been observed at the nests of other alcid species, including birds being absent from the nest site for up to 15 days before returning to lay an egg (H. Carter, pers. comm.). It is during this time of absence from the nest site that the female is usually feeding heavily and waiting for the egg(s) to form. The duration of egglaying varies among species based on body size, and the size and number of eggs laid (Welty 1975). This behavior may erroneously be attributed to "prospecting" behavior if follow-up work is not conducted in subsequent weeks.

To locate nests by monitoring birds flying into the forest, observers should focus on some key characteristics of nesting birds. These behaviors include: (1) single, silent birds flying straight and direct below the canopy at relatively consistent times during dawn and dusk; (2) loud wing beats or sounds of a bird taking flight from a specific tree; (3) adults carrying fish; (4) murrelet vocalizations from within a specific tree; and (5) flight or vocalization activity in a given tree or area at dusk (usually indicating an adult coming in to feed a chick). Evening surveys can also be used to help confirm nests, although murrelet behavior in the evening is not consistent, except during the chick rearing period. In addition, the discovery of eggshells on the forest floor could indicate current or recent nesting activity in a nearby tree. The tail-chasing and other behaviors reported to suggest nearby nesting by Naslund and Hamer (unpubl. rep.) were not consistently observed at nest sites during our extensive observations at the nests in this study and other nest projects in Oregon (e.g., Nelson and Peck 1995).

Locating Nests

No nests were located in some sites (n = 11 [61%] on the Elliott and n = 6 [50%] on the north coast) that were determined to be occupied based on surveys. This result does not indicate that murrelets are not using these sites for nesting or activities related to nesting. Instead it may indicate: (1) that tree climbing and tree climbers are not always successful in locating old nests; (2) that our sample size (number of climbing plots per site) was not large enough to capture the patches of habitat where the murrelets are potentially nesting; (3) our limited surveys in these sites were inadequate for tracking murrelets to nests or; (4) murrelets were not nesting in these sites during the years in which the trees were climbed or surveys conducted. While tree climbing is known to be successful at finding nests, no data are available to assess its level of accuracy for determining presence or absence. A comparison of tree climbing results with those of protocol surveys is needed to assess the success of tree climbing for finding murrelet nests. With respect to sample size, additional plots in our study sites may have allowed for more success in sampling patches of murrelet habitat. As an example, in the Silver Beaver site, the climbers noted that the climbing plots were located in areas where moss and cover was limited in the top half of the tree crowns, perhaps because of microclimate or wind. However, from these treetops they could see trees in other areas of the site that had large, full crowns and an abundance of moss throughout the canopy. Plots in these areas may have produced nests assuming the habitat was more appropriate for nesting.

While dawn surveys have been used successfully for locating active nests (Nelson and Hamer 1995a, Nelson and Peck 1995, this study), extensive effort is expended for each discovery because murrelet nests are concealed within the forest canopy and breeding birds are cryptic at nest sites. Nest discovery is even more difficult in areas with apparent low density of murrelets (*e.g.*, the Elliott State Forest) and low nest densities. However, we have demonstrated in this study that the combination of using tree climbing and surveys is the most effective means for locating a relatively large numbers of old and active murrelet nests (compared with past efforts); our methods are only surpassed by the intensive and expensive use of radio telemetry (F. Cooke, pers. comm.).

The paired plot and cluster sampling methods were the most successful in locating nests. However, the paired plot method was biased by ODF's establishment of one of the plots and the cluster sampling was biased by locating additional climbing plots adjacent to known nest plots. These biases, in addition to our use of a variety of plot establishment methods (and the clumped nature of our study sites on only three areas of western Oregon), affected the inferences we could make with our results; our results are only applicable to the areas where we conducted our sampling. The method that is least biased and easy to implement is the grid method. We suggest this method be used for locating nests across large stands and geographic areas. When study sites are randomly sampled and plots randomly selected, inferences using this method could be made across the sampling universe or target population. Depending on project objectives, the cluster sampling method would also be a useful tool for exploring the question of nest density in greater detail.

Management Implications

This study indicated that murrelets were nesting in large trees with numerous platforms, abundant substrate, and vertical cover. They were also nesting in habitat patches within our study sites that included numerous platforms and platform trees. Some differences existed in the characteristics of nest sites on the north coast and Elliott State Forests pertaining to forest type, platform tree distribution, and micro-climate. Additionally, differences in historic fires and management of these stands, in addition to variation in growing conditions, probably explained some of the variation between study areas. Despite these differences, the overall key characteristics of murrelet nest sites at the platform (large platforms with substrate and cover), tree (trees with numerous substrate-covered platforms), and site (high densities of platform trees) scales remain the most important components for nesting on State Lands in western Oregon. These should be the components that ODF attempts to maintain and create within the north coast and Elliott State Forests when managing for Marbled Murrelets and their habitat.

Based on the results of our study, we recommend that forest managers consider platform tree abundance and abundance of platforms (including dwarf mistletoe) with adequate cover and moss when attempting to provide suitable habitat for this threatened seabird. In addition, access variables, such as canopy layers and distance to edge (or other measures of flight space) should be addressed when managing habitat for murrelets. Several means for providing these characteristics, in the context of the managed forest, include: (1) using a variety of silvicultural treatments to create large platforms and clumps of platform trees. These treatments could include, for example, some thinning in currently unsuitable and unoccupied habitat to allow for large crown and platform creation, or inoculating patches of trees with dwarf mistletoe to create large limbs at younger tree ages; (2) selecting specific locations to locate future murrelet habitat, including along streams or in areas with suitable micro-climates for growth of abundant moss; and (3) creating new habitat in areas adjacent to existing murrelet nesting habitat. In addition, because our data indicated that murrelet nest densities appear to be very low, many or larger stands of suitable habitat will be necessary for providing for viable breeding populations of murrelets.

These suggestions seem simple and straightforward, however nest success will ultimately effect the suitability of sites for murrelet use. Unfortunately because of small sample sizes we were not able to provide information on the characteristics of successful and failed nests. However, there will be a trade-off in thinning projects, balancing the need to create murrelet platforms with future access to nests and nest success. The potential effects of habitat management on the risk of predation should be considered in any management projects. Therefore, we recommend that these management actions be completed as part of a long-term research project exploring the best means for creating suitable murrelet habitat. While conducting this research, data should be collected on the characteristics that provide for successful nesting (see research recommendations below), so the appropriate tree spacing and forest openings (those that minimize predation) can be provided.

We also believe the habitat management recommendations listed in the Marbled Murrelet Recovery Plan (USFWS 1997) should be considered when managing for murrelets and providing for viable populations, including: (1) maintaining all occupied sites; (2) maintaining other older-aged forests for recruitment habitat; (3) providing buffers to existing habitat to maintain its integrity and minimize predation; and (4) creating new habitat with characteristics similar to current nesting and occupied habitat, and in areas adjacent to existing murrelet habitat. This would not only allow for larger blocks of murrelet habitat but also provide buffers to existing habitat and potentially allow murrelets to expand into the newly created habitat. Murrelets appear to have high site fidelity (Hamer and Nelson 1995) and there is no evidence they will move across the landscape into newly created sites.

Some biases in the study design and field methods limit the inferences that can be made with these data. First of all, we randomly selected stands for tree climbing from the pool of known occupied sites, and this pool of sites was primarily biased by the location of proposed timber sales. Second, some of our tree climbing methods were biased. And third, our sampling within each forest did not completely cover the range of conditions in which murrelets were nesting (e.g., very little if any sampling was done in stands with limited densities of platform trees). These biases have implications for the inferences we can make from our data; basically they apply only to the areas where we conducted the sampling and should be applied with caution to other areas in western Oregon, outside Oregon, or other ODF ownerships.

Based on this study, we recommend that additional murrelet research in Oregon and elsewhere be conducted to: (1) determine the importance of moss depth, canopy layers, and distance to edge on the probability of murrelet nesting; (2) explore the relationship between murrelet nest success and platform, tree and site characteristics; (3) determine the trade-off between murrelet access to nesting areas and rates of predation; and (4) explore the effects of year to year conditions in the marine environment on Marbled Murrelet nest success. Because this study focused on the within-stand characteristics of Marbled Murrelet nest sites, additional murrelet research should also be conducted to explore murrelet habitat relationships at the landscape and geographic scales.

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Appendix 1. Structure and characteristics of study sites on the Clatsop State Forest, including fire and management history.

Study Site	Abundant Cohort Tree Age	Nest Tree Ages (*n*=3)	Site Description	Last Fire	Management History
Ebsen Road	60 - 78+	90+, 90+, 90+	young stand of WH with DF, SS, RA[a] and remnant trees	?	Clear-cut in the 1930's; commercial thinning in 1976; trees left behind in logging; natural regeneration
Lost Creek Headwaters	50-65+	n/a	mixed age mature stand of WH with DF, SS, RA[a], and remnant trees	?	Clear-cut in the 1940's; some WH left behind in logging; natural regeneration

[a] WH = western hemlock, DF = Douglas-fir, SS = Sitka spruce, RA = red alder.

Appendix 2. Structure and characteristics of study sites on the Tillamook State Forest, including fire and management history.

Study Site	Abundant Cohort Tree Age	Nest Tree Ages (n = 23)	Site Description	Last Fire	Management History
Big Rackheap	100	97, 107, 117, 124, 132, 142, 146, 150, 213, 232	mature hemlock stand with a few scattered individual remnant trees	1800's	logged 1900-1910; 1954 high grading; trees left behind in fires and logging; natural regeneration
Bearly Rackheap	90	85, 210, 400+	mature hemlock stand with individual scattered remnant trees	1800's	logged 1900-1910; 1954 high grading; trees left behind in fires and logging; natural regeneration
Coal Creek	70	145	young DF[a] stand with a few patches of residual WH[a] trees (nest was in one of these patches)	1800's	logged 1930 (high grading); partially thinned in 1978; trees left behind in fires and logging; natural regeneration
County Line	67-74	n/a	mixed age mature stand of WH with DF, SS, RA[a], and remnant trees	late 1800's	logged late 1920's or early 1930's; natural regeneration; stand improvements in 1980's
Crystal Barn	68 [b] 143-166 [c]	n/a	mature stand dominated by DF[a] on upper slope and SS and WH[a] on lower slope	early 1900's	lower slope high graded in early 1930's; natural regeneration

Appendix 2 cont. Structure and characteristics of study sites on the Tillamook State Forest, including fire and management history.

Study Site	Abundant Cohort Tree Age	Nest Tree Ages (n = 23)	Site Description	Last Fire	Management History
Helloff	45-85	n/a	mixed young and mature of WH stand with some DF and RA[a]. Remnant trees present.	1890-1914	some salvage logging after fire; natural regeneration; commercial thinning in 1970's
Jacoby Patterson	77-88	n/a	mixed young and mature stand of WH with DF, SS, RA[a], and remnant trees	1890-1910	natural regeneration; commercial thinning in late 1960's
Low Simmons	65-92	66, 131	young hemlock stand with scattered remnant trees; RA[a] dominant	1800's	High graded around 1930; natural regeneration
North Rector	80-110	80, 86, 107 [d]	large mature stand with few remnant trees	1890	1880 wind throw area; trees left behind in fires; natural regeneration; thinned 1972
Stuart Creek	161-175	n/a	mature stand of WH and RA[a] with some RC, DF and SS	1850-early 1900's	natural regeneration no known management

[a] WH = western hemlock, DF = Douglas fir, SS = Sitka spruce, RC = western redcedar, RA = red alder.
[b] on lower slope; [c] on upper slope; [d] 5 nests in this tree.

Appendix 3. Structure and characteristics of study sites on the Elliott State Forest, including fire and management history.

Study Site	Abundant Cohort Tree Age	Nest Tree Ages[a] (n = 11)	Site Description	Last Fire	Management History
Elk Creek	132-230+	216	mixed age mature stand with remnant trees	1868	commercial thinning in 1960's
Elk Pass	145	n/a	mixed age mature stand with remnant trees	1770	commercial thinning in late 1960's
Goody Ridge	127	n/a	mixed age mature stand of DF with WH and BM[b] in understory	1868	no management
Joe Buck	132-150	150	small patch of large trees in mixed age mature stand	1868	no management in patch; adjacent to clearcut
Knife Bend	120	n/a	mixed age mature stand with remnant trees	1868	commercial thinning in 1970's
Knife Otter	132-225+	135, 165, 152	mixed age mature stand with remnant trees	1868	no logging; some thinning
Lower Fish	230+	230+	small patch old-growth which survived the 1868 fire	1770	no management in patch; adjacent to corridor thinning
No Name	137	n/a	mature stand of DF and WH; riparian area	1868	no management

Appendix 3 cont. Structure and characteristics of study sites on the Elliott State Forest, including fire and management history.

Study Site	Abundant Cohort Tree Age	Nest Tree Ages[a] (n = 11)	Site Description	Last Fire	Management History
Panther Elk	132-230+	363	mixed age mature stand with remnant trees	1868	thinning in 1960's
Salander Headwaters	126	n/a	old-growth stand of DF[b]	1868	thinning in mid 1970's
Schumacher Creek	115	n/a	mature stand of DF with remnant trees	1868	thinning in mid 1970's
Silver Beaver	132-225+	270	mixed age mature with many remnant trees	1868	no logging; some thinning
Silver Creek	230+	250, 260, 289	large old-growth stand	1770	mortality salvage in 1960's
South Panther	120	n/a	mature stand of DF with WH and BM[b] in understory	1868	thinning in mid 1970's
South Umpcoos	123	n/a	mature stand of DF; riparian area	1868	thinning in mid 1970's

[a] Nest tree ages are extrapolated from 12 inch core samples.
[b] DF = Douglas fir, WH = western hemlock, BM = bigleaf maple.

Appendix 4. Study sites, year, and number of Marbled Murrelet nests by methods used for locating nests on the Clatsop, Tillamook and Elliott State forests, 1995-1999.

Site	Site #	Year	Plot #s	# of Nests (nest plot #)
Paired Climbing Plots				
<u>*Tillamook State Forest*</u>				
Bearly Rackheap [a]	101.0	1995	2,3	2 (1,2 [a])
Coal Creek [a]	10.0	1995	1,3	0
North Rector [a]	9.0	1995	1,3	0
<u>*Elliott State Forest*</u>				
Elk Creek	5.1	1995	1,2	0
Silver Beaver	6.1	1995	1,2	0
South Umpcoos	15.3	1995	1,2	0
Joe Buck	16.2	1995	1,2	0
Joe Buck	20.1	1995	1,2	0
Joe Buck	20.2	1995	1,2	0
Silver Creek	22.2	1995	1,2	3 (2)
Lower Fish	26.1	1995	1,2	0
Lower Fish	26.2	1995	1,2	0
Knife Bend [b]	27.2	1995	1,2	0
Schumacher Creek	29.1	1995	1,2	0
Elk Pass	31.1	1995	1,2	0
Elk Pass	31.2	1995	1,2	0
Elk Pass	39.1	1995	1,2	0
Panther Elk	41.2	1995	1,2	1 (1)
No Name [b]	70.1	1995	1,2	0
Lower Fish	81.1	1995	1,2	1 (1)
Lower Fish	81.2	1995	1,2	0
Intensive Climbing				
<u>*Tillamook State Forest*</u>				
Big Rackheap	100.0	1995	I-1 through 1-7 E-1,E-2,E-4,E-5	1 (E-2)
Grid Climbing				
<u>*Clatsop State Forest*</u>				
Ebsen Road	70.0	1997	11,30,43,53	2 (43,53)
Lost Creek Headwaters	1.0	1997	35,69,79,157	0
<u>*Tillamook State Forest*</u>				
Crystal Barn	108.0	1996	4,20,31,52	0
Low Simmons	105.0	1996	3,46,55,67	1 (3)
County Line	8.0	1997	36,68,77,99,126	0
Jacoby Patterson	103.0	1997	50,106,260,308	0
Helloff	18.0	1998	34,73,79,92	0
Stuart Creek	106.0	1998	5,12,14,19	0

Appendix 4 cont. Study sites, year, and number of Marbled Murrelet nests by methods used for locating nests on the Clatsop, Tillamook and Elliott State Forests, 1995-1999.

Site	Site #	Year	Plot #s	# of Nests (nest plot #)
Grid Climbing cont.				
Elliott State Forest				
Knife Otter	173.0	1996	2,6,8,9,19,21,30,45,54	2 (8,9)
Silver Beaver	6.1	1996	4,24,33,64,39,43,45,54,59,61	1 (59)
Salander Headwaters	282.0	1997	13,32,50,62	0
South Panther	703.0	1997	11,15,51,122	0
Goody Ridge	231.0	1997/98	4,17,30,38	0
Climbing in Areas of Bird Activity				
Tillamook State Forest				
Coal Creek	10.0	1995	n/a	1 (near 2)
North Rector	9.0	1995/1997	n/a	2/1
Low Simmons	105.0	1998	n/a	1
Elliott State Forest				
Joe Buck	20.1	1995	n/a	1 (near 1)
Forest Surveys [c]				
Tillamook State Forest				
North Rector	9.0	1997/1998	n/a	1/1 [d]
Big Rackheap	100.0	1997/1998	n/a	2/1
Bearly Rackheap	101.0	1998	n/a	1
Elliott State Forest				
Elk Creek	5.1	1995	n/a	1 (1)
Cluster Climbing Plots				
Clatsop State Forest				
Ebsen Road	70.0	1998	53(N,S,E,W,SE,NW)	1 (53E)
Tillamook State Forest				
Big Rackheap	100.0	1998	E2(S,W,SE,SW)	4 (SE,SW,S) [e]
Big Rackheap	100.0	1999	E2(SW,SSE,WSW,W)	2 (W, SW)
Low Simmons	105.0	1999	3(Center,SW,E,S,SE,W)	0
Elliott State Forest				
Silver Beaver	6.1	1998	59(S,W,NW,SW)	0
Knife Otter	173.0	1998	8(N,S,E,W,NW,SE,SW,NE)	1 (8SW)

[a] three plots were climbed in these sites. Plot 2 was not used in the analyses because their selection was not random. Plot 2 in the Bearly Rackheap site contained a nest which was used in the nest characteristics analysis.
[b] not known to be occupied, as no surveys were conducted or only presence/absence was recorded during surveys.
[c] nests found by observing bird behavior during forest surveys, not by tree climbing.
[d] two additional nests were found at this site in 1994.
[e] two nests were found in the southeast plot and one each in the southwest and south.

Appendix 5. Characteristics of Marbled Murrelet nest trees on the Tillamook and Elliott State Forests, 1994 and 1995.

Study Site	# Nests	Tree Species	Diameter (dbh, cm)	Height (m)	#Platforms
Tillamook State Forest					
North Rector 1994	2	WH [a]	108.0	47.7	21
		WH	89.4	50.0	4
North Rector 1995	1	WH [a]	108.0	47.7	21
Coal Creek	1	WH	124.0	42.0	9
Big Rackheap	1	WH	107.7	33.5	24
Bearly Rackheap	2	RC	177.0	47.1	15
		WH	76.0	39.3	14
Elliott State Forest					
Elk Creek	1	WH	94.0	46.2	22
Joe Buck	1	DF	119.0	66.4	12
Silver Creek	3	DF	126.1	71.1	17
		DF	177.6	85.1	8
		DF	119.5	75.3	42
Panther Elk	1	DF	161.5	64.9	9
Lower Fish	1	DF	212.5	76.3	24
Overall (x ± SE)	14	WH, DF, RC	134.2 ± 11.5	57.3 ± 4.6	17.0 ± 2.8

[a] Two nests in this tree.

Appendix 6. Characteristics of Marbled Murrelet nest trees on the Tillamook and Elliott State Forests, 1996.

Study Site	# Nests	Tree Species [a]	Diameter (dbh, cm)	Height (m)	# Platforms
Tillamook State Forest					
Low Simmons	1	WH	89.0	43.9	15
Elliott State Forest					
Silver Beaver #59	1	DF	118.9	57.2	36
Knife Otter #8	1	DF	113.0	52.0	60
Knife Otter #9	1	WH	97.6	47.2	63
Overall (x ± SE)	4	DF/WH	104.6 ± 6.9	50.1 ± 2.9	43.5 ± 11.3

[a] DF=Douglas-fir, WH=western hemlock

Appendix 7. Characteristics of Marbled Murrelet nest trees on the Clatsop and Tillamook State Forests, 1997.

Study Site	# of Nests	Tree Species [a]	Diameter (dbh, cm)	Height (m)	# Platforms
Clatsop State Forest					
Ebsen Road 43	1	WH	111.4	49.5	28
Ebsen Road 53	1	WH	131.0	45.1	28
Tillamook State Forest					
Big Rackheap 100.2 [b]	1	WH	91.1	36.3	29
Big Rackheap 100.3 [c]	1	SS	79.4	45.4	10
North Rector 9.4,5 [d]	2	WH	108.0	47.7	21
North Rector 9.6	1	WH	87.5	47.0	24
Overall ($x \pm SE$)	7	WH, SS	100.1 ± 9.4	44.7 ± 2.2	23.8 ± 3.6

[a] WH=western hemlock, DF=Douglas-fir, SS=Sitka spruce
[b] also known as Little Rackheap
[c] also known as Gods Valley West
[d] this tree has a total of 5 documented nests in it, but was only counted once for overall means.

Appendix 8. Characteristics of Marbled Murrelet nest trees on the Clatsop, Tillamook and Elliott State Forests, 1998.

Study Site	# of Nests	Tree Species [a]	Diameter (dbh, cm)	Height (m)	# Platforms
Clatsop State Forest					
Ebsen Road 53E	1	SS	168.0	55.7	71
Tillamook State Forest					
Big Rackheap 100.4	1	WH	142.3	50.3	42
Big Rackheap 100.5	1	WH	49.0	36.0	13
Big Rackheap 100.6	1	WH	60.5	33.8	13
Big Rackheap 100.7	1	WH	85.9	43.9	24
Big Rackheap 100.8 [b]	1	WH	104.2	46.3	12
Bearly Rackheap 101.3	1	WH	93.9	37.5	17
North Rector 9.7 [c]	1	WH	108.0	47.7	21
Low Simmons 105.2	1	WH	115.9	43.4	32
Elliott State Forest					
Knife Otter 8 SW	1	DF	146.3	65.1	92
Overall ($x \pm SE$)	10	WH, SS	107.3 ± 13.3	45.7 ± 3.4	35.1 ± 9.5

[a] WH=western hemlock, DF=Douglas-fir, SS=Sitka spruce
[b] also known as Little Rackheap
[c] this tree has a total of 5 documented nests in it, but was only counted once for overall means.

Appendix 9. Characteristics of Marbled Murrelet nest trees on the Tillamook State Forest, 1999.

Study Site	# of Nests	Tree Species [a]	Diameter (dbh, cm)	Height (m)	# Platforms
Tillamook State Forest					
Big Rackheap 100.9	1	WH	70.3	40.8	8
Big Rackheap 100.10	1	WH	131.7	48.0	29
Overall (x ± SE)	2	WH	101.0 ± 30.7	44.4 ± 3.6	18.5 ± 10.5

[a] WH=western hemlock

Appendix 10. Characteristics of Marbled Murrelet nest limbs on the Tillamook and Elliott State Forests, 1994 and 1995.

Study Site	# Nests	Limb Height (m)	Limb Diameter at Bole (cm)	Limb Diameter at Nest (cm)	Distance from Trunk (cm)	Cover (%)		Moss Depth (mm)	Moss (%)	Lichens (%)
						Vertical	Horizontal [a]			
Tillamook State Forest										
North Rector 1994	2	28.0 [b]	11.6	11.5-11.8	18.0	100	83	27 [c]	98	2
		13.6	14.3	20.1-31.1	153.7	85	53	76	100	0
North Rector 1995	1	27.3 [b]	15.9	14.1-14.7	26.0	95	80	9	95	1
Coal Creek	1	36.2	23.0	21.2-22.4	44.2	10	63	67	98	1
Big Rackheap	1	28.0	26.0	24.0-33.5	200.0	100	76	15	100	5
Bearly Rackheap	2	38.7	14.0	14.0-25.5	20.5	10	83	65	50	2
		15.3	36.0	36.0-42.0	13.5	70	43	30	90	2
Elliott State Forest										
Elk Creek	1	33.3	14.5	18.3-24.0	72.0	70	59	44	50	5
Joe Buck	1	17.0	22.0	22.0-30.0	43.0	10	63	40	60	10
Silver Creek	3	33.2	15.3	15.0-15.3	0.0	65	55	20	100	5
		38.7	21.3	14.3-16.0	214.0	40	100	30	90	10
		43.3	16.0	20.0-24.0	142.0	50	15	60	90	1
Panther Elk	1	45.3	23.0	?-29.0	201.0	100	35	80	70	15
Lower Fish	1	74.8	21.0	24.0-30.0	72.0	30	26	110	90	10
Overall (x ±SE)	14	33.8 ± 4.1	19.6 ± 1.7	21.6 - 25.0 ±2.1 - 2.3	80.0 ± 20.4	75.0 ± 6.7	55.3 ± 5.7	48.1 ± 7.8	84.4 ± 5.0	4.9 ± 1.2

[a] mean of all measurements taken.
[b] two nests in this tree.
[c] measurement taken in nest cup due to lack of moss immediately adjacent to the nest.

Appendix 11. Characteristics of Marbled Murrelet nest limbs on the Tillamook and Elliott State Forests, 1996.

Study Site	# Nests	Limb Height (m)	Limb Diameter at Bole (cm)	Limb Diameter at Nest (cm)	Distance from Trunk (cm)	Cover (%) Vertical	Cover (%) Horizontal [a]	Moss Depth (mm)	Moss (%)	Lichens (%)
Tillamook State Forest										
Low Simmons	1	17.8	16.5	26.6	36.0	100	80	20	90	1
Elliott State Forest										
Silver Beaver #59	1	36.7	17.0	22.0	62.0	25	56	40	90	20
Knife Otter #8	1	38.6	13.0	24.0	29.0	80	48	50	90	0
Knife Otter #9	1	21.2	13.5	13.0	162.0	100	33	30	98	2
Overall (x ± SE)	4	28.6 ± 5.3	15.0 ± 1.0	21.4 ± 3.0	72.3 ± 30.7	76.3 ± 17.7	54.3 ± 9.8	35.0 ± 6.5	92.0 ± 2.0	5.8 ± 4.8

[a] horizontal cover is mean of all measurements taken.

Appendix 12. Characteristics of Marbled Murrelet nest limbs on the Clatsop and Tillamook State Forests, 1997.

Study Site	# Nests	Limb Height (m)	Limb Diameter at Bole (cm)	Limb Diameter at Nest (cm)	Distance from Trunk (cm)	Cover (%) Vertical [a] (cover above nest) [b]	Cover (%) Horizontal [c]	Moss Depth (mm)	Moss (%)	Lichens (%)
Clatsop State Forest										
Ebsen Road 43	1	25.3	14	14	0	95 (40)	49.4	45	90	5
Ebsen Road 53	1	28.1	36.6	17	41	95 (5)	56.9	55	100	1
Tillamook State Forest										
Big Rackheap 100.2 [d]	1	9.9	20	25	227	100 (85)	62.5	7	40	0
Big Rackheap 100.3 [e]	1	13	11.6 [f]	24.7	350	100 (95)	20.6	41	45	0
North Rector 9.4	1	33.3	13 [f]	16.1	50	80 (40)	80	35	75	1
North Rector 9.5	1	34	12.2 [f]	19	144	95 (90)	75	55	80	1
North Rector 9.6	1	24.4	6.8 [f]	19 [f]	220	99 (15)	40.6	0	0	0
Overall (x ± SE)	8	23.7 ± 1.8	15.6 ± 1.8	19.6 ± 1.0	121.8 ± 21.5	95.1 ± 1.5	54.2 ± 4.9	45.0 ± 6.2	73.8 ± 6.6	2.1 ± 1.2

[a] Cover over nest regardless of height.
[b] Cover directly above the nest cup, in a 2 meter diameter circle, $\leq$2 meters vertical distance.
[c] Mean of all measurements taken.
[d] Also known as Little Rackheap.
[e] Also known as Gods Valley West.
[f] Measurement taken without moss.

Appendix 13. Characteristics of Marbled Murrelet nest limbs on the Clatsop, Tillamook and Elliott State Forests, 1998.

Study Site	# Nests	Limb Height (m)	Limb Diameter at Bole (cm)	Limb Diameter at Nest (cm)	Distance from Trunk (cm)	Cover (%) Vertical [a] (cover above nest) [b]	Cover (%) Horizontal [c]	Moss Depth (mm)	Moss (%)	Lichens (%)
Clatsop State Forest										
Ebsen Road 53E	1	26	18	16.5	30	80 (10)	31.3	55	100	1
Tillamook State Forest										
Big Rackheap 100.4	1	33.9	27	17	158	95 (65)	85	38	50	20
Big Rackheap 100.5	1	19	18.2	18.6	58	95 (40)	18.1	61	60	0
Big Rackheap 100.6	1	13.2	8.9	14.5	100	100 (65)	68.1	50	80	1
Big Rackheap 100.7	1	25.8	13.5 [d]	14.4	103	90 (45)	61.3	90	95	0
Big Rackheap 100.8 [e]	1	21	10.7 [d]	21.6 [d]	125	100 (75)	65	10	80	1
Bearly Rackheap 101.3	1	32.7	14.6	24	185	95 (65)	53.1	50	100	0
North Rector 9.7	1	21.0	7.4	26	40	100 (35)	70.6	40	80	1
Low Simmons 105.2	1	21.8	17.5	19.2	121	98 (50)	55	30	85	2
Elliott State Forest										
Knife Otter 8SW	1	19.9	14.5	27	113	99 (5)	28.8	100	95	1
Overall ($\bar{x} \pm$ SE)	10	23.4 ± 2.0	15.0 ± 1.8	19.9 ± 1.4	103.3 ± 15.6	95.2 ± 2.0	53.6 ± 6.7	48.5 ± 5.6	82.5 ± 5.3	2.7 ± 1.9

[a] Cover over nest regardless of height.
[b] Cover directly above the nest cup, in a 2 meter diameter circle, $\leq$ 2 meters vertical distance.
[c] Mean of all measurements taken.
[d] Measurement taken without moss
[e] Also known as Little Rackheap 1998.

Appendix 14. Characteristics of Marbled Murrelet nest limbs on the Tillamook State Forest, 1999.

Study Site	# Nests	Limb Height (m)	Limb Diameter at Bole (cm)	Limb Diameter at Nest (cm)	Distance from Trunk (cm)	Cover (%)		Moss Depth (mm)	Moss (%)	Lichens (%)
						Vertical [a] (cover above nest) [b]	Horizontal [c]			
Tillamook State Forest										
Big Rackheap E-2, 2W	1	27.3	14.2	18.3	33.0	100 (45)	77	85	47	15
Big Rackheap E-2, 2SW	1	31.4	12.2	16.4	14	80 (40)	56	30	100	0
Overall ($\bar{x}$ + SE)	2	29.4 $\pm$ 2.1	13.2 $\pm$ 1.0	17.4 $\pm$ 1.0	23.5 $\pm$ 9.5	90.0 $\pm$ 10.0	66.5 $\pm$ 10.5	19.3 $\pm$ 10.8	73.5 $\pm$ 26.5	7.5 $\pm$ 7.5

[a] Cover over nest regardless of height.
[b] Cover directly above the nest cup, in a 2 meter diameter circle, $\leq$ 2 meters vertical distance.
[c] Mean of all measurements taken.

Appendix 15. Dates and outcomes of surveys conducted on the Tillamook and Elliott State Forests, 1995.

Study Site	Site #	Date	Observer [a]	Plot/Location	Behavior: Presence (# visual)	Behavior: Circling	Behavior: Below Canopy	Total # of Detections
Tillamook State Forest								
North Rector	9.0	7/26	AKW/SKH	on road at nests	21 (4)	0	13	34
			SKH	2	0	0	0	0 [b]
		7/27	AKW	at nests	9 (0)	0	8	17
			SKH	at nests	9 (3)	0	4	13
			SKN	at nests	4 (0)	0	7	11
		7/28	AKW	at nests	13 (0)	0	16	29
			SKH	at nests	11 (0)	0	1	12
Coal Creek	10.0	7/12	AKW	near 1	21 (0)	0	0	21 [b]
			SKH	at nest	41 (0)	0	0	41
		8/02	AKW	near 1	125 (0)	0	0	125
			SKH	at nest	104 (7)	2	0	106
Big Rackheap	100.0	6/22	AKW	I-1 (center)	42 (3)	0	0	42
			SKH	I-2	32 (4)	0	0	32
		6/23	AKW	I-1	33 (7)	0	2	35
			SKH	bet I-1 and I-3	28 (1)	0	0	28
		7/06	AKW	I-1 (edge)	57 (3)	0	5	62
			SKH	bet I-1 and I-3	49 (1)	3	0	52
		7/13	AKW	I-1	103 (8)	0	12	115
			SKH	bet I-1 and I-3	76 (0)	0	0	76
			SKN	bet I-1 and I-3	62 (3)	2	2	66
		7/24	AKW	bet I-1 and I-3	103 (2)	0	0	103
			SKH	bet I-1 and I-3	110 (0)	0	0	110
		7/25	AKW	bet I-1 and I-3 (on creek)	66 (0)	0	3	69
			SKH	bet I-1 and I-3	109 (1)	0	0	109
		8/01	AKW	E-2 (center)	55 (0)	0	0	55
			SKH	E-2 (nest)	50 (0)	0	0	50
		8/04	AKW	E-2 (center)	28 (0)	0	0	28
			SKH	E-2 (nest)	16 (0)	0	0	16

Appendix 15, cont. Dates and outcomes of surveys conducted on the Tillamook and Elliott State Forests, 1995.

Study Site	Site #	Date	Observer [a]	Plot/Location	Behavior: Presence (# visual)	Behavior: Circling	Behavior: Below Canopy	Total # of Detections
Tillamook State Forest, cont.								
Bearly Rackheap	101.1	7/07	AKW	1 (near nest)	19 (0)	0	4	23
			MAW	1 (near creek)	11 (0)	0	11	22
		7/10	AKW	1 (across creek)	17 (0)	0	5	22
			SKH	1 (nest)	21 (0)	0	0	21
		7/11	AKW	2 (nest)	37 (6)	0	4	41
			SKH	2	29 (3)	1	1	31
		7/31	AKW	2 (nest)	11 (0)	0	0	11
			SKH	2	12 (1)	0	3	15
		8/03	AKW	2 (nest)	38 (0)	0	0	38
			SKH	2	41 (0)	0	1	42
Elliott State Forest								
Elk Creek	5.1	8/07	AKW	at nest	2 (0)	0	3	5
			SKH	at nest	1 (0)	0	3	4
			SKN	at nest	0	0	3	3
		8/08	AKW	at nest	0	0	0	0
			KMJ	at nest	0	0	3	3
		8/08pm	SKN	at nest	0	0	5	5
		8/09	SKN	at nest	7 (1)	0	4	11
		8/10	AKW	at nest	0	0	1	1
			SKH	at nest	0	0	3	3
		8/11	AKW	at nest	0	0	2	2
		8/12pm	SKN	at nest	2 (0)	0	2	4
		8/13	SKN	at nest	1 (0)	0	2	3
		8/14	AKW/SKH	at nest	2 (0)	0	2	4
		8/16	AKW/SKH	at nest	0	0	4	4

Appendix 15, cont. Dates and outcomes of surveys conducted on the Tillamook and Elliott State Forests, 1995.

Study Site	Site #	Date	Observer [a]	Plot/Location	Behavior: Presence (# visual)	Behavior: Circling	Behavior: Below Canopy	Total # of Detections
Elliott State Forest, cont.								
Elk Creek, cont.	5.1	8/16pm	AKW	near nest, on road	0	0	4	4
			SKH	at nest	0	0	4	4
		8/17	AKW/SKH	at nest	0	0	4	4
		8/17pm	AKW/SKH	at nest and on road	0	0	2	2
		8/18	AKW/SKH	at nest and on road	0	0	6	6
		8/19pm	SKH/KMJ	at nest and on road	0	0	0	0
Silver Beaver	6.1	6/28	AKW	on road [c]	0	0	0	0
			SKH	on road	0	0	0	0
Joe Buck	20.1	7/18	AKW	1 (nest)	1 (0)	0	0	1
			SKH	on river, near 20.2 plot 1	1 (0)	1	2	4
Silver Creek	22.2	7/21	AKW	2 (by nest 1)	3 (3)	0	6	9
			SKH	2 (by nests 2 and 3)	0	0	0	0
Lower Fish	26.1	7/17	AKW	across river from plot 1	2 (0)	0	0	2
			SKH	on road [c]	2 (0)	0	0	2
Elk Pass	31.2	6/27	AKW	on road above 1	0	0	0	0
			SKH	on road above 2	0	0	0	0
Panther Elk	41.2	6/30	AKW	1 (across creek from nest)	0	0	0	0
			SKH	1 (nest)	0	0	0	0
Lower Fish	81.1	6/29	AKW	on road below 1	0	0	0	0
			SKH	on road below 2 [d]	0	0	0	0

[a] AKW = Amanda K. Wilson (formerly A.K. Hubbard); SKH = Stephanie K. Hughes; SKN = S. Kim Nelson; MAW = Michael A. Wilson; KMJ = Kevin M. Jordan.
[b] survey incomplete; stopped before official end time because of weather, tape malfunction, or other factors.
[c] surveyed from station that Robert Fields reported seeing single, silent, murrelet.
[d] surveyed from station that ODF observer reported seeing single, silent, murrelet coming out of stand.

Appendix 16. Dates and outcomes of surveys conducted on the Elliott State Forest, 1996.

Study Site	Site #	Date	Observer [a]	Plot/Location	Behavior: Presence (# visual)	Behavior: Circling	Behavior: Below Canopy	Total # of Detections
Silver Beaver	6.1	7/01	AKW	54/cutbank above road	0	0	0	0
			SKH	59/on road by nest	0	0	0	0
		7/08	AKW	45/west side of drainage	0	0	0	0
			SKH	45/east side of drainage	0	0	0	0
		7/24	AKW	54/cutbank above road	0	0	0	0
			SKH	59/on road by nest tree	0	0	0	0
Elk Creek	5.1	7/02	AKW	1/west on nest @ marsh	0	0	0	0
			SKH	1/road below nest	0	0	0	0
		7/17	AKW	1/road below nest	2	0	0	2
			SKH	1/west of nest @ marsh	0	0	13	13
		7/18	AKW	9040 rd. above marsh	1	0	0	0
			SKH	1/west of nest @ marsh	0	0	15	15
		7/19	AKW	1/on Elk Creek, below nest	0	0	0	0
			SKH	1/road below nest tree	0	0	0	0
		7/26	AKW	1/west of nest @ marsh	1	0	15	16
			SKH	1/road below nest tree	6	0	18	24
		7/29	AKW	1/west of nest @ marsh	8	0	32	40
			SKH	1/road below nest tree	19	0	30	49
		8/01	SKH	1/north of nest tree in site	1	0	1	2
		8/02	SKH	1/west of nest @ marsh	4	0	7	11
		8/05	AKW	1/west of nest @ marsh	0	0	0	0
			SKH	1/road below nest tree	0	0	0	0
		8/06	AKW	1/road below nest tree	0	0	0	0
Knife Otter	173.0	7/03	AKW	8/in site by nest tree	0	0	0	0
			SKH	9/ at nest tree	0	0	0	0
		7/22	AKW	6/jct. of 8000 & 7200 roads	0	0	0	0
		7/31	AKW	6/jct. of 8000 & 7200 roads	0	0	0	0
			SKH	6/w. fk. Millicoma and Knife Cr.	0	0	0	0

Appendix 16, cont. Dates and outcomes of surveys conducted on the Elliott State Forest, 1996.

Study Site	Site #	Date	Observer [a]	Plot/Location	Behavior: Presence (# visual)	Behavior: Circling	Behavior: Below Canopy	Total # of Detections
Silver Creek	22.2	7/09	AKW	2/by nest 1	0	0	0	0
			SKH	2/by nests 2 and 3	0	0	0	0
Lower Fish	26.1	7/10	AKW	1/on w.fk. Millicoma River	0	0	2	2
			SKH	1/on road	0	0	2	2
		7/15	AKW	1/on w.fk. Millicoma River	0	0	1	1
			SKH	1/on road	0	0	1	1
		7/16	AKW	on road between 26.1-26.2	0	0	0	0
			SKH	1/on road	0	0	0	0
		7/23	AKW	1/on w.fk. Millicoma River	1	0	0	1
			SKH	1/on road	1	0	0	1
		7/30	AKW	1/on w.fk. Millicoma River	0	0	0	0
			SKH	1/on road	0	0	0	0
Lower Fish	81.1	7/11	AKW	1/on Fish Creek	0	0	0	0
			SKH	1/on road, north of plot	0	0	0	0
		7/25	SKH	w.fk. Millicoma and Fish Cr.	0	0	0	0
Joe Buck	20.2	7/12	AKW	1/w.fk. Millicoma and Buck Cr.	0	0	0	0
No Name	70.1	7/25	AKW	1/on road	0	0	0	0

[a] AKW = Amanda K. Wilson (formerly A.K. Hubbard); SKH = Stephanie K. Hughes

Appendix 17. Dates and outcomes of surveys conducted on the Clatsop, Tillamook and Elliott State Forests, 1997.[a]

Study Site	Site #	Date	Observer [a]	Plot/Station	Behavior: Presence (# visual)	Behavior: Circling	Behavior: Below Canopy	Total # of Detections
Clatsop State Forest								
Ebsen Road	70.0	5/14 6/9 7/2,15	AKW, DDG, KHA, MAW, SKF	53/1,3,4 43/4,5	0	0	0	0
Tillamook State Forest								
Bearly Rackheap	101.0	5/19,22,23 6/16-20 7/8,9,16,29,30,31 8/4	AKW, DDG, KHA, SKF	1/1,2 2/1-10,12-15	381 (18)	2	93	476
Big Rackheap	100.0	5/15,20,23,26-28 6/10,11,18,21,27,28,30 7/15-17,22,24,28,30,31 8/6-8,12-14,19	AKW, DBB, DDG, KHA, MAW, SKF	I1/1,2; I2/1,3 I3/1; E2/1,2 100.2 [c]/1,2 100.3 [d]/3-9,11	422 (37)	9	118	549
Coal Creek	10.0	5/13 6/13 8/15	AKW, DDG, KHA, SKF	Stations 1-4	0	0	0	0
County Line	8.0	7/18	AKW	Station 1	1	0	0	0
Low Simmons	105.0	5/14 7/1,7,29 8/5	AKW, DDG, KHA, SKF	Stations 1-4	2 (1)	0	6	8
North Rector	9.0	5/6 6/9-12 7/3,10,11,14,16-18, 21,23-25 8/1,14	AKW, DBB DDG, KHA, MAW, SKF	Stations 1-3, 5-12, 15-22	588 (10)	5	152	745

Appendix 17, cont. Dates and outcomes of surveys conducted on the Clatsop, Tillamook and Elliott State Forests, 1997.[a]

Study Site	Site #	Date	Observer [a]	Plot/Station	Behavior: Presence (# visual)	Behavior: Circling	Behavior: Below Canopy	Total # of Detections
Elliott State Forest								
Elk Creek	5.1	5/29 6/3,25 7/24,25	DDG, KHA, SKF	Stations 1,3,4,5	6 (0)	0	28	34
Elk Pass	31.1	6/25	KHA	Station 1	0	0	0	0
Joe Buck	16.2	6/24	DDG	Station 1	0	0	0	0
Joe Buck	20.1	6/26	DDG, KHA	Station 1,2	0	0	1	1
Knife Otter	173.0	5/28 6/23,24 7/21	DDG, KHA, SKF	Stations 1-4	3 (1)	0	1	4
Lower Fish	81.1	5/30 6/6,23	DDG, SKF	Stations 1,2	0	0	0	0
Panther Elk	41.2	6/5,26	DDG, SKF	1/1,4	0	0	0	0
Silver Beaver	6.1	6/2,27 7/23	DDG, KHA SKF	Stations 1,3	0	0	0	0
Silver Creek	22.2	6/4,27 7/22	DDG, KHA SKF	2/1,2	0	0	0	0

[a] Due to the large number of surveys done, a summation of each site is presented.
[b] AKW = Amanda K. Wilson, DBB = David B. Buchholz, DDG = Diane D. Gilbert, KHA = Kimberly H. Augenfeld, MAW = Michael A. Wilson, SKF = Suzanne K. Freeman.
[c] 100.2 is the nest site referred to as Little Rackheap, 1997.
[d] 100.3 is the nest site referred to as Gods Valley West.

Appendix 18. Dates and outcomes of surveys conducted on the Clatsop, Tillamook and Elliott State Forests, 1998.[a]

Study Site	Site #	Date	Observer [b]	Plot/Station	Behavior: Presence (# visual)	Behavior: Circling	Behavior: Below Canopy	Total # of Detections
Clatsop State Forest								
Ebsen Road	70.0	5/20 6/9	KJC, NRK, SKF	43/5 53/1,4	0	0	0	0
Tillamook State Forest								
Bearly Rackheap	101.0	5/18,29 6/4,12,22,26,29 7/7,9,13-16,18,19, 24,25,27,28,31 8/2,11	CRK, DBB, DPM, KAC KJC,NRK RAB,RAH, SKF	1/1-7 2/1-3, 7-9, 30, 31,40	1166 (60)	7	132	1305
Big Rackheap	100.0	5/12,19,21,29 6/1-3,8,12,15 7/1,6,17,21-24,27-31 8/3,4,6,10	CRK, DPM, KJC, NRK, SKF	I1/1,4 I2/1-3,4,5,7 E2/1-6,8,10 100.2 [c]/1-3,5,6,9 100.3 [d]/3,4,7,15,20,21	491 (53)	7	162	660
Coal Creek	10.0	5/26,27 6/5 7/20 8/5	DPM, KJC, NRK, SKF	Stations 1-8	82 (4)	0	57	139
Low Simmons	105.0	5/28 6/23,26,27 7/3,7 8/11,22	DBB, DPM, KHA, KJC, NRK, SKF	Stations 1-5, 8-10	2 (2)	0	10	12
North Rector	9.0	5/13-15,22,25,30 6/10,11,16-20,24,28,30 7/8,10 8/4	DBB, DPM, KJC, NRK, SKF	Stations 1,2, 7-9,11,13,25-28, 31-38,40	599 (25)	4	145	748

Appendix 18, cont. Dates and outcomes of surveys conducted on the Clatsop, Tillamook and Elliott State Forests, 1998.[a]

Study Site	Site #	Date	Observer [b]	Plot/Station	Behavior: Presence (# visual)	Behavior: Circling	Behavior: Below Canopy	Total # of Detections
Elliott State Forest								
Elk Creek	5.1	6/5,18,25 7/2,17,23,24,30,31 8/6,7,10-12,14,18	CRK, KAC, RAB, RAH, RER, SJW	Stations 1-8	92 (17)	9	118	219
Joe Buck	20.1	6/4 7/2,8,22 8/7	CRK, RAB, REF, RER, SJW	Stations 1,2	0	0	0	0
Knife Otter	173.0	5/18 6/12,26 7/15,24	KAC, RAB, RAH, RER	Stations 1-5	0	0	0	0
Lower Fish	81.1	5/18 6/9,19 7/2,7,15,24	CRK, KAC, RAH, RER	Stations 1,2	3 (0)	0	0	3
Panther Elk	41.2	6/5,19,26 7/8,24	KAC, RAB, RAH, RER	Stations 3-6	1 (0)	0	0	1
Silver Beaver	6.1	5/28 6/11,18,25 7/6,12,23	CRK, KAC, RAB, RAH, RER	Stations 1-3	5 (0)	0	5	10
Silver Creek	22.2	5/28 6/12,25 7/12 8/6	KAC, RAH RER, SJW	2/1-3	0	0	0	0
Alder Fork	42.0	5/12,14,19,22,26,27 6/2,3,9,10,15-17,24,29 7/1,14,20-22,27-29 8/3-5	CRK, KAC RAB, RAH RER, SJW	10/3,6,7,12,13 11/2,3,15 12/4,5,14,11 13/8,14; 14/1,9,10,14	4 (0)	0	0	4

Appendix 18, cont. Dates and outcomes of surveys conducted on the Clatsop, Tillamook and Elliott State Forests, 1998.[a]

Study Site	Site #	Date	Observer [b]	Plot/Station	Behavior			Total # of Detections
					Presence (# visual)	Circling	Below Canopy	
Elliott State Forest cont.								
Larson Creek	66.0	5/13,14,22,27 6/1,3,8,10,15-17,29,30 7/7,10,16,19,27,28 8/4,5	KAC, RAH	6/4,5,7 7/8-11 8/3,10 9/1,2,6	13 (0)	1	0	14
Palouse Creek	99.0	5/13,20,21 6/4,11,22,30 7/9,16,23,30	CRK, KAC, RAB, RAH RER, SJW	4/2,3,7 5/1,4,5,8,9	52 (3)	0	2	54
Roberts Creek	2.0	5/12,19,22,26 6/1,8,15,16,23 7/1,10,17,29 8/5,6	CRK, KAC RAB, RAH, RER, SJW	1/1,2,5,10,13 2/3,4,7,9,14 3/6,8,11,12,14	3 (1)	0	0	3

[a] Due to the large number of surveys done, a summation of each site is presented.
[b] CRK = Christopher R. Knauf, DBB = David B. Buchholz, DPM = David P. McCarthy, KAC = Karen A. Cradler, KHA = Kimberly H. Augenfeld, KJC = Kristen J. Charleton, NRK = Nikki R. Krocker, RAB = R. Alan Bates, RAH = Ross A. Hubbard, RER = Raymond E. Rainbolt, SJW = Stephen J. Williamson, SKF = Suzanne K. Freeman
[c] 100.2 is the area referred to as Little Rackheap.
[d] 100.3 is the nest site referred to as Gods Valley West.

Appendix 19. Dates and outcomes of surveys conducted on the Clatsop and Tillamook State Forests, 1999.[a]

Study Site	Site #	Date	Observer [b]	Plot/Station	Behavior			Total # of Detections
					Presence (# visual)	Circling	Below Canopy	
Clatsop State Forest								
Ebsen Road	70.0	5/12,19,26 6/3,29 8/2	CRK, DPM, KAC, RAH, RER	Station 1,4,5	0	0	0	0
Tillamook State Forest								
Bearly Rackheap	101.0	5/6,10,18,25 6/2,8,9,15,17,22-25,30 7/2,6-10,12,14,23,24,26 8/10,11,23	CRK, DPM, KAC, RAH, RER	Stations 1-9,12-15, 17,18,29-34,36	401 (23)	21	67	489
Big Rackheap	100.0	5/10,11,13,14,17,18,20, 21,24,25 6/1,4,5,7,10,11,14,16,18, 19,21,23,28 7/1,3,13,15,16,19,20,23, 25-30 8/1-5,9-11,16-18,20	CRK, DPM KAC, RAH, RER	Stations 1-5, 7 E2/1-5,7,11-13 I2/1,2,4,7,8 100.3 [c]/3,5-7, 9,10,12,14,15 100.2 [d]/1-3,5,6,8-17	428 (52)	28	125	581
Coal Creek	10.0	5/7,17,22,27 7/16,17,21,22,24,30 8/6,12	CRK, DPM, KAC, RAH, RER	Stations 1-4, 7-9 Coal Creek North/ 1-5	36 (13)	12	97	145
Low Simmons	105.0	5/12,19,26 6/3,22,29 7/3,7,31 8/14	CRK, DPM KAC, RAH	Stations 1-5	12 (1)	3	6	21
North Rector	9.0	5/11,20,27 6/2,11,28 7/19,29 8/13	CRK, DPM, KAC, RAH	Stations 1,2,7,26, 28,35	5 (0)	0	1	6

[a] Due to the large number of surveys done, a summation of each site is presented.
[b] CRK = Christopher R. Knauf, DPM = David P. McCarthy, KAC = Karen A. Cradler, RAH = Ross A. Hubbard, RER = Raymond E. Rainbolt
[c] 100.2 is the area referred to as Little Rackheap.
[d] 100.3 is the nest site referred to as Gods Valley West.