Recommendations and Supporting Analysis of Conservation Opportunities for the Marbled Murrelet Long-Term Conservation Strategy

○ March 2008 (V.8.0) Errata ○

The March 2008 version of the report has been replaced with the September 2008 final version.

- Update your printed March versions into final September versions by *inserting the updated pages in this errata document into your printed March report*.
- This errata document is a compilation of only those pages that have changed since the March 2008 version. Tables 1, 2, and 3 (below) summarize these changes.

Table 1. New additions included in the September 2008 Science Team Report.

Added to the report:	**Inserted pages:**
Chapter 6	Added whole chapter
Appendix H	Added whole appendix

Table 2. Summary of revisions to the March 2008 Science Team Report which turned it into the September 2008 final report.

Updated:	**Updated page numbers:**
Title page,	-
Summary of Recommendations	A
Table of Contents	iii, v, x
Executive Summary	19, 36, 37
Chapter 1	7
Chapter 2	2, 34, 36, 37, 38
Chapter 3	10, 17, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 40, 41, 43, 45, 47, 49, 51, 52, 54, 55, 56, 58, 60, 61
Chapter 4	5, 8, 15, 16, 17, 18, 19
Chapter 5	15
Chapter 7	7,9,16
Appendix D	1, 2

Table 3. Detailed Science Team Report issues and a description of how these issues were addressed.

Issue	Location in report	Solution	# of pages
Updated numbers	SOR A	Changed 177,000 to 176,000; 57,000 to 55,000.	1
Revise title page and table of contents	title page iii v x	• Updated cover page with new date • Updated chapter 6 section of table of contents • Updated appendix H title in table of contents • Updated list of tables with table 6-1	4
Updated number	ES-19	Updated 116,800 to 118,000 per table ES-2	1
Used the word "prediction" in Summary	ES-36	Changed to projection	1
Text below figure caption is in arial font	ES-37	Changed font to times new roman	1
Table in middle of page	1-7	Reformatted table to top of page	1
Need to replace photo (fig 2.1)	2-2	Replaced Karlson photo with Barna photo which we bought. Updated caption to show photo credit (Photo by Aaron Barna Photography)	
Malt 2007 is an unpublished masters dissertation	2-34, 2-36, 2-37, 2-38, 4-17, 4-18	Cited the published article: Malt and Lank 2007.	6
Missing piece of information	3-10	Added a sentence to paragraph two	1
Websites inconsistently in blue and black font	3-15, 4-8	Made font black and de-underlined	2
Updated numbers for Table 3-13	3-58	Changed: • Goodman Creek Marbled Murrelet from 5774 to 577 • Kalaloch Occupied from 2327 to 2255 and updated Grand Total • Kalaloch Not Occupied Old Forest from 219 to 291 and updated Grand Total	1
OESF maps are missing yellow on all but two maps	Pages 3-: 40, 41*, 43, 45, 47*, 49, 51, 52, 54,	• Replaced maps in the report. • Also: 3-58 (updated 116,800 to 118,000 per table ES-2; changed 5774 to 577 in table 3-13)	11 already counted

Issue	Location in report	Solution	# of pages
	55*, 56*, 58	* = updated these maps per one revised OESF polygon.	p 3-58
SWWA and Straits maps are based on incorrect data because when murr planning and policy were merged a reconciling step was missed, thus making the MMMAs bigger than they actually are. Update numbers in the text next to the maps (tables are fine).	Pages 3-: 17, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 60, 61	Data was corrected April 2008, maps were updated. Updated MMMA acres on the followingpages: • 3-17 (changed 63,737 to 63,471; 25,793 to 25,686; 2,659 to 2,552; 1,076 to 1,033) • 3-20 (649 to 646; 263 to 262) • 3-23 (498 to 491; 202 to 199) • 3-26 (13,385 to 13,763; 5,417 to 5,570; 452 to 317; 183 to 128)	15
Ppa should be ppa	4-5	Table 4-1: de-capitalizes row two "P" in ppa	1
Add reference to Appendix H	4-15, 4-16, 4-18, 4-19, 5-15	• Added a sentence to the end of the first paragraph in section 4.7, to Table 4-4, and to the end of sections 4.8 and 4.10. • 5-15 Deleted footnote and inserted sensitivity analysis appendix information in introductory paragraph	5
Update literature cited	7-7, 7-9, 7-16	• 7-16 Deleted double citation of Malt 2007 (stuck in the Mahon citation). Replaced Malt 2007 with Malt and Lank 2007 • 7-9 Added Ford 2000 citation from chapter 6 • 7-7 Added Chatterjee and Hadi 1998 citation from appendix (H)	3
Revise Appendix D	D-1, D-2	Added to the intro, added a concluding paragraph	2
		Total pages replaced	*56*

Recommendations and Supporting Analysis of Conservation Opportunities for the Marbled Murrelet Long-Term Conservation Strategy

Prepared for:
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Hamer Environmental, L.P.
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and
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September 2008

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SUMMARY OF RECOMMENDATIONS

The Science Team reviewed the objectives for the marbled murrelet conservation strategy in the Washington Department of Natural Resources' 1997 Habitat Conservation Plan (HCP). From these commitments, the Team identified the biological goals for the Long-Term Conservation Strategy to be to manage forest habitat to contribute to 1) a stable or increasing population; 2) an increasing geographic distribution; and 3) a population that is resilient to disturbance.

The Science Team recommends that DNR manage 176,000 acres of DNR-managed lands on the Olympic Peninsula and in Southwest Washington for the development and maintenance of high-quality nesting habitat for the marbled murrelet. The Science Team uses the term "high-quality nesting habitat" to denote nesting habitat that has the highest likelihood of supporting successfully reproductive marbled murrelets in a landscape. Such habitat is characterized by the Science Team as forest stands that 1) have very large, tall trees with broad, deep crowns that support potential nest platforms; 2) have multiple canopy layers and canopy gaps, and; 3) are situated within a secure landscape that minimizes predation and allows for the successful fledging of young. The Team recommends that identified areas be actively managed through silviculture, emphasizing the goal of habitat development.

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Throughout the area of the proposed Long-Term Conservation Strategy, the Science Team recommends that DNR defer all sites currently identified as occupied (55,000 acres) from harvest for the duration of the HCP.

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The Science Team proposes distinct landscape approaches for the Southwest Washington, Olympic Experimental State Forest and Straits Analysis Units. In Southwest Washington, nine landscapes comprising 66,000 acres are identified where specific "marbled murrelet management areas" (MMMAs) are delineated. Those MMMAs are found in the Salmon Creek, Skamokawa, Browning, Elochoman, Chehalis, Grays, Humptulips, Nemah and Lebam blocks. Within each MMMA, 100 percent of the area is recommended to be managed with the goal of creating high-quality nesting habitat.

In the Olympic Experimental State Forest (OESF), recommended conservation emphasis differs among the 11 landscape planning units (LPUs). The greatest emphasis on conservation is placed in the Dickodochtedor, Goodman Creek, and Kalaloch LPUs, where 39,000 acres are delineated into MMMAs that will be managed to achieve and maintain at least 50 percent of those areas as

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4. ***Emphasis on marbled murrelet conservation model (Dickodochtedor, Goodman Creek, and Kalaloch LPUs)*:** The emphasis on marbled murrelet conservation model will apply in the Sitka spruce zone of three coastal plain LPUs with some existing older forest: Dickodochtedor, Goodman Creek, and Kalaloch. To limit potential negative fragmentation effects, MMMAs were located adjacent to federal lands or in areas with a high density of DNR-managed lands, and avoided areas of higher human impact with enriched corvid populations. Active management in the emphasis areas is hypothesized to improve their contribution to achieving the goal of population stability, while their location in the Sitka spruce zone is intended to contribute to distribution and resilience goals.

The specific elements of these approaches are detailed and mapped for each of the 11 LPUs in chapter 3.0.

Conservation Approach for a Marbled Murrelet Long-Term Conservation Strategy in the Straits Analysis Unit

Non-federal lands in the Straits Analysis Unit occur in a narrow peripheral band, approximately four to nine miles wide, on the northern and eastern Olympic Peninsula. DNR-managed lands (118,000 acres) comprise approximately one-fourth of the non-federal land base in the analysis unit (Figures ES-5A and ES-5B).

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Marbled murrelets have been observed moving throughout the waters surrounding the Olympic Peninsula and engaging in very long commuting flights (over 50 miles one-way) between nesting and foraging areas (Bloxton and Raphael 2006, 2007). These long-distance movements suggest that marbled murrelet nesting habitat in the Straits Analysis Unit should be considered in the context of the entire Olympic Peninsula. The nature and abundance of existing potential marbled murrelet habitat on federal and DNR-managed forests, as well as results of comprehensive inland surveys for marbled murrelets on DNR-managed lands (Harrison et al. 2003), suggest that state forests currently provide only a relatively minor contribution to the carrying capacity for marbled murrelets in the Straits Analysis Unit. The habitat known to be occupied on DNR-managed lands in the Straits Analysis Unit occurs predominantly in smaller, isolated stands compared to the adjacent, extensive old-growth forests found on federal lands. Additionally, the quality of these occupied stands is almost exclusively second growth Douglas-fir forest. Consequently, the Science Team recommended that all currently known occupied marbled murrelet sites be

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the Straits and SWWA are the projected outcome of timber harvests in areas not recommended to be designated for conservation emphasis as noted in the previous paragraph.

A Comparison of the No Management and Habitat Management Scenarios

SUMMARY: Both the No Management and Habitat Management scenarios implement the Science Team's goals for marbled murrelet conservation, but they differ in their simulated management approaches, portraying passive and active silvicultural applications, respectively. The projections show very little difference in their projected outcomes for marbled murrelet populations, although higher quality habitat developed at an increased rate under the Habitat Management simulation.

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Both the No Management and Habitat Management scenarios reflect the habitat objectives and geography of the Science Team's recommended approach to long-term marbled murrelet conservation. They differed only in their simulated management approaches, portraying a passive and active application of silviculture within the MMMAs designated in SWWA and the OESF. Projected management and its outcomes did not differ between those scenarios across the remainder of DNR-managed lands in those analysis units. That is, 66,000 of 324,000 acres in SWWA and 50,000 of 271,000 acres in the OESF were designated as MMMAs. These lands were the basis for the comparisons reported here against the background of implementing DNR policies and mandates over the rest of state forests in those analysis units.

Projections of the scenarios demonstrated very little difference in their projected outcomes for marbled murrelet populations (Figure ES-10). The most pronounced difference is for SWWA in 2067, when *K'* is projected to be 308 under Habitat Management compared to 275 under No Management. Within the MMMAs, the difference between No Management and Habitat Management were more pronounced. Projections for *K'* in 2067 were 130 and 158, respectively, or 22% greater with Habitat Management. In the OESF, the No Management scenario projected a slightly greater *K'* in 2067; 422 versus 414 for Habitat Management. This is a confounding projected outcome, and seems unlikely in view of management applied specifically for the purpose of accelerated habitat development under the Habitat Management scenario and habitat gains projected in SWWA. This phenomenon requires further investigation to explore the causes of this result in order to inform future modeling efforts. Habitat Management projected

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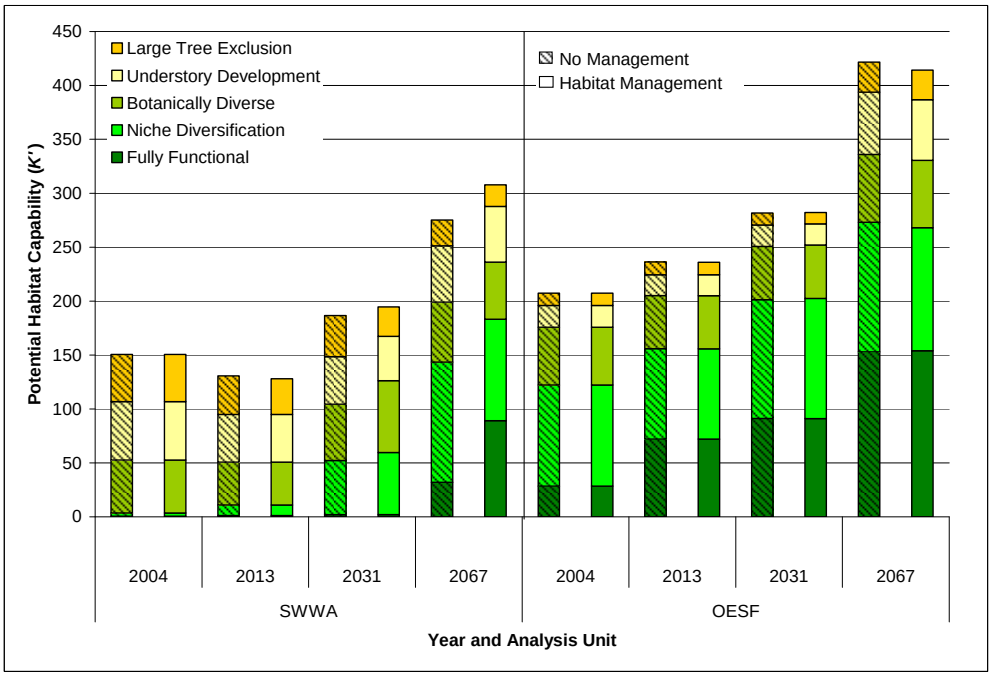

Figure ES-10. The Current and Projected Future Capability of DNR-Managed Forests to Support Marbled Murrelet Populations (*K'*) in SWWA and OESF Analysis Units for the No Management and Habitat Management Scenarios.

somewhat greater edge effects, with 80% versus 81% of *K'* from interior habitat in SWWA, and 86% versus 90% in the OESF.

A Comparison of Marbled Murrelet Habitat on DNR-Managed Lands within and outside Marbled Murrelet Management Areas

SUMMARY: Currently, both SWWA and the OESF provide a small proportion of the total area's habitat capability on DNR-managed lands. The focus of retaining and/or developing high-quality marbled murrelet habitat within MMMAs was expected by the Science Team to increase habitat quality and increase habitat abundance as a function of the amount and quality of habitat existing or projected to exist within them. Active silvicultural treatments (Habitat Management) are projected to increase these values and their capability to support marbled murrelet populations, particularly in interior forests.

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Table 1-1. Marbled Murrelet Science Team Members.

Name	Agency
Martin G. Raphael, Ph.D.	U.S. Forest Service, Pacific Northwest Research Station
S. Kim Nelson, M.S.	Oregon State University
Paula Swedeen, Ph.D.	Consultant
Mark Ostwald, B.S	U.S. Fish and Wildlife Service
Kim Flotlin, B.S.	U.S. Fish and Wildlife Service
Steve Desimone, M.S.	Washington Department of Fish and Wildlife
Scott Horton, Ph.D.	Washington Department of Natural Resources
Peter Harrison, B.S.	Washington Department of Natural Resources
Danielle Prenzlow Escene, M.S.	Washington Department of Natural Resources
Weikko Jaross, M.S.	Washington Department of Natural Resources

in the Columbia, South Coast, Straits, and OESF Planning Units. The Science Team consisted of biologists with marbled murrelet expertise from academic and research institutions, USFWS, Washington Department of Fish and Wildlife (WDFW), and DNR.

The Science Team held regular meetings beginning in January 2004. Data gathered during the Interim Conservation Strategy phases were reviewed and organized for further analysis. Next, the team began to develop conservation recommendations for opportunities for the LTCS. The Science Team's recommendations for conservation opportunities for an LTCS do not include the North Puget and South Puget Planning Units. The marbled murrelet inventory

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surveys in the North Puget Planning Unit began in 2001 and are not yet complete. The surveys in the South Puget Planning Unit are planned for spring 2008. LTCSs for these two remaining units will be completed after surveys have been conducted or when USFWS and DNR deem it appropriate to develop an LTCS.

The following chapters of this document describe conservation opportunities for marbled murrelet habitat on DNR-managed forested lands developed by the Science Team for the South Coast, Columbia, Straits, and OESF HCP Planning Units. The document is organized as follows:

- **Chapter 2.0, "Marbled Murrelet Ecology and Life History,"** discusses marbled murrelet biology and ecology.

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feathers) (Figure 2-2). Juvenile (hatch-year) plumage is dusky mottled below, but by the first winter the lower body is mostly white and indistinguishable from adults (Carter and Stein 1995) (Figure 2-3).

In 1997, the American Ornithologists' Union recognized the marbled murrelet and the long-billed murrelet as separate species on the basis of molecular analysis (Friesen et al. 1996b). Long-billed murrelets are found in northeastern Asia, but occasionally occur as vagrants in North America as a result of Southern and Pacific Decadal Oscillation events (Sealy et al. 1991, Friesen et al. 1996b, Mlodinow 1997).

Marbled murrelet populations consist of three distinct genetic groups found in the western and central Aleutian Islands, eastern Aleutian Islands to northern California, and central California, respectively (Friesen et al. 1996b, Congdon et al. 2000, McShane et al. 2004, Friesen et al. 2005, Piatt et al. 2007). Piatt et al. (2007) concluded that marbled murrelet populations in the west and central Aleutian Islands and central California are peripheral populations and thus are the most vulnerable to extinction because of their small population sizes, isolation from other marbled

Figure 2-1. Marbled Murrelet Adult in Breeding Plumage. Photo by Aaron Barna Photography.

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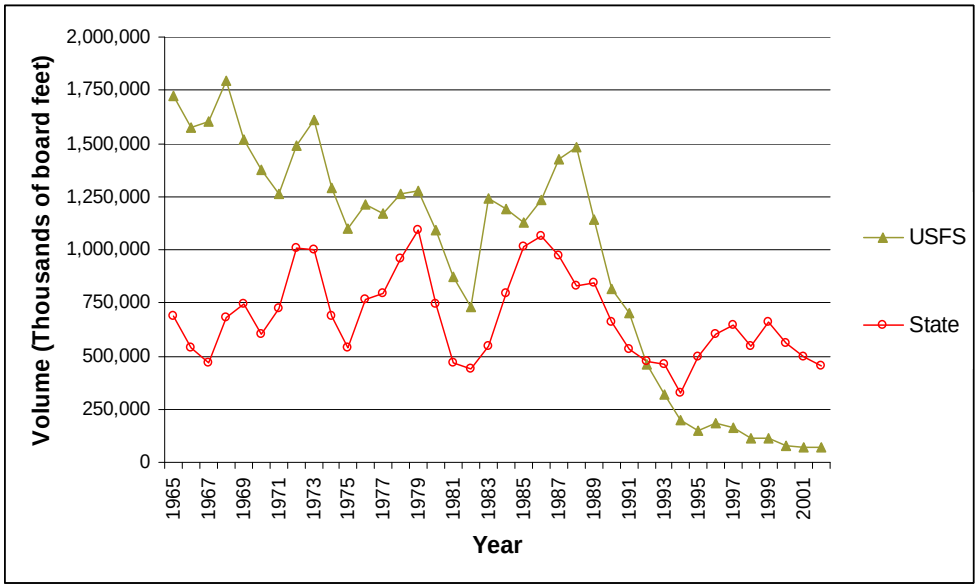

Figure 2-10. Recent Trends in Washington Timber Harvests on Public Lands (DNR 2004a).

Old-growth forests in Washington, Oregon, California, and some areas of British Columbia have been reduced by over 80% from historic levels (USFWS 1997, Burger 2002), leaving small, isolated stands of older trees for nesting marbled murrelets (McShane et al. 2004). The magnitude of habitat fragmentation and effects of creation of forest edges by clearcut logging on marbled murrelets are unclear, and field data are somewhat contradictory (Burger 2002).

2.7a Microclimate Edge Effects

Forest fragmentation results in abiotic changes to forest structure which affects nest site suitability (Malt and Lank 2007). Chen et al. (1993, 1995) found fragmented stands and forest edge areas to have higher winds, increased solar radiation, and lower humidity than contiguous mature and old-growth forests. Malt and Lank (2007) found that sites at timber harvest edge (both clearcuts and regenerating forests) had lower moss abundance than interior sites and natural edge sites (stream corridors and avalanche chutes) due to stronger winds, higher temperature variability and lower moisture retention when compared with interior sites. Burger (2002) found that marbled murrelets are more likely to select suitable nest trees and stands with high rates of lichen and

associated with preferred nesting substrate conditions and provide flight access routes to nests (Burger 2002). Burger and Page (2007) note many discrepancies in this research, specifically regarding the conclusion made by Zharikov et al. (2006) that marbled murrelets prefer smaller patch sizes 25 acres (10 hectares) versus larger habitat patches up to 494 acres (200 hectares). Burger and Page (2007) caution that this is a misleading conclusion, and should not draw forest managers to change their management plans in mitigating for marbled murrelet nesting habitat.

2.7c Predation Threats

Malt and Lank (2007) analyzed edge effects of forest fragmentation on predation rates at Nimkish Valley and Desolation Sound in southwest British Columbia. Malt and Lank's (2007) study compared predation at interior forest stands and three types of forest edge: lands adjacent to clearcuts, lands adjacent to regenerating forests, and lands adjacent to natural edges such as stream corridors or avalanche chutes. Using artificial marbled murrelet nest eggs and fledglings, Malt and Lank (2007) found that predation rates were the highest at edge sites adjacent to clearcuts and low at all other remaining sites, suggesting that predation rates may decline at forest edges as adjacent clearcuts regenerate over time. They found no difference in predation rates between natural forest edges, and interior sites.

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McShane et al. (2004) summarized general patterns that have emerged from research results on predation risk relative to fragmentation and forest edges:

- Higher nest predation in areas with high predator densities.
- Increased abundance or diversity of predators with increasing habitat variety and complexity.
- Increased abundance of some corvid species (jays, crows, ravens, etc.) along edges or in forest fragments near human activities.
- High nest predation by corvids along edges near human activities or in areas of low forest cover.
- High predation risk by small mammals in a variety of habitats, including interior forests and along human-created edges.

Marbled murrelets are highly vulnerable to nest site predation. By far, the greatest threat to marbled murrelets from forest fragmentation is increased levels of nest site predation associated

with forest edges (USFWS 1997). Based on a compilation of surveys by Nelson and Hamer (1995b), 72% of nests (n=32) with known outcomes failed. Fifty-six percent of these failures resulted from predation. In a study of marbled murrelets in central California, Peery (2004) determined a failure rate of 84% (n=19) with predation causing nest failure at 67 to 84% of failed nests. Most active marbled murrelet nests that have been detected and monitored have failed; most failures appear to be the result of predation (Nelson and Hamer 1995b, Hamer and Meekins 1999, Manley and Nelson 1999, Bradley 2002, Nelson and Wilson 2002, Hebert and Golightly 2003, Manley 2003, Peery 2004). Predation has consistently been the most significant cause of nest failure, with corvids being the primary predator (Nelson and Hamer 1995b, Raphael et al. 2002b).

Corvids were the primary predator of active marbled murrelet nests (Raphael et al. 2002b) and corvids and squirrels were the key predators at artificial nests (Nelson and Hamer 1995b, reviewed in Raphael et al. 2002b, Malt and Lank 2007). Forest fragmentation, as well as urbanization and agriculture have resulted in dramatic population growth of several corvid species in the west (Marzluff et al. 1994). Corvid populations will likely continue to increase with increased urbanization and the creation of new clearcuts that support berry-producing plants (Marzluff and Restani 1999).

Common ravens and Steller's jays (*Cyanocitta stelleri*) are known egg and chick predators, while sharp-shinned hawks have also been found to take chicks. Suspected predators at nest sites include great horned owls (*Bubo virginianus*), barred owls (*Strix varia*), Cooper's hawks (*Accipiter cooperii*), northwestern crows (*Corvus caurinus*), American crows (*Corvus brachyrhynchos*), gray jays (*Perisoreus canadensis*), peregrine falcons, northern goshawks, sharp-shinned hawks and red-shouldered hawks (*Buteo lineatus*) (Nelson and Hamer 1995b, Nelson 1997, Manley 1999, Raphael et al. 2002b, Vigallon and Marzluff 2005).

Multiple artificial nest studies in Oregon and Washington documented that the risk of predation by jays increased with jay abundance (Luginbuhl et al. 2001, Vigallon and Marzluff 2005). Luginbuhl et al. (2001) found that the rate of artificial nest predation in contiguous and complex mature and old-growth forest landscapes was directly correlated to corvid abundance. Although corvids in general are successful at preying on marbled murrelet chicks and eggs, only common

ravens are known to be capable of flushing brooding or incubating adults from nests (Nelson and Hamer 1995b, Singer et al. 1991, Suddjian 2003).

Predation by mammals at marbled murrelet nests has only recently been documented, and is thought to be a significant cause of nest failure (Nelson and Hamer 1995b, Nelson 1997, Manley and Nelson 1999, Burger 2002, Malt and Lank 2007). The first documented case of predation on a marbled murrelet nest egg by a Douglas squirrel (*Tamiasciurus douglasii*) was made by Bloxton and Raphael (2006). In Pacific Northwest conifer forests, several small mammal species are known to visit tree canopies (Bradley and Marzluff 2003). Experimental studies in Washington and Oregon provide strong evidence for mammalian predation of marbled murrelet eggs and nestlings (Marzluff et al. 1999, Marzluff et al. 2000, Luginbuhl et al. 2001, Raphael et al. 2002b, Bradley and Marzluff 2003). In experimental studies involving artificial nest eggs and pigeon nestlings, the following mammals have all made documented attacks: northern flying squirrel (*Glaucomys sabrinus*), Douglas squirrel, red squirrel (*Tamiasciurus hudsonicus*), deer mice (*Peromyscus maniculatus* and *P. keeni*), bushy-tailed woodrat (*Neotoma cinerea*), and an unidentified mustellid (Marzluff et al. 1999, Flaherty et al. 2000, Luginbuhl et al. 2001, Bradley and Marzluff 2003, Malt and Lank 2007).

A study by Flaherty et al. (2000) concluded that northern flying squirrels are unlikely to be able to break into marbled murrelet eggs, suggesting that both mouth gape and egg shell thickness could limit egg predation. In a southwestern British Columbia study using artificial eggs and nestlings and real marbled murrelet nests, Malt and Lank (2007) found Douglas squirrel (native to Washington State) and red squirrel (not found in the marbled murrelet's habitat range in Washington) predation rates to be higher at all types of forest edge (including natural edges) than interior sites. Malt and Lank's study (2007) found squirrels more likely to attack nest eggs than nestlings.

With the exception of Malt and Lank's study (2007), artificial nest studies showed corvids to be the primary predators on eggs, whereas mammals, given their olfaction, were more adept than corvids at depredating simulated nestlings.

2.8 Conclusion

Habitat loss is the primary cause for decline in marbled murrelets, with habitat fragmentation causing increased rates of predation and changes in microhabitat quality in remaining habitat.

murrelet habitat conservation. The Science Team recommends deferral of all known occupied marbled murrelet sites located inside proposed MMMAs.

In some cases, the Science Team has recommended moderated forest management to complement deferred areas and habitat areas within MMMAs. In these areas, retention of forest structure around areas being recommended specifically for habitat creation and maintenance is proposed. These include areas not required for meeting habitat thresholds in MMMAs, and buffers around occupied sites and old forest.

Finally, the Science Team anticipates that other conservation strategies being implemented in fulfillment of the HCP on DNR-managed lands will complement the recommended marbled murrelet conservation measures. Conservation measures including the northern spotted owl strategy, riparian forest restoration strategy, and efforts to protect unstable landforms, to name a few, are expected to develop a matrix of complex forest structure on the landscape and support marbled murrelet biological goals. An assessment of these conservation strategies as to their expected contribution to marbled murrelet habitat is recommended.

Table 3-2. Definitions for Habitat Terms Used in this Document. Please Note that the Terms Defined in this Table Have a Very Specific Meaning Related to this Document and the Processes it Describes, and May Not Apply Beyond this Specific Context.

Habitat Term	Definition
Suitable Habitat	Identified by Step One of the Marbled Murrelet Interim Conservation Strategy (DNR 1997a, p. IV.39). Suitable habitat is defined as a contiguous forested area meeting all of the following three criteria: 1. At least five acres in size 2. Containing an average of at least two potential "nesting platforms" per acre. Nesting platforms are defined as any large limb or other structure, such as a mistletoe broom, at least 50 feet above ground and at least 7 inches in diameter. 3. Within 50 miles of marine waters. Distance is determined from the Pacific coast, from Puget Sound, or from Rice Island (located in the Columbia River upstream from the Astoria Bridge), whichever is closest to the site.
Reclassified Habitat	Identified by Step Two of the Marbled Murrelet Interim Conservation Strategy (DNR 1997a) through the use of a habitat relationship study predictive model (Prenzlow Escene 1999). Two classes of habitat were identified based on this model: 1. **Marginal habitat**: defined as those lands expected to contain a maximum of five percent of the occupied sites on DNR-managed lands within each planning unit. These areas were made available for harvest. All known occupied sites were deferred from harvest, and were not included in this habitat designation. 2. **High-quality habitat:** in contrast to marginal habitat, this is defined as those lands expected to contain at least 95% of the occupied sites on DNR-managed lands within each planning unit. This habitat is frequently referred to simply as "reclassified habitat."

Old Forest	The term "old forest habitat" is used in the HCP to help define northern spotted owl habitat in the conservation strategy for the OESF (DNR 1997a, p. IV.88). Old forest habitat was identified in the OESF in fulfillment of that strategy, and was then used by the Science Team to help identify areas likely to provide nesting habitat and therefore make a contribution to marbled murrelet conservation.

3.2c Marbled Murrelet Management Areas in SWWA

Seventeen ownership blocks of DNR-managed lands were delineated by the Science Team and subsequently reviewed and edited by the local biologists (Figure 3-3). These ownership blocks (planning blocks) were delineated as logical groupings of DNR-managed lands.

Figure 3-4 is the chart of overall scores for SWWA. The overall scores ranged from 0.88 for the Lake Creek block to 8.41 for the Nemah block. The top five blocks down to Skamokawa were considered the highest priority. The second six blocks, including Humptulips through Pe Ell, were considered a secondary priority, except Capitol which contained no occupied sites and is not discussed in this report. The bottom six blocks from Lincoln to Lake Creek were considered the lowest priority, do not contain occupied sites, and therefore are not discussed in this report.

3.2d Delineation of Marbled Murrelet Management Areas

MMMAs in SWWA were delineated to retain all occupied sites; retain mature forest; block up, connect, and buffer mature forest; and reduce the negative effect of forest edge on nest success by considering the ratio of DNR-managed lands to privately managed, commercial forests. The purpose of retaining mature forest around occupied sites is to create core areas[1] of high-quality habitat. In addition to the large MMMAs, 13 isolated occupied sites were delineated for protection as MMMAs. The isolated occupied sites are areas where DNR-managed lands are small "islands" surrounded by non-DNR land (Salmon Creek, Browning, and Nemah) or are in areas of medium priority according to the scorecard (Humptulips and Lebam). The large MMMAs in SWWA, totaling 63,471 acres (25,686 hectares), along with 2,552 additional acres (1,033 hectares) of MMMAs from isolated occupied sites, are recommended to be managed to become 100% marbled murrelet high-quality nesting habitat. The Science Team delineated MMMAs in SWWA in an iterative process that:

- Used the scorecard exercise to help consider the relative importance of each planning block to the stated biological goals.
- Examined amounts and locations of past and current marbled murrelet activity.
- Reviewed amounts and locations of mature forest conditions.

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[1] Core areas are defined as high-quality nesting habitat 170 acres (69 hectares) or larger and greater than 328 feet (100 meters) from an edge.

omitted because it contains no known marbled murrelet activity and no late-successional forest, and because it shares a border with privately managed lands. All of the omitted area has at least 20% privately managed lands in the 1.24 mile (2.00 kilometer) moving-window analysis or neighborhood analysis (a value for each cell is established as a function of its neighboring cells within a specified distance, or window). The delineation of the northeast section follows streams, roads, forest inventory units, or a linear connection between them. Four isolated occupied sites, located south and west of the large Nemah MMMA, are included in four additional MMMAs, totaling 1,742 acres (705 hectares). These occupied sites are each buffered by a small amount of DNR-managed land. The land outside these occupied sites is included in the MMMAs.

Browning MMMAs: All four of the large MMMAs retain and buffer occupied sites and block up disconnected areas of mature forest (Figure 3-6). The northernmost management area of the Browning block is 646 acres (262 hectares) and is delineated by occupied sites, DNR-managed lands, forest inventory units, and the linear connection between forest inventory units. The next MMMA in the Browning block, traveling south, is 2,889 acres (1,169 hectares) and is delineated by DNR-managed lands, forest inventory units, roads, and, in some areas, the linear connection between forest inventory units. The next MMMA is 444 acres (180 hectares) and is simply a large buffer around an occupied site. It is delineated by roads, forest inventory units, and the linear connection between them. The southernmost MMMA of the Browning block is 5,134 acres (2,078 hectares) and is delineated by DNR-managed lands, forest inventory units, the linear connection between inventory units, as well as orthophoto-interpreted stand types. One isolated occupied site located on the west side of the Browning block is 113 acres (46 hectares) and is considered an additional MMMA. It is surrounded by a small amount of DNR-managed land that is not included in the MMMA.

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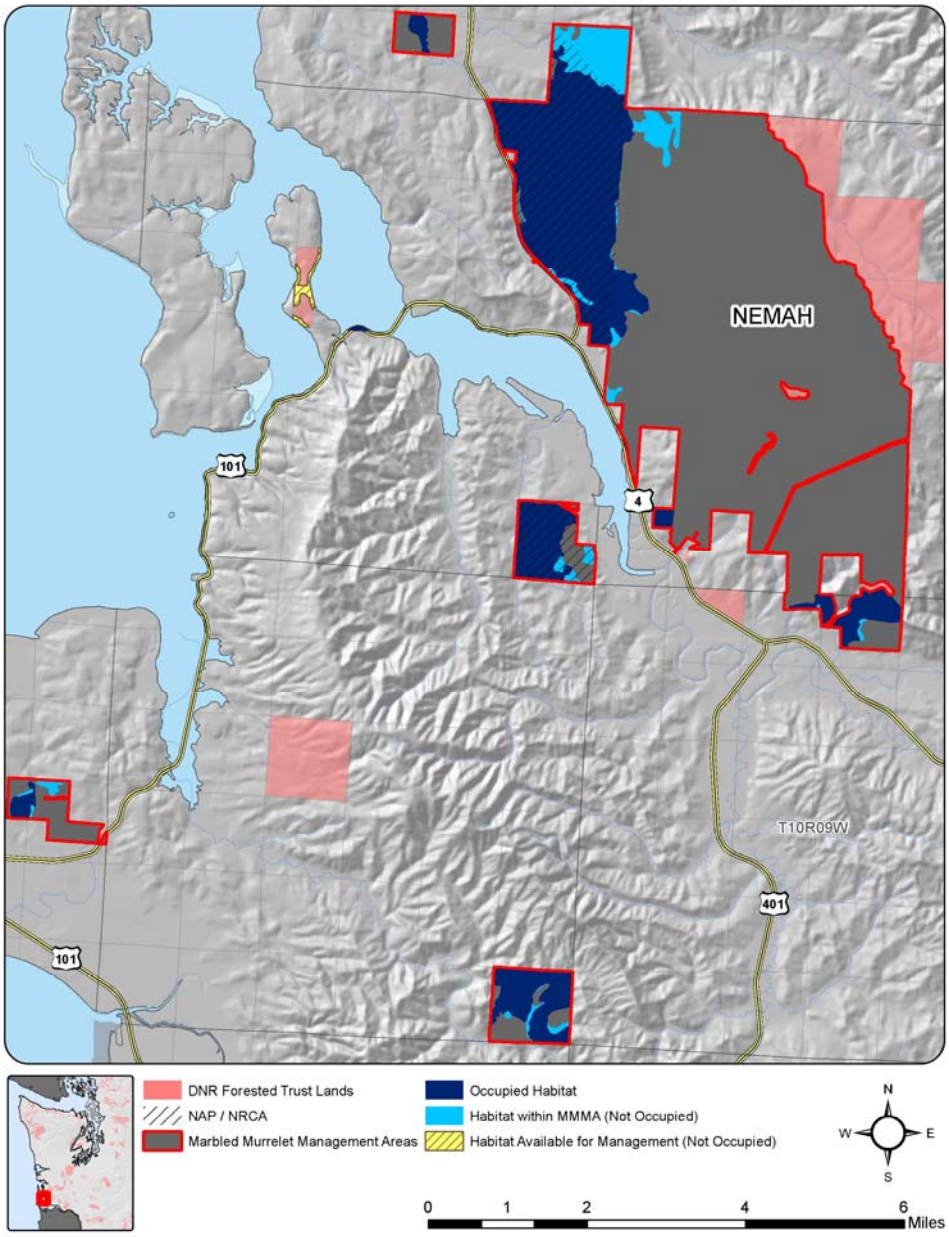

Figure 3-5 Proposed Science Team Land Allocations for Marbled Murrelet Management Areas in the Nemah Planning Block.

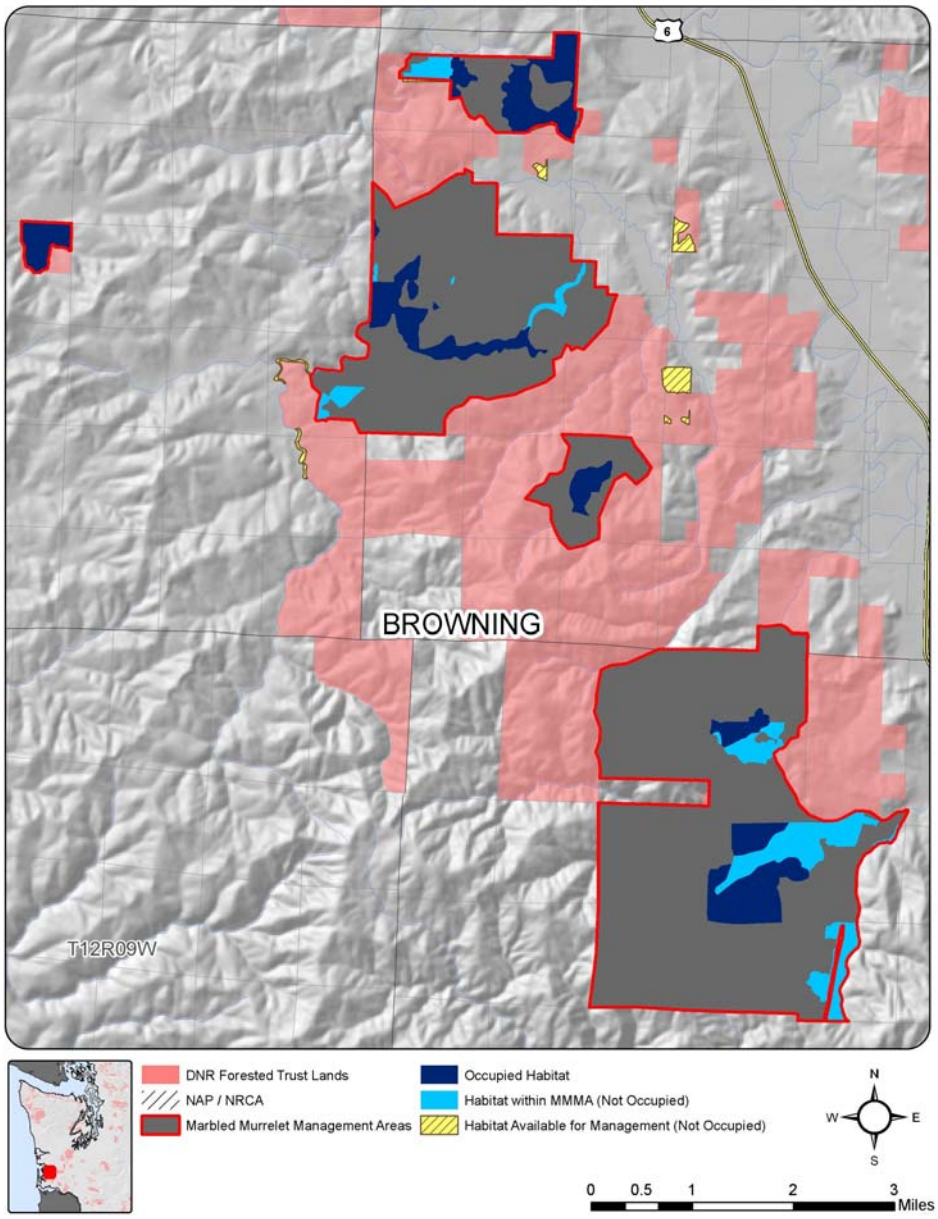

Figure 3-6. Proposed Science Team Land Allocations for Marbled Murrelet Management Areas in the Browning Planning Block.

Salmon Creek MMMAs: Both of the large MMMAs connect occupied sites and block up disconnected areas of mature forest (Figure 3-7). The first MMMA on the west side of the Salmon Creek block is 4,987 acres (2,018 hectares) and is delineated by the extent of DNR-managed lands, except the southern tip. The southern tip of DNR-managed lands is omitted because it contains no known marbled murrelet activity and no late-successional forest, and it borders privately managed lands. The entire omitted southern tip contains at least 50% privately managed lands in the 1.24 mile (2.00 kilometer) moving-window analysis. The delineation of the southern tip follows roads and forest inventory units. The eastern border of the western management area omits a large section of early successional forest because there is no known marbled murrelet activity. The delineation of the eastern border follows roads and forest inventory units. The second MMMA on the east side of the Salmon Creek block is 3,420 acres (1,384 hectares) and is delineated by the extent of DNR-managed lands. The western border of the MMMA encompasses areas of mature forest. The delineation of the western border follows forest inventory units. One isolated occupied site is located southwest of the Salmon Creek block. It is a quarter-section, 159 acres (64 hectares) that is not buffered by additional DNR-managed land; thus the entire occupied site is the MMMA.

Elochoman MMMAs: The southern MMMA of the Elochoman block is 491 acres (199 hectares) and is simply a large buffer around an occupied site, but also blocks up some disconnected areas of mature forest (Figure 3-8). It is delineated by DNR-managed lands, forest inventory units, and the linear connection between them. The large, northern MMMA is 9,734 acres (3,939 hectares), captures one occupied site, and blocks up many widespread areas of late-successional forest. The western border of the MMMA is delineated by DNR-managed lands. The northern border is delineated by forest inventory units. The eastern and southern borders are delineated by DNR-managed lands and by Wahkiakum County trust lands.

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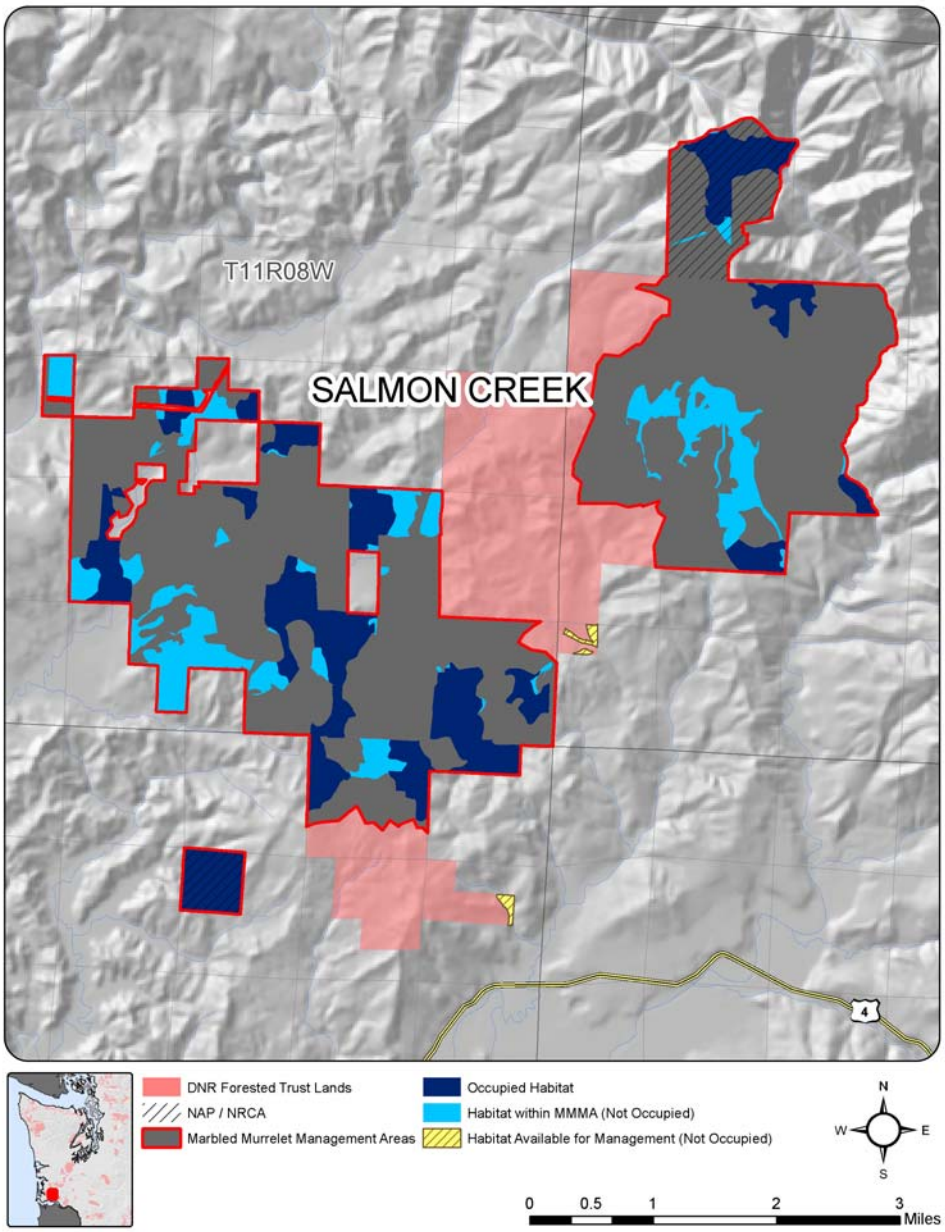

Figure 3-7. Proposed Science Team Land Allocations for Marbled Murrelet Management Areas in the Salmon Creek Planning Block.

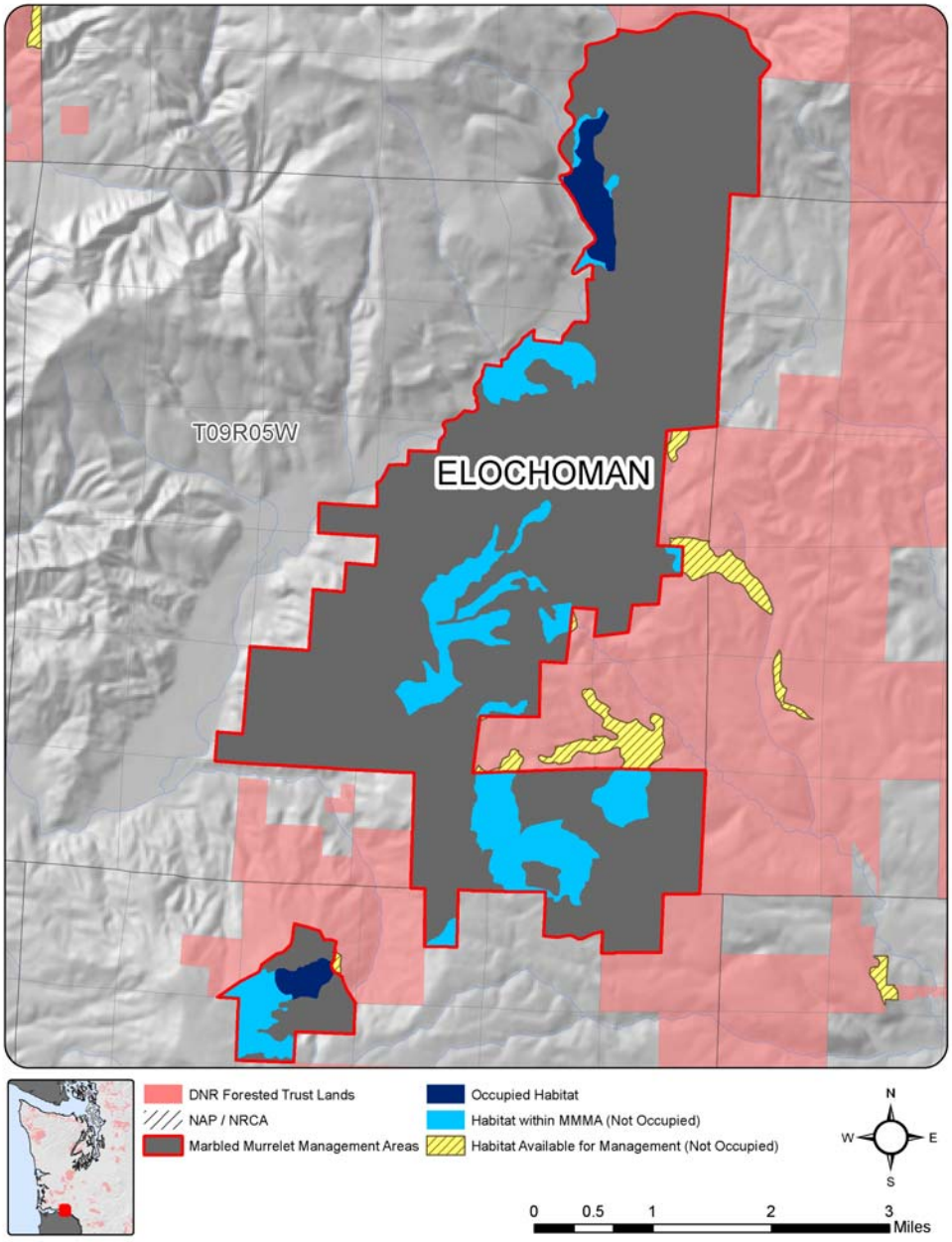

Figure 3-8. Proposed Science Team Land Allocations for Marbled Murrelet Management Areas in the Elochoman Planning Block.

Skamokawa MMMA: The MMMA is 13,763 acres (5,570 hectares), connects occupied sites, and blocks up disconnected areas of mature forest (Figure 3-9). All but the northwest, northeast, and southeast corners of the MMMA are delineated by the extent of DNR-managed lands. The three corners are omitted because they contain no known marbled murrelet activity and little to no late-successional forest, and because they border privately managed lands. The omitted northwest corner contains at least 60%, the northeast corner 40%, and the southeast corner 30% privately managed lands in the 1.24 mile (2.00 kilometer) moving-window analysis. The delineation of the corners follows forest inventory units and orthophoto-interpreted stand types. The southeast corner is also partially delineated by an occupied site and a linear connection between forest inventory units.

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Humptulips MMMAs: Five isolated occupied sites located in the Humptulips block total 317 acres (128 hectares) and are considered additional MMMAs (Figure 3-10). They are surrounded by small amounts of DNR-managed land, but DNR-managed lands outside the occupied sites are not included in the MMMAs.

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Grays MMMAs: These management areas include DNR-managed Natural Area Preserves Bone River and Niawiakum River (Figure 3-11). They total 3,371 acres (1,364 hectares) and encompass two occupied sites. They are delineated entirely by the extent of DNR-managed lands. One isolated occupied site northeast of the large MMMA is 34 acres (14 hectares) and is considered an additional MMMA. It is surrounded by a small amount of DNR-managed land that is not included in the MMMA.

Chehalis MMMAs: The northern and southeastern MMMAs of the Chehalis block are 1,132 and 828 acres (458 and 335 hectares), respectively, and are simply large buffers around occupied sites (Figure 3-12). They are delineated by DNR-managed lands, forest inventory units, and, in some areas, the linear connection between them. The southwestern MMMA is 3,282 acres (1,328 hectares), buffers one occupied site adjacent to DNR-managed lands, and retains a large area of mature forest. It is also delineated by DNR-managed lands and forest inventory units.

Lebam MMMA: One isolated occupied site located in the Lebam block is 187 acres (76 hectares) and is considered an additional MMMA (Figure 3-13). It is buffered by a large amount of DNR-managed land that is not included in the MMMA.

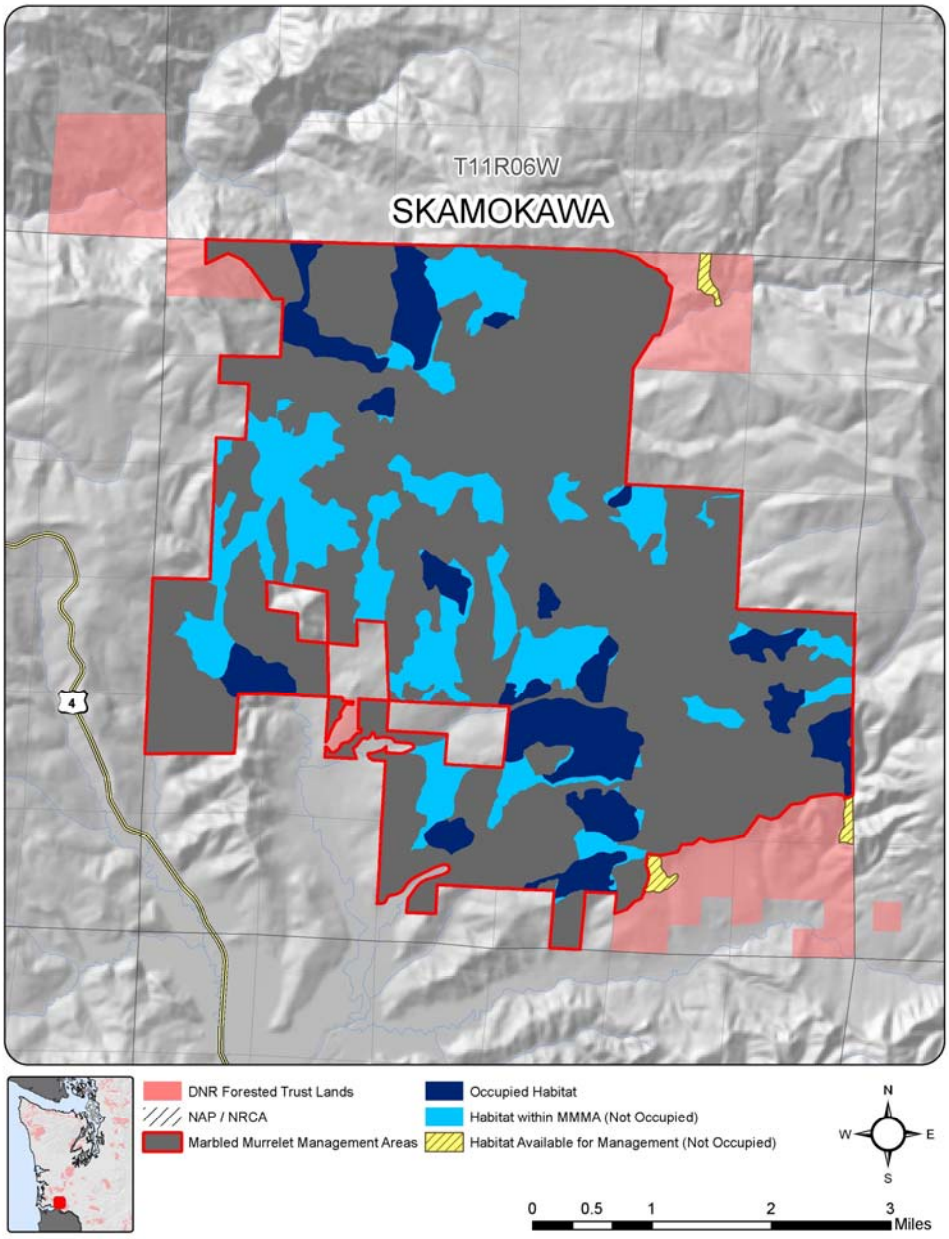

Figure 3-9. Proposed Science Team Land Allocations for Marbled Murrelet Management Areas in the Skamokawa Planning Block.

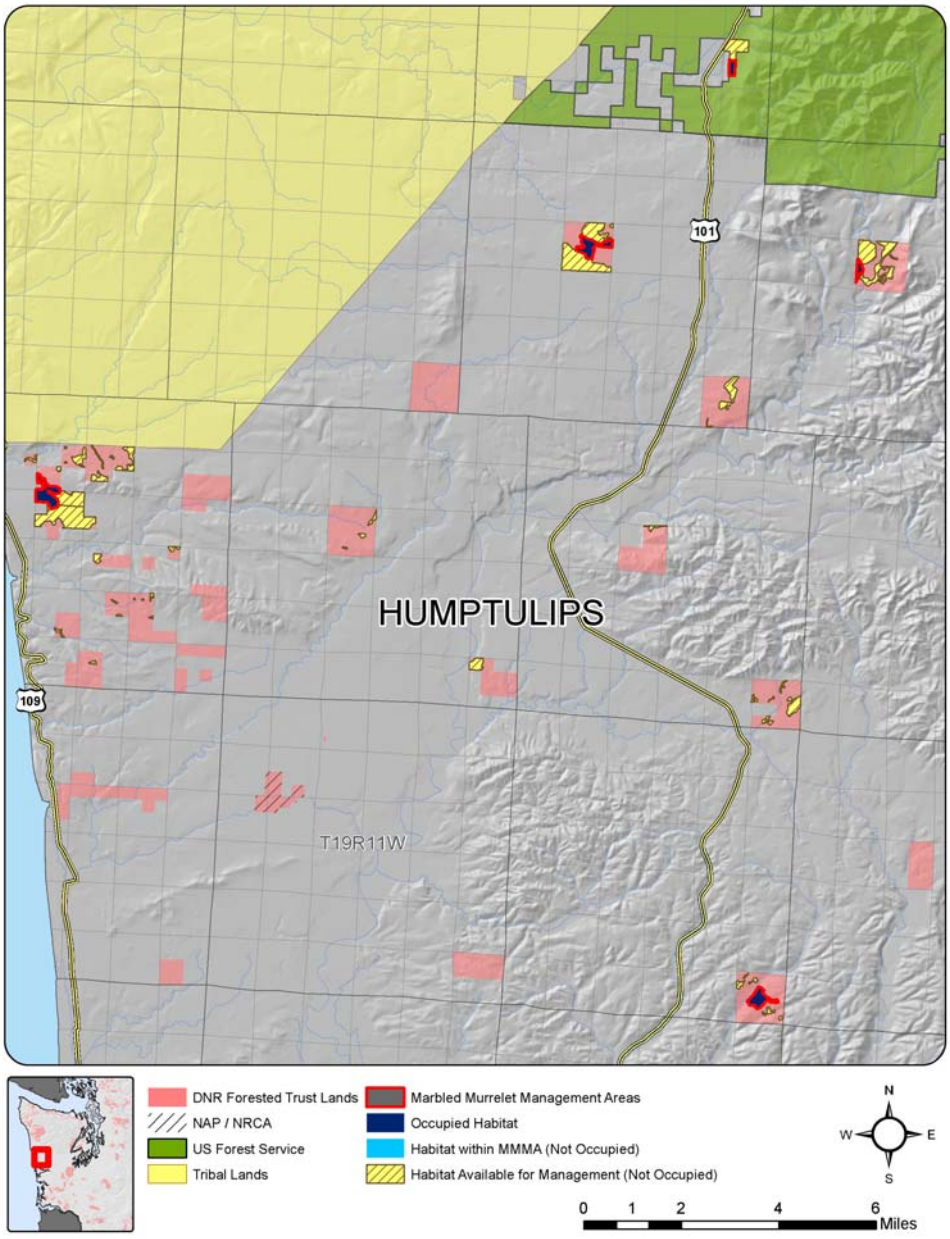

Figure 3-10. Proposed Science Team Land Allocations for Marbled Murrelet Management Areas in the Humptulips Planning Block.

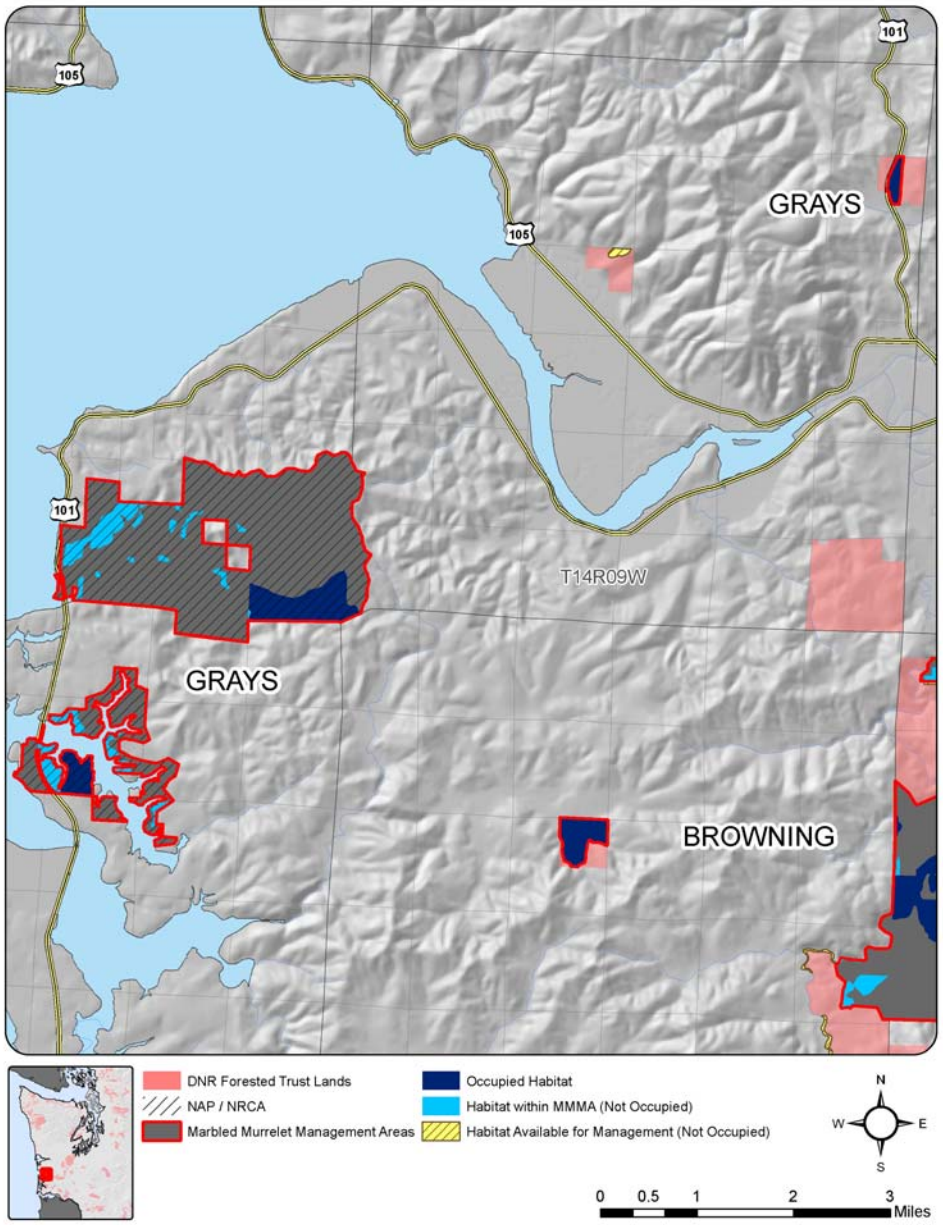

Figure 3-11. Proposed Science Team Land Allocations for Marbled Murrelet Management Areas in the Grays Planning Block.

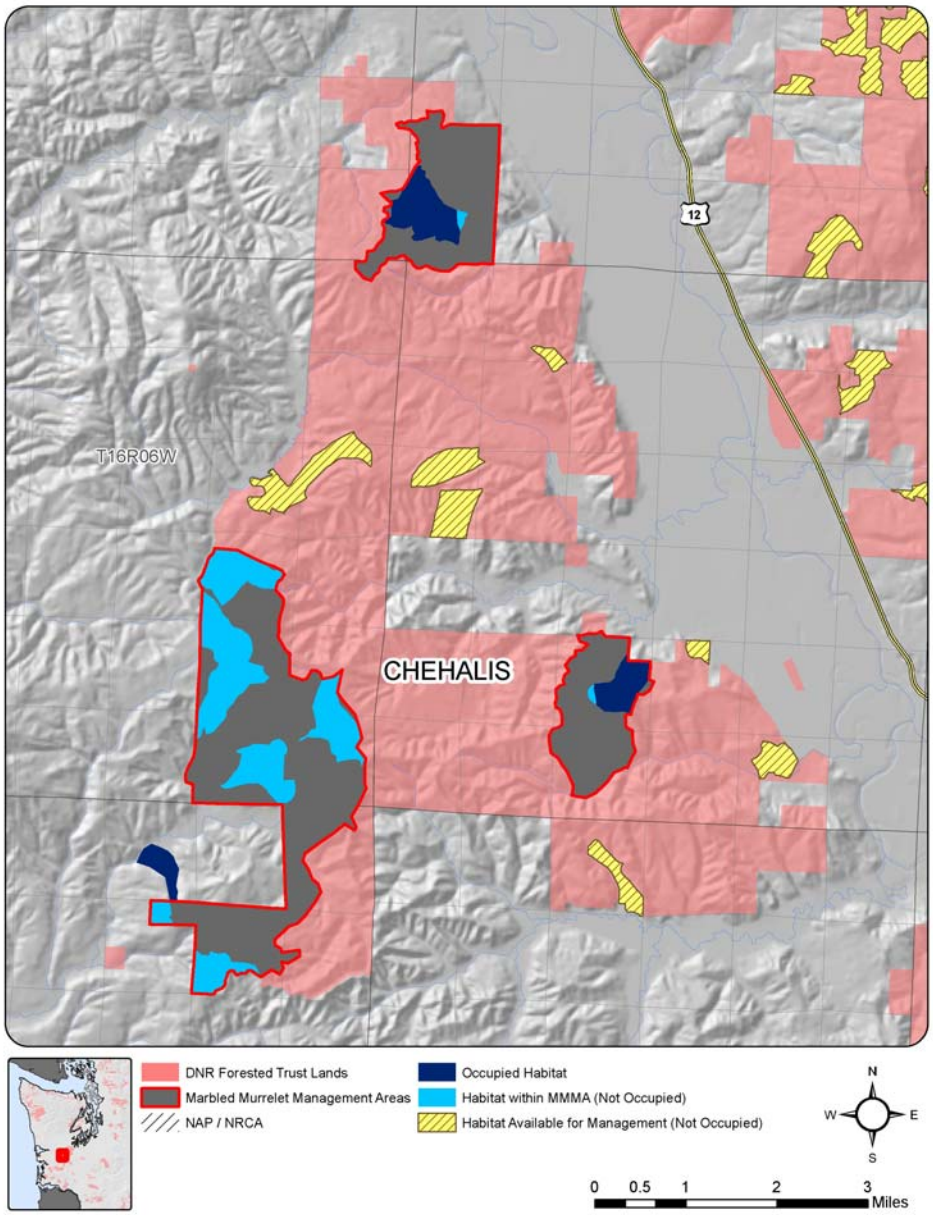

Figure 3-12. Proposed Science Team Land Allocations for Marbled Murrelet Management Areas in the Chehalis Planning Block.

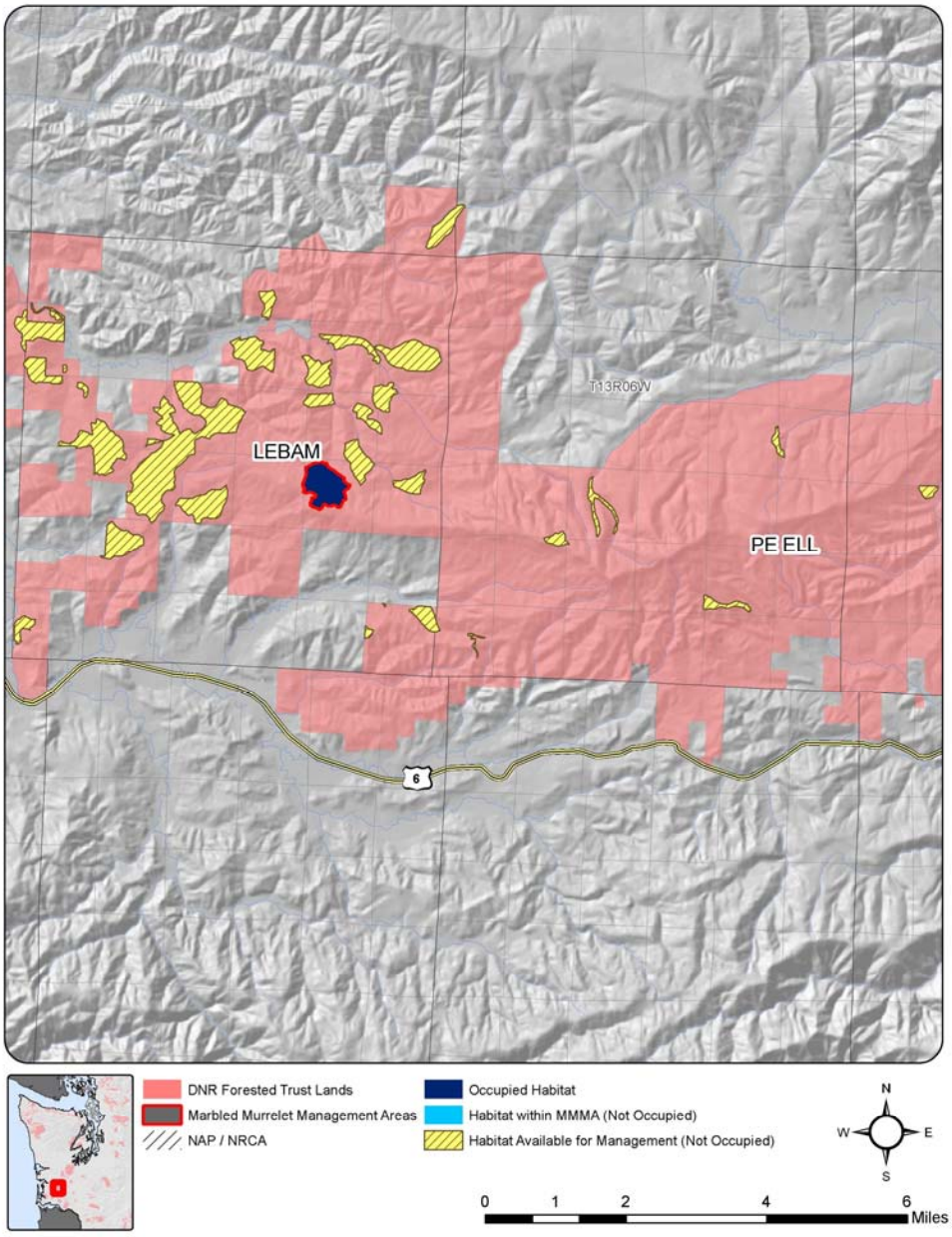

Figure 3-13. Proposed Science Team Land Allocations for Marbled Murrelet Management Area in the Lebam Planning Block.

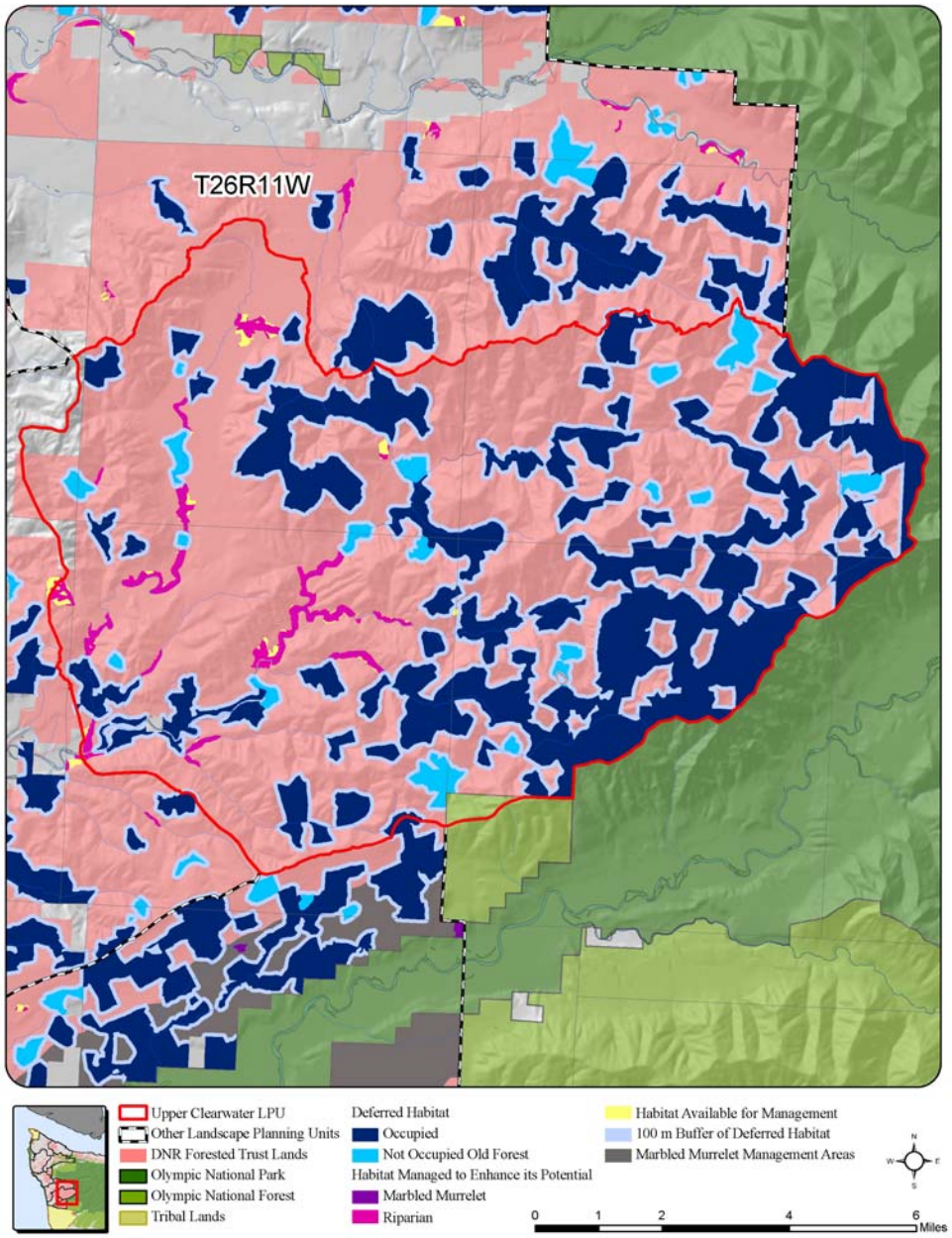

Figure 3-15. Proposed Science Team Land Allocations for Upper Clearwater LPU.

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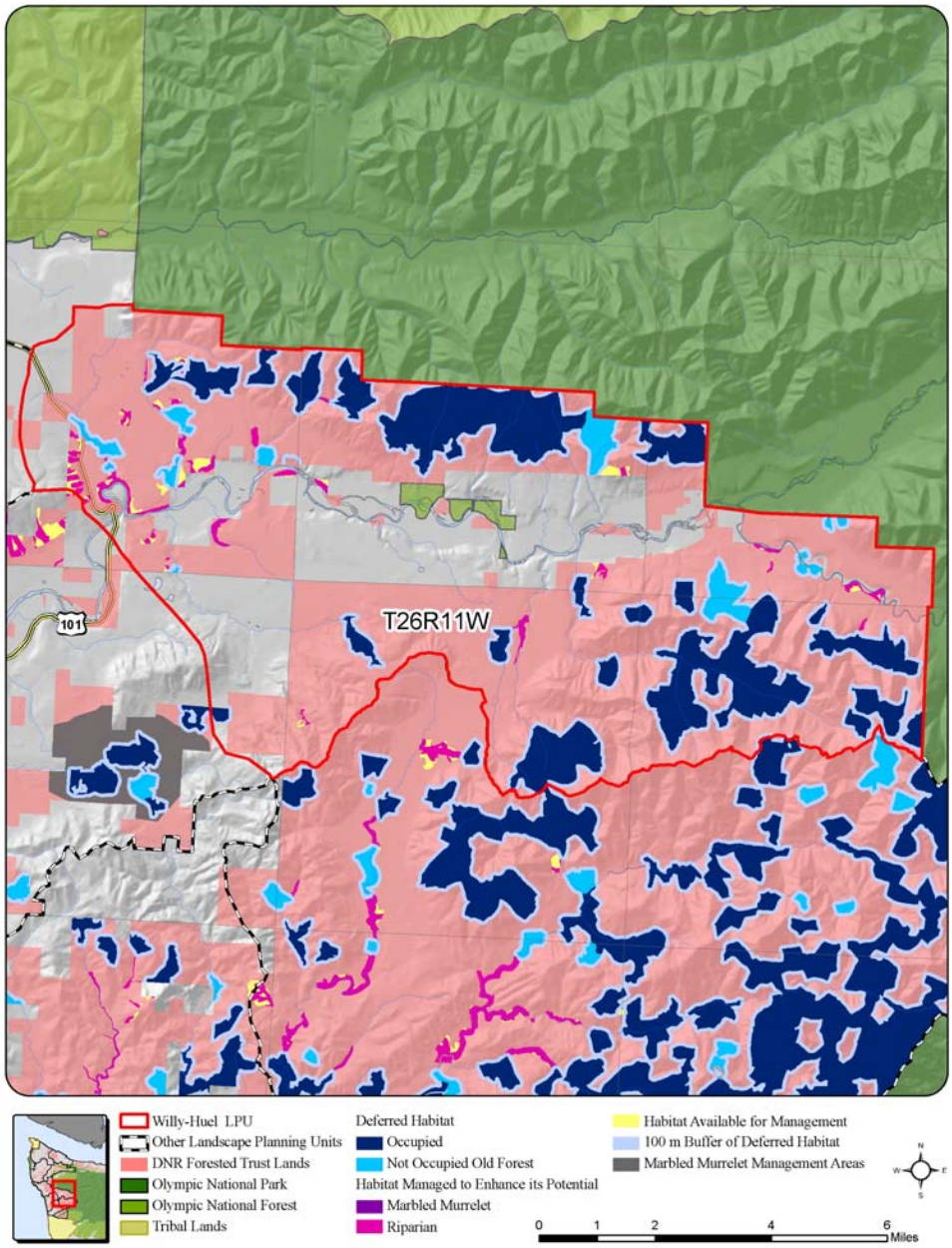

Figure 3-16. Proposed Science Team Land Allocations for Willy-Huel LPU.

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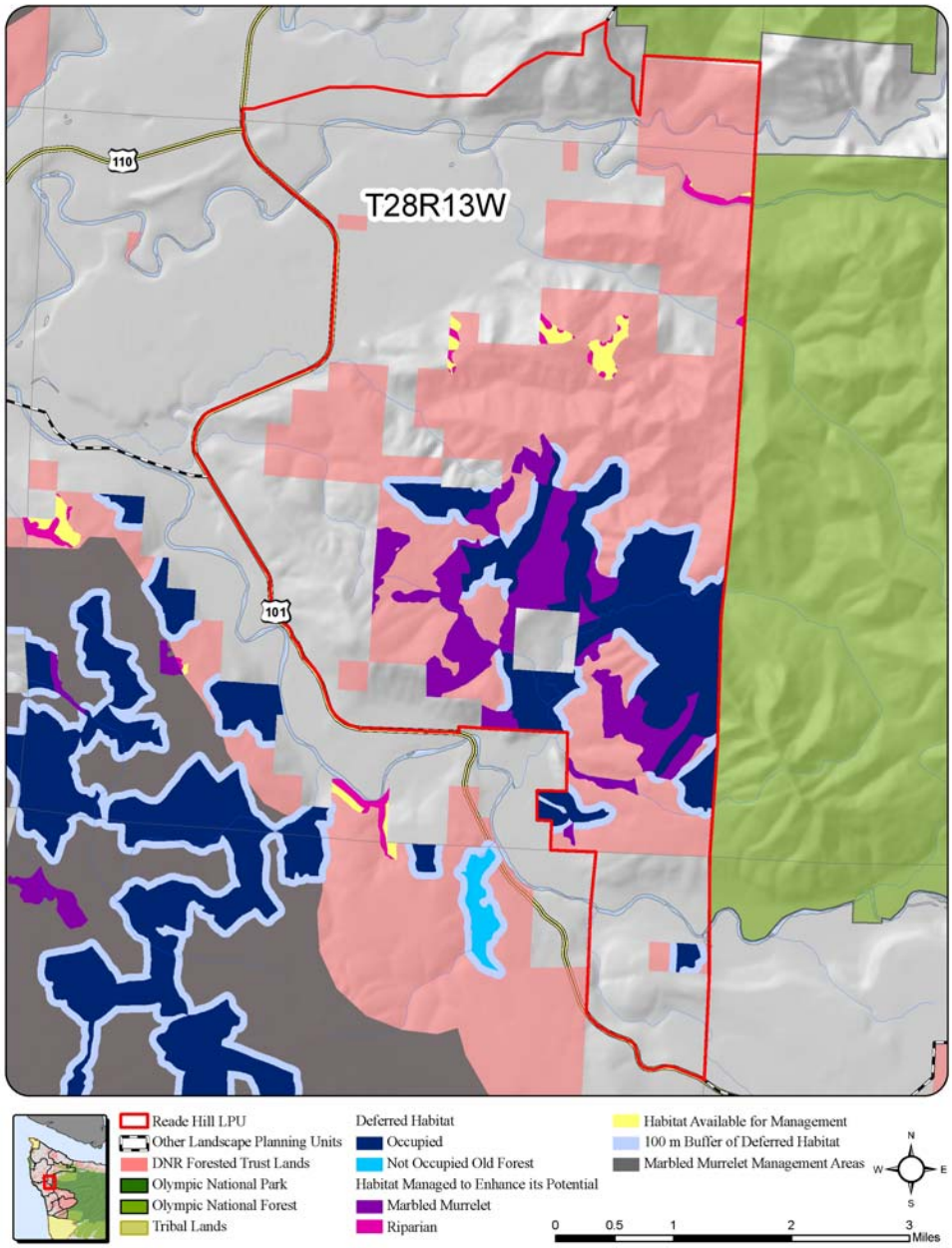

Figure 3-17. Proposed Science Team Land Allocations for Reade Hill LPU.

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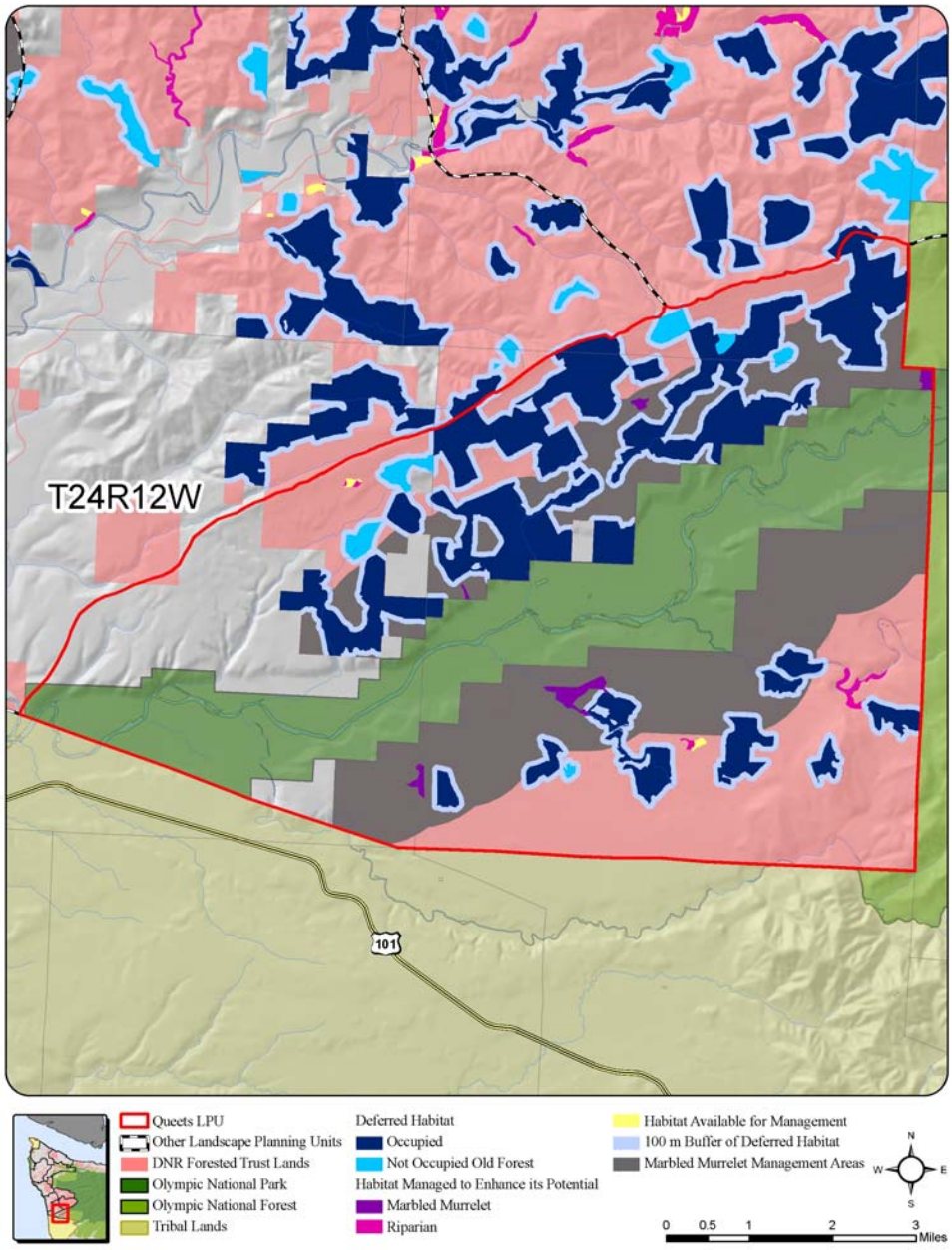

Figure 3-18. Proposed Science Team Land Allocations for Queets LPU.

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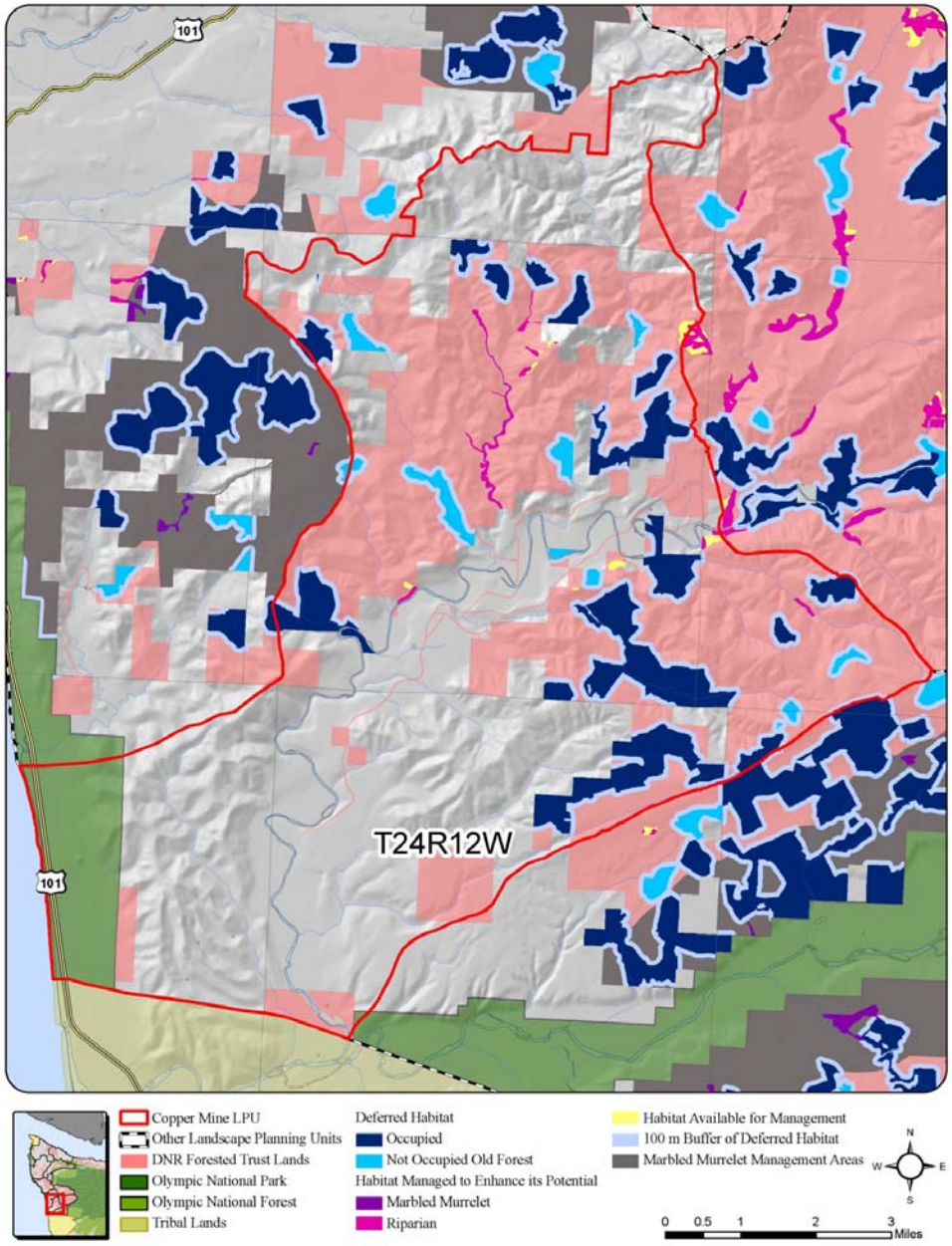

Figure 3-19. Proposed Science Team Land Allocations for Copper Mine LPU.

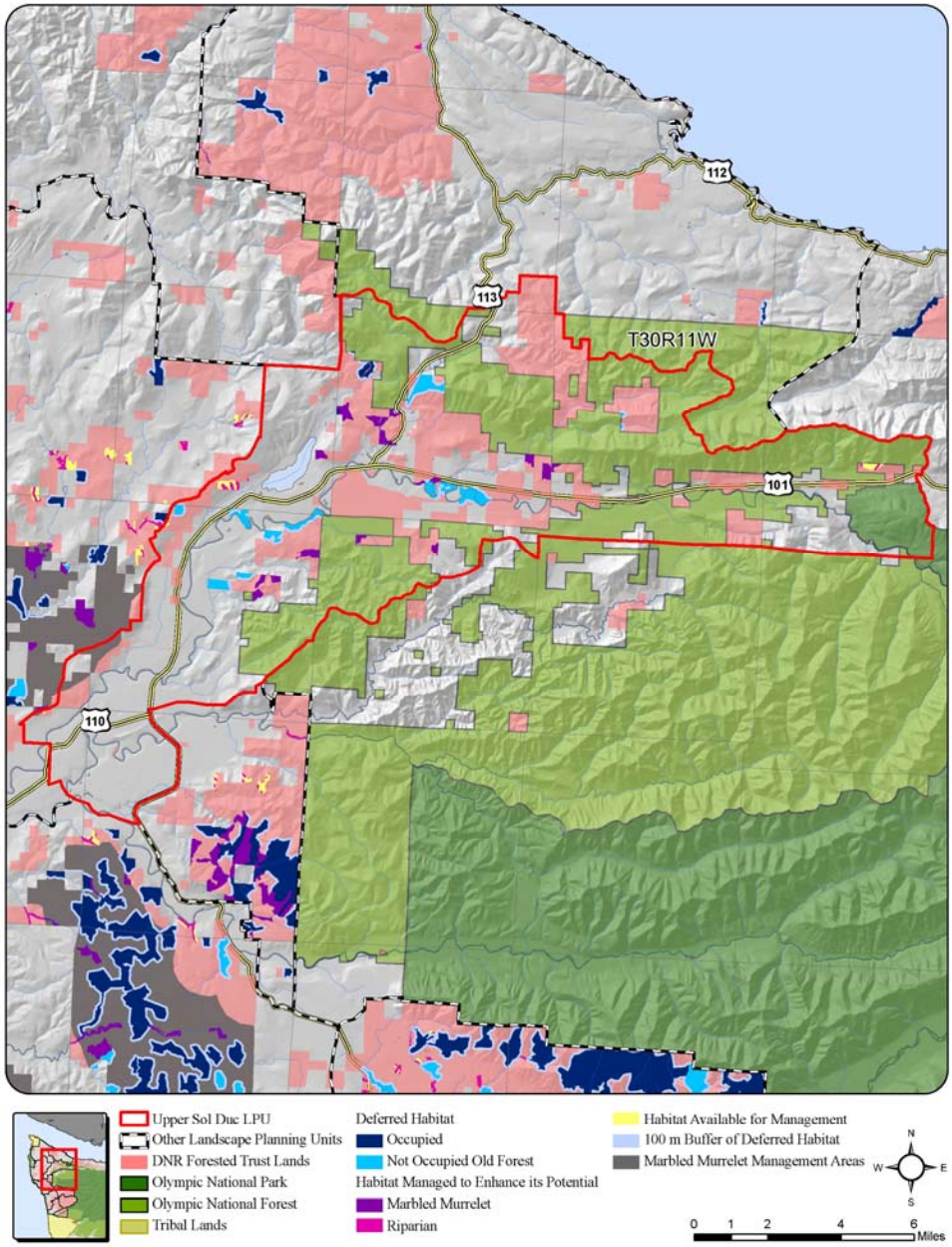

Figure 3-20. Proposed Science Team Land Allocations for Upper Sol Duc LPU.

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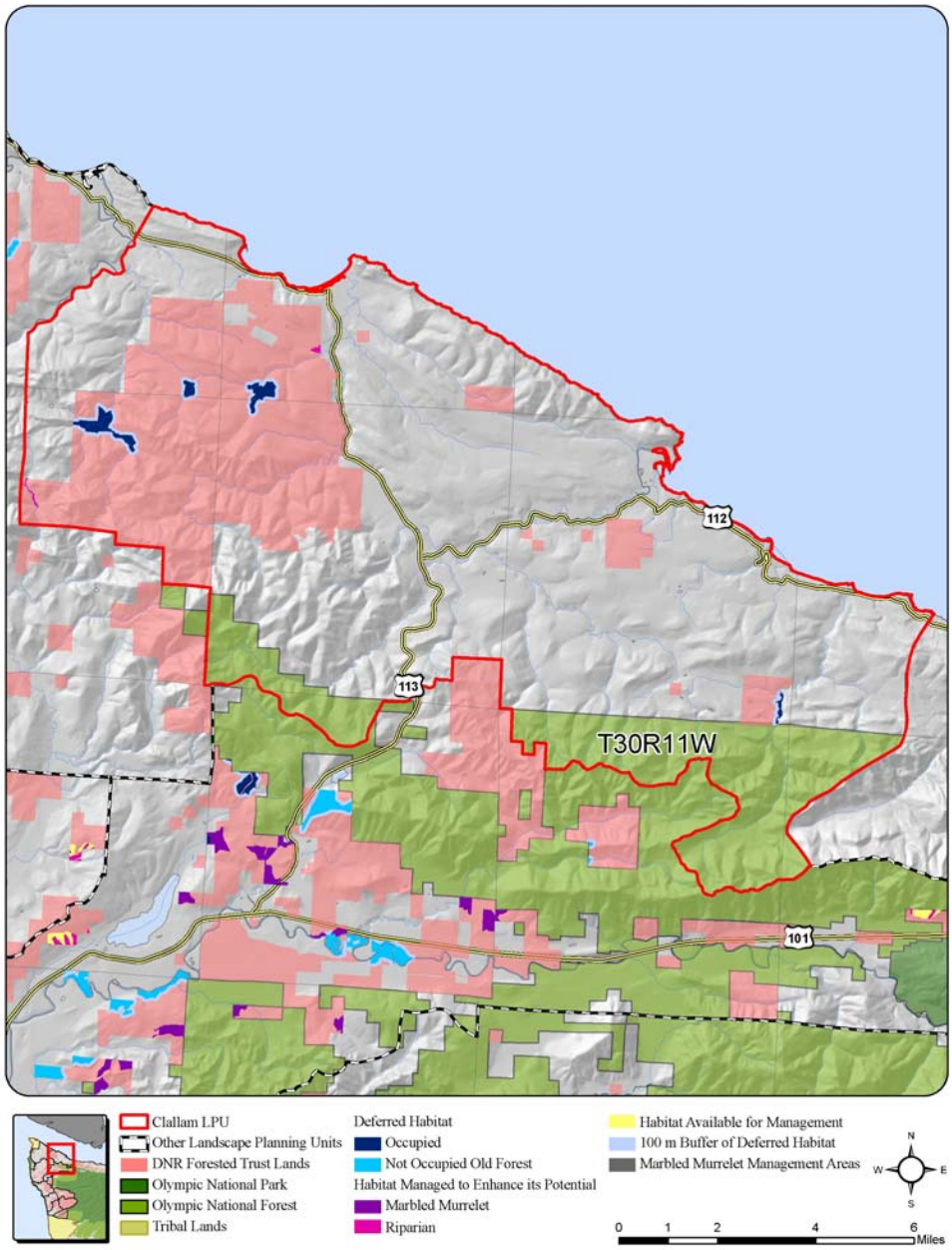

Figure 3-21. Proposed Science Team Land Allocations for Clallam LPU.

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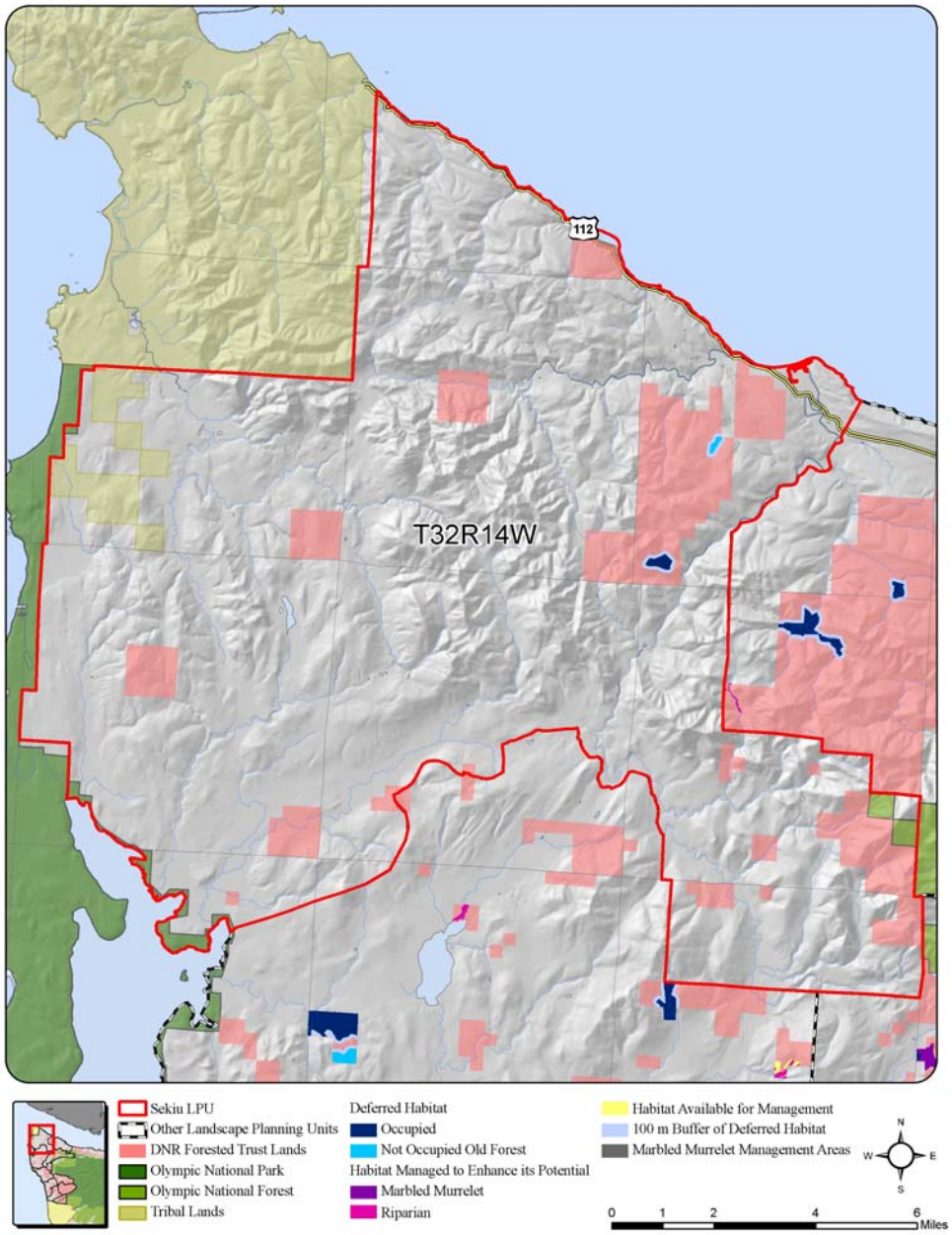

Figure 3-22. Proposed Science Team Land Allocations for Sekiu LPU.

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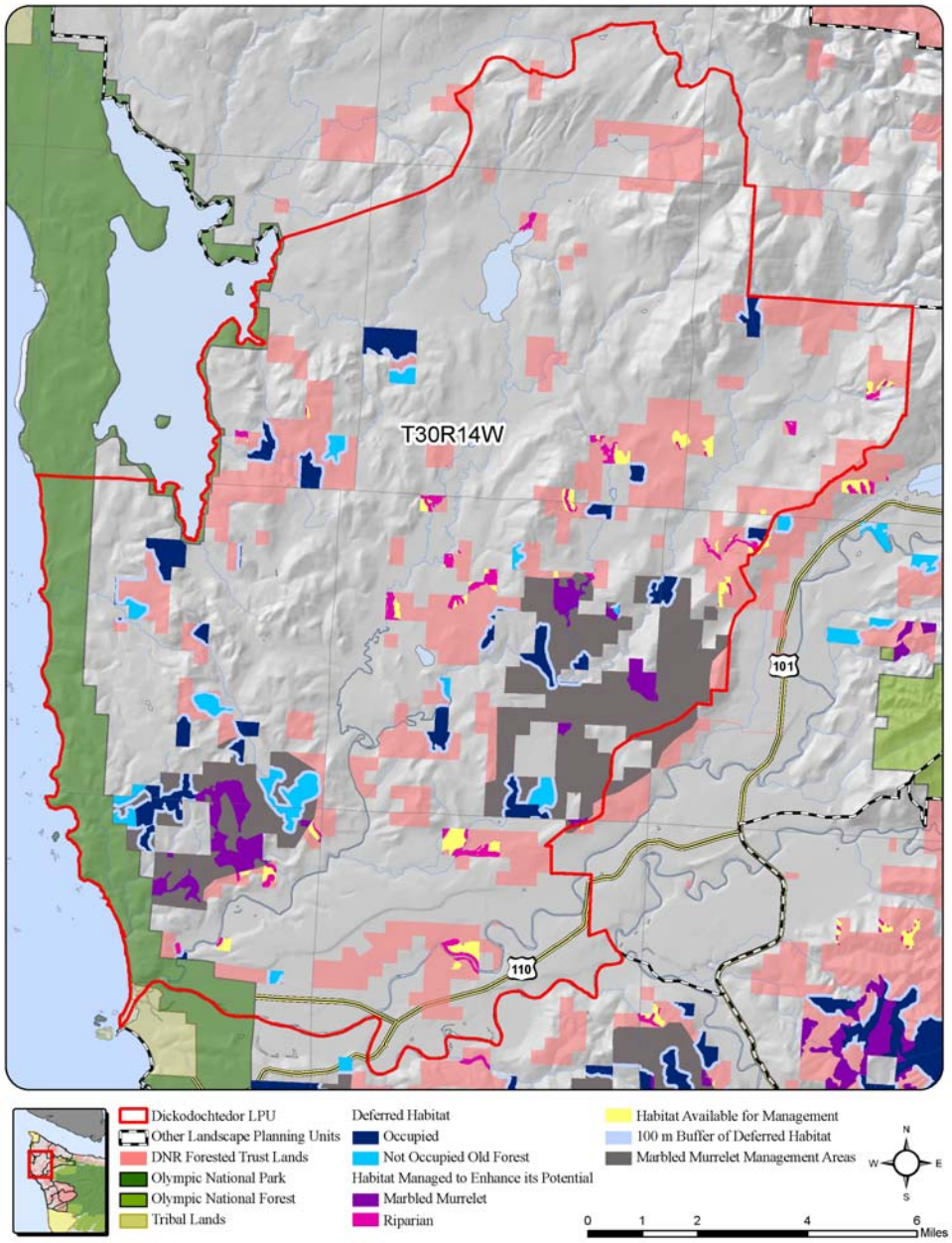

Figure 3-23. Proposed Science Team Land Allocations for Dickodochtedor LPU.

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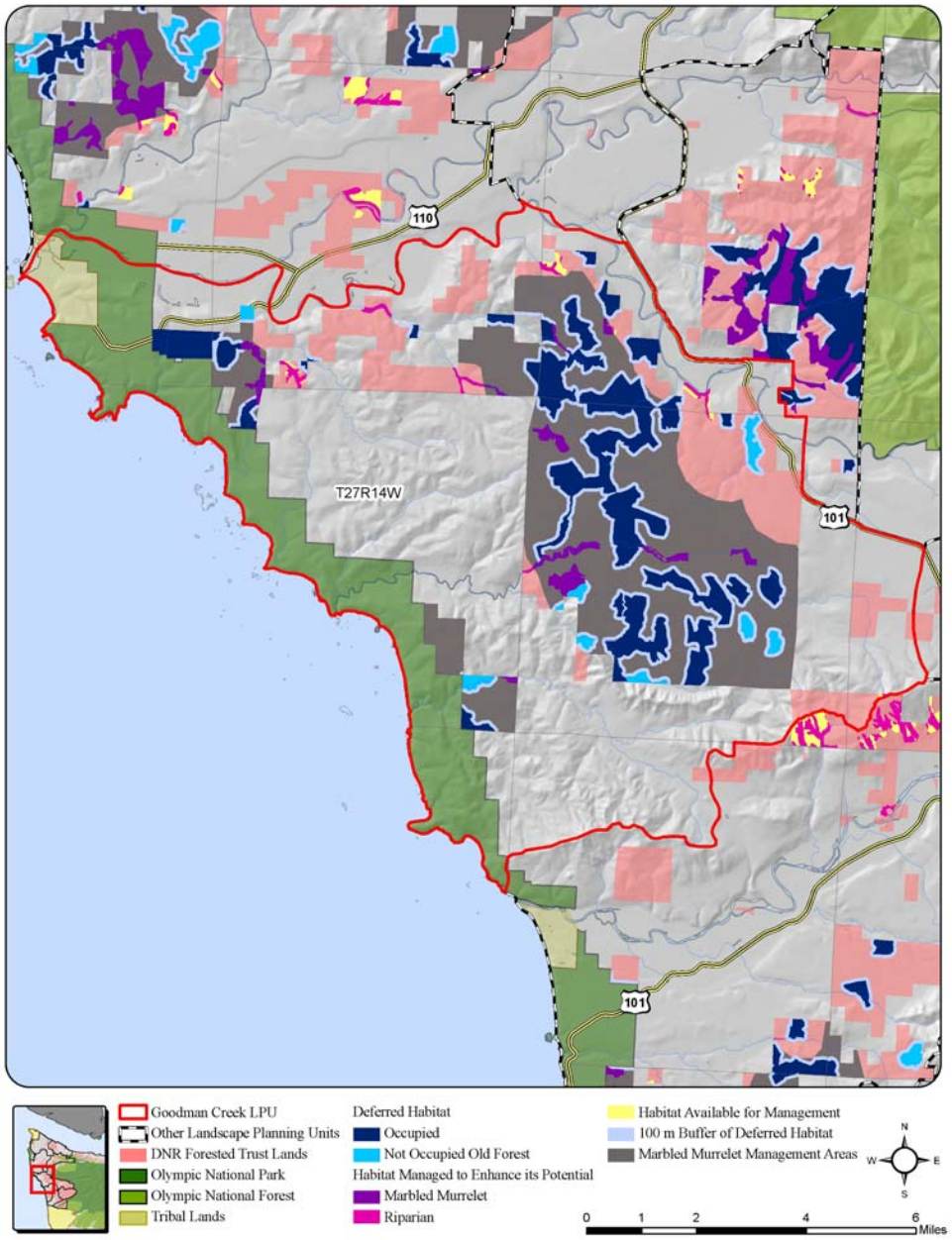

Figure 3-24. Proposed Science Team Land Allocations for Goodman Creek LPU.

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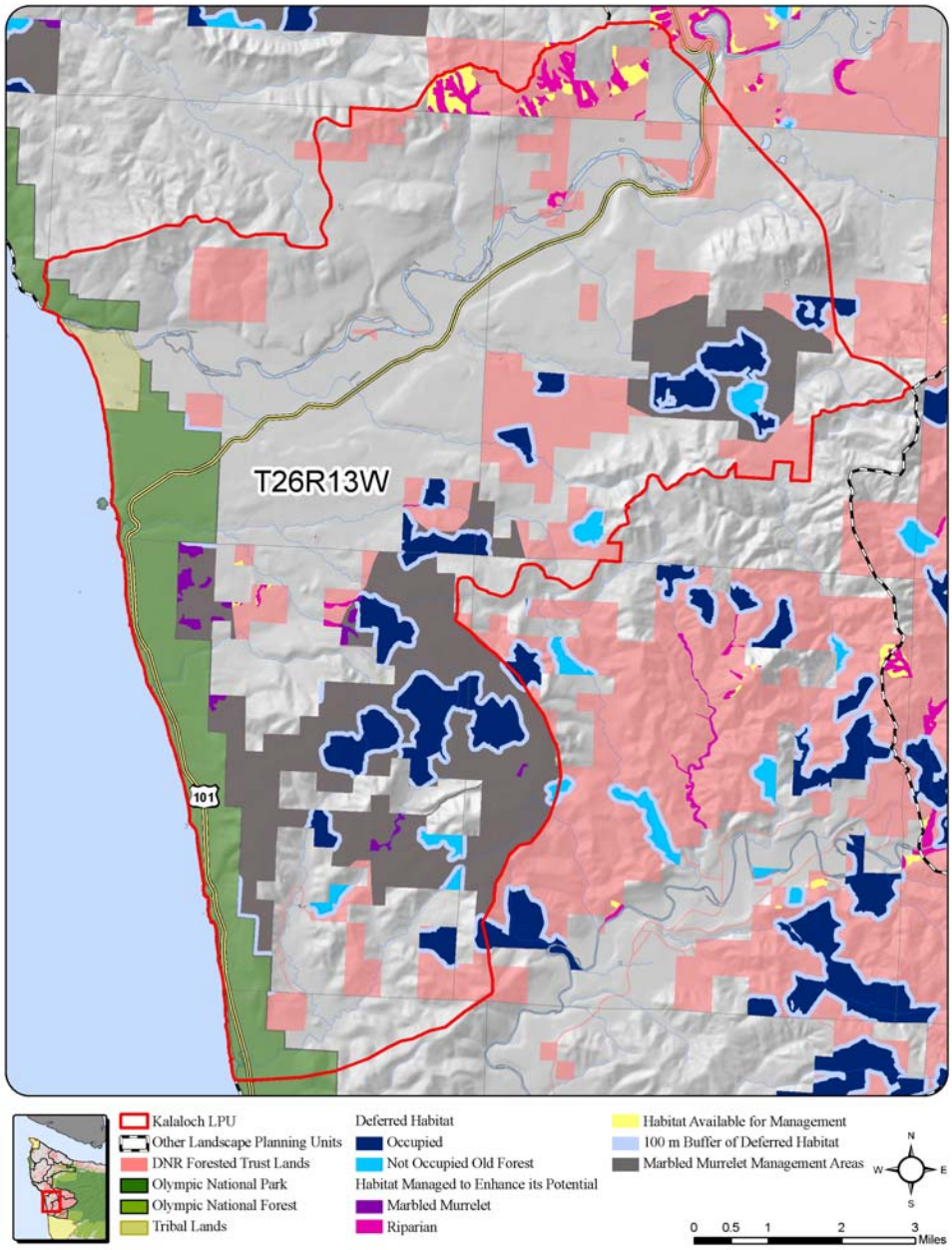

Figure 3-25. Proposed Science Team Land Allocations for Kalaloch LPU.

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Table 3-13. Olympic Experimental State Forest Landscape Planning Unit Habitat Calculations.

Landscape	Acres of DNR-Managed Forestland					
	Total Habitat	Deferred		Not Occupied Non-Old Forest Habitat		
				Managed to Enhance Habitat Potential[2]		
		Occupied	Not Occupied Old Forest[1]	Marbled Murrelet	Riparian[3]	Available for Management
OESF Map Legend Color		*Dark Blue*	*Blue*	*Purple*	*Pink*	*Yellow*
Upper Clearwater	16,608	14,266	1,183	0	995	164
Willy-Huel	8,675	6,960	833	0	592	290
Reade Hill	2,558	1,470	0	954	52	82
Queets	5,220	4,752	255	137	59	17
Copper Mine	3,422	2,820	389	0	148	65
Upper Sol Duc	1,669	42	797	663	48	119
Clallam	348	319	0	0	28	1
Sekiu	85	62	23	0	0	0
Dickodochtedor	5,259	2,005	829	1,141	656	628
Goodman Creek	5,586	4,310	432	577	188	79
Kalaloch	3,391	2,255	291	198	394	253
Grand Total	**52,821**	**39,261**	**5,033**	**3,670**	**3,160**	**1,698**

[1] The term "old forest habitat" is used in the HCP to help define northern spotted owl habitat in the conservation strategy for the OESF (DNR 1997a, p. IV.88). Old forest habitat was identified in the OESF in fulfillment of that strategy, and was then used by the Science Team to help identify areas likely to provide nesting habitat and therefore make a contribution to marbled murrelet conservation.
[2] The acre summary columns (except Total Habitat) are mutually exclusive.
[3] All riparian habitat will be managed according to the DNR riparian conservation strategy for the Olympic Experimental State Forest (DNR 1997a).

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3.4 Conservation Approach for a Marbled Murrelet Long-Term Conservation Strategy in the Straits

Non-federal lands in the Straits Analysis Unit occur in a narrow peripheral band, approximately four to nine miles (6 to 14 kilometers) wide, on the northern and eastern Olympic Peninsula (Figures 3-26 and 3-27). DNR-managed lands (118,000 acres [47,753 hectares]) comprise approximately one-fourth of the non-federal land base in the analysis unit (Table 3-1, Figures 3-26 and 3-27). Similar to the other non-federal forests, they are almost exclusively second- and third-growth forests that regenerated after commercial timber harvest, land-clearing, and

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associated wildfires in the late 19th and early 20th centuries, and from subsequent commercial harvests and reforestation. Thus, high-quality inland habitat for the marbled murrelet is scarce on

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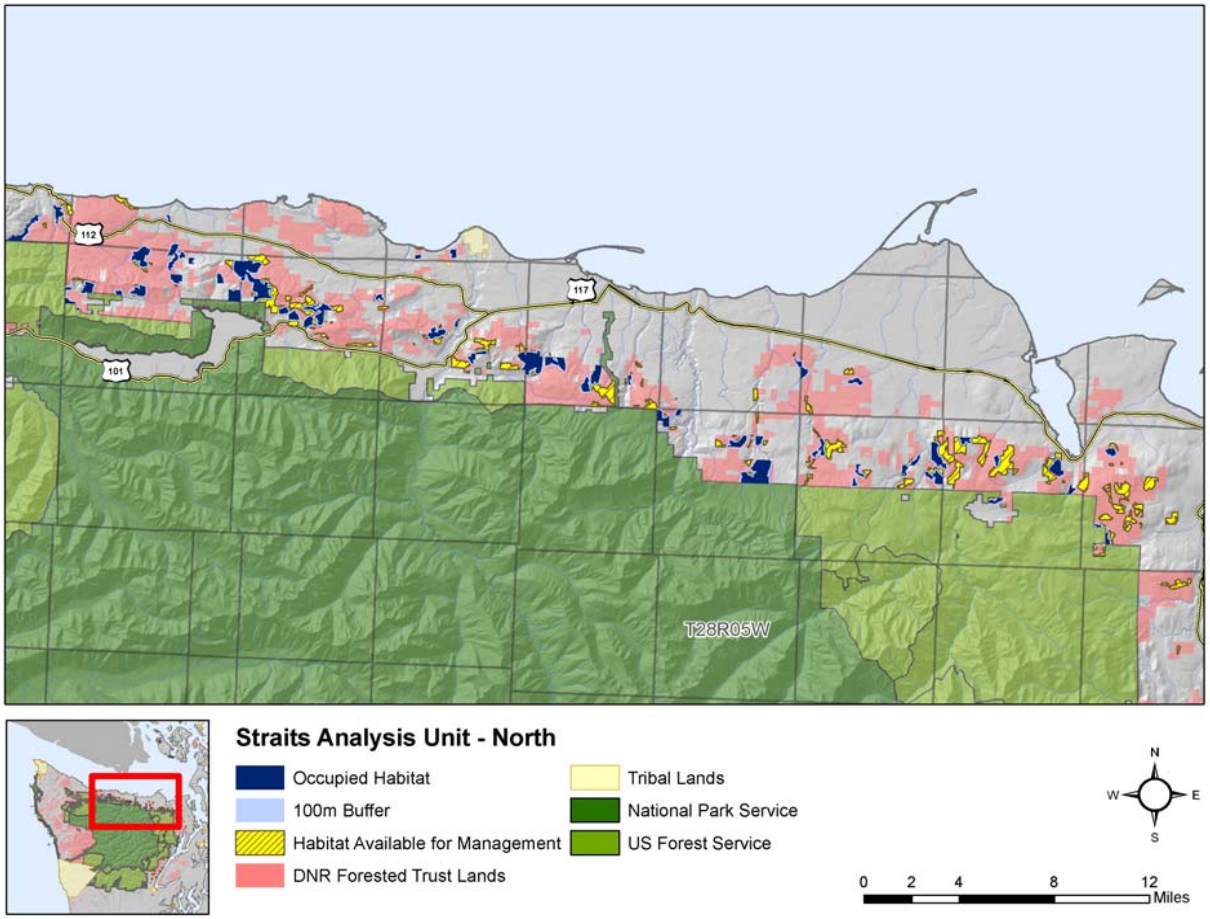

Figure 3-26. Overview of the Proposed Science Team Land Allocations for the North Portion of the Straits Analysis Unit.

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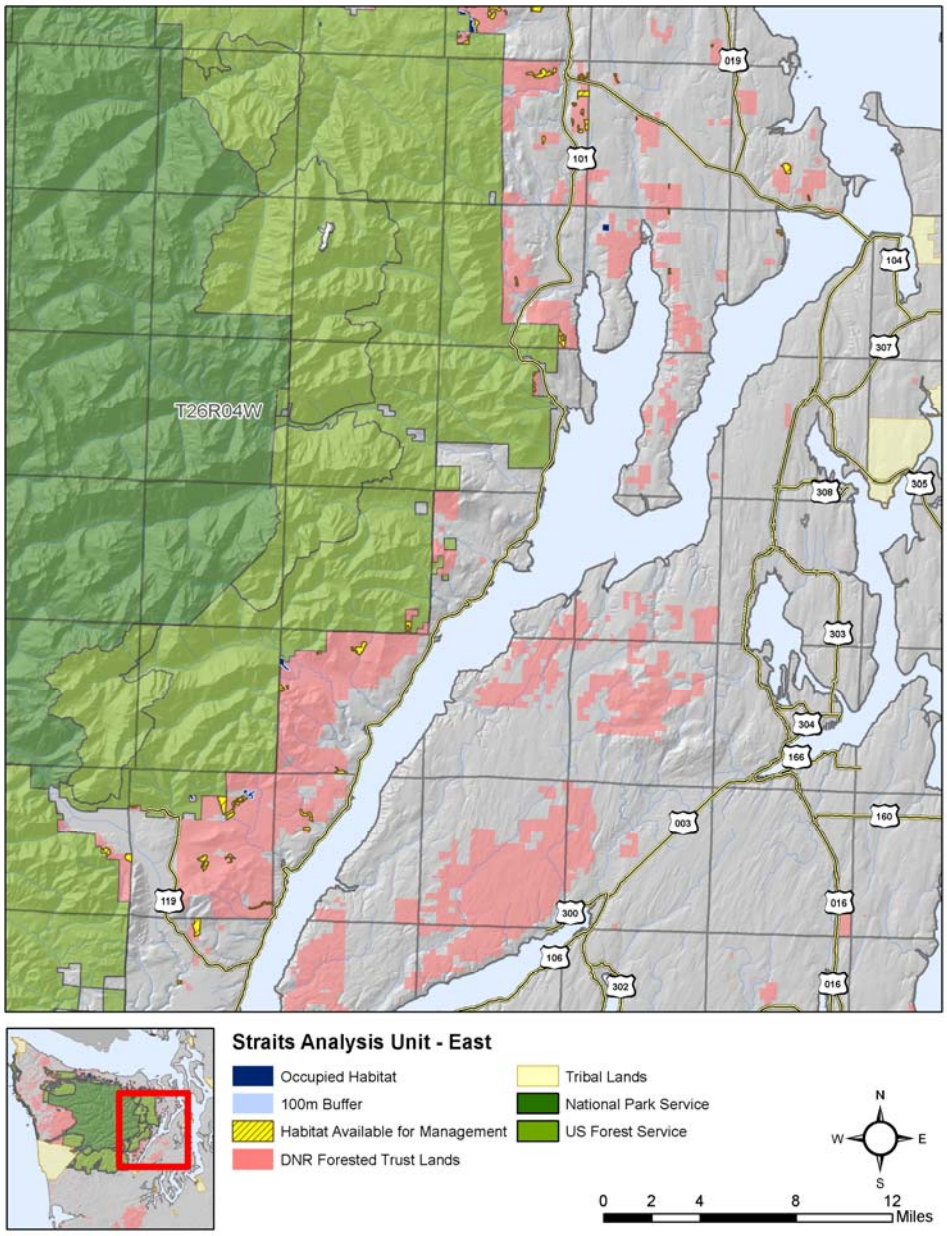

Figure 3-27. Overview of the Proposed Science Team Land Allocations for the East Portion of the Straits Analysis Unit.

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canopies have been consistently found to have the greatest likelihood of marbled murrelet use (reviewed by Burger 2002 and McShane et al. 2004). Neither of these characteristics were directly measured during DNR's forest inventory; instead they were inferred from inventory-based stand tables.

The number of canopy layers was estimated with the methods of Crookston and Stage (1999), while platform abundance was estimated with a model (Duke 1997) developed from field studies in SWWA in support of the Washington Forest Practices protocols for identifying marbled murrelet habitat (Washington Forest Practices Board 2005 [WAC 222-12-090]). Murrelet use (i.e., "occupancy") was estimated in inland surveys (Ralph et al. 1994) at 355 sites conducted from 1994 to 2001 on DNR-managed lands in the SWWA Analysis Unit (see Prenzlow Escene 1999 and Harrison et al. 2003 for survey reports).

Logistic regression models were built from all possible subsets of three independent variables (platforms per acre [ppa], numbers of canopy layers [lyr], and their interaction [ppa * lyr]) against the dependent variable of occupancy. Number of survey visits and number of visits with at least one detection of occupancy were used to incorporate the uncertainty of detecting occupancy with inland surveys (J. Baldwin, pers. comm.). The model with the lowest AIC value (model one in Table 4-1) provided the best fit to the marbled murrelet survey results, while five of the other models (models two through six) fit reasonably well and therefore provide some empirical support (Burnham and Anderson 2002).

Only the model with exclusively canopy layers (model seven) failed to provide a good fit to the survey data; models that incorporated ppa and/or the interaction of ppa and lyr were reasonably supported by the data. Thus, model selection and averaging techniques (Burnham and Anderson

Table 4-1. All Possible Logistic Models Fit to the Marbled Murrelet Survey Results, their ΔAIC Values, and a Normalized Measure of the Weight of Evidence that Model *i* was the Best among the Set (*w*).

Model	Variables			ΔAIC	*w*(*i*)
1		lyr	ppa * layer	0.0	0.58
2	ppa	lyr	ppa * layer	1.3	0.30
3	ppa			4.8	0.05
4	ppa	lyr		6.1	0.03
5	ppa		ppa * layer	6.5	0.02
6	ppa		ppa * layer	8.1	0.01
7		lyr		29.2	0.00

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Diverse, Niche Diversification, and Fully Functional stages of stand development, respectively (Brodie et al. 2004, Appendix B). These probabilities (P_{stage}) were used to modify the predicted contribution to K of current and projected future habitat in DNR-managed stands as $K_{stage} = K * P_{stage}$. For example, applying this concept to the Botanically Diverse stage (P=0.47), K_{BDS} = (170 acres/marbled murrelet) * 0.47 = 1 acre / 0.00295597 marbled murrelets, which translates to 338.3 acres (136.9 hectares) of Botanically Diverse forest / 1 marbled murrelet. Extending this concept to a 100-acre (40-hectare) Botanically Diverse stand, K_{stand} = (170 acres/marbled murrelet) * 0.47 * 100 acres = 0.296 "marbled murrelet units."

The same concepts were applied to forest cover across the entire planning area to assess current and future marbled murrelet habitat on all other forestlands with methods broadly consistent with those used for DNR-managed lands. The need to estimate edge effects and to project forest succession across the analysis units required the use of classified satellite imagery (82-foot x 82-foot [25-meter x 25-meter] pixels) developed by the Interagency Vegetation Mapping Project (IVMP) (http://www.blm.gov/or/gis/index.php) from images collected between 1992 and 1996 (estimation of edge effects are discussed in section 4.8). These IVMP data were also used by Bloxton and Raphael (2007) as input data to their marbled murrelet habitat estimates. The methods of Green et al. (1993) were used with the IVMP data to classify land cover on non-DNR ownerships. Land cover was assigned to six classes: late-, mid-, and early-seral conifer; a non-conifer class that included early clearcuts, meadows, and hardwoods; non-forest; and water.

Forest land managers on the Olympic Peninsula and SWWA can be broadly classified as DNR, federal, and other. Federally managed forests are in Olympic National Park, a wilderness area, and Olympic National Forest, which has much congressionally-designated wilderness as well as other areas, most of which are currently managed to maintain or restore late-successional forests (USDA and USDI 1994). Other forest managers include forest industry, Native American tribes, and small private landowners. Based on two separate habitat estimates reported by Raphael et al. (2006) and the considerable local knowledge of the Science Team, existing late-seral conifer on federally managed forests was assigned P=0.68. (The midpoint of the P applied to the more structurally complex stages, Botanically Diverse, Niche Diversification, and Fully Functional.) Meanwhile, existing late-seral conifer on other forests (DNR- and privately managed lands) was assigned P=0.31. (The midpoint of the P applied to the less structurally complex stages that

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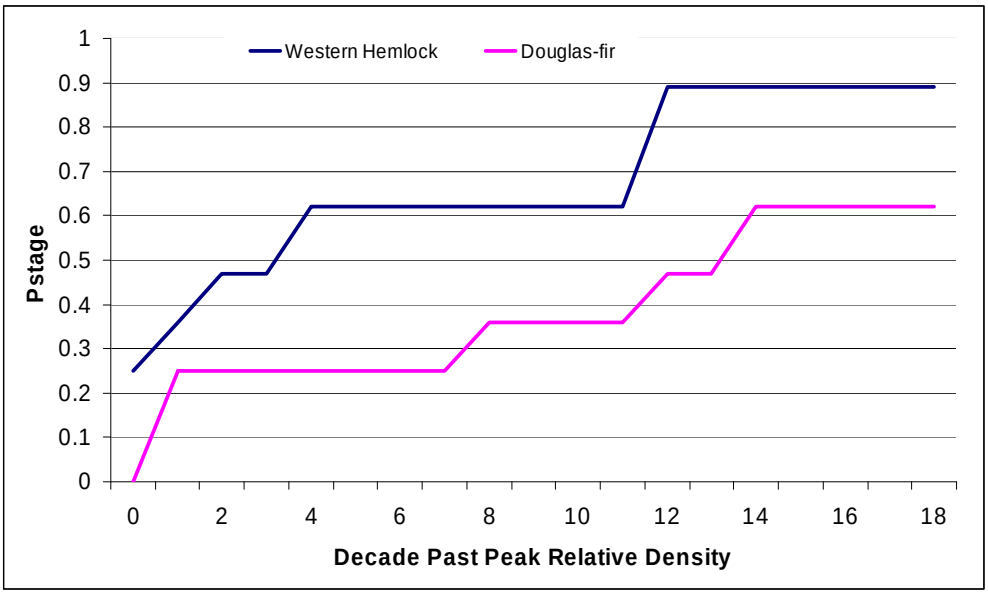

Figure 4-3. Science Team Assumptions Regarding the Rate at which Transitions Occur among Categories of P_{stage} Values for Marbled Murrelet Habitat Quality in Western Hemlock and Douglas-Fir Dominated Stands.

4.7 Summary of the Projected Current and Future Contribution of Forest Stands to Marbled Murrelet Carrying Capacity

The series of relationships and assumptions described above lead to a set of explicit assumptions regarding the P_{stage} values, which vary according to three dimensions: land ownership, existing versus projected land cover, and the application of a variety of projected management regimes for DNR-managed lands (see section II below). The P_{stage} values that are assumed to result from the relationship with these dimensions are summarized in Table 4-4. The influence of uncertainty in the classification of habitat to a particular stand development stage on *K'* is examined in a sensitivity analysis in Appendix H.

Projections of the capability of new habitat to support additional marbled murrelets depend on individuals immigrating to and breeding in these new habitats. The extent to which this will occur will depend on reproductive success and the reduced influence of environmental factors such as corvid presence, although reductions in edge effects could reduce predation.

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Table 4-4. Summary Assumptions Regarding Marbled Murrelet Habitat Potential (P_{stage}) for Two Classifications of Forest Successional Stages.

		Relative Marbled Murrelet Habitat Potential (P_{stage})				
Stand Development Stages (Brodie et al. 2004)	**Seral Stages (Green et al. 1993)**	**Existing and Projected Future Conifer Stands on DNR-Managed Land**	**Existing Conifer Forest in Olympic National Park and Olympic National Forest**	**Other[1] Existing Conifer Forests**	**Projected Future Conifer Forests in Previously Harvested Areas of Olympic National Forest**	**Projected Future Riparian Conifer Forests in Previously Harvested Riparian Areas Outside of Olympic National Forest**
Ecosystem Initiation	Non-conifer (in part)	0	0	0	0	0
Sapling Exclusion	Early-seral	0	0	0	0	0
Pole Exclusion	Mid-seral	0	0	0	0	0
Large Tree Exclusion	Late-seral	0.25	0.68[2]	0.31[2]	0.20[3]	0.13[3]
Understory Development	Late-seral	0.36	0.68	0.31	0.20	0.13
Botanically Diverse	Late-seral	0.47	0.68	0.31	0.20	0.13
Niche Diversification	Late-seral	0.62	0.68	0.31	0.20	0.13
Fully Functional	Late-seral	0.89	0.68	0.31	0.20	0.13

[1] Predominantly private and tribal land.
[2] See discussion for these calculations in section 4.4.
[3] See discussion for these calculations in section 4.5.
Note: Assumptions on the influence of land ownership, existing versus projected land cover on non-DNR ownerships, and several potential forest management regimes for DNR-managed lands on P_{stage} are discussed in the preceding section. The influence of uncertainty in the classification of habitat to a particular stand development stage on *K'* is examined in a sensitivity analysis in Appendix H.

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4.8 Edge Effects on Quality of Marbled Murrelet Habitat and Its Potential Influence on Carrying Capacity

Edge is believed to be an important factor influencing marbled murrelet nesting success; it is also a complex and poorly understood phenomenon. The method of addressing edge effects employed by the Science Team was strongly influenced by studies by Nelson and Hamer (1995) and Manley and Nelson (1999).

The Science Team reviewed and attempted to apply landscape-level predation effects as investigated in studies on the Olympic Peninsula in Washington State (Marzluff et al.1999). Analysis from this unpublished study suggests that edge effects influencing marbled murrelet nesting are more complex than the simple negative relationship that forms the basis for the nest predation analysis outlined below. While negative effects can be expected at most forest edges bordering clearcuts or young forest, other factors such as forest structure, human influence, elevation (Bradley [2002] found fewer predators at higher elevations), distance from edge and type of edge (natural edges such as avalanche chutes seem to produce less severe edge impacts [Malt and Lank 2007]) can change this relationship.

The Science Team is not aware of any peer reviewed research documenting a more complex model for understanding influences of edge on nesting marbled murrelets. The Science Team was therefore unable to incorporate a more sophisticated model into their analysis.

Manley and Nelson (1999) found that for a collection of well-observed marbled murrelet nests in British Columbia, Washington, Oregon, and California, nest success within 164 feet (50 meters) of the forest edge was 38% (n=29 nests) while nest success at greater distances was 55% (n=29 nests). Sixty percent of all nests failed because of predation. These observations, coupled with hypotheses that edges between early and late-seral forest support increased predator abundance and/or lead to decreased concealment of nests (Nelson and Hamer 1995b), suggested to the Science Team that current and projected edge effects on habitat quality should be considered as a criterion for evaluating potential outcomes of alternatives for DNR's LTCS.

The Science Team decided to employ a simple assumption regarding edge effects while acknowledging the considerable uncertainty that surrounds the core hypothesis of a simple relationship between proximity to stand edge and nest success. Elements of this uncertainty include the definition of what constitutes an "edge" and observations of the absence of a negative

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edge effect at a large sample (n=137) of marbled murrelet nests located with radiotelemetry in southwestern British Columbia (Malt and Lank 2007, Zharikov et al. 2006, Bradley 2002). Additional uncertainty derives from the apparently complicated relationship among the interaction of human residential, agricultural, and recreational developments with edge effects (Raphael et al. 2002b).

Based on the observed relationship of diminished nest success with stand edges (Manley and Nelson 1999), the Science Team determined to discount the predicted contribution of edge-influenced potential marbled murrelet habitat to carrying capacity. A 164-foot (50-meter) distance reflecting edge effects (Manley and Nelson 1999) and the values for low and high nest success hypothesized by McShane et al. (2004) (0.38 and 0.54, respectively) were used together to determine a discount factor, or P_{edge}, of 0.70 (0.38 / 0.54 = 0.70; i.e. success at edges is assumed to be 70% of forest interior values). This discount factor (0.70) was used to modify the predicted contribution to *K* of current or potential future edge-influenced habitat as $K_{edge} = K_{stage} * P_{edge}$. Predictions of *K* across edge and interior ($K_{interior}=K_{stage}$) habitat are summarized as $K' = K_{edge} + K_{interior}$. Thus for example, applying this concept to a 100-acre (40-hectare) stand in the Botanically Diverse (Appendix B) stage (*P*=0.47) with 50 acres (20 hectares) of interior and 50 acres (20 hectares) of edge influence, K' = (170 acres / marbled murrelet) * [(0.47 * 50 acres) + (0.47 * 0.70 * 50 acres)] = 0.251 "marbled murrelet units." In this example, *K'* is 85% of the estimated *K* of 0.296 presented in the earlier example (see section 4.4), which did not consider the negative influence of edges.

Areas of potential marbled murrelet habitat subject to edge effects were identified and summarized using the 82-foot (25-meter) resolution GIS grids that represented current and projected land cover. The land cover categories of Green et al. (1993) were the basis for determining edge-influenced areas of potential marbled murrelet habitat that occurred only in the late-seral category. Non-forest, non-conifer, and early-seral conifer were considered "edge-creating" categories. Among DNR's SDS categories, Ecosystem Initiation and Sapling Exclusion were considered edge-creating when adjacent to categories that provided some *K*. The influence of uncertainty in the estimation of the edge coefficient (0.70) on *K'* is examined in a sensitivity analysis in Appendix H.

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4.9 The Habitat Capability (*K'*) Equation

The variables described above for habitat capability (*K'*) are summarized in equations here:

$K_{interior}$ = (P_{stage} * Interior Acres) / 170 acres/murreletK_{edge} = (P_{stage} * P_{edge} * Edge Acres) / 170 acres/murrelet

$K' = K_{edge} + K_{interior}$

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4.10 The Influence of Distance from Marine Habitat on the Quality of Inland Marbled Murrelet Habitat and its Effects on Carrying Capacity

Radiotelemetry studies in southwestern British Columbia (Hull et al. 2001) suggest that 40 miles (64 kilometers) is a reasonable one-way commuting distance for nesting marbled murrelets. The at-sea distribution of marbled murrelets during the breeding season (Miller et al. 2006) and results of DNR's inland marbled murrelet surveys in the South Coast and Columbia HCP Planning Units (see Prenzlow Escene 1999 and Harrison et al. 2003 for survey reports) confirm that the value of inland habitat declines dramatically beyond 40 miles (64 kilometers) from marine foraging areas.

The Science Team applied an arbitrary discount factor of 0.25 to reflect the diminished potential contribution to *K'* of stands more than 40 miles (64 kilometers) from marine waters with an observed high density of marbled murrelets during the breeding season (see Figure 3-1, Miller et al. 2006). Thus, in the previous calculation of *K'*, which resulted in an estimate of 0.251, if that stand were more than 40 miles (64 kilometers) from a marine foraging area, its adjusted *K'* would be 0.251 * 0.25 = 0.063 "marbled murrelet units." Within the analysis areas, locations distant from marine foraging areas were exclusively in the far eastern portion of the SWWA Analysis Unit (Figure 3-1). The influence of uncertainty in the estimation of the coefficient for distance from marine waters (0.25) on *K'* is examined in a sensitivity analysis in Appendix H.

II. METHODS FOR PROJECTING THE DEVELOPMENT OF MARBLED MURRELET HABITAT UNDER THE SCIENCE TEAM'S RECOMMENDED CONSERVATION APPROACH

As described in chapter 3.0, the Science Team designated the total area of all MMMAs as approximately 116,000 acres (47,000 hectares) of forested state trust lands. These MMMAs were designated so that management within them would have the explicit objective of enhancing existing lower-quality habitat and developing new habitat in areas that have not been found to be occupied. This section summarizes the methods and assumptions used to project forest growth and response to silviculture in those MMMAs (see Appendix C for specific model inputs). The principal objective of this modeling exercise was to provide an objective, repeatable, quantitative

assessment of the results of proactive silviculture intended to maximize the quality and quantity of marbled murrelet habitat, according to the unique conditions desired for each MMMA, within

5.5 Summary and Discussion

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Chapter 4.0 provides a discussion of the hypotheses and assumptions that are the basis for the analyses reported here. A brief review of those hypotheses and assumptions, as well as the uncertainty around them can help the reader interpret the results of those analyses from both a quantitative and qualitative perspective. Additionally, a sensitivity analysis was conducted on the potential habitat capability (*K'*) model, describing how the uncertainty in estimation or classification of the factors listed below may contribute to habitat capability (Appendix H).

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Below is a summary of how knowledge and hypotheses regarding marbled murrelet biology and forest ecology were translated into specific assumptions concerning how forest habitat supports marbled murrelet populations and how forest succession, with and without active silvicultural intervention, influences the development of marbled murrelet habitat.

1. **Habitat area—**The assumption that 170 acres (69 hectares) of suitable forest habitat provides sufficient opportunities to support one nesting marbled murrelet is substantiated by inland studies using radar to estimate marbled murrelet numbers and radiotelemetry to assess inland behavior (Burger 2002, Raphael et al. 2002a, Peery et al. 2004, Bloxton and Raphael 2007), as well as by estimates of marbled murrelet numbers on adjacent marine foraging areas (Miller et al. 2006). However, it is likely there is a fine-grained variability in this relationship that is overlooked by the simple assumption used in these analyses.

2. **Stand characteristics—**The abundance of potential nesting platforms and the presence of complex canopy structure are well known as essential elements of marbled murrelet nesting habitat (Grenier and Nelson 1995, Hamer and Nelson 1995). The assumed relationship of habitat value with stand structure and composition as within Table 4-4 was derived from empirical studies of marbled murrelet behavior in DNR-managed stands (Prenzlow Escene 1999), but the generalization that used SDS categories as surrogates for those structural elements has not been validated with field studies. It is likely that Table 4-4 depicts general trends in potential habitat value (Prenzlow Escene et al. 2006), but the precise numerical estimates should be considered as working hypotheses. Additionally, recent studies have located marbled murrelet nests in what appear to be unsuitable land cover categories (Hamer

and Nelson 1995, Bradley and Cooke 2001, M. Raphael pers. comm.), though these nests were generally in old forests, rather than heavily managed forest landscapes. These discoveries probably reflect the inability of coarse-grained, i.e., stand-level, classifications to

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APPENDIX D
SCIENCE TEAM RECOMMENDATIONS:
ROADS, YARDING AND SALVAGE IN OCCUPIED SITES

D.1 Road and Yarding Corridor Access

Ideally, occupied sites should not be disturbed. The Science Team recognizes, within limits, the need for DNR to access the land base for habitat restoration activities with roads and yarding corridors. Before considering road access through an occupied site, all alternative access routes should be thoroughly explored and impacts as to the effects of modifying occupied patch size should also be examined. If access through an occupied site is necessary, special attention should be given to maintain the integrity of the occupied site and to minimize the effects of human activities. The Science Team recommends that all efforts be made to minimize:

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- Loss of core areas of high-quality nesting habitat.
- Loss of platform trees with special priority given to the protection of multi-platform trees.
- Disturbance during critical nesting season (1 April through 31 August) including observing daily peak activity periods for marbled murrelets (one hour before sunrise to two hours after; one hour before sunset to one hour after) (Washington Forest Practices Rules 2001 [WAC 222-16-010]).
- Frequency of road use (i.e., mainline road vs. gated or temporary road).

D.2 Salvage

Salvage is defined as removing downed trees, particularly in the case of catastrophic natural events such as windthrow and fire. When salvage is being considered within Marbled Murrelet Management Areas, the primary consideration should be the maintenance of high-quality nesting habitat followed by the restoration of remaining habitat within the stand.

The Science Team Recommends that salvage be given the following considerations:

- Priority should be given to maintaining all standing trees.
- When removing salvage trees, consider options (legacies) for the development of a replacement buffer.

- If harvest of standing trees is necessary, limit loss of platform trees with special priority given to multi-platform trees.

- Salvage should occur outside of the critical nesting season.
- When salvaging within an occupied site, salvage should not have a negative effect on functional habitat.

The Science Team further recommends that the above guidelines be followed for proposed salvage within isolated occupied sites outside of MMMAs in the OESF, and for all occupied sites within the Straits Analysis Unit. In addition, DNR should maintain the integrity (and therefore the function) of buffers around occupied sites during salvage operations and if necessary, develop a replacement buffer to the extent that a buffer no longer exists due to windthrow or other factors.

Once a long-term conservation strategy is adopted by DNR, it is recommended that the implementation document provides additional details, methods, and justification for habitat loss and salvage within occupied sites.

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Table 1-1. Marbled Murrelet Science Team Members.

Name	**Agency**
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