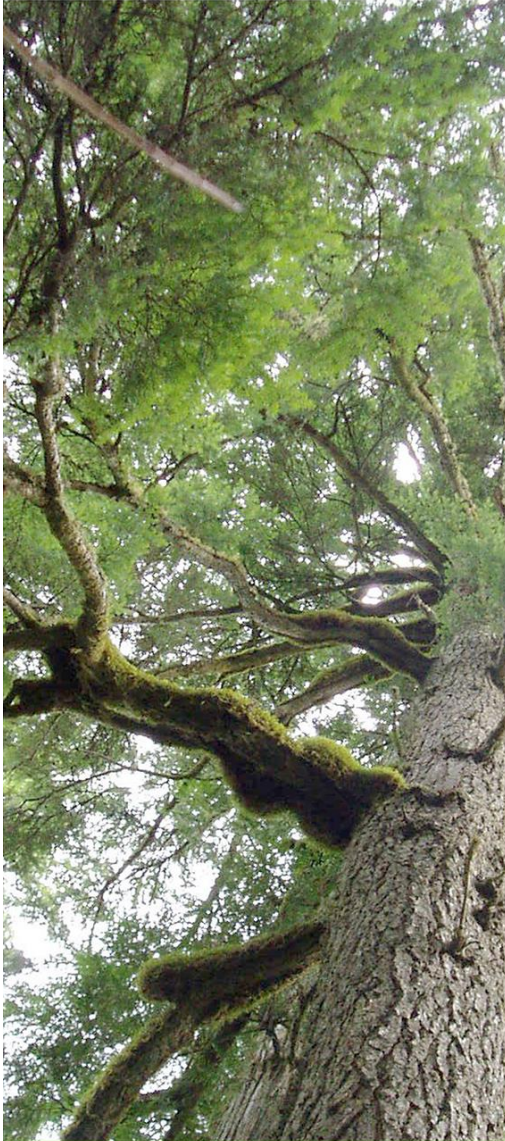


N A T U R A L

R E S O U R C E S



# Final State Trust Lands Habitat Conservation Plan AMENDMENT

## Marbled Murrelet Long-Term Conservation Strategy

December, 2019



Murrelet photo courtesy [www.hamerenvironmental.com](http://www.hamerenvironmental.com)



WASHINGTON STATE DEPARTMENT OF  
**NATURAL RESOURCES**  
HILARY S. FRANZ | COMMISSIONER OF PUBLIC LANDS

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December 2019

Dear Reader,

The Board of Natural Resources has adopted a long-term conservation strategy for the marbled murrelet. The strategy is an amendment to Washington State Department of Natural Resources' (DNR) 1997 *State Trust Lands Habitat Conservation Plan* (1997 HCP) and replaces the interim strategy under which DNR has been operating since 1997.

The marbled murrelet is a small, fast-flying seabird that spends most of its life at sea and nests on the large branches of conifer trees in older forests. Due to inland habitat loss, threats to the marine environment, and other stressors, the marbled murrelet is listed as threatened on the federal Endangered Species List.

Under the long-term strategy, conservation is concentrated in 20 "special habitat areas" on DNR-managed lands. Special habitat areas are designed to improve murrelet nesting success by reducing habitat fragmentation and disturbances to nesting birds. Located in areas that are strategically important to murrelet survival, all but one special habitat area includes one or more occupied sites where murrelet presence has been documented through field surveys. In addition, the strategy includes conservation measures to help prevent disturbance from ongoing forest management and land use activities such as road building. By protecting strategically important areas and minimizing disturbances to nesting birds, DNR expects to contribute to the long-term conservation of the species while providing certainty for timber harvest and other management activities on DNR-managed lands.

The long-term strategy was based on two decades of research and analysis and was developed in cooperation with U.S. Fish and Wildlife Service. It underwent extensive environmental review and public comment through the publication of a draft environmental impact statement (EIS) in 2016, a revised draft EIS in 2018, and a final EIS in 2019. It was adopted by the Board of Natural Resources on December 3, 2019. As part of this process, U.S. Fish and Wildlife Service issued DNR an amended incidental take permit for the marbled murrelet and other species covered by the amended 1997 HCP.

We invite you to learn more about the long-term strategy and the biology of this remarkable bird. The attached document describes the strategy in detail. Thank you for your interest in the sustainable management of state trust lands.

Sincerely,

A handwritten signature in black ink, appearing to read "Hilary Franz", with a large, sweeping flourish extending to the right.

Hilary Franz  
Commissioner of Public Lands

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# Final State Trust Lands Habitat Conservation Plan AMENDMENT

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## Marbled Murrelet Long-term Conservation Strategy

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December 2019



Washington State Department of Natural Resources  
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# Table of Contents

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<b>Section 1.0 Introduction</b> .....	1
1.1 Overview and Background .....	1
1.2 Plan Area / Permit Area .....	4
1.3 Permit Duration .....	4
1.4 Alternatives to the Taking.....	5
1.5 Coordination with Federal and State Agencies .....	9
<b>Section 2.0 Project Description and Covered Activities</b> .....	11
2.1 Project Description.....	11
2.2 Covered Activities .....	11
<b>Section 3.0 Covered Species</b> .....	13
3.1 Covered Species.....	13
3.1.1 Status and Distribution.....	13
3.1.2 Habitat Characteristics and Use .....	14
3.1.3 Occurrence in the Project Area.....	15
3.2 Species in the Plan Area That do Not Need Coverage and Why.....	15
<b>Section 4.0 Environmental Setting</b> .....	17
<b>Section 5.0 Potential Biological Impacts and Take Assessment</b> .....	19
5.1 Direct and Indirect Impacts .....	19
5.2 Anticipated Take of the Covered Species .....	20
5.3 Anticipated Impacts of Take on Critical Habitat.....	22
5.4 Anticipated Impacts of the Taking .....	22
<b>Section 6.0 Conservation Program</b> .....	24
6.1 Biological Goals .....	25
6.2 Biological Objectives .....	25
6.3 Measures to Avoid, Minimize, and Mitigate Take.....	26
6.3.1 Murrelet Specific .....	26
6.3.1.1 Occupied Sites and Occupied Site Buffers.....	26

6.3.1.2 Strategic Locations .....	27
6.3.1.3 SHAs .....	28
6.3.2 Non-Murrelet Specific .....	30
6.3.3 Restrictions on Management and Recreation Activities .....	32
6.3.4 Metering .....	32
6.3.5 Significant Contribution .....	32
6.4 Adaptive Management .....	33
6.5 Reporting .....	35
<b>Section 7.0 Changed and Unforeseen Circumstances, Uncertainty</b> .....	<b>37</b>
7.1 Changed Circumstances .....	37
7.2 Unforeseen Circumstances .....	37
7.3 Uncertainty .....	38
<b>Section 8.0 Funding</b> .....	<b>41</b>
<b>Section 9.0 References</b> .....	<b>43</b>
<b>Section 9.2 List of Preparers</b> .....	<b>49</b>

## ***List of Appendices and Attachments***

<b>Appendix A:</b>	Tables
<b>Appendix B:</b>	Figures
<b>Appendix C:</b>	Background Reports/Supporting Documents: Attachment C-1, Potential Impacts and Mitigation Focus Paper Attachment C-2, Population Viability Analysis Attachment C-3, Estimating the Location and Quality of Marbled Murrelet Habitat Focus Paper (P-stage) Attachment C-4, Long-term Forest Cover Focus Paper Attachment C-5, Uncertainties in the Marbled Murrelet Long-term Conservation Strategy
<b>Appendix D:</b>	Board of Natural Resources Resolution 1559 and Transmittal Letter from U.S. Fish and Wildlife Service for the Incidental Take Permit



## ***Acronyms***

DNR	Washington State Department of Natural Resources
FIU	Forest inventory unit
1997 HCP	State Trust Lands Habitat Conservation Plan
IA	Implementation Agreement
ITP	Incidental Take Permit
LTFC	Long-term forest cover
OESF	Olympic Experimental State Forest
SHA	Special habitat area
USFS	U.S. Department of Agriculture Forest Service
USFWS	U.S. Fish and Wildlife Service
UW	University of Washington College of Forest Resources
WDFW	Washington Department of Fish and Wildlife

## ***Terms***

Interim Strategy	Marbled Murrelet Interim Conservation Strategy
Long-term Strategy	Marbled Murrelet Long-term Conservation Strategy

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# Introduction

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## ***1.1 Overview and Background***

This Amendment changes Washington State Department of Natural Resources' (DNR) [\*State Trust Lands Habitat Conservation Plan \(1997 HCP\)\*](#), under which DNR has operated since January 30, 1997. Specifically, this Amendment replaces the interim marbled murrelet conservation strategy (Interim Strategy) described in the 1997 HCP with the long-term marbled murrelet conservation strategy (Long-term Strategy) envisioned in the 1997 HCP.

DNR will continue to operate under the Interim Strategy until DNR's Incidental Take Permit (ITP) has been amended pursuant to this Amendment. Upon amendment of the ITP, DNR's operations will conform to the Long-term Strategy described in this Amendment, and commitments expressed in the Interim Strategy will be extinguished unless expressly incorporated into the Long-term Strategy.

DNR's 1997 HCP features an interim conservation strategy for the marbled murrelet (murrelet, *Brachyramphus marmoratus*) because at the time the 1997 HCP was developed (mid 1990s), information about murrelet habitat use, both generally and specific to DNR-managed HCP lands, was not sufficient to design and implement a long-term conservation strategy. Further, a federal recovery plan, which would have helped inform the 1997 HCP, had not yet been developed. The Interim Strategy emphasizes development of needed information about murrelet habitat relationships and conserves habitat on DNR-managed HCP lands so management would not foreclose future options for the Long-term Strategy.

Major components of the Interim Strategy are 1) conservation of suitable murrelet habitat (suitable habitat<sup>1</sup>) on DNR-managed HCP lands until spatially explicit habitat relationships studies are completed, 2) surveys of suitable habitat estimated to support at least 95 percent of the murrelet occupied sites on DNR-managed HCP lands in each HCP planning unit (reclassified habitat) to determine murrelet occupancy, 3) protection of all murrelet occupied sites on DNR-managed HCP lands, and 4) participation in collaborative scientific studies aimed at improving scientific knowledge of murrelet habitat relationships (DNR 1997).

DNR completed spatially explicit habitat relationship studies directed by the Interim Strategy in five of the six HCP planning units within the murrelet's Washington range: Columbia, North Puget, Olympic Experimental State Forest (OESF), South Coast, and Straits (Table A-1 in Appendix A). A habitat relationship study was not attempted in the South Puget HCP planning unit, which contains the Seattle metropolitan area and the least amount of suitable habitat. All reclassified habitat identified through habitat relationships studies was surveyed within three of the HCP planning units: Columbia, South Coast, and Straits. Most (75 percent) reclassified habitat was surveyed in the OESF HCP planning unit. Surveys were truncated in the OESF HCP planning unit after many occupied sites had been identified, protection of sites occupied by murrelets as well as other conservation commitments and operational constraints encompassed much of the reclassified habitat that remained to be surveyed, and DNR biologists felt that murrelet habitat relationships in the OESF HCP planning unit had become sufficiently

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<sup>1</sup> Suitable habitat is "a contiguous forested area at least five acres in size, containing an average of at least two potential nesting platforms per acre, and within 50 miles of marine waters" (DNR 1997, p. IV.41).

clear to confidently develop the Long-term Strategy. About half (48 percent) of the reclassified habitat was surveyed in the North Puget HCP planning unit. Unsurveyed, reclassified habitat in the OESF and North Puget HCP planning units, totaling 16,327 acres, has been conserved pending adoption of the Long-term Strategy. No habitat was surveyed in the South Puget HCP planning unit, in which a habitat relationships study was not undertaken. Overall, approximately 150,000 acres have been conserved pending adoption of a murrelet long-term conservation strategy (refer to Table A-1 for details).

From 1997 through 2009, DNR participated in several collaborative scientific studies on murrelet habitat relationships and predation risk, led by U.S. Fish and Wildlife Service (USFWS); University of Washington College of Forest Resources (UW); and U.S. Forest Service (USFS) Pacific Northwest Research Station, Olympia Forestry Sciences Laboratory. DNR contributed more than \$0.8 million<sup>2</sup> to these collaborative projects. DNR also supported at-sea surveys carried out by Washington State Department of Fish and Wildlife (WDFW) to estimate numbers and distribution of murrelets. DNR contributed over \$0.3 million to these surveys. Several peer-reviewed scientific publications (refer to Table A-2 in Appendix A) as well as numerous unpublished reports and presentations at professional conferences resulted from this body of work.

In 2004, DNR convened a team of 10 biologists and forestry professionals from DNR and other organizations (Science Team) to develop a set of recommendations for DNR to consider when developing the Long-term Strategy. The Science Team completed its work and published its report in 2008 (Raphael and others 2008). Biological goals that the Science Team identified for DNR were “to manage forest habitat to contribute to 1) a stable or increasing [murrelet] population; 2) an increasing geographic distribution; and 3) a population that is resilient to disturbance.” The Science Team made quantitatively and spatially explicit recommendations for the types, amounts, distribution, and configuration of murrelet habitat on DNR-managed HCP lands that it felt were needed to accomplish these goals. They developed a marbled murrelet habitat model, P-stage, which became fundamental in the development of the Long-term Strategy. The Science Team also re-delineated the boundaries of murrelet occupied sites on DNR-managed HCP lands. In 2010, following the Science Team’s re-delineation of occupied site boundaries, DNR added approximately 16,356 acres of habitat to its

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<sup>2</sup> Throughout this Amendment, expenditures are rounded to the nearest \$0.1 million.

conservation of occupied sites. The Science Team did not attempt to reconcile its recommendations with DNR’s other management responsibilities; with the exception of special consideration of impacts to Wahkiakum and Pacific counties (as requested by DNR), the Science Team’s work purely represents a biological conservation perspective.

All of these components of the Interim Strategy—spatially explicit habitat relationship study on DNR-managed HCP lands, occupancy surveys of reclassified habitat, protection of all occupied sites on DNR-managed HCP lands, participation in collaborative scientific studies to improve the knowledge base from which to proceed, expert synthesis and formulation of biological recommendations, and adoption of enhanced occupied site boundaries—have been brought to bear on development of the Long-term Strategy described in this Amendment. All told, DNR has expended more than \$16.8 million to implement the Interim Strategy and prepare the Long-term Strategy.

## 1.2 Plan Area / Permit Area

The plan and permit area (plan area) for this Amendment is the same as the “permit lands” for the 1997 HCP that are described in Section 15.1, “Permit Lands Description,” of the 1997 Implementation Agreement (IA). The plan area encompasses all DNR-managed HCP lands in the range of the northern spotted owl (*Strix occidentalis caurina*) and include approximately 1.9 million acres of forestland<sup>3</sup>. Pursuant to Section 17.0 of the IA, “Land Transfers, Purchases, Sales, and Exchanges,” the 1997 HCP recognizes that DNR has an active program of land acquisitions and disposals. As a result of these activities, the total acres of DNR-managed HCP lands will fluctuate over time.

## 1.3 Permit Duration

Upon amendment of DNR’s ITP, this Amendment will remain in full force and effect until the end of the initial 70-year term of the 1997 HCP, ITP, and IA, as described in Section 19.1, “Term of Permit,” of the IA. This period began on 30 January 1997 and

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<sup>3</sup> *Fiscal Year 2018 HCP Annual Report*, found at [https://www.dnr.wa.gov/publications/lm\\_trust\\_land\\_hcp\\_annual\\_rprt\\_2018.pdf?vbnoprs](https://www.dnr.wa.gov/publications/lm_trust_land_hcp_annual_rprt_2018.pdf?vbnoprs)

will end on 29 January 2067. Pursuant to Sections 19.2 and 19.3 of the IA, “Permit Renewal” and “Permit Continuation,” the 1997 HCP, ITP, and IA may be extended for up to 30 additional years. This Amendment would remain in full force and effect for the duration of any such extensions.

## 1.4 Alternatives to the Taking

As an alternative to the incidental taking authorized by the ITP, which is avoided, minimized, and mitigated according to terms of the 1997 HCP and IA, DNR could relinquish incidental take coverage for the murrelet, cancel its murrelet conservation strategy, and avoid any incidental taking of murrelets by adopting a “no take” posture for its operations, following the Washington State forest practices rules (Title 222 WAC). This possibility is contemplated in Section 27.0 of the IA, “Termination and Mitigation after Termination.” As described in the *Long-term Conservation Strategy for the Marbled Murrelet Final Environmental Impact Statement* for the (FEIS) prepared in conjunction with this Amendment (DNR and USFWS 2019), DNR did not choose this alternative for the following reasons:

- “Removing HCP coverage would not provide DNR with certainty that it could meet its trust obligations through continued, sustainable timber management.
- Managing under only the forest practices rules would mean potential costly delays to the timber sale process due to required surveys of each stand for marbled murrelet occupancy (a one- to two-year process with up to 18 site visits [Evans Mack and others 2003]) and consultation with USFWS each time potential impacts to habitat are identified.
- Performing the sustainable harvest calculation that DNR relies on to plan its harvest schedules would be very difficult with this level of uncertainty.
- Removing HCP coverage also would be unlikely to contribute to conservation efforts for the marbled murrelet, because DNR would not be setting aside lands to protect and grow murrelet habitat over the long term, but would instead be managing habitat on a piecemeal basis. Managing this way could foreclose future options for habitat development in areas strategically important to the bird’s population” (DNR and USFWS 2019, Section 2.1).

DNR and USFWS analyzed eight alternative conservation strategies that differ from the Long-term Strategy described in this Amendment. The alternatives are described in detail as alternatives A through H in Chapter 2 of the FEIS. The Long-term Strategy, like the alternatives, would not alter the 1997 HCP in any way except to replace the Interim Strategy with a long-term approach to murrelet conservation. None of the alternatives differ from the Long-term Strategy in Plan Area, Permit Area, Permit Duration, Covered Activities, or Covered Species. All of the alternatives share common elements with the Long-term Strategy. To varying degrees, the alternatives differ from the Long-term Strategy in amount, location, and configuration of land designated for marbled murrelet conservation; restrictions on management and recreation activities; and/or habitat development activities. DNR and USFWS considered, but did not analyze, six other proposed conservation strategies that fell outside the need and purpose of this Amendment.

The Long-term Strategy is similar to Alternative H, which is described in the FEIS (DNR and USFWS 2019). Like Alternative H, the Long-term Strategy described in this Amendment focuses its marbled murrelet-specific conservation into 20 special habitat areas (SHA) that are distributed across strategically important locations for the marbled murrelet. The only difference between the Long-term Strategy and Alternative H is that the Long-term Strategy includes 441 more acres of long-term forest cover (LTFC) than Alternative H (for a total of 604,907 acres versus 604,466 acres of LTFC, respectively). These additional acres are located in southwest Washington. The Long-term Strategy also accounts for the possibility of natural disturbances occurring, with mitigation exceeding impact by 706 adjusted acres.

DNR chose the Long-term Strategy described in this Amendment for the following reasons:

- The Long-term Strategy best meets DNR’s need and purpose for this Amendment. The purpose includes the following objectives:
  - **“Objective 1, Trust Mandate:** Generate revenue and other benefits for each trust by meeting DNR’s trust responsibilities, including making trust property productive, preserving the corpus of the trust, exercising reasonable care and skill in managing the trust, acting prudently with respect to trust property, acting with undivided loyalty to trust



beneficiaries, and acting impartially with respect to current and future trust beneficiaries.

- **Objective 2, Marbled Murrelet Habitat:** Provide forest conditions in strategic locations on forested trust lands that minimize and mitigate incidental take of marbled murrelets resulting from DNR forest management activities. In accomplishing this objective, DNR expects to make a significant contribution to maintaining and protecting marbled murrelet populations.
  - **Objective 3, Active Management:** Promote active, innovative, and sustainable management on state trust lands.
  - **Objective 4, Operational Flexibility:** Provide flexibility to respond to new information and site specific conditions.
  - **Objective 5, Implementation Certainty:** Adopt feasible, practical, and cost-effective actions that are likely to be successful and can be sustained throughout the life of the 1997 HCP” (DNR and USFWS 2019, Section 1.2).
- The other alternatives do not meet the need and purpose as well as the Long-term Strategy:
    - **Alternative A** does not provide long-term management certainty for DNR, does not provide long-term murrelet habitat development, and does not concentrate conservation in strategic locations.
    - **Alternative B** under-mitigates incidental take by 33 percent (DNR and USFWS 2019, Figure 2.4.5), does not provide long-term murrelet habitat development, and does not concentrate conservation in strategic locations.
    - **Alternatives C and E** over-mitigate incidental take by 62 percent and 74 percent, respectively (DNR and USFWS 2019, Figure 2.4.5), and introduce unproven approaches, such as timber management in and near murrelet conservation areas, to achieve their biological objectives.

- **Alternative D** over-mitigates incidental take by 11 percent (DNR and USFWS 2019, Figure 2.4.5) and results in a decline of up to 38 percent in nesting carrying capacity for the first 20 years following implementation (refer to Appendix C, Attachment C-1, Figure 2[b]).
  - **Alternative F** over-mitigates incidental take by 251 percent (DNR and USFWS 2019, Figure 2.4.5) and introduces unproven approaches, such as using silviculture to restore murrelet habitat, to achieve its biological objectives.
  - **Alternative G** over-mitigates incidental take by 188 percent (DNR and USFWS 2019, Figure 2.4.5), reduces the effectiveness of or makes impracticable other HCP conservation strategies, and introduces unproven approaches, such as using silviculture to restore murrelet habitat, to achieve its biological objectives.
- The Long-term Strategy does the best job of balancing mitigation and incidental take, with mitigation slightly exceeding anticipated incidental take to account for additional uncertainty, substantiated by best available science, that is not already included in the design of the Long-term Strategy (refer to Appendix C, Attachment C-5).
  - The Long-term Strategy achieves the second highest level of revenue for DNR’s trust beneficiaries.
  - The Long-term Strategy puts forth a robust combination of existing nesting areas (occupied sites) protection and strategic, long-term habitat development, as envisioned in *Recovery Plan for the Threatened Marbled Murrelet (Brachyramphus marmoratus) in Washington, Oregon, and California* (USFWS’ recovery plan, USFWS 1997).
  - The Long-term Strategy concentrates long-term habitat development in strategic locations that have a disproportionately high significance for murrelet conservation.
  - The Long-term Strategy minimizes incidental take related to management and recreation activities by restricting these activities in murrelet conservation areas.

- The Long-term Strategy does not rely upon unproven approaches or methods to achieve its biological objectives.
- The Long-term Strategy is consistent with DNR's *Policy for Sustainable Forests* (DNR 2006a) and all aspects of DNR's regulatory environment.

## **1.5 Coordination with Federal and State Agencies**

DNR collaborated with USFWS to construct the analytical framework that underlies this Amendment. DNR and USFWS staff met regularly from 2012 through 2019 to jointly produce environmental analyses and documents to meet the requirements of both the National Environmental Policy Act and the Washington State Environmental Policy Act.

Several components of the Interim Strategy were accomplished through collaboration with other federal and state agencies. In 1994, DNR paid WDFW \$0.4 million to perform murrelet surveys in the OESF HCP planning unit. As described in Section 1.1 of this Amendment, DNR participated in and contributed over \$1.1 million to collaborative scientific studies of murrelet habitat relationships, ecology, and distribution led by USFWS, UW, USFS, and WDFW. Five of the 10 members of the Science Team were from federal entities and state entities other than DNR: Oregon State University (1), USFS (1), WDFW (1), and USFWS (2). Taken together, these surveys, scientific studies, and analyses yielded foundational information for development of the Long-term Strategy and in the case of occupied site boundary re-delineation, led to conservation enhancements that were immediately implemented to strengthen the Interim Strategy.

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# Project Description and Covered Activities

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## ***2.1 Project Description***

This Amendment replaces the Interim Strategy under which DNR has operated since January 30, 1997 with a long-term marbled murrelet conservation strategy, as envisioned in the 1997 HCP.

## ***2.2 Covered Activities***

Covered activities are the same as those described in Section 16.0, “Forest Product Sales and Other Management Activities Other Than Land Sales, Purchases, and Exchanges,” and Section 17.0, “Land Transfers, Purchases, Sales, and Exchanges,” of the IA. No activities have been added or deleted.

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# Covered Species

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## 3.1 Covered Species

This Amendment covers the marbled murrelet. This Amendment does not cover any other species.

### ■ 3.1.1 Status and Distribution

The marbled murrelet is classified as threatened by USFWS and endangered by WDFW. In Washington, at-sea population monitoring from 2001 to 2017 indicated a 3.9 percent decline in the murrelet population annually (McIver and others 2019). Data from 2001 to 2015 indicate a 44 percent reduction in the population since 2001 (Desimone 2016). “The distribution of murrelets in Washington includes the southern Salish Sea and the outer coast” and “...The known terrestrial nesting habitat distribution includes western Washington coniferous forest within about 55 miles of marine water

...” (Desimone 2016). This distribution has not changed since the HCP was adopted in 1997. The status of the murrelet is described in USFWS’s most recent 5-year review (USFWS 2019), which concluded that the threatened status for the marbled murrelet in Washington, Oregon, and California is appropriate. Recent, detailed descriptions of the murrelet’s status and distribution can be found in WDFW’s *Periodic Status Review for the Marbled Murrelet* (Desimone 2016), the updated *Status and Trend of Marbled Murrelet Populations and Nesting Habitat* (USFS 2018), *Marbled Murrelet Effectiveness Monitoring, Northwest Forest Plan 2018 Summary Report* (McIver and others 2019), and *Marbled Murrelet (Brachyramphus marmoratus) 5-year Status Review* (USFWS 2019).

### ■ 3.1.2 Habitat Characteristics and Use

Murrelets use DNR-managed HCP lands exclusively for nesting. “In Washington, Marbled Murrelets usually nest in older forests dominated by western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*), Douglas-fir (*Pseudotsuga menziesii*) and western redcedar (*Thuja plicata*) trees that have large branches and support substantial moss, epiphytes and debris to form platforms on which a single egg is laid (Hamer and Nelson 1995, Ralph and others 1995, Nelson 1997, Nelson and others 2006, Wilk and others 2016). While most nests are on large limbs (for example, 12 to 29 inches [30 to 75 centimeters] in width) of trees that are more than 150 years old (Hamer and Nelson 1995, Burger 2002, Wilk and others 2016), relatively younger patches of predominantly western hemlock (70 to over 100 years old) with mistletoe infection, moss, and epicormic branching have been used for nesting in southwestern Washington (Hamer and Nelson 1995, Nelson and Hamer 1995). Nesting habitat includes forest structure of sufficient height and depth to provide vertical and horizontal cover to the nest and nest tree. “This structure appears to enhance microclimate conditions and minimizes predation risk by providing hiding cover” (Raphael and others 2002, Meyer and others 2004, Huff and others 2006 as cited in Desimone 2016). These habitat attributes were generally known when the Interim Strategy was adopted in 1997, but understanding has evolved over the past 22 years, particularly around younger forest conditions suitable for nesting (Nelson and Wilson 2002), relationships between forest nesting habitat and marine foraging areas (Raphael and others 2016), and the influence of forest habitat conditions on predation risk (Plissner and others 2015).



### ■ 3.1.3 Occurrence in the Project Area

Marbled murrelets are elusive and secretive birds, which makes finding their nest sites or nest trees difficult. On DNR-managed lands, only 13 nest locations have been identified out of a total of 53 sites in Washington State<sup>4</sup>. As a surrogate for identifying the actual nest site or nest tree and its surrounding habitat, a method of surveying for nesting related behaviors or evidence of chicks is used to establish “occupancy” of murrelet use of forest lands (Ralph and others 1995, Evans Mack and others 2003). Murrelets nest throughout the project area. However, not all habitat on DNR-managed HCP lands is occupied by murrelets. DNR and WDFW maintain detailed records of murrelet detections on DNR-managed HCP lands. Figure B-1 in Appendix B provides an overview of murrelet occupied sites on DNR-managed HCP lands.

## ***3.2 Species in the Plan Area That do Not Need Coverage and Why***

Coverage for other listed species and unlisted species of concern that occur in the plan area is provided by the other conservation strategies in the 1997 HCP. These strategies remain in full force and effect.

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<sup>4</sup> Numbers of known nest locations were generated from a 7/9/2019 query of the MMOCCUROBS\_SV feature class, which is managed by WDFW.

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# Environmental Setting

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*The environmental setting for this Amendment is described in detail in Chapter 3 of the FEIS.*



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# Potential Biological Impacts and Take Assessment

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## ***5.1 Direct and Indirect Impacts***

“Habitat” in this Long-term Strategy does not solely include actual nest sites or nest trees and their surrounding forests. Because of the inherent difficulties with finding murrelet nest sites and the uncertainties associated with surveys using nesting behavior characteristics, DNR and USFWS used cautious assumptions to identify potential habitat. The Long-term Strategy uses a murrelet habitat model, P-stage, to represent forest stands that express a likelihood of being occupied by murrelets. P-stage is based on a separate logistic regression model of marbled murrelet nesting habitat as it relates to stand development in natural forests (Raphael and others 2008). P-stage attempts to generalize and classify levels of habitat quality as they relate to forest stand

characteristics. P-stage is constructed and used in a way that incorporates the uncertainty between occupancy and actual nest sites. For example, it groups stands with varying probabilities of occupancy into six classes (.25, .36, .47, .62, .89, and 1) (refer to Appendix C, Attachment C-3). Direct and indirect impacts described in this Amendment are related to their impact on existing and future murrelet habitat.

DNR's activities cause direct and indirect impacts to marbled murrelets. Timber harvest and thinning can remove current or potential future habitat and increase deleterious edge effects on nearby habitat. Roads and trails built for access to and through DNR-managed HCP lands can cause direct impacts by removing habitat and also increase disturbance effects by creating forest edges. Other disturbance effects including audio-visual disturbance, predator attraction, and impulsive noise can cause both direct and indirect impacts to nesting murrelets. Cumulatively, these impacts can result in reduced habitat quantity and quality (DNR and USFWS 2019). The Long-term Strategy described in this Amendment protects murrelet occupied sites and adds new areas in which murrelet habitat will be protected and developed over the life of the 1997 HCP, with the expectation that these areas will be occupied at some future time by murrelets.

## **5.2 Anticipated Take of the Covered Species**

For purposes of this Amendment, take is described in terms of habitat as a surrogate for take of individual murrelets. "The marbled murrelet was federally listed as a threatened species mainly due to the substantial loss of older forest nesting habitat" (USFWS 1997, p. 4). It would not be practicable—and less meaningful—to attempt to express take as a number of individual murrelets. Methods used to enumerate individual murrelets contain weaknesses, due to the murrelet's small size, secretive nesting behaviors, and the vast plan area (1.38 million acres of DNR-managed HCP lands within the 55-mile inland range of the marbled murrelet).

The Long-term Strategy's use of habitat as a surrogate to express the anticipated level of take of individual murrelets is consistent with the *Habitat Conservation Planning and Incidental Take Permit Processing Handbook* (USFWS 2016). (Refer to Section 5.1 of this Amendment for a description of P-stage, the habitat model used in this Long-term Strategy). There are approximately 207,066 acres of marbled murrelet habitat on DNR-managed lands. To describe and compare habitat losses and gains over time and among diverse geographies within the plan area, habitat of various qualities and configurations was quantitatively adjusted according to the analytical framework to

account for probability of occupancy, edge effects, location, and timing (refer to Appendix C, Attachment C-1). The calculation of take and mitigation for this Amendment is based upon the analytical framework and is represented as “adjusted acres.” This Amendment anticipates the loss of approximately 38,000 raw acres of existing habitat, which equates to 11,085 adjusted acres of habitat over the 48 years that remain in the initial 70-year term of the 1997 HCP. The Amendment expects the loss of an additional 114 adjusted acres of habitat due to yarding corridors and new road construction through occupied sites, occupied site buffers and SHAs (10 adjusted acres from yarding corridors, 104 adjusted acres from new road construction). This take is mitigated by the Long-term Strategy, which includes an anticipated gain of 11,905 adjusted acres of habitat over the same period. The net gain in habitat on DNR-managed HCP lands over the next 48 years is anticipated to be 706 adjusted acres. Total acres of habitat on DNR-managed lands is projected to increase to over 272,000 acres.

These estimates of habitat losses and gains do not take into account noise and visual disturbance resulting from permitted activities<sup>5</sup> because disturbance from these activities does not result in habitat removal. Several permitted activities have the potential to cause disturbance to marbled murrelets. The most common and widespread types of disturbance include activities that occur over a short duration at a low intensity, such as green collecting, pre-commercial thinning, non-motorized trail use, or minor road maintenance. Other activities include those that are transient and widely distributed, ground-based disturbances, such as firewood collection, road reconstruction, major road and trail maintenance, communications facility maintenance, timber harvest, motorized trail use, and new road and bridge construction. Ground-based activities that may result in disturbance at discrete facilities include campground use and maintenance, sand and gravel extraction, and blasting. In addition, campground use and maintenance activities are expected to result in potential injury and/or mortality to murrelets in the form of increased nest predation. Sand and gravel extraction, as well as blasting within 328 feet (100 meters) of nesting murrelets, also could result in injury and/or mortality. Aircraft noise from activities such as aerial herbicide application are also expected to disrupt normal behaviors. Refer to Appendix A, Table A-8 for the

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<sup>5</sup> “Disturbance from permitted activities” means activities that cause a murrelet to delay or avoid nest establishment, flush away from an active nest site, or abort a feeding attempt during incubation or brooding of nestlings, for example audio and visual disturbances or increased attraction of predators to nest sites.

types of disturbance expected to occur and the amount of area (adjusted acres) expected to be affected by each impact type annually, averaged over the remaining term of the 1997 HCP. Some disturbance estimated in one category will overlap in space and time with disturbance estimated in another category, so estimates of acres impacted may reflect additive impacts.

The Long-term Strategy incorporates conservation measures that minimize or eliminate the risk of these impacts (DNR and USFWS 2019). These conservation measures are described in Appendix A, Table A-4 of this Amendment.

### **5.3 Anticipated Impacts of Take on Critical Habitat**

None of the incidental take anticipated under this Amendment involves critical habitat. Per *Endangered and Threatened Wildlife and Plants; Final Designation of Critical Habitat for the Marbled Murrelet* (USFWS 1996, USFWS 2016), “any lands within critical habitat that are covered by a legally-operative incidental take permit for marbled murrelets based on an approved HCP that addresses conservation of the marbled murrelet are excluded from the critical habitat while the permit is active.” DNR-managed HCP lands are covered by such an ITP.

### **5.4 Anticipated Impacts of the Taking**

DNR manages approximately 9 percent of the total land area within the murrelet’s Washington range (DNR and USFWS 2019). Habitat on DNR-managed HCP lands (207,066 acres) comprises approximately 14 percent of the total nesting habitat within the murrelet’s Washington range (DNR and USFWS 2019). Given these small percentages, DNR’s actions have limited potential to influence the trajectory of the Washington murrelet population.

To inform development of the Long-term Strategy, DNR and USFWS commissioned population viability analyses to understand the extent to which DNR’s actions could influence both the Washington murrelet population and the population of murrelets nesting on DNR-managed HCP lands (refer to Appendix C, Attachment C-2). Two modeling frameworks were employed “that differed in assumptions about future impacts of environmental factors on murrelets beyond habitat change on DNR lands” (Appendix C, Attachment C-2, p. 3): 1) a “risk” framework that assumed the current



rate of population decline<sup>6</sup> would continue even after the population reached nesting carrying capacity, although at a slower rate, due to other environmental factors; and 2) an “enhancement” framework that assumed the rate of population decline would level out at a future point when the population reached equilibrium with nesting carrying capacity and thereafter the population could increase in response to increases in nesting habitat. The analysis included all alternatives presented in the FEIS. For the purposes of this Amendment, the results for the Long-term Strategy are considered approximately the same as the results for Alternative H in the population viability analyses (Appendix C, Attachment C-2).

For both the risk and enhancement frameworks, and for both the Washington murrelet population and the population of murrelets nesting on DNR-managed HCP lands, the analyses projected that the Long-term Strategy would decrease quasi-extinction probabilities and increase the size of the population at the end of the 1997 HCP’s initial 70-year term, compared to either the modeling baseline or DNR continuing to operate under the Interim Strategy (Appendix C, Attachment C-2). The analyses also projected that the Long-term Strategy would result in no net loss of murrelet habitat capacity, an approximate 85 percent increase in nesting carrying capacity, and a slight increase in murrelet nest success on DNR-managed HCP lands (Appendix C, Attachment C-2).

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<sup>6</sup> The marbled murrelet meta-population model and population viability analysis (refer to Appendix C, Attachment C-2) was parameterized using at-sea survey data from Zones 1 and 2 (Washington) over the period of 2001 through 2015. Over this time period, the Washington murrelet population declined by an average of 4.4 percent per year (Desimone 2016). However, more recent at-sea survey data are now available through 2017/2018 (McIver and others 2019). For more information why more recent data was not used, refer to Appendix C, Attachment C-2.

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# Conservation Program

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## ***6.1 Biological Goals***

The biological goal of the Long-term Strategy is to avoid, minimize, and mitigate the incidental take of murrelets resulting from DNR’s forest management activities, in a manner that increases the habitat capacity of DNR-managed HCP lands over the life of the 1997 HCP.

## ***6.2 Biological Objectives***

Biological objectives that will be pursued to achieve the biological goal are as follows:

- Maintain murrelet occupied sites on DNR-managed HCP lands for the duration of the 1997 HCP. As of the date on which the ITP is amended, there are 388 occupied sites on DNR-managed lands.

- Increase the habitat capacity of DNR-managed HCP lands by creating a network of 20 SHAs. Emphasize distribution of habitat in strategic locations and take full advantage of habitat in areas managed for multiple conservation objectives. Manage these SHAs to promote the development of secure, high-quality nesting habitat and to avoid disrupting murrelet nesting and reproduction.
- Meter the harvest of 5,000 adjusted acres of murrelet habitat for the first decade following implementation to maintain current habitat capacity while greater, future habitat capacity is developed.

### **6.3 Measures to Avoid, Minimize, and Mitigate Take**

The concept of LTFC is central to the Long-term Strategy. LTFC is “lands on which DNR maintains and grows forest cover for conservation purposes, including habitat conservation for the marbled murrelet, through the life of the 1997 HCP” (DNR and USFWS 2019). Under the Long-term Strategy, LTFC includes both murrelet-specific conservation areas and other areas that have multiple conservation objectives (refer to Appendix C, Attachment C-4). The Long-term Strategy includes a total of 604,907 acres of LTFC: 37,456 acres in areas managed primarily for murrelet habitat, and 567,000 acres in areas that have multiple conservation objectives (Refer to Appendix A, Table A-3).

#### **■ 6.3.1 Murrelet Specific**

##### **6.3.1.1 OCCUPIED SITES AND OCCUPIED SITE BUFFERS**

Protecting and buffering occupied sites achieves the first of the Long-term Strategy’s three biological objectives and gives effect to Section II.D.3.1.1.1, “Maintain occupied nesting habitat,” and Section II.D.3.1.1.3, “Maintain and enhance buffer habitat surrounding occupied habitat,” in the USFWS recovery plan (USFWS 1997). “The loss of occupied nesting habitat appears to be the primary cause of marbled murrelet population declines in Washington ... The low reproductive potential of this species, and lack of knowledge concerning its ability to locate and reestablish new nesting areas after elimination of nesting habitat, makes it imperative to maintain all occupied nesting habitat” (USFWS 1997, p. 138).

DNR will protect murrelet habitat and restrict management activities and recreation in all murrelet occupied sites on DNR-managed HCP lands as of the date on which the ITP is amended. “Occupied sites” for this amendment means those sites that were delineated by the Science Team and described in Section 2.1 of the FEIS (DNR and USFWS 2019) and are depicted in Appendix B, Figure B-2. “Protect murrelet habitat” means exclude variable retention harvest. “Restrict management and recreation activities” means restricting activities that may remove or damage trees (Appendix A, Table A-4), cause audio or visual disturbances, or attract predators to nest sites. Based on the Science Team-delineated murrelet occupied sites (16,356 additional acres identified), DNR will conserve 59,331 acres (Table A-3) within 388 murrelet occupied sites. Most of these acres (85 percent) are within areas that have multiple conservation objectives. DNR will not provide murrelet-specific habitat protection or restrict management and recreation activities in any additional murrelet occupied sites that are discovered after its ITP has been amended.

“Maintaining buffers around occupied habitat will mediate the effects of edge by helping to reduce environmental changes within the stand, reduce loss of habitat from windthrow and fire, reduce fragmentation levels, increase the amount of interior forest habitat available, and potentially help reduce predation at the nest. To have the greatest benefits, buffer widths should be a minimum of 300-600 feet and should consist of whatever stand age is present” (USFWS 1997, p. 140).

DNR will apply a 328-foot (100-meter) buffer to the outer boundary of all recorded occupied sites on DNR-managed HCP lands as of the date on which the ITP is amended. Within occupied site buffers, DNR will exclude variable retention harvest and restrict management and recreation activities that may remove or damage trees, or disrupt murrelet nesting (Appendix A, Table A-4). Based on currently recorded occupied sites, DNR will conserve 32,777 acres of buffers around 388 murrelet occupied sites. About half of these buffer acres (16,906 acres, 51.6 percent) are within areas that have multiple conservation objectives. DNR will not buffer any occupied sites that are discovered after its ITP has been amended.

#### **6.3.1.2 STRATEGIC LOCATIONS**

Additional murrelet-specific conservation will be concentrated in strategic locations. Strategic locations are geographic areas within Washington that have a

disproportionately high importance for murrelet conservation (DNR and USFWS 2019). In identifying strategic locations, DNR and USFWS considered factors such as proximity to marine waters (within 40 miles or less), proximity to marine areas with higher-than-average densities of murrelets, abundance of nesting habitat, abundance and distribution of occupied sites, future habitat capacity, protection from disturbance, and proximity to federal lands.

Three strategic locations were identified by DNR and USFWS: Southwest Washington, the OESF and Straits (west of the Elwha River), and North Puget. DNR-managed HCP lands in the Southwest Washington strategic location are close to marine waters and are disproportionately important as murrelet nesting habitat because federal forest lands are lacking in this area. DNR-managed lands in the OESF and Straits (west of the Elwha River) strategic location contain an abundance of high-quality habitat and are close to marine waters with higher-than-average densities of murrelets. DNR-managed HCP lands in the North Puget strategic location provide nesting habitat within easy traveling distance of heavily used murrelet foraging areas in the Salish Sea, around the San Juan Islands. The Long-term Strategy will result in a net increase of 65,772 acres of habitat across all DNR-managed HCP lands within the range of the marbled murrelet by the end of the 1997 HCP's initial 70-year term, 21,992 acres of which will occur in these strategic locations (Appendix A, Table A-5).

USFWS' recovery plan acknowledges DNR's 1997 HCP and reinforces the significance of these strategic locations. In Section II.D.2.1, "Protect terrestrial habitat essential for murrelet recovery," USFWS' recovery plan characterizes "Suitable habitat within 64 kilometers (40 miles) of the coast on State lands in Washington" as "essential nesting habitats that occur on forest lands under non-Federal management" and concludes that "These areas are critical for improving the distribution of both the population and suitable habitat, especially in southwest Washington" (UWFWS 1997, p. 132).

### **6.3.1.3 SHAS**

To accomplish the second of the Long-term Strategy's biological objectives, DNR will create a network of SHAs that emphasizes the strategic locations described in Section 6.3.1.2 of this Amendment (Appendix B, Figure B-2). "Special habitat areas are designed to reduce edge and fragmentation and increase interior forest around

occupied sites and existing habitat in specific geographic areas to benefit the species” (DNR and USFWS 2019). The SHA network gives effect to Section II.D.3.2.1, “Increase the amount and quality of suitable nesting habitat;” Section II.D.3.2.1.1, “Decrease fragmentation by increasing the size of suitable stands to provide a larger area or interior forest conditions;” and Section II.D.3.2.1.2, “Protect ‘recruitment’ nesting habitat to buffer and enlarge existing stands, reduce fragmentation, and provide replacement habitat for current suitable nesting habitat lost to disturbance events,” in USFWS’ recovery plan.

“An increase in amount and quality of suitable nesting habitat is important in all zones. However, it is especially important in the Western Washington Coast Range ... In these areas, remaining patches of suitable nesting habitat are relatively small and fragmented, involve private and state lands, and are vitally important for maintaining the small populations in these areas; thus, blocking up habitat is needed to increase patch size” (USFWS 1997, p. 142). “Stands (currently 80 years old or older) that will produce suitable habitat within the next few decades are the most immediate source of new habitat and may be the only replacement for existing habitat lost to disturbance (e.g., timber harvest, fires, etc.) over the next century. Such stands are particularly important because of the vulnerability of many existing habitat fragments to fire and wind and the possibility that climate change will increase the effects of the frequency and severity of natural disturbances” (USFWS 1997, p. 143).

The SHA network comprises 20 SHAs that together encompass 46,925 acres. Most (19, 95 percent) SHAs contain at least one occupied site (Appendix A, Table A-6). SHAs range in size from 338 acres to 7,549 acres, averaging 2,346 acres (Appendix A, Table A-6). Habitat categories in SHAs are occupied site, habitat, future habitat, “security forest”, future security forest, and non-forested. Habitat means DNR forest inventory units (FIU) that have been assigned a P-stage value<sup>7</sup> of at least 0.25. Future habitat means FIUs that do not currently meet this threshold but are projected to develop a P-stage value of at least 0.25 before the end of the 1997 HCP’s initial 70-year term. Security forest means FIUs that will not develop a P-stage value of at

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<sup>7</sup> The P-stage model, developed by the Science Team, classifies DNR-managed HCP forestlands based on their relative value for murrelet use, represented as probability of occupancy, using DNR’s forest stands data (in other words, stand origin, stand age, and dominant tree species) expressed as a value between 0 and 1. Development and use of the P-stage model are described in detail in Appendix C, Attachment C-3.

least 0.25 before the end of the 1997 HCP’s initial 70-year term, but have a closed canopy and trees greater than 80 feet tall. Future security forest means FIUs that do not yet meet the definition of security forest but are projected to reach that threshold before the end of the 1997 HCP’s initial 70-year term. Security forest protects habitat from deleterious edge effects including microclimate change, windthrow, predation, and disturbance.

Occupied sites and current habitat comprise 28,823 acres (61 percent) of the 46,925 acres within SHAs. Another 5,052 acres (10.8 percent) is future habitat.<sup>8</sup> All but 1,014 acres of the remaining acreage is either security forest or future security forest (Appendix A, Table A-6). Within SHAs, DNR will exclude variable retention harvest and restrict management and recreation activities that may remove or damage trees, or disrupt murrelet nesting (Appendix A, Table A-6).

### 6.3.2 Non-Murrelet Specific

Within the murrelet’s Washington range, variable retention harvest<sup>9</sup> already is excluded from 567,451 acres of DNR-managed HCP lands, but may be allowed in areas identified as “other long-term forest cover” under specific conditions<sup>10</sup>. These lands are being managed under strategies and prescriptions designed for other purposes of

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<sup>8</sup> These totals include non-forested acres, whereas Appendix A, Table A-6 reports acres for occupied sites, current habitat, and future habitat separately from non-forested acres.

<sup>9</sup> Variable retention harvesting is a timber harvest system characterized by stand-specific objectives, a harvest prescription designed to accomplish those objectives, and retention of structural elements such as large, live trees; snags; and logs.

<sup>10</sup> Other LTFC includes existing northern spotted owl high-quality habitat, which includes the following DNR-mapped habitat classes as of 2018: old forest, high-quality nesting habitat, and A and B habitat per the definitions in the 1997 HCP (DNR 1997, p. 12). It also includes riparian areas managed under the HCP riparian conservation strategy; uncommon habitats and special habitat features protected under the HCP multi-species conservation strategy; all remaining old-growth forest, genetic resources, and special habitat features protected under DNR’s *Policy for Sustainable Forests* (DNR 2006a); natural area preserves and natural resources conservation areas; and inoperable or inaccessible areas. Variable retention harvests in these areas may only occur where it is consistent with the applicable restrictions or conditions, including all applicable terms and conditions of the 1997 HCP and the IA. Examples of where variable retention harvest may be consistent with these restrictions or conditions include in allotted acres of variable retention harvest in the *OESF HCP Planning Unit Forest Land Plan* (DNR 2016) or hardwood conversions in the *Implementation Procedures for the HCP Riparian Forest Restoration Strategy* (DNR 2006b).



maintaining forest cover and developing structurally complex forest conditions over time, that also provide LTFC for murrelets. These lands include the following:

- Riparian areas managed under the 1997 HCP riparian conservation strategies.
- All remaining old-growth forests (stands that are 5 acres or larger, originated naturally before 1850, and in a fully functional stage of stand development) on DNR-managed HCP lands.
- Existing northern spotted owl high-quality habitat, which includes “the following DNR mapped habitat classes as of 2018: old forest, high-quality nesting habitat, and A and B habitat per the definitions in the 1997 HCP (DNR 1997, p. 12)” (DNR and USFWS 2019).
- Uncommon habitats and special habitat features protected under the 1997 HCP multi-species conservation strategy.
- Natural area preserves and natural resources conservation areas.
- Genetic resources and special habitat features protected under DNR’s *Policy for Sustainable Forests* (DNR 2006a).
- Inoperable areas and inaccessible areas.

Murrelet habitat quality on these lands is variable. Not all contain murrelet habitat, and portions are not forested. Nevertheless, in the aggregate, these lands provide significant mitigation in the form of habitat, future habitat, and security forest.

These lands contain 85.0 percent of the area within occupied sites, 51.6 percent of the area within occupied site buffers, and 72.4 percent of the area within SHAs (Appendix A, Table A-3). These lands not only anchor the Long-term Strategy’s murrelet-specific conservation components, but will develop additional habitat capacity around occupied sites and SHAs over time. To complete its second biological objective, the Long-term Strategy reinforces the significance of these lands by adding new, murrelet-specific restrictions on certain management and recreation activities (Appendix A, Table A-4). Management and recreation activities in these lands must comply with both existing restrictions and, where applicable, new, murrelet-specific restrictions.

### 6.3.3 Restrictions on Management and Recreation Activities

A wide range of forest management and recreation activities has the potential to negatively affect forest structure, disrupt murrelet nesting, and thereby reduce the effectiveness of the conservation components described in sub-sections 6.3.1.1, 6.3.1.3, and 6.3.2 of this Amendment. To avoid and minimize such impacts, these activities are restricted under the Long-term Strategy (Appendix A, Table A-4 in).

### 6.3.4 Metering

DNR will delay (“meter”) harvest of 5,000 adjusted acres of murrelet habitat that it would otherwise be authorized to harvest upon amendment of its ITP until the end of the first decade following implementation. The specific location and quality of habitat to be metered will be at DNR’s discretion. These metered acres will become available for harvest at the beginning of the second decade.

Metering will maintain habitat capacity while additional habitat develops under the Long-term Strategy. Population viability analyses commissioned by DNR and USFWS indicate that metering will slightly improve projected (modeled) viability of the murrelet population on DNR-managed lands, and will prevent the short-term decline in nesting carrying capacity that otherwise would occur during the first decade of the Long-term Strategy (Appendix C, Attachment C-2).

### 6.3.5 Significant Contribution

As envisioned in the 1997 HCP, the Long-term Strategy helps “meet the recovery objectives of the U.S. Fish and Wildlife Service” and makes “a significant contribution to maintaining and protecting marbled murrelet populations” (DNR 1997, p. IV.44). The Long-term Strategy fulfills these commitments by delivering conservation envisioned in USFWS’s recovery plan (USFWS 1997) and critical habitat designation (USFWS 1996). Section II.B, “Recovery strategy for the Marbled Murrelet,” of USFWS’ recovery plan concludes that “Adequately designed and implemented HCPs will be very important in the conservation of marbled murrelets on state and private lands and are likely to be the most effective and acceptable means of protecting most occupied sites on non-federal lands in the near future and potentially providing replacement habitat in the long term. Lands covered by approved HCPs would not require additional protection (e.g., designation as critical habitat)” (USFWS 1997, p. 120). Section II.D.2.1, “Protect terrestrial habitat essential for murrelet recovery,”

sharpens this conclusion: “Habitat conservation plans with appropriate measures to minimize and mitigate incidental take in the short term while providing for maintenance or creation of habitat for the long term probably offer the best means for conservation of the species on non-Federal lands” (USFWS 1997, p. 133). The Long-term Strategy puts forth this combination of occupied site protection and strategic, long-term habitat development.

The Long-term Strategy incorporates specific recommendations in Section II.D.3, “Incorporate management recommendations for protected habitat areas,” of USFWS’s recovery plan that apply to the management of nesting habitat: 3.1.1.1, “Maintain occupied nesting habitat;” 3.1.1.3, “Maintain and enhance buffer habitat surrounding occupied habitat;” 3.1.3, “Minimize nest disturbances to increase reproductive success;” 3.2.1.1, “Decrease fragmentation by increasing the size of suitable stands to provide a larger area of interior forest conditions;” and 3.2.1.2, “Protect ‘recruitment’ nesting habitat to buffer and enlarge existing stands, reduce fragmentation, and provide replacement habitat for current suitable nesting habitat lost to disturbance events” (USFWS 1997, p. 138-143). The Long-term Strategy’s SHA network contributes to the landscape-level recommendations in Section II.D.3: 3.1.1.2, “Maintain potential and suitable habitat in larger contiguous blocks while maintaining current north/south and east/west distribution of nesting habitat;” 3.2.2.1, “Improve and develop north/south distribution of nesting habitat;” and 3.2.2.2, “Improve and develop east/west distribution of nesting habitat” (USFWS 1997, p. 139-146).

The phrases “help meet the recovery objectives of the U.S. Fish and Wildlife Service” and “make a significant contribution to maintaining and protecting marbled murrelet populations” do not mean that DNR has an obligation to either recover the murrelet or sustain the Washington murrelet population. Rather, these phrases mean that if DNR designs and implements an effective Long-term Strategy, then the habitat thereby provided is likely to contribute to the broader murrelet conservation goals expressed in USFWS’s recovery plan.

## ***6.4 Adaptive Management***

DNR’s adaptive management obligations are not changed by this Amendment. Section 24.5 of the IA describes and governs DNR’s adaptive management commitments under the 1997 HCP, including this Amendment. “Adaptive management provides for ongoing modifications of management practices to respond to new information and

scientific developments. The monitoring and research provisions of the 1997 HCP are in part designed to identify modifications to existing management practices” (DNR 1997, p. B.10). Section 24.5 of the IA identifies two murrelet-specific adaptive management practices, one that was completed during the Interim Strategy (“the habitat definitions will be refined for each planning unit as a result of DNR’s habitat relationships study”) and another that will be completed when the Long-term Strategy is adopted (“the interim conservation strategy will be replaced with a long-term management plan upon completion of the inventory survey phase”) (DNR 1997, p. B.11).

Section V of the 1997 HCP (“Plan Implementation”) states DNR’s expectation “to determine whether the Amendment is implemented as written” (DNR 1997, p.V.1). “Implementation monitoring will document the types, amounts, and locations of forest management activities carried out on DNR-managed lands in each HCP planning unit, both inside and outside areas addressed by the conservation strategies. Activities in areas addressed by the HCP will be described in sufficient detail to document compliance with the requirements of the conservation strategies” (DNR 1997, P. V.2).

Implementation monitoring of the Amendment will periodically describe changes in landscape-level habitat conditions in areas managed to provide murrelet habitat. Implementation monitoring will include a summary of the quantity and quality of habitat (P-stage) in occupied sites, occupied site buffers, SHAs, and areas of LTFC not included in the preceding categories, by HCP planning unit in gross and adjusted acres. Natural disturbance that occurs in these areas will be tracked through the reporting of salvage activities. In addition, during the first decade of implementation, DNR will report on the delay of 5,000 adjusted acres of habitat (refer to “Metering” in Section 6.3.4 of this Amendment). These summaries and activities will be documented in the HCP Annual Report.

Section V also states DNR’s expectations “to initiate [murrelet] effectiveness monitoring in all planning units where murrelet nesting habitat is a management goal once the long-term murrelet conservation strategy has been designed and implemented” and “to initiate [murrelet] validation monitoring in the OESF once the long-term murrelet conservation strategy is in place.” (DNR 1997, p. V.3).

“Effectiveness monitoring will document changes in habitat conditions, including general forest structure, specialized habitat features (e.g., in-stream large woody debris,

marbled murrelet nesting platforms), and spotted owl prey populations, that result from timber harvest and other forest management activities carried out pursuant to the 1997 HCP. Only habitat areas addressed by the conservation strategies, i.e., riparian, spotted owl nesting roosting, and foraging (NRF), spotted owl dispersal, and marbled murrelet habitat areas, will be monitored for effectiveness. Within these habitat areas, representative samplings will be monitored, which means not all managed acres or management activities will be monitored” (DNR 1997, p. V.2). The Amendment is based upon conservation of existing marbled murrelet habitat and permitting stands to naturally develop into marbled murrelet habitat over time in LTFC. Accordingly, marbled murrelet effectiveness monitoring will document changes in habitat conditions over time within a representative sample of SHAs.

“Validation monitoring, which will occur only within the OESF HCP planning unit, will document spotted owl and marbled murrelet use of areas managed to provide nesting habitat, and salmonid use of streams crossing DNR-managed lands. For spotted owls and marbled murrelets, validation monitoring will rely upon surveys to detect changes in site occupancy, numbers and locations of breeding pairs, and reproduction, as appropriate for each species” (DNR 1997, p. V.2). Accordingly, murrelet validation monitoring will document marbled murrelet use of select areas managed to provide murrelet habitat. Monitoring will rely upon surveys to detect changes in site occupancy in the OESF HCP planning unit.

Even as new technologies emerge in the future, and DNR integrates those technologies into its management activities, DNR does not expect to change the use and definition of P-stage to identify marbled murrelet habitat. However, DNR expects that as technology evolves over time, so will methods for collecting DNR’s forest inventory data.

Murrelet research priorities are outlined on pages V.6 through V.8 of the 1997 HCP. These priorities were accomplished as part of the Interim Strategy and during development of the Long-term Strategy.

## **6.5 Reporting**

DNR’s reporting obligations are not changed by this Amendment. Section 17.2, “Notification and Annual Review of Land Transactions,” and Section 20.0, “Reporting and Inspections,” of the IA; and Section V, “Plan Implementation,” of the 1997 HCP describe DNR’s reporting obligations under the 1997 HCP, including this Amendment.

In addition, DNR will follow the procedures of Section 17.2 of the IA to notify USFWS when DNR knows that a holder of mineral rights or other legal right (for example, easement) in the plan area may be exercising those rights in a manner that impacts DNR lands managed under the Long-term Strategy.

# Changed and Unforeseen Circumstances, Uncertainty

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## **7.1 Changed Circumstances**

The existing “Changed and Unforeseen Circumstances” provisions in the IA are not changed by this Amendment. Beyond the 1997 HCP’s adaptive management capacity to address changed circumstances, Section 24.0, “Extraordinary Circumstances,” of the IA describes the process that DNR and USFWS will follow should extraordinary circumstances arise in connection with the 1997 HCP, including this Amendment (DNR 1997, p. B.9).

## **7.2 Unforeseen Circumstances**

The existing “Unforeseen Circumstances” provisions in the IA are not changed by this Amendment. Section 23.0, “Unforeseen Circumstances,” of the IA describes the process

that DNR and USFWS will follow should unforeseen circumstances arise in connection with the 1997 HCP, including this Amendment (DNR 1997, p. B.9).

### 7.3 Uncertainty

While the amount of scientific information that is available for the marbled murrelet has continued to increase since 1997, uncertainties continue to exist. Murrelets are difficult to detect, especially in nature when inland, and tend to nest high up in the canopy. There are also uncertainties in marbled murrelet nest site selection, nest success, and landscape characteristics. All of these factors result in gaps in understanding of habitat use by the species (Plissner and others 2015).

The Long-term Strategy utilizes a habitat model and analytical framework to calculate impacts and mitigation that lends towards conservation of the species when the science is not clear. The Long-term Strategy was intentionally developed to mitigate against the full spectrum of uncertainties surrounding murrelet habitat conservation recognized by DNR and USFWS on DNR-managed HCP lands. These uncertainties include potential effects of natural disturbances such as wildfires and windthrow, effects of climate change on Washington's forests, imperfect knowledge of murrelet biology and population dynamics, and uncertainties related to implementation of the Interim Strategy (in other words, difficulties encountered during the North Puget HCP planning unit habitat relationships study, lack of a habitat relationships study for the South Puget HCP planning unit, incomplete surveys of reclassified habitat in the OESF and North Puget HCP planning units, evolution of the murrelet survey protocol over the 13-year period during which DNR was carrying out surveys, and the 10- to 17-year lag between ending surveys of reclassified habitat and developing the Long-term Strategy).

Uncertainties may exist in the data depicting existing conservation. For example, the amount of LTFC that is mapped now may change over time as field inspections more accurately map lands in some categories. These potential changes are not expected to be significant at the landscape scale. These site-specific field inspections occur before any management activities are implemented and will ensure that any sensitive features that are protected under DNR's policies are identified accurately and managed consistent with those policies. Refer to Appendix C, Attachment C-5 for additional uncertainties and the methods DNR employed to address them during the Interim Strategy and in the Long-term Strategy.



Using best available science at the time, the Long-term Strategy was designed to take these uncertainties into account. The choices that were made at every step over the eight-year period during which DNR worked with USFWS to design the strategy (assumptions, definitions, methods, inclusions and exclusions, amounts) sought to redress known and potential uncertainties. Both agencies recognized these uncertainties as they were encountered and factored them into the interactive process of selecting conservation options. The result is a well-integrated Long-term Strategy that reflects these decisions, is more than the sum of its parts, and is robust in the face of uncertainty. Specific, additional mitigation against uncertainty is derived from providing habitat mitigation that exceeds anticipated taking by 706 adjusted acres (6.3 percent) and by metering the harvest of 5,000 adjusted acres of habitat as described in Section 6.3.4 of this Amendment.

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# Funding

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DNR’s funding obligations are not changed by this Amendment. As expressed in Section V of the 1997 HCP, “Plan Implementation,” and Section 18.0, “Funding,” of the IA, DNR shall submit to the Washington State Legislature, on at least a biennial basis, an agency operating and capital budget for asset management that will be adequate to fulfill DNR’s obligations under the 1997 HCP, ITP, and IA, including this Amendment. Failure by DNR to ensure that adequate funding is provided to implement the 1997 HCP shall be grounds for suspension or partial suspension of the ITP. The IA also commits USFWS to include in its annual budget requests sufficient funds to fulfill their respective obligations under the 1997 HCP, ITP, and IA.

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# Appendix

# A

## Tables

### Table A-1

Habitat relationships studies and surveys of reclassified habitat carried out as part of Washington State Department of Natural Resources' (DNR) Marbled Murrelet Interim Conservation Strategy

### Table A-2

Peer-reviewed literature from research supported by DNR as part of its Marbled Murrelet Interim Conservation Strategy, 1997 through 2017

### Table A-3

Acres of marbled murrelet habitat conserved under DNR's Marbled Murrelet Long-term Conservation Strategy

### Table A-4

Marbled murrelet-specific restrictions and conditions on management and recreation activities within conservation components of DNR's Marbled Murrelet Long-term Conservation Strategy

### Table A-5

Projected changes in acres of marbled murrelet habitat within strategic locations emphasized in DNR's Marbled Murrelet Long-term Conservation Strategy, 2018 through 2057

### Table A-6

Marbled murrelet special habitat areas designated as part of DNR's Marbled Murrelet Long-term Conservation Strategy



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**Table A-1. Habitat relationships studies, surveys of reclassified habitat carried out, and acres conserved as part of Washington State Department of Natural Resources' Marbled Murrelet Interim Conservation Strategy (Interim Strategy)<sup>1</sup>**

HCP planning unit	Year habitat relationships study completed	Years surveys of reclassified habitat carried out	Acres of reclassified habitat identified <sup>2</sup>	Acres reclassified habitat surveyed (% of reclassified habitat in planning unit)	Number of occupied sites identified <sup>3</sup>	Acres of occupied habitat conserved pending adoption of a long-term murrelet conservation strategy <sup>3</sup>	Additional acres conserved pending adoption of a long-term murrelet conservation strategy <sup>4</sup>
<b>Columbia</b>	1999	1998-2001	6,635	6,635 (100%)	22	2,980	6,001
<b>North Puget</b>	2000	2001-2008	5,247	2,541 (48%)	69	3,853	47,130
<b>OESF</b>	2002	1996-2002	54,308	40,687 (75%)	199	25,874	43,357
<b>South Coast</b>	1999	1998-2001	20,288	20,288 (100%)	46	5,752	18,045
<b>South Puget</b>	not attempted	n/a	1,164	n/a	3	576	20,680
<b>Straits</b>	2000	2000-2003	15,397	15,397 (100%)	58	3,940	13,324
<b>Total</b>	2002	1996-2008	103,040	85,660 (83%)	397	42,975	148,537

<sup>1</sup> Acres in this table are derived from DNR's Marbled Murrelet Policy GIS data queried on 7/12/2019 for implementation of the Interim Strategy.

<sup>2</sup> Reclassified habitat includes those stands identified in DNR's database as reclassified, reclassified plus, and potential suitable. Other potential habitat that has not been field-verified but has been conserved under the Interim Strategy is included in the column "Additional acres conserved pending adoption of a long-term murrelet conservation strategy." Refer to Appendix I of the 2019 FEIS for definitions of "potential suitable" habitat.

<sup>3</sup> Includes both occupied sites identified by DNR and occupied sites identified through surveys conducted by Washington Department of Fish and Wildlife and other parties, as well as confirmed observations of murrelet nests, chicks, eggs, and eggshells. In South Puget HCP planning unit, some habitat was evaluated for occupancy with radar, which is not within Pacific Seabird Group audio/visual survey protocol (Evans Mack 2003). Acres in this column do not include adjustments delineated by the Science Team.

<sup>4</sup> Includes those stands identified in DNR's database as reclassified, reclassified plus, potential unverified, potential suitable, newly identified suitable habitat, Science Team-delineated occupied sites (that are not included in the "Acres of occupied habitat conserved" column), additional deferral areas identified by the Science Team, and occupied site buffers.

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**Table A-2. Peer-reviewed literature from research supported by Washington Department of Natural Resources as part of its interim marbled murrelet conservation strategy, 1997 through 2017**

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**Table A-3. Acres of marbled murrelet habitat conserved under Washington Department of Natural Resources Marbled Murrelet Long-term Conservation Strategy**

Conservation component	Acres of LTFC conserved		
	Murrelet specific (refer to Section 6.3.1)	Existing conservation (refer to Section 6.3.2)	Total
Occupied sites (see Section 6.3.1.1)	8,900		59,331
Occupied site buffers (see Section 6.3.1.1)	15,871		32,777
Special habitat areas (SHA) (see Section 6.3.1.3)		33,952	46,637 <sup>1</sup>
Other LTFC (see Section 6.3.2)	n/a		
<b>Total</b>	37,456	*	*

\* Total conservation acres cannot be totaled because there is overlap between the types of conservation areas.

<sup>1</sup> The 288 acres difference from the total SHA acres in Table A-6 arises from 238.1 non-forested acres that are excluded from this table because they are not LTFC, 38.3 non-forested acres of occupied sites which are already included in the 8,900 acres for the murrelet specific conservation component for occupied sites, and 11.6 non-forested acres that are excluded that result from geoprocessing of DNR’s large data overlay.

**Table A-4. Marbled murrelet-specific restrictions and conditions on management and recreation activities within conservation components of Washington State Department of Natural Resources' Marbled Murrelet Long-term Conservation Strategy**

To read the table, apply the strictest rule for the area where an operation is to occur. For example, if an activity occurs in both an occupied site and a special habitat area (SHA), apply the rule that results in the least potential impact to the marbled murrelet. In limited cases, rules that apply to a management activity will vary depending upon the location of the conservation component where the activity will occur. For example, non-motorized trails development is allowed in occupied sites located outside of SHAs but not in occupied sites located within SHAs.

- cells shaded orange indicate activities that are not allowed under any circumstances
- cells shaded yellow indicate activities limited by murrelet-specific restrictions or conditions
- cells shaded blue indicate activities not limited by murrelet-specific restrictions or conditions
- **all activities are subject to any other (i.e., non-murrelet) applicable restrictions or conditions, including all applicable terms and conditions of the HCP and the IA**

Activity	Conservation component			
	Occupied sites	Occupied site buffers	Special habitat areas	Other LTFC <sup>1</sup>
<b>Management activities</b>				
variable-retention timber harvest	not allowed			allowed in non-murrelet habitat
tailholds, guylines, and rigging (harvest-related infrastructure)	must install outside of the nesting season <sup>2</sup> <u>AND</u> avoid impacts to platform trees when possible	avoid impacts to platform trees when possible <u>AND</u> must follow limited operating periods <sup>3</sup> if carried out during the nesting season <sup>2</sup>	avoid impacts to platform trees when possible <u>AND</u> must follow limited operating periods <sup>3</sup> if carried out during nesting season <sup>2</sup> and within 328 feet of an occupied site	allowed
yarding corridors	allowed when no other route is feasible <u>AND</u> must consult with USFWS to minimize impacts	allowed when no other route is feasible <u>AND</u> must follow limited operating periods <sup>3</sup> if carried out during the nesting season <sup>2</sup>		allowed
salvage, recovery, and post-salvage reforestation or regeneration (including silvicultural treatments)	must not diminish the quality or amount of habitat <u>AND</u> a) must follow a site-specific restoration plan prepared with input from a DNR biologist <u>AND</u> b1) must take place outside of the nesting season <sup>2</sup> when feasible <u>OR</u> b2) must follow limited operating periods <sup>3</sup> if carried out during the nesting season <sup>2</sup> <u>AND</u> c) must consult with USFWS if standing platform trees will be felled			allowed

**Table A-4. Marbled murrelet-specific restrictions and conditions on management and recreation activities within conservation components of Washington State Department of Natural Resources' Marbled Murrelet Long-term Conservation Strategy**

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Activity	Conservation component			
	Occupied sites	Occupied site buffers	Special habitat areas	Other LTFC <sup>1</sup>
<b>Management activities</b>				
thinning and related silviculture	not allowed	only allowed in non-murrelet habitat outside of SHAs <u>OR</u> within SHAs that are located in NRF OR dispersal management areas OR the OESF <sup>4</sup> following the conditions below: a) allowed only in the outer 164 feet of the buffer in non-murrelet habitat, <u>AND</u> b) must follow a specific management objective to enhance or maintain security forest with a windfirm canopy by thinning from below, maintaining a minimum RD of 35 with no gap <sup>5</sup> creation <u>AND</u> c) must follow limited operating periods <sup>3</sup> if carried out during the nesting season <sup>2</sup>	only allowed in non-murrelet habitat within SHAs that are located in NRF or dispersal management areas or the OESF <sup>4</sup> following the conditions below: a) must follow a specific management objective to development northern spotted owl habitat, and maintain a minimum RD of 35, which may include gap <sup>6</sup> creation <u>AND</u> b) must follow limited operating periods <sup>3</sup> if carried out during the nesting season <sup>2</sup>	allowed in non-murrelet habitat

**Table A-4. Marbled murrelet-specific restrictions and conditions on management and recreation activities within conservation components of Washington State Department of Natural Resources' Marbled Murrelet Long-term Conservation Strategy**

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Activity	Conservation component			
	Occupied sites	Occupied site buffers	Special habitat areas	Other LTFC <sup>1</sup>
<b>Management activities</b>				
PCT (stands less than 20 years old)	not allowed	must follow limited operating periods <sup>3</sup> if carried out during the nesting season <sup>2</sup>	allowed	allowed
forest health treatments (e.g., root rot, Swiss needle cast, prescribed burning)	must identify a specific forest health problem and follow a site-specific management prescription <u>to address the problem AND</u> a1) must take place outside of the nesting season <sup>2</sup> when feasible <u>OR</u> a2) must follow limited operating periods <sup>3</sup> if carried out during the nesting season <sup>2</sup> <u>AND</u> b) prescribed burning must take place outside of the nesting season <sup>2</sup>	must identify a specific forest health problem and follow a site-specific management prescription to address the problem <u>AND</u> a) must follow limited operating periods <sup>3</sup> during the nesting season <sup>2</sup> <u>AND</u> b) within 1320 feet (¼ mile) of occupied sites, prescribed burning must take place outside of the nesting season <sup>2</sup>	must identify a specific forest health problem and follow a site-specific management prescription to address the problem <u>AND</u> a) must follow limited operating periods <sup>3</sup> during the nesting season <sup>2</sup> <u>AND</u> b) within 1320 feet (¼ mile) of occupied sites, prescribed burning must take place outside of the nesting season <sup>2</sup>	allowed in non-murrelet habitat, subject to all applicable terms and conditions of the HCP and the IA in habitat must follow a site-specific management prescription <u>AND</u> a) must follow limited operating periods <sup>3</sup> during the nesting season <sup>2</sup> <u>AND</u> b) within 1320 feet (¼ mile) of occupied sites, prescribed burning must take place outside of the nesting season <sup>2</sup>

**Table A-4. Marbled murrelet-specific restrictions and conditions on management and recreation activities within conservation components of Washington State Department of Natural Resources' Marbled Murrelet Long-term Conservation Strategy**

To read the table, apply the strictest rule for the area where an operation is to occur. For example, if an activity occurs in both an occupied site and a Special Habitat Area (SHA), apply the rule that results in the least potential impact to the marbled murrelet. In limited cases, rules that apply to a management activity will vary depending upon the location of the conservation component where the activity will occur. For example, non-motorized trails development is allowed in occupied sites located outside of SHAs but not in occupied sites located within SHAs.

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Activity	Conservation component			
	Occupied sites	Occupied site buffers	Special habitat areas	Other LTFC <sup>1</sup>
<b>Management activities</b>				
new road construction, new landings, waste area construction, existing pit expansion	allowed, consistent with Washington State Forest Practices Rules for forest roads (Title 222 WAC), when no other route is feasible <u>AND</u> a) must consult with USFWS to minimize impacts <u>AND</u> b1) must take place outside of the nesting season <sup>2</sup> when feasible <u>OR</u> b2) must follow limited operating periods <sup>3</sup> if carried out during the nesting season <sup>2</sup>	allowed, consistent with Washington State Forest Practices Rules for forest roads (Title 222 WAC), when no other route is feasible <u>AND</u> a) if in habitat, must consult with USFWS to minimize impacts <u>AND</u> b1) must take place outside of the nesting season <sup>2</sup> when feasible <u>OR</u> b2) must follow limited operating periods <sup>3</sup> if carried out during the nesting season <sup>2</sup>		allowed

**Table A-4. Marbled murrelet-specific restrictions and conditions on management and recreation activities within conservation components of Washington State Department of Natural Resources' Marbled Murrelet Long-term Conservation Strategy**

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Activity	Conservation component			
	Occupied sites	Occupied site buffers	Special habitat areas	Other LTFC <sup>1</sup>
<b>Management activities</b>				
road reconstruction or maintenance	must meet Washington State Forest Practices road standards <u>AND</u> a1) must take place outside of the nesting season <sup>2</sup> when feasible <u>OR</u> a2) must follow limited operating periods <sup>3</sup> during the nesting season <sup>2</sup>		must meet Washington State Forest Practices road standards <u>AND</u> must follow limited operating periods <sup>3</sup> during the nesting season <sup>2</sup>	allowed
road decommissioning or abandonment	must take place outside of the nesting season <sup>2</sup> when feasible <u>OR</u> must follow limited operating periods <sup>3</sup> during the nesting season <sup>2</sup>		allowed	
new rock pit development	not allowed			allowed in non-murrelet habitat, subject to all applicable terms and conditions of the HCP and the IA not allowed in habitat
blasting	within 1320 feet (¼ mile) of occupied sites, must take place outside of the nesting season <sup>2</sup> when feasible <u>OR</u> must follow limited operating periods <sup>3</sup> during the nesting season <sup>2</sup>			

**Table A-4. Marbled murrelet-specific restrictions and conditions on management and recreation activities within conservation components of Washington State Department of Natural Resources' Marbled Murrelet Long-term Conservation Strategy**

To read the table, apply the strictest rule for the area where an operation is to occur. For example, if an activity occurs in both an occupied site and a Special Habitat Area (SHA), apply the rule that results in the least potential impact to the marbled murrelet. In limited cases, rules that apply to a management activity will vary depending upon the location of the conservation component where the activity will occur. For example, non-motorized trails development is allowed in occupied sites located outside of SHAs but not in occupied sites located within SHAs.

- cells shaded **orange** indicate activities that are not allowed under any circumstances
- cells shaded **yellow** indicate activities limited by murrelet-specific restrictions or conditions
- cells shaded **blue** indicate activities not limited by murrelet-specific restrictions or conditions
- **all activities are subject to any other (i.e., non-murrelet) applicable restrictions or conditions, including all applicable terms and conditions of the HCP and the IA**

Activity	Conservation component			
	Occupied sites	Occupied site buffers	Special habitat areas	Other LTFC <sup>1</sup>
<b>Management activities</b>				
crushing, pile-driving	must take place outside of the nesting season <sup>2</sup> if feasible <u>OR</u> follow limited operating periods <sup>3</sup> during the nesting season <sup>2</sup>		within 361 feet of occupied sites, must take place outside of the nesting season <sup>2</sup> if feasible <u>OR</u> follow limited operating periods <sup>3</sup> during the nesting season <sup>2</sup>	
DNR-operated or DNR-contracted aircraft - Boeing CH-47	not allowed within 795 feet of an occupied site--distance or altitude-- during the nesting season <sup>2</sup>			
DNR-operated or DNR-contracted aircraft - Boeing 107/CH-46, Sikorsky S-64	not allowed within 450 feet of an occupied site--distance or altitude during the nesting season <sup>2</sup>			
DNR-operated or DNR-contracted aircraft - small helicopters and fixed-wing aircraft	not allowed within 330 feet of an occupied site--distance or altitude-- during the nesting season <sup>2</sup>			
non-invasive research	allowed			



**Table A-4. Marbled murrelet-specific restrictions and conditions on management and recreation activities within conservation components of Washington State Department of Natural Resources' Marbled Murrelet Long-term Conservation Strategy**

To read the table, apply the strictest rule for the area where an operation is to occur. For example, if an activity occurs in both an occupied site and a Special Habitat Area (SHA), apply the rule that results in the least potential impact to the marbled murrelet. In limited cases, rules that apply to a management activity will vary depending upon the location of the conservation component where the activity will occur. For example, non-motorized trails development is allowed in occupied sites located outside of SHAs but not in occupied sites located within SHAs.

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Activity	Conservation component			
	Occupied sites	Occupied site buffers	Special habitat areas	Other LTFC <sup>1</sup>
<b>Management activities</b>				
cutting of trees for research purposes	not allowed unless approved by both DNR and USFWS	only allowed in non-murrelet habitat outside of SHAs <u>OR</u> within SHAs that are located in NRF or dispersal management areas, or the OESF <sup>4</sup> , following the conditions below:  a) allowed only in the outer 164 feet of the buffer, <u>AND</u>  b) must follow a specific management objective to enhance or maintain security forest with a windfirm canopy by thinning from below, maintaining a minimum RD of 35 with no gap <sup>5</sup> creation <u>AND</u>  c) must follow limited operating periods <sup>3</sup> if carried out during the nesting season <sup>2</sup>	only allowed in non-murrelet habitat within SHAs that are located in NRF or dispersal management areas or the OESF <sup>4</sup> following the conditions below:  a) must follow a specific management objective to development northern spotted owl habitat, and maintain a minimum RD of 35, which may include gap creation <sup>6</sup> <u>AND</u>  b) must follow limited operating periods <sup>3</sup> if carried out during the nesting season <sup>2</sup>	allowed in non-murrelet habitat  within murrelet habitat must obtain approval from DNR and USFWS

**Table A-4. Marbled murrelet-specific restrictions and conditions on management and recreation activities within conservation components of Washington State Department of Natural Resources' Marbled Murrelet Long-term Conservation Strategy**

To read the table, apply the strictest rule for the area where an operation is to occur. For example, if an activity occurs in both an occupied site and a Special Habitat Area (SHA), apply the rule that results in the least potential impact to the marbled murrelet. In limited cases, rules that apply to a management activity will vary depending upon the location of the conservation component where the activity will occur. For example, non-motorized trails development is allowed in occupied sites located outside of SHAs but not in occupied sites located within SHAs.

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- **all activities are subject to any other (i.e., non-murrelet) applicable restrictions or conditions, including all applicable terms and conditions of the HCP and the IA**

Activity	Conservation component			
	Occupied sites	Occupied site buffers	Special habitat areas	Other LTFC <sup>1</sup>
<b>Management activities</b>				
fire suppression activities (including air operations)	follow Minimum Impact Suppression Tactics as defined in National Wildfire Coordinating Group 2003 or future updates			
other management activities	management activities not listed in this table are subject to all applicable terms and conditions of the HCP and the IA			
<b>Recreation activities</b>				
existing trails and facilities (including trailheads, parking lots, restrooms, campgrounds)	allowed			
new or expanded facilities (such as trailheads, parking lots, restrooms and campgrounds)	evaluate for impacts on murrelets and murrelet habitat and consult with USFWS if potential impacts are identified			allowed in non-murrelet habitat

**Table A-4. Marbled murrelet-specific restrictions and conditions on management and recreation activities within conservation components of Washington State Department of Natural Resources' Marbled Murrelet Long-term Conservation Strategy**

To read the table, apply the strictest rule for the area where an operation is to occur. For example, if an activity occurs in both an occupied site and a Special Habitat Area (SHA), apply the rule that results in the least potential impact to the marbled murrelet. In limited cases, rules that apply to a management activity will vary depending upon the location of the conservation component where the activity will occur. For example, non-motorized trails development is allowed in occupied sites located outside of SHAs but not in occupied sites located within SHAs.

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- all activities are subject to any other (i.e., non-murrelet) applicable restrictions or conditions, including all applicable terms and conditions of the HCP and the IA

Activity	Conservation component			
	Occupied sites	Occupied site buffers	Special habitat areas	Other LTFC <sup>1</sup>
<b>Recreation activities</b>				
new or expanded trails	not allowed in SHAs motorized not allowed outside SHAs non-motorized allowed outside of SHAs following the conditions below: a) must not diminish the quality or amount of habitat <u>AND</u> b) must consult with USFWS if standing platform trees will be felled		not allowed	allowed
conversion of existing non-motorized trails to motorized use	not allowed			allowed
decommission or abandon illegal trails	allowed outside nesting season <sup>2</sup> <u>OR</u> follow limited operating periods <sup>3</sup> if during nesting season <sup>2</sup>		allowed	
maintenance or improvements within the footprint of existing facilities, trails, trailheads (including upgrades to address health, safety, or environmental damage concerns)	allowed outside nesting season <sup>2</sup> <u>OR</u> follow limited operating periods <sup>3</sup> if during nesting season <sup>2</sup>			allowed

---

<sup>1</sup> Other long-term forest cover (other LTFC) includes existing northern spotted owl high-quality habitat, which includes the following DNR-mapped habitat classes as of 2018: old forest, high-quality nesting habitat, and A and B habitat per the definitions in the 1997 HCP (DNR 1997, p. 12). It also includes riparian areas managed under the HCP riparian conservation strategy, uncommon habitats and special habitat features protected under the HCP multi-species conservation strategy, all remaining old-growth forest, genetic resources and special habitat features protected under DNR’s *Policy for Sustainable Forests* (DNR 2006), natural area preserves and natural resources conservation areas, and inoperable or inaccessible areas. Variable retention harvests in these areas may only occur where it is consistent with the applicable restrictions or conditions, including all applicable terms and conditions of the HCP and the IA. Examples of where variable retention harvest may be consistent with these restrictions or conditions include in allotted acres of variable retention harvest in the *OESF HCP Planning Unit Forest Land Plan* (DNR 2016) or hardwood conversions in the *Implementation Procedures for the HCP Riparian Forest Restoration Strategy* (DNR 2006).

<sup>2</sup> “Nesting season” means April 1 through September 23 (USFWS 2013).

<sup>3</sup> “Limited operating periods” means that activities may only be carried out from two hours after sunrise to 2 hours before sunset (USFWS 2012).

<sup>4</sup> SHAs within NRF or dispersal management areas or OESF where thinning is allowed include Clallam East, Clallam West, Lake Shannon East, Queets, and Reade Hill in their entirety, and portions of Middle Fork and Pilchuck River. Other SHAs where thinning is not allowed include Browning, Deer Creek, Elochoman, Hazel, Marsh, North Crescent East, North Crescent West, Radar Bear North, Radar Bear South, Salmon Creek South, Skamokawa North Skamokawa South, Sumas.

<sup>5</sup> Thinning to reduce tree density is allowed, but the intentional creation of gaps is not allowed.

<sup>6</sup> Gaps in SHAs must be less than or equal to 0.25 acres.

**Table A-5. Projected changes in raw acres of marbled murrelet habitat within strategic locations, other high value landscapes, and marginal landscapes emphasized in Washington State Department of Natural Resources' marbled murrelet long-term conservation strategy, 2018 through 2067**

Strategic location or landscape	Raw acres of murrelet habitat <sup>1</sup>		
	2018	2067 (projected)	Change
Southwest Washington	26,332	36,283	+9,951
OESF and Straits of Juan de Fuca (west of the Elwha River)	74,801	74,939	+138
North Puget	60,161	72,064	+11,904
Other High Value Landscapes	41,830	65,767	+23,937
Marginal Landscapes	3,943	23,786	+19,843
<b>Total</b>	<b>207,066</b>	<b>272,839</b>	<b>+65,772</b>

<sup>1</sup> Sums of individual strategic location and landscape acres may not sum to total due to rounding.

**Table A-6. Marbled murrelet special habitat areas designated as part of Washington State Department of Natural Resources' Marbled Murrelet Long-term Conservation Strategy**

Name	Category (acres)						Percent habitat at end of HCP's 70-year term <sup>1</sup>
	Occupied site	Habitat	Future habitat	Security forest + future security forest	Non-forested	Total	
1. Sumas	0	1,325	359	383	41	2,108	80
2. Middle Fk.	293	864	593	674	63	2,486	70
3. Lk. Shannon E	377	363	0	302	88	1,130	66
4. Deer Ck.	266	481	160	141	52	1,100	82
5. Hazel	90	213	75	111	13	502	75
6. Pilchuck R.	101	946	404	362	48	1,861	78
7. Marsh	92	229	0	17	0	338	95
8. Clallam W	173	116	20	100	3	412	75
9. Clallam E	105	3,012	272	406	23	3,819	89
10. N Crescent W	261	1076	870	144	8	2,358	94
11 N Crescent E	890	429	245	303	32	1,898	82
12. Reade Hill	1,403	1,129	0	660	45	3,238	78
13. Queets	3,530	647	110	3,035	227	7,549	57
14. Browning	345	303	35	145	1	829	82
15. Radar Bear N	2,409	593	22	365	38	3,426	88
16. Radar Bear S	273	404	835	728	110	2,351	64
17. Salmon Ck. S	1,026	763	226	1,614	115	3,744	54
18. Skamokawa N	391	298	0	619	27	1,336	52

**Table A-6. Marbled murrelet special habitat areas designated as part of Washington State Department of Natural Resources' Marbled Murrelet Long-term Conservation Strategy**

Name	Category (acres)						Percent habitat at end of HCP's 70-year term <sup>1</sup>
	Occupied site	Habitat	Future habitat	Security forest + future security forest	Non-forested	Total	
<b>19. Skamokawa S</b>	1,038	2,053	700	1,860	65	5,717	66
<b>20. Elochoman</b>	180	336	127	67	15	724	89
<b>Total</b>	13,245	15,578	5,052	12,036	1,014	46,925	72

<sup>1</sup> (Occupied site acres + habitat acres + future habitat acres) divided by total acres.

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**Table A-7: Estimated Acres of Habitat (Raw acres) by HCP Planning Unit as of the Date the Permit is Approved**

HCP Planning Unit	Existing Habitat (Raw Acres) <sup>1</sup>
Columbia	14,554
Olympic Experimental State Forest	68,309
North Puget	76,893
South Coast	17,786
South Puget	14,733
Straits	14,287
Total	207,066

<sup>1</sup>Sum of individual HCP planning unit acres does not equal total due to rounding.

**Table A-8. Estimated Acreage of Inland Habitat Exposed to Noise Disturbance Annually During the Nesting Season, by Activity Group**

<b>Activity group</b>	<b>Stressor</b>	<b>Distance</b>	<b>Duration</b>	<b>Response/impact</b>	<b>Average habitat disturbed annually during nesting season (adjusted acres)</b>
<b>Group 1</b> <b>(Includes green collecting, pre-commercial thinning, non-motorized trail use, minor road maintenance)</b>	Ground-based noise and visual disturbance	≤328 feet (100 meters)	< 1 day	No significant response based on duration; minimal to no impacts	9,200
<b>Group 2</b> <b>(Includes firewood collection, road reconstruction, major road and trail maintenance, communications facilities)</b>	Ground-based noise and visual disturbance	≤328 feet (100 meters)	< 7 days	Aborted feedings, adults flushing; disruption of normal behaviors	310
<b>Group 3</b> <b>(Campground use and maintenance)</b>	Ground-based noise and visual disturbance  Predator attraction	≤328 feet (100 meters)	> 1 month	Increased predation risk, aborted feedings, adults flushing; potential injury and/or mortality	142
<b>Group 4</b> <b>(Includes noise from timber harvest, motorized trail use, new road and bridge construction)</b>	Ground-based noise and visual disturbance	≤328 feet (100 meters)	>7 days, < 1 month	Aborted feedings, adults flushing; disruption of normal behaviors	1,630

**Table A-8. Estimated Acreage of Inland Habitat Exposed to Noise Disturbance Annually During the Nesting Season, by Activity Group**

Activity group	Stressor	Distance	Duration	Response/impact	Average habitat disturbed annually during nesting season (adjusted acres)
<b>Group 5 (Sand and gravel extraction, blasting)</b>	Ground-based noise and visual disturbance	≤ 1,312 feet (400 meters)	>7 days, < 1 month	Hearing damage from blast noise (within 100 m), aborted feedings, adults flushing; injury; disruption of normal behaviors	52
<b>Group 6 (Aerial herbicide application)</b>	Aircraft noise	≤328 feet (100 meters)	< 7 days	Aborted feedings, adults flushing; disruption of normal behaviors	50

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# Appendix **B**

## Figures

Figure B-1. Marbled murrelet occupied sites on lands managed by Washington State Department of Natural Resources

Figure B-2. Marbled murrelet special habitat areas designated as part of Washington State Department of Natural Resources' Marbled Murrelet Long-term Conservation Strategy

Figure B-3. Browning Special Habitat Area

Figure B-4. Clallam East Special Habitat Area

Figure B-5. Clallam West Special Habitat Area

Figure B-6. Deer Creek Special Habitat Area

Figure B-7. Elochoman Special Habitat Area

Figure B-8. Hazel Special Habitat Area

Figure B-9. Lake Shannon Special Habitat Area

Figure B-10. Marsh Special Habitat Area

Figure B-11. Middle Fork Special Habitat Area

Figure B-12. North Crescent East Special Habitat Area

Figure B-13. North Crescent West Special Habitat Area

Figure B-14. Pilchuck River Special Habitat Area

Figure B-15. Queets Special Habitat Area

Figure B-16. Radar Bear North Special Habitat Area

Figure B-17. Radar Bear South Special Habitat Area

Figure B-18. Reade Hill Special Habitat Area

Figure B-19. Salmon Creek South Special Habitat Area

Figure B-20. Skamokawa North Special Habitat Area

Figure B-21. Skamokawa South Special Habitat Area

Figure B-22. Sumas Special Habitat Area



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Figure B-1. Marbled murrelet occupied sites on lands managed by Washington State Department of Natural Resources

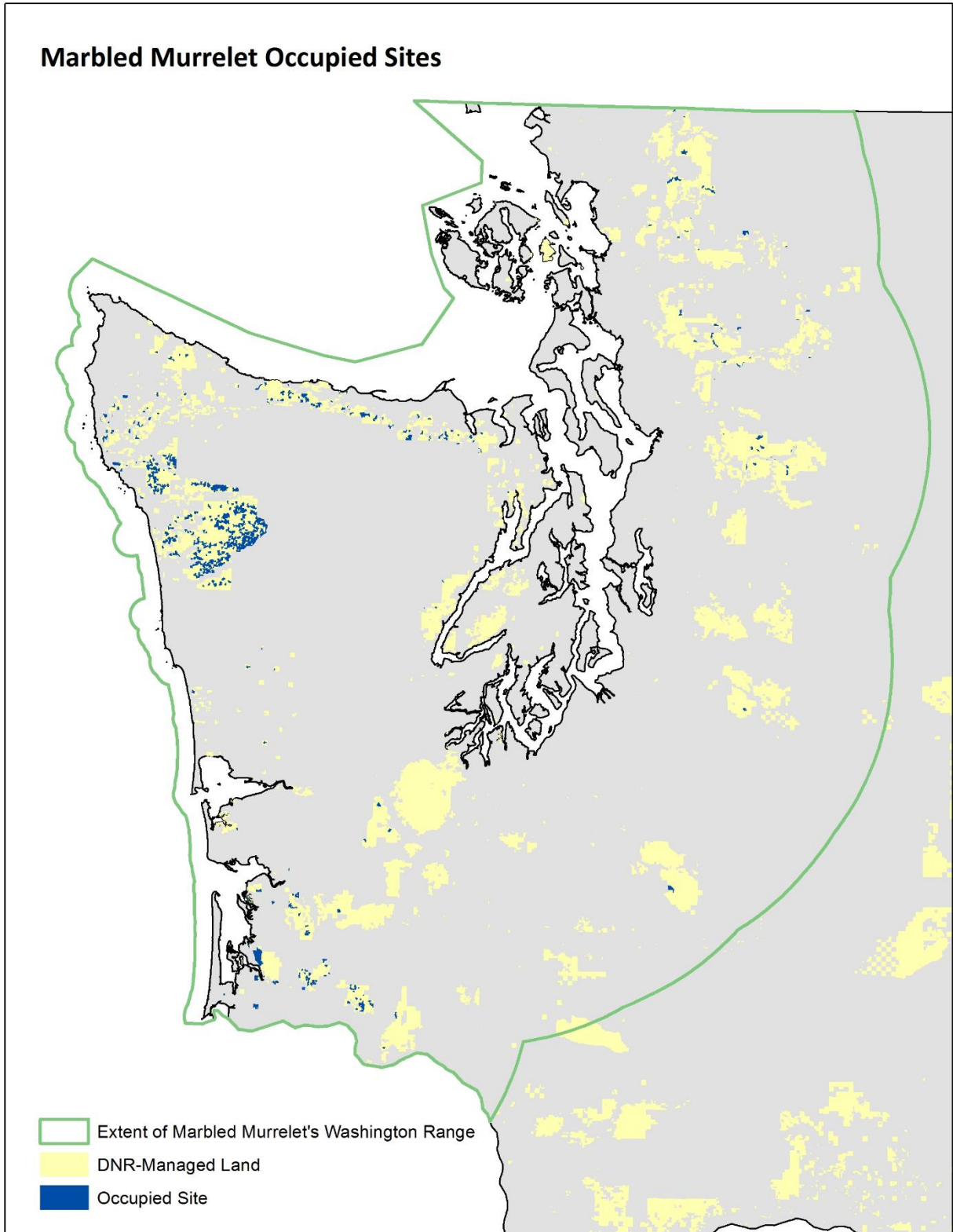


Figure B-2. Marbled murrelet special habitat areas designated as part of Washington State Department of Natural Resources' Marbled Murrelet Long-term Conservation Strategy

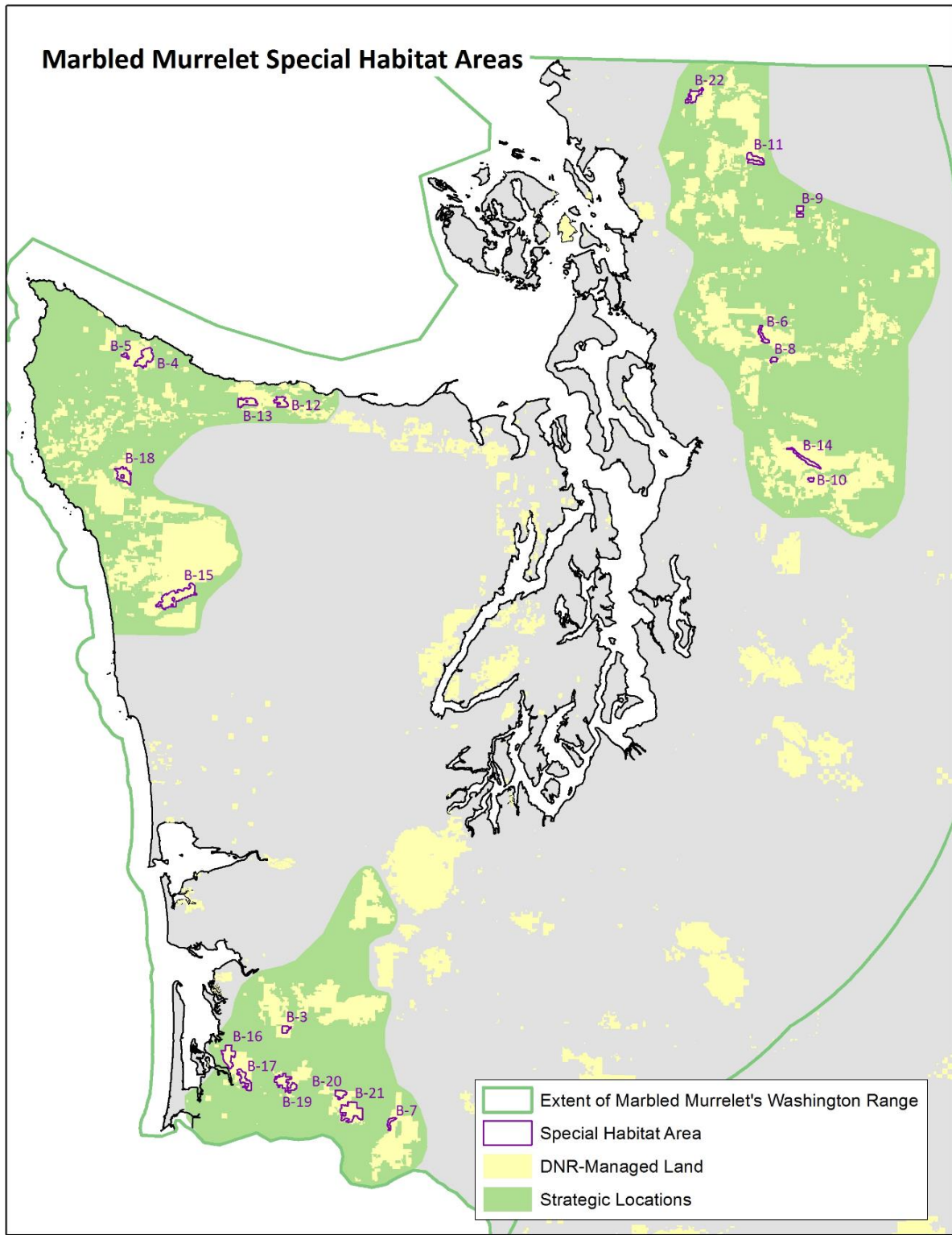
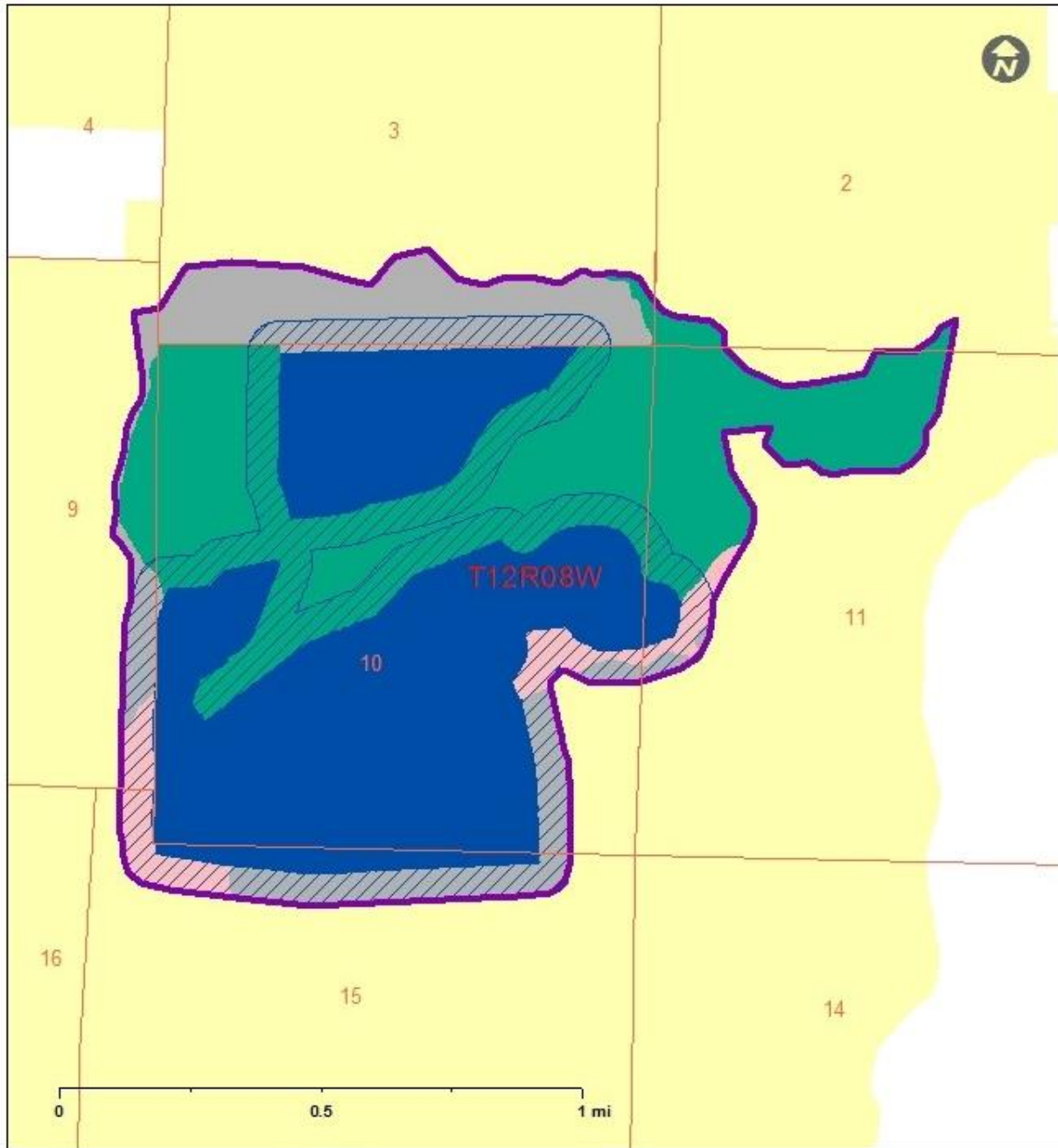




Figure B-3. Browning Special Habitat Area



- |                      |                                    |
|----------------------|------------------------------------|
| Townships            | Occupied Site Buffer               |
| Sections             | Occupied Site                      |
| Special Habitat Area | Current Habitat                    |
| DNR-Managed Land     | Future Habitat                     |
|                      | Current and Future Security Forest |
|                      | Non-forested                       |

Figure B-4. Clallam East Special Habitat Area

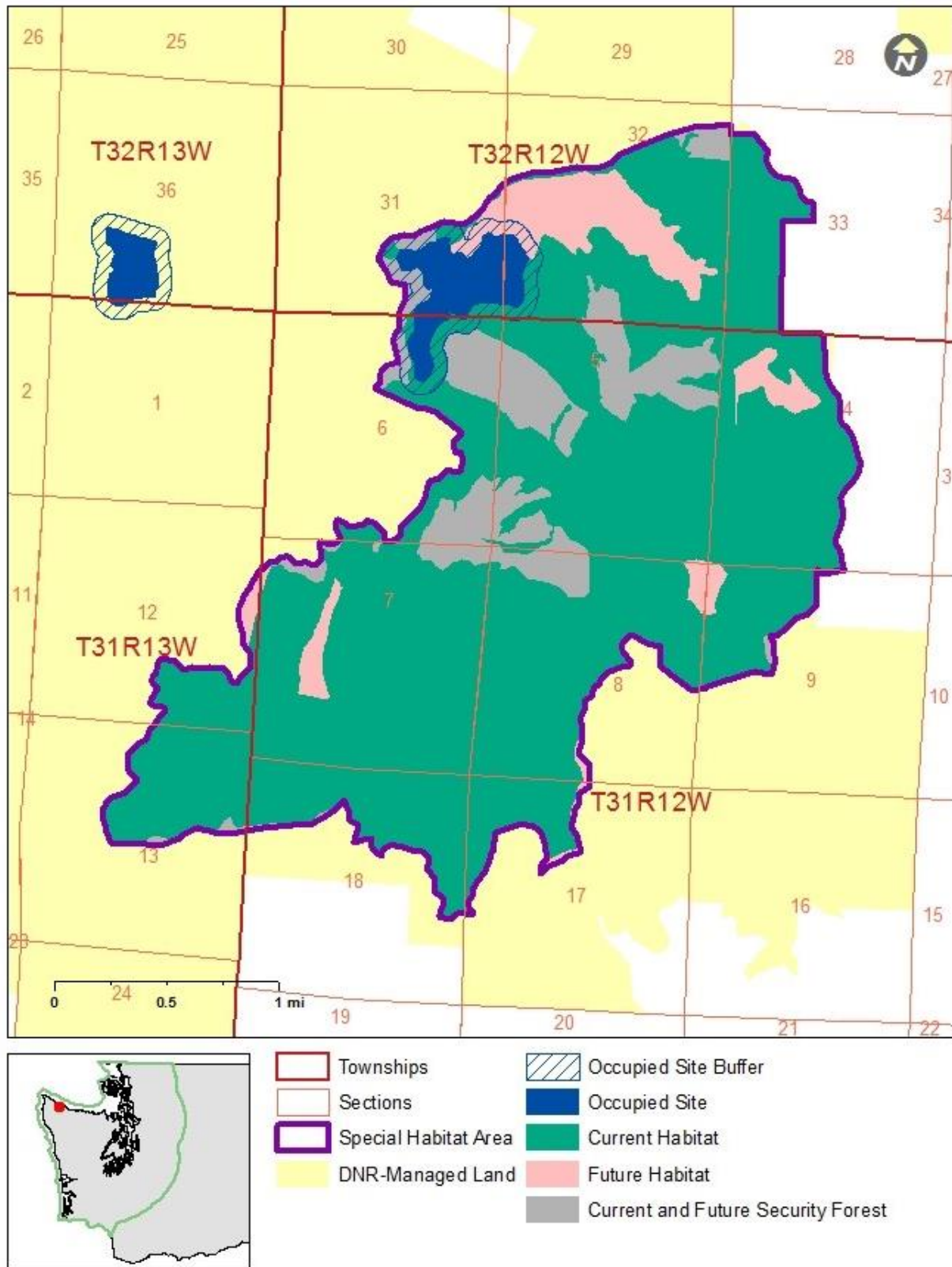


Figure B-5. Clallam West Special Habitat Area

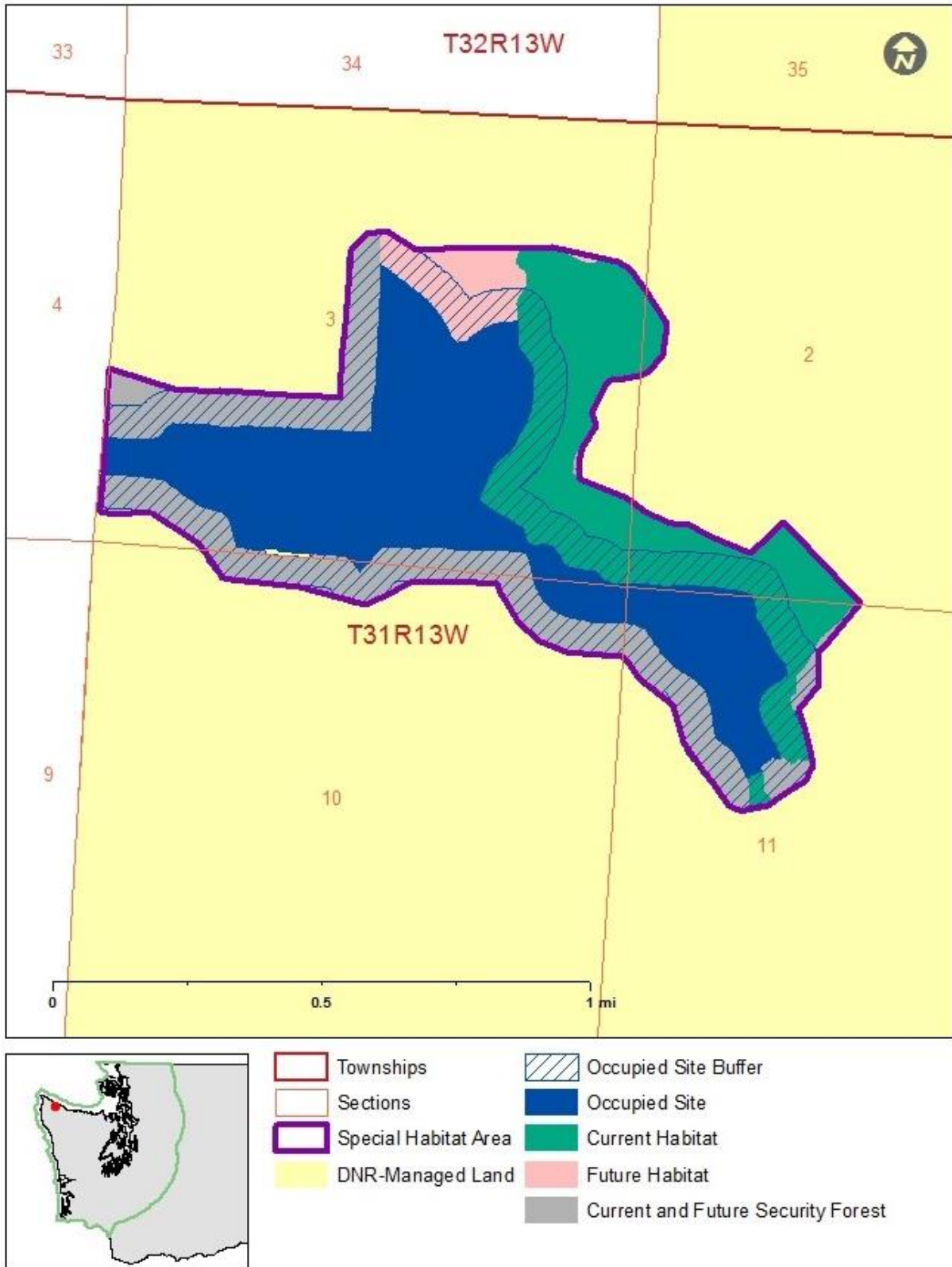
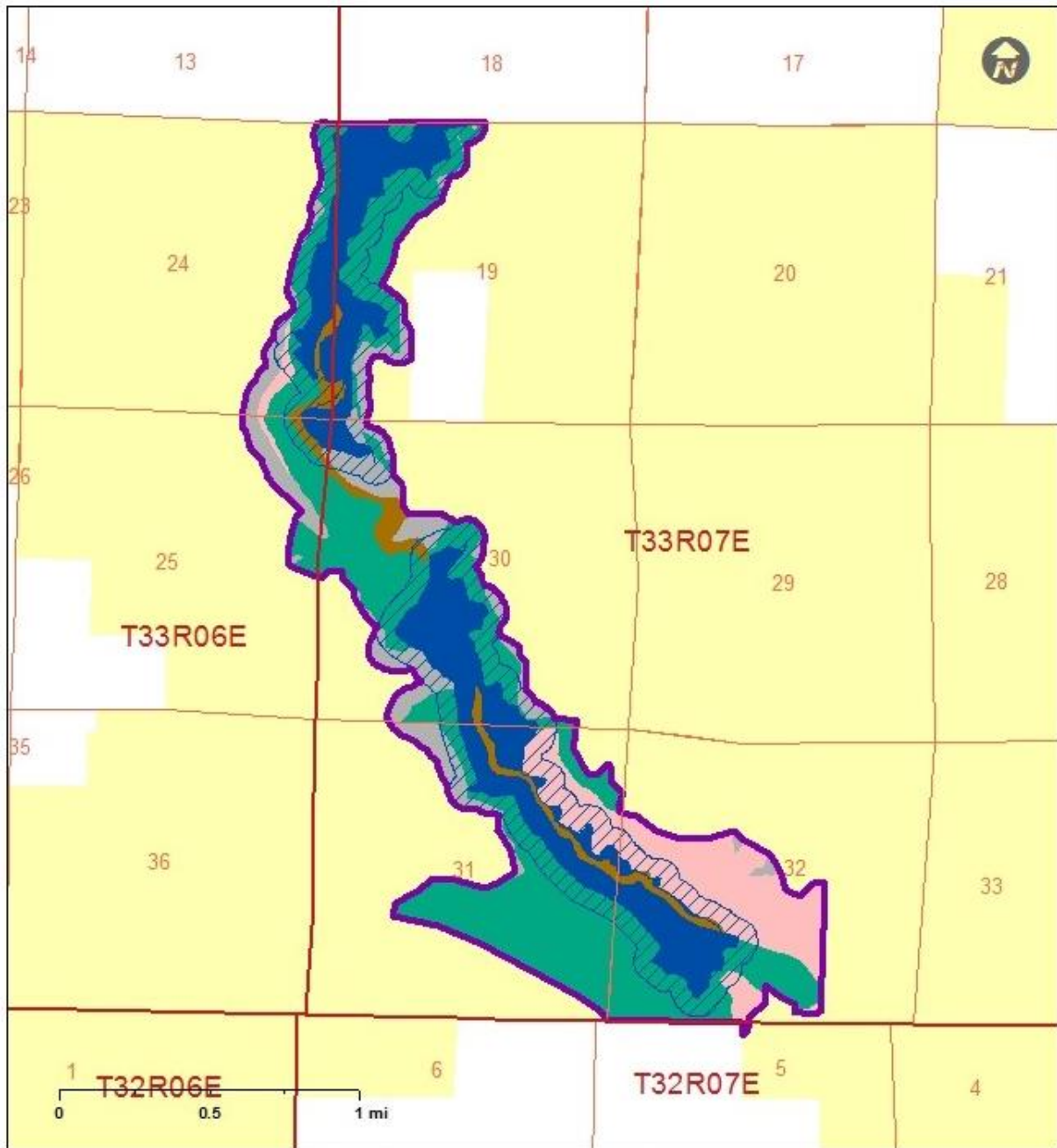


Figure B-6. Deer Creek Special Habitat Area



- |                      |                                    |
|----------------------|------------------------------------|
| Townships            | Occupied Site Buffer               |
| Sections             | Occupied Site                      |
| Special Habitat Area | Current Habitat                    |
| DNR-Managed Land     | Future Habitat                     |
|                      | Current and Future Security Forest |
|                      | Non-forested                       |

Figure B-7. Elochoman Special Habitat Area

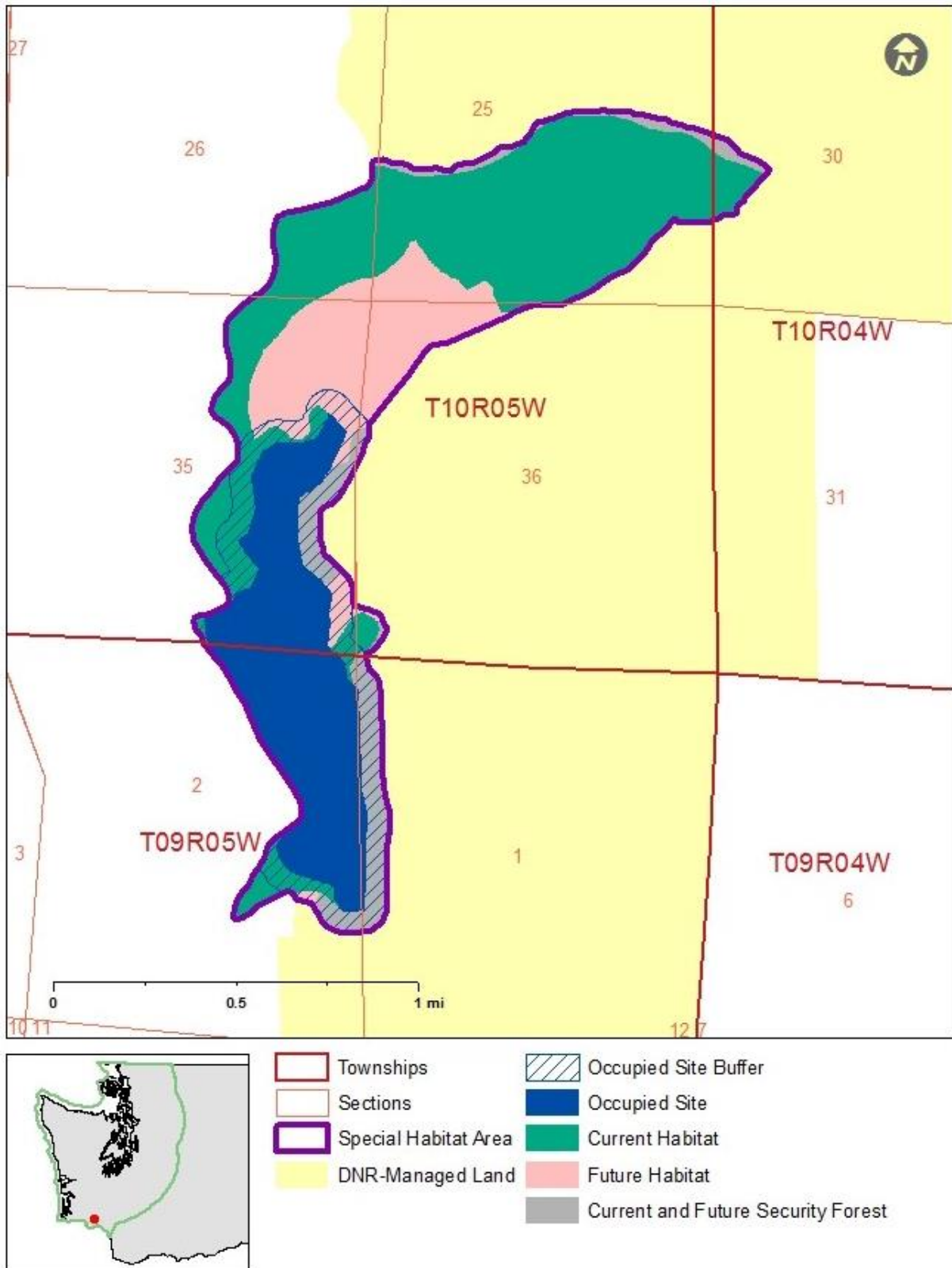


Figure B-8. Hazel Special Habitat Area

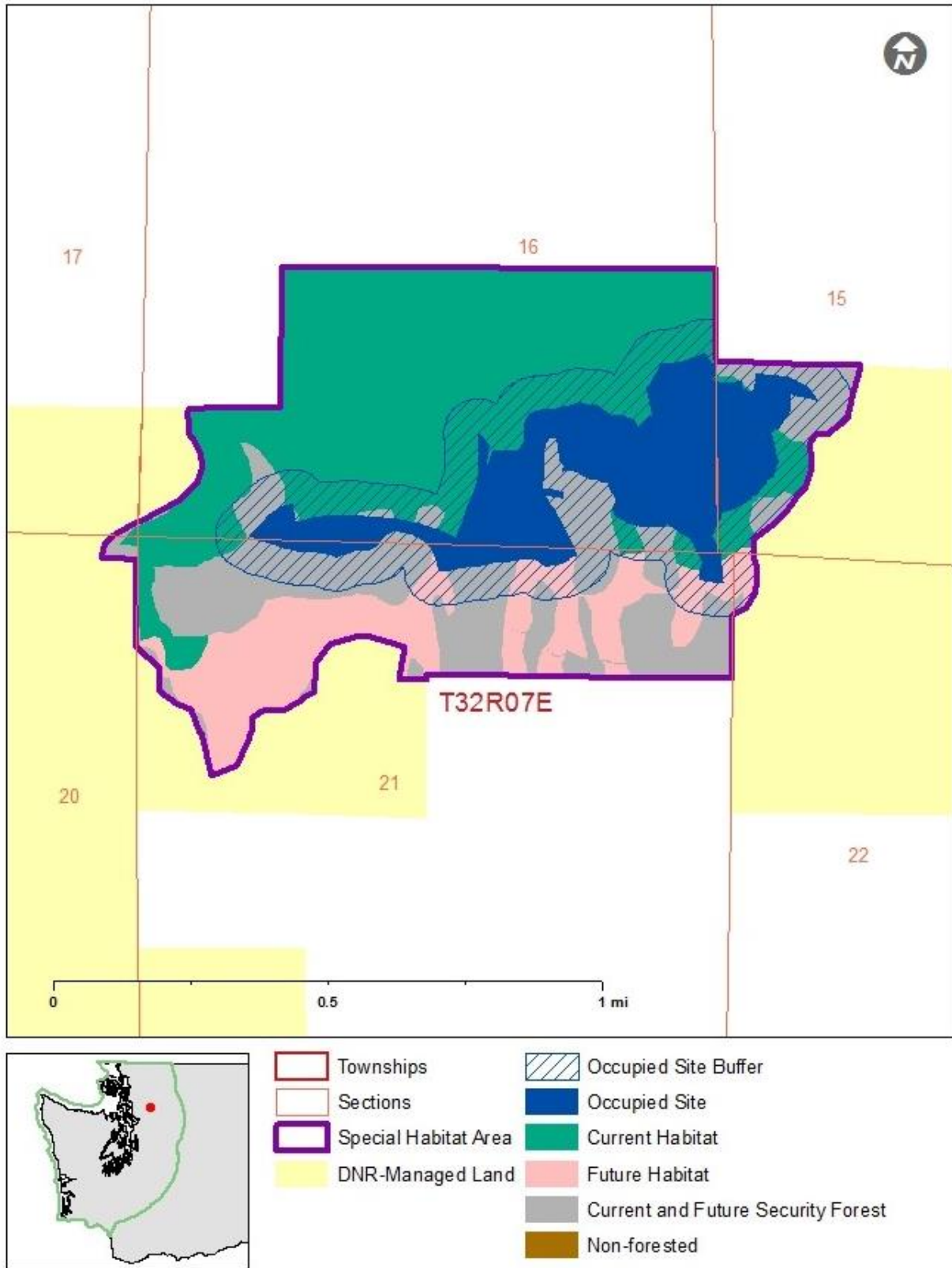


Figure B-9. Lake Shannon Special Habitat Area

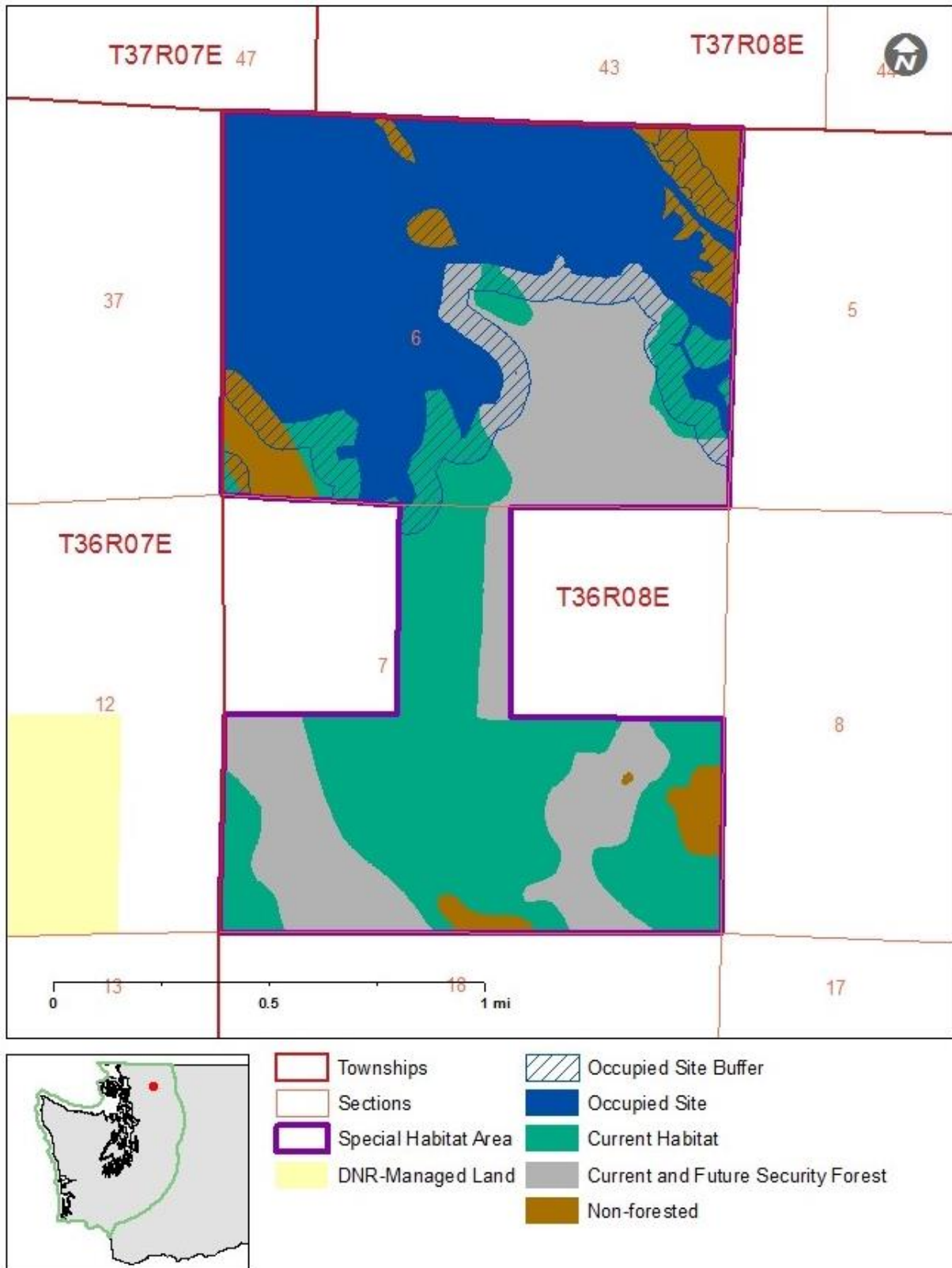


Figure B-10. Marsh Special Habitat Area

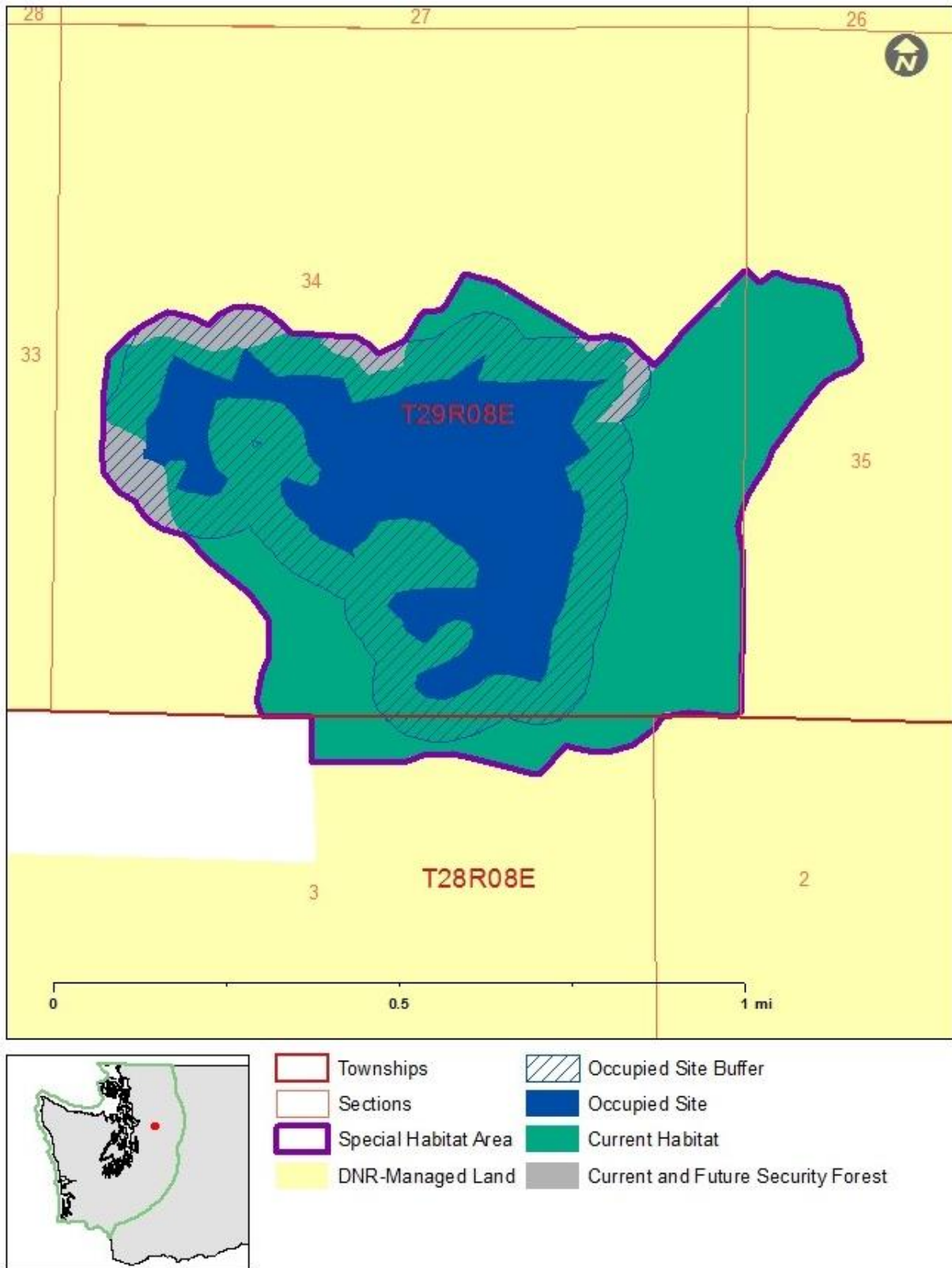




Figure B-11. Middle Fork Special Habitat Area

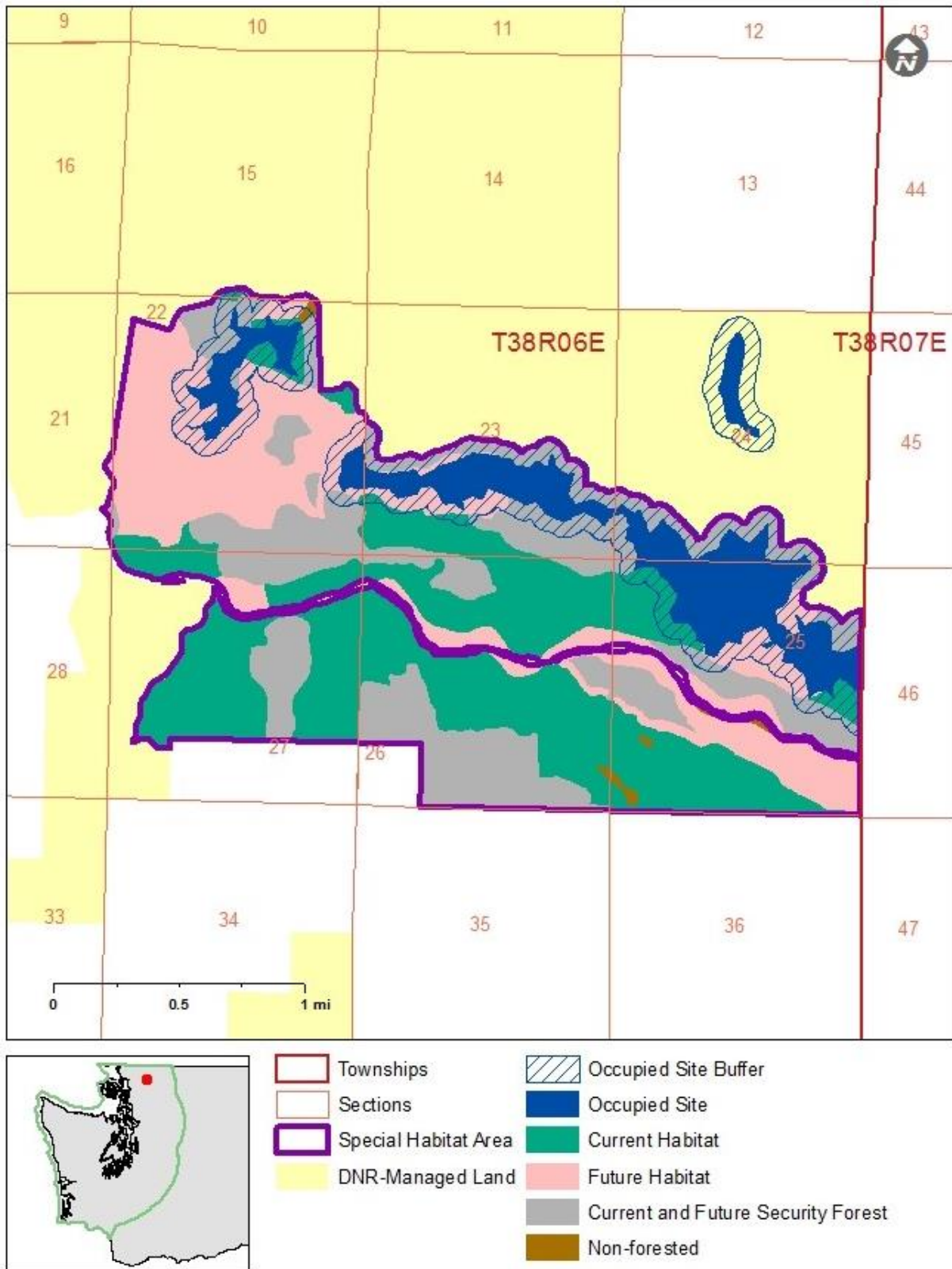


Figure B-12. North Crescent East Special Habitat Area

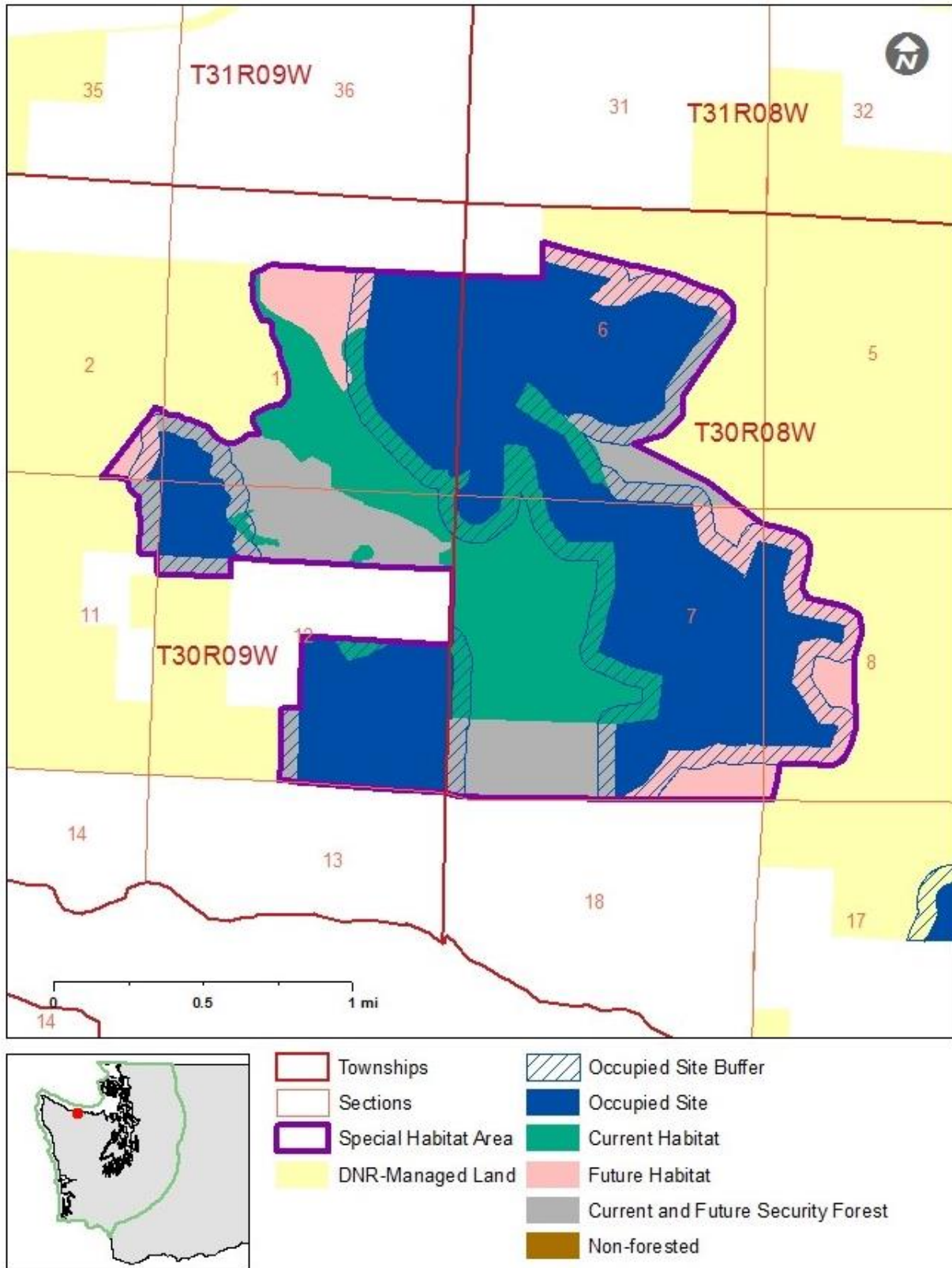


Figure B-13. North Crescent West Special Habitat Area

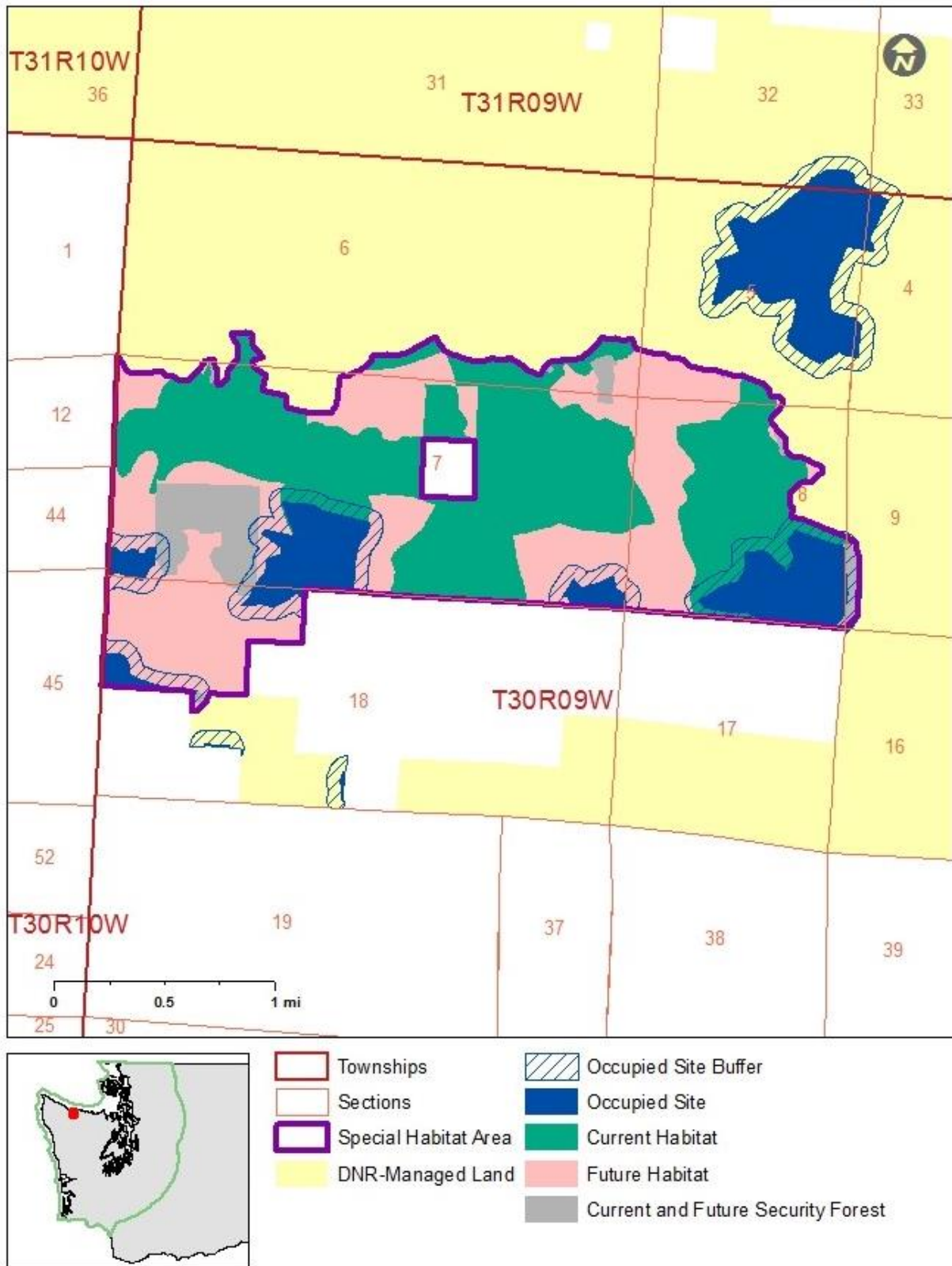


Figure B-14. Pilchuck River Special Habitat Area

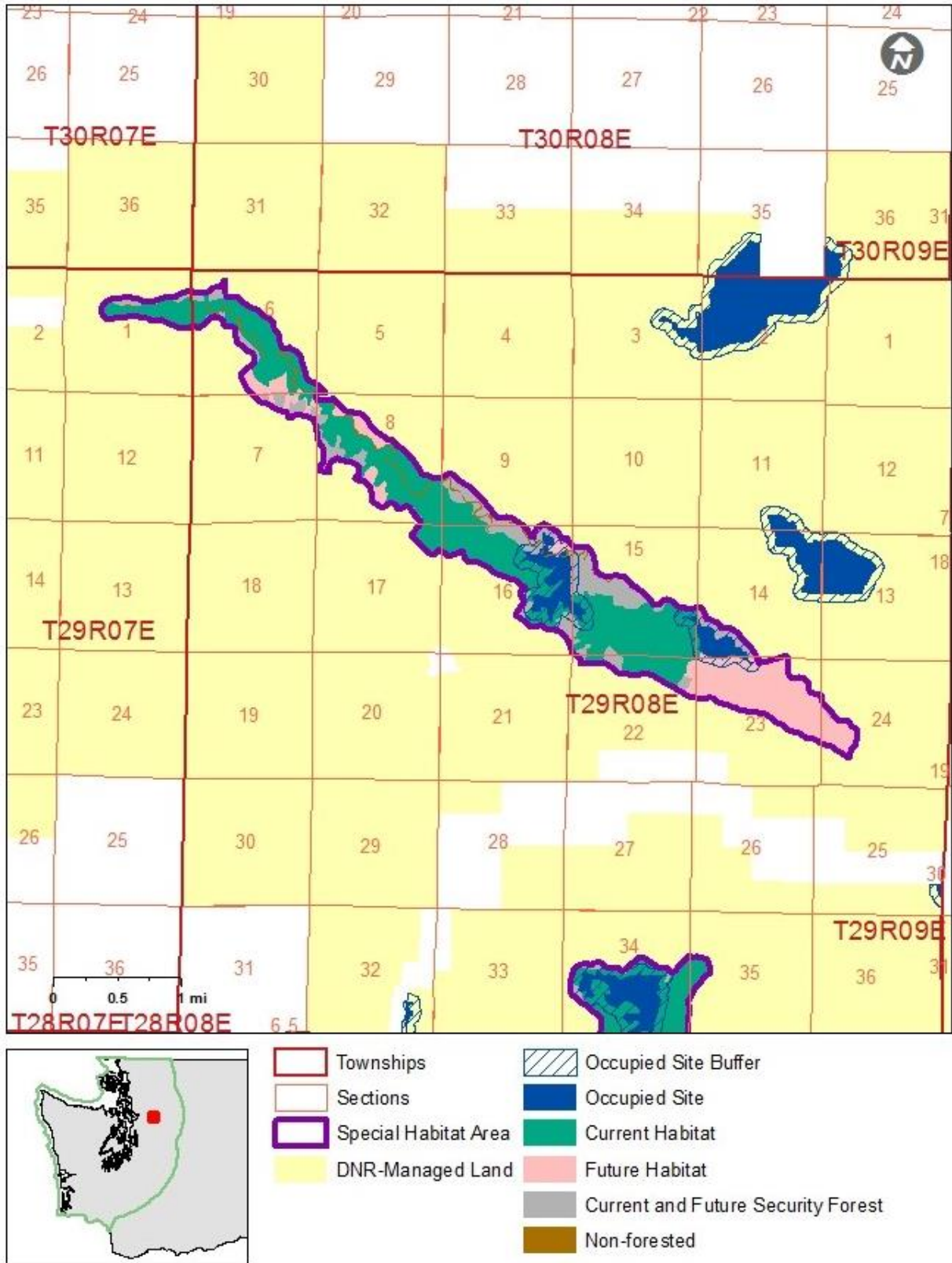


Figure B-15. Queets Special Habitat Area

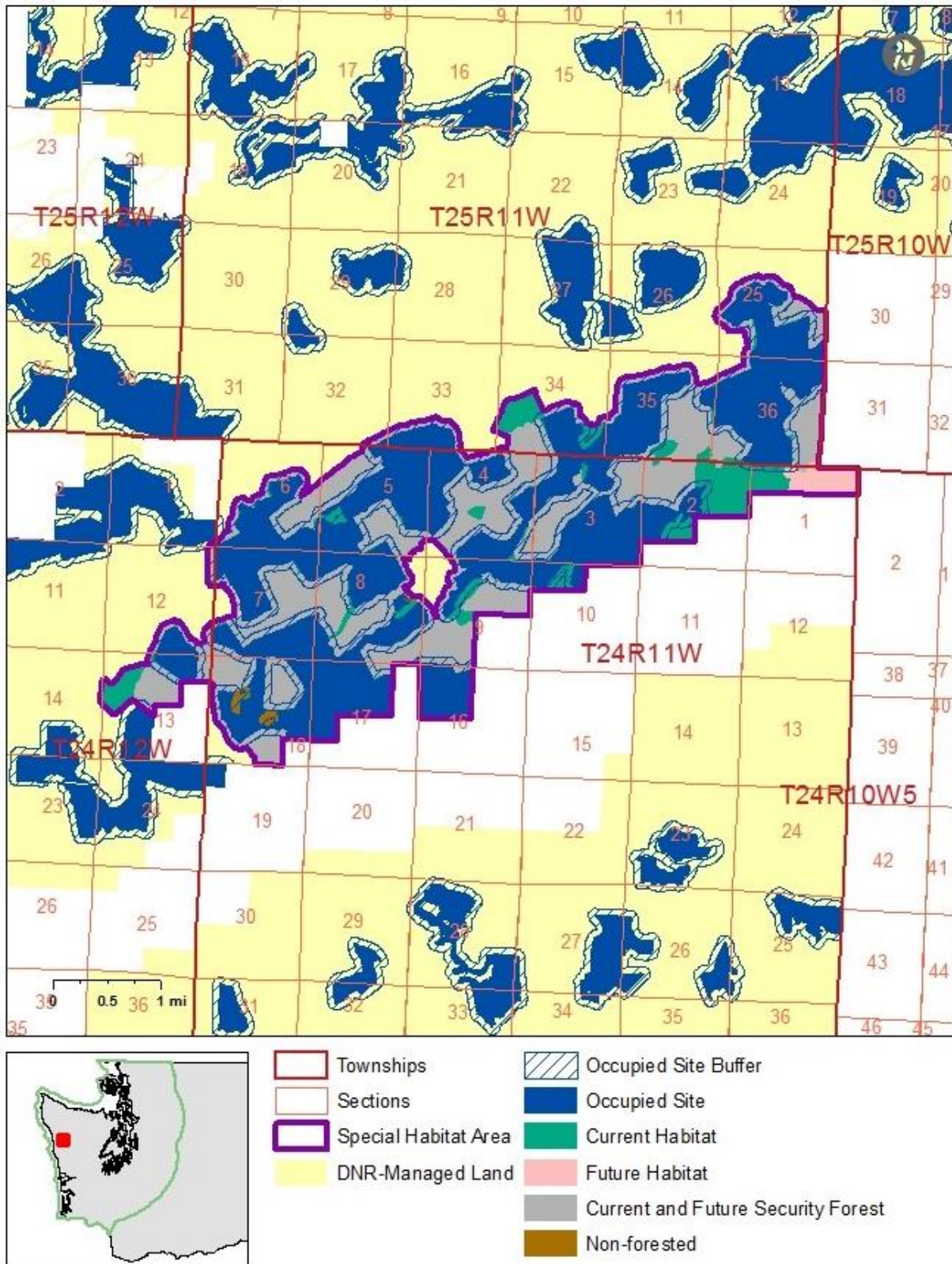


Figure B-16. Radar Bear North Special Habitat Area

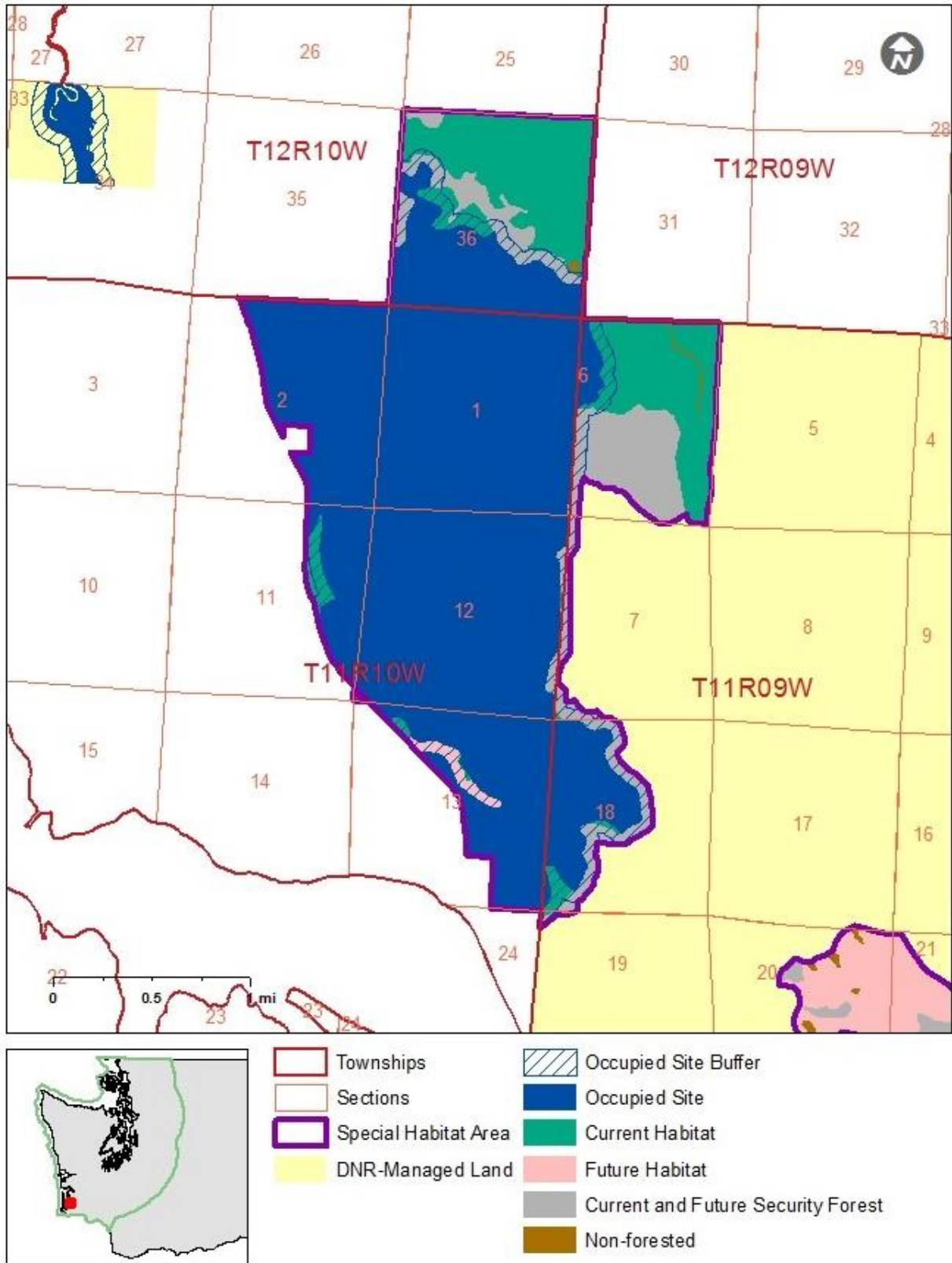


Figure B-17. Radar Bear South Special Habitat Area

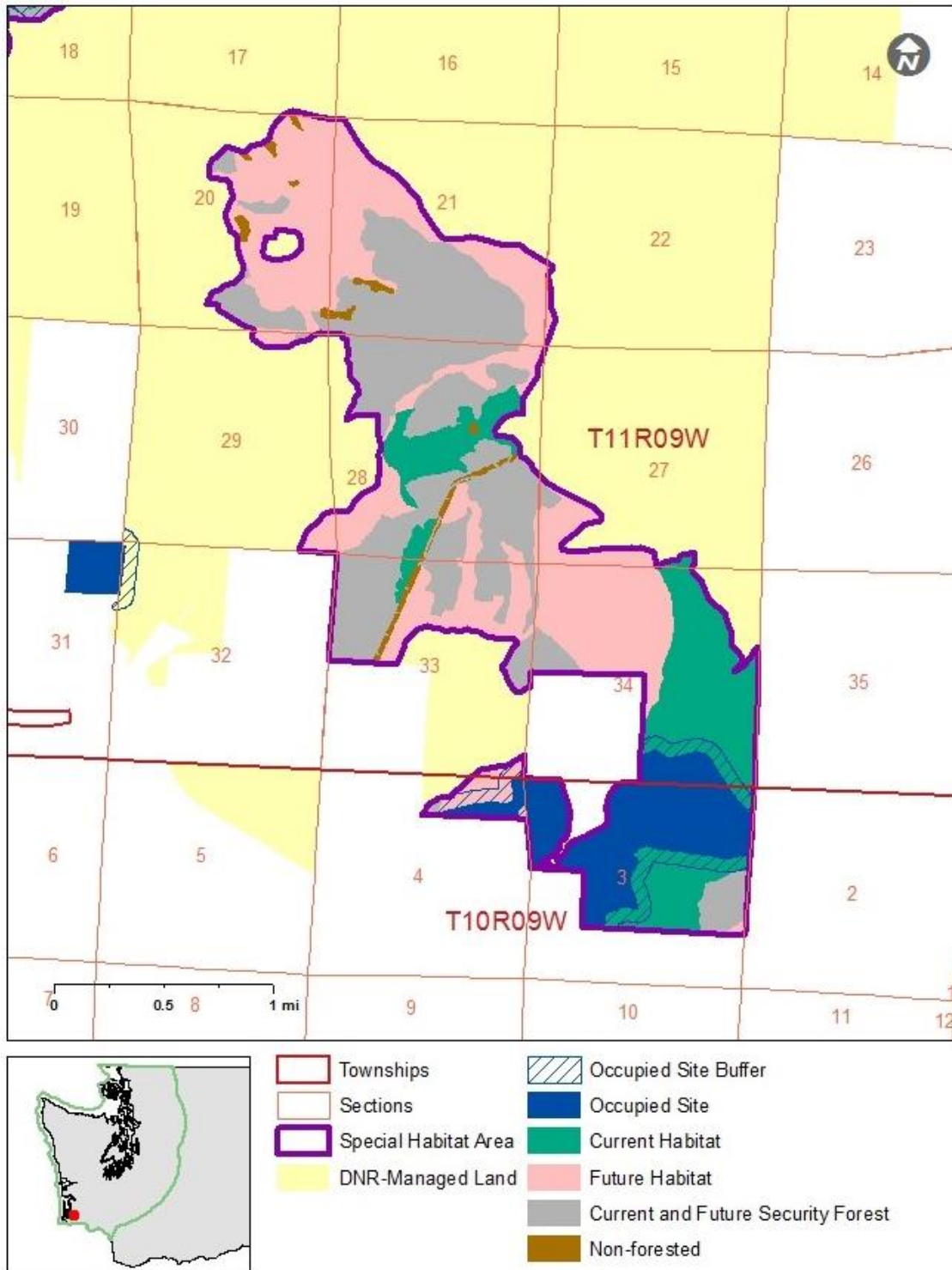


Figure B-18. Reade Hill Special Habitat Area

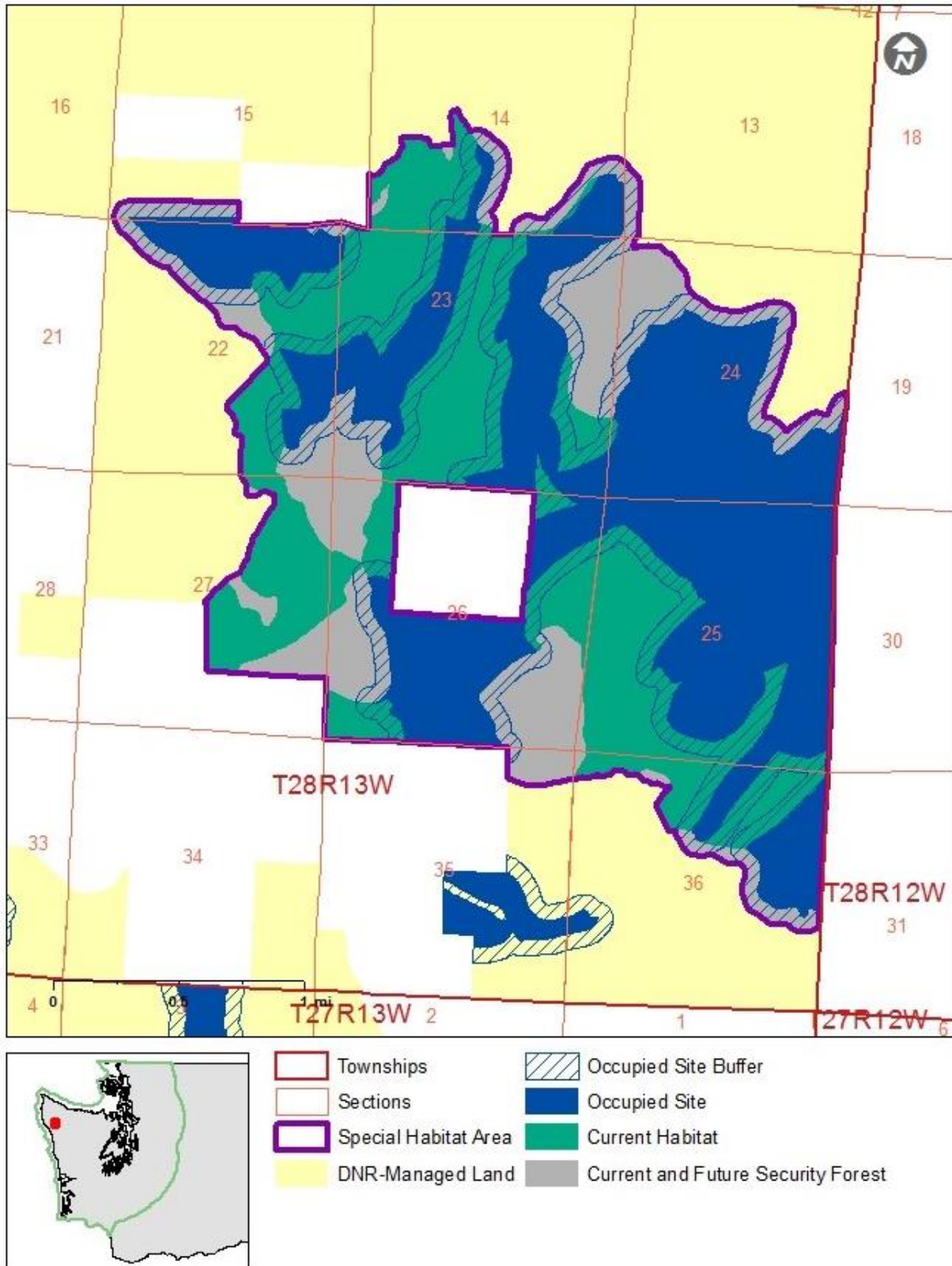




Figure B-19. Salmon Creek South Special Habitat Area

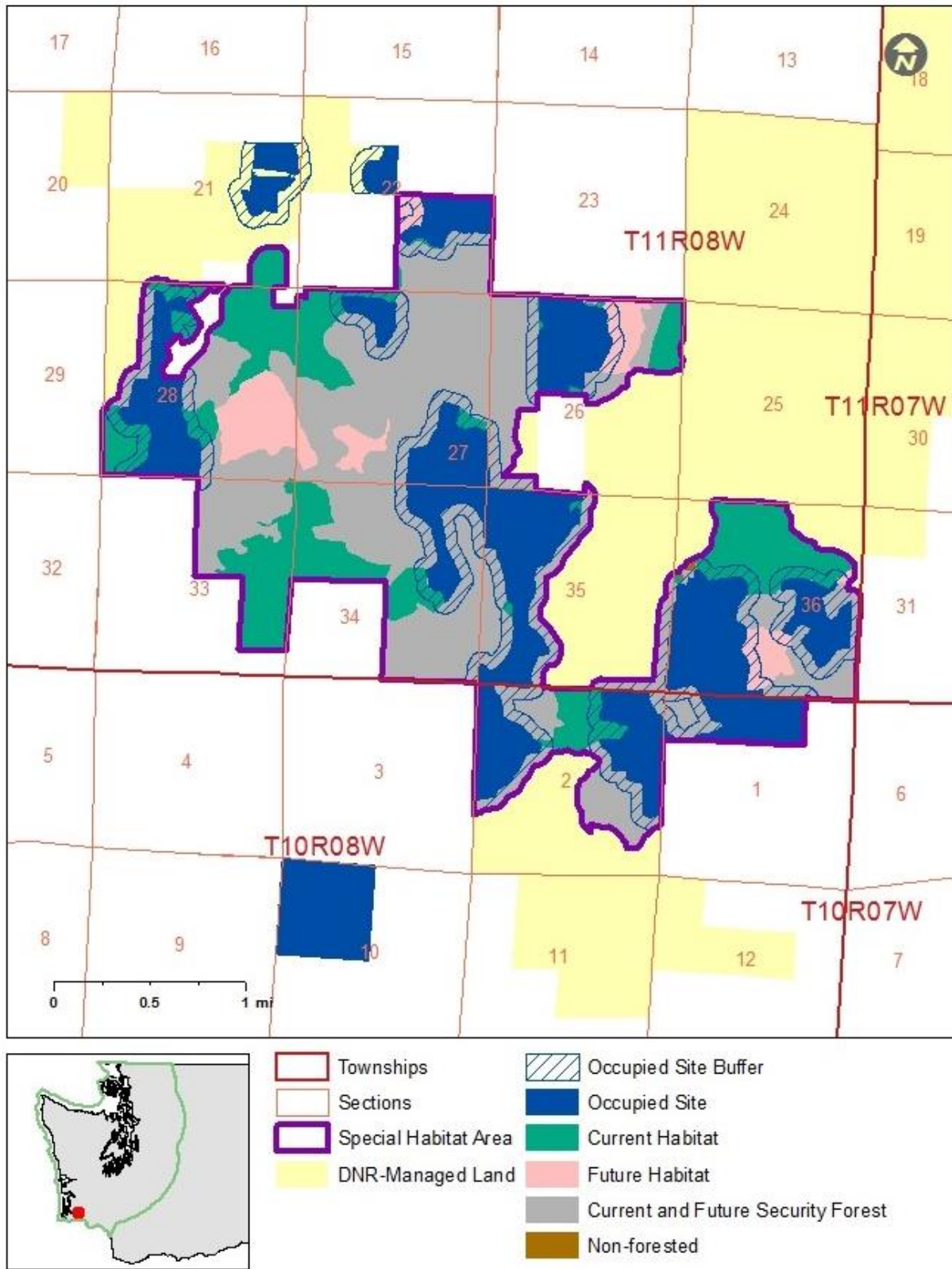


Figure B-20. Skamokawa North Special Habitat Area

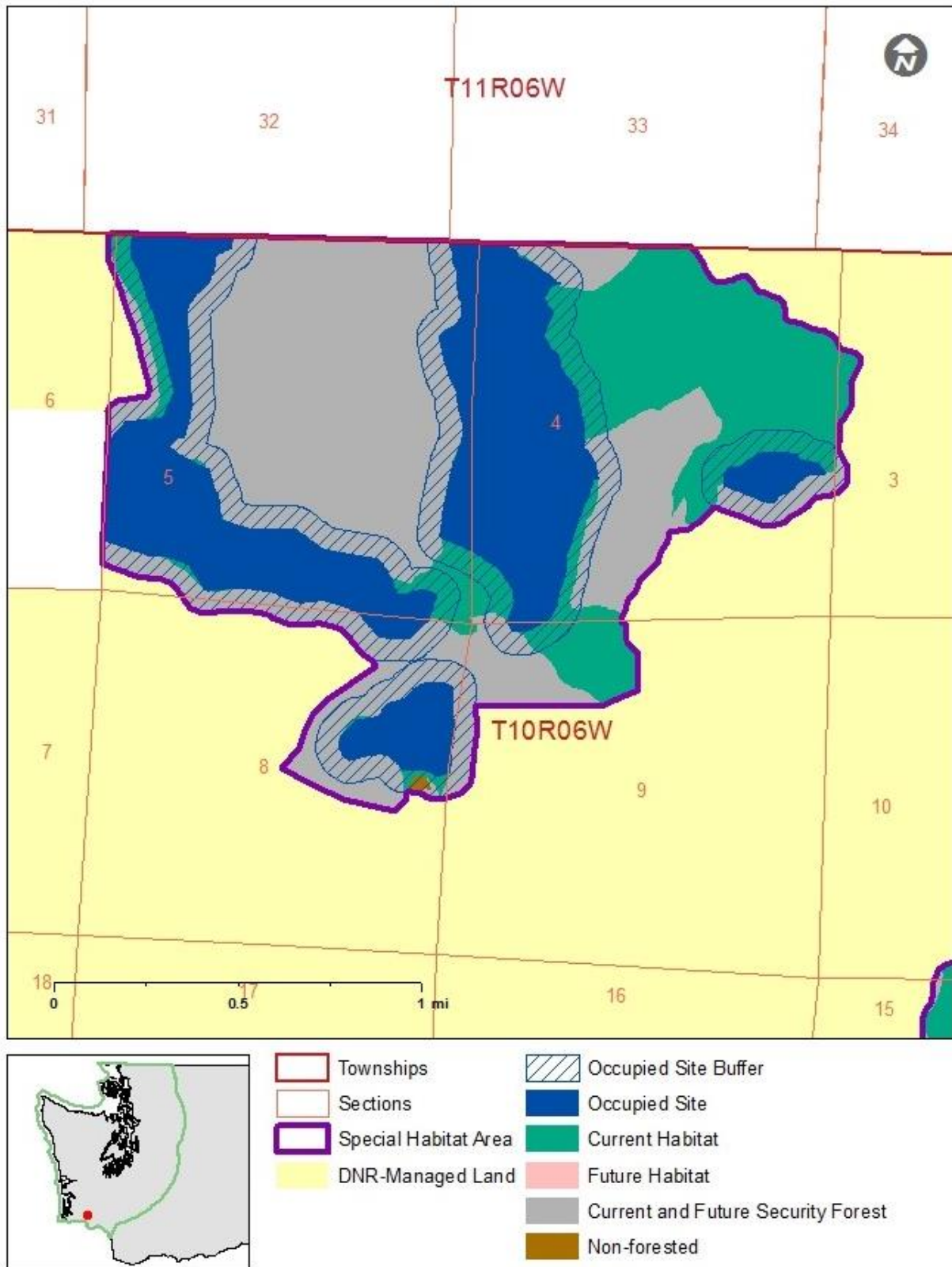


Figure B-21. Skamokawa South Special Habitat Area

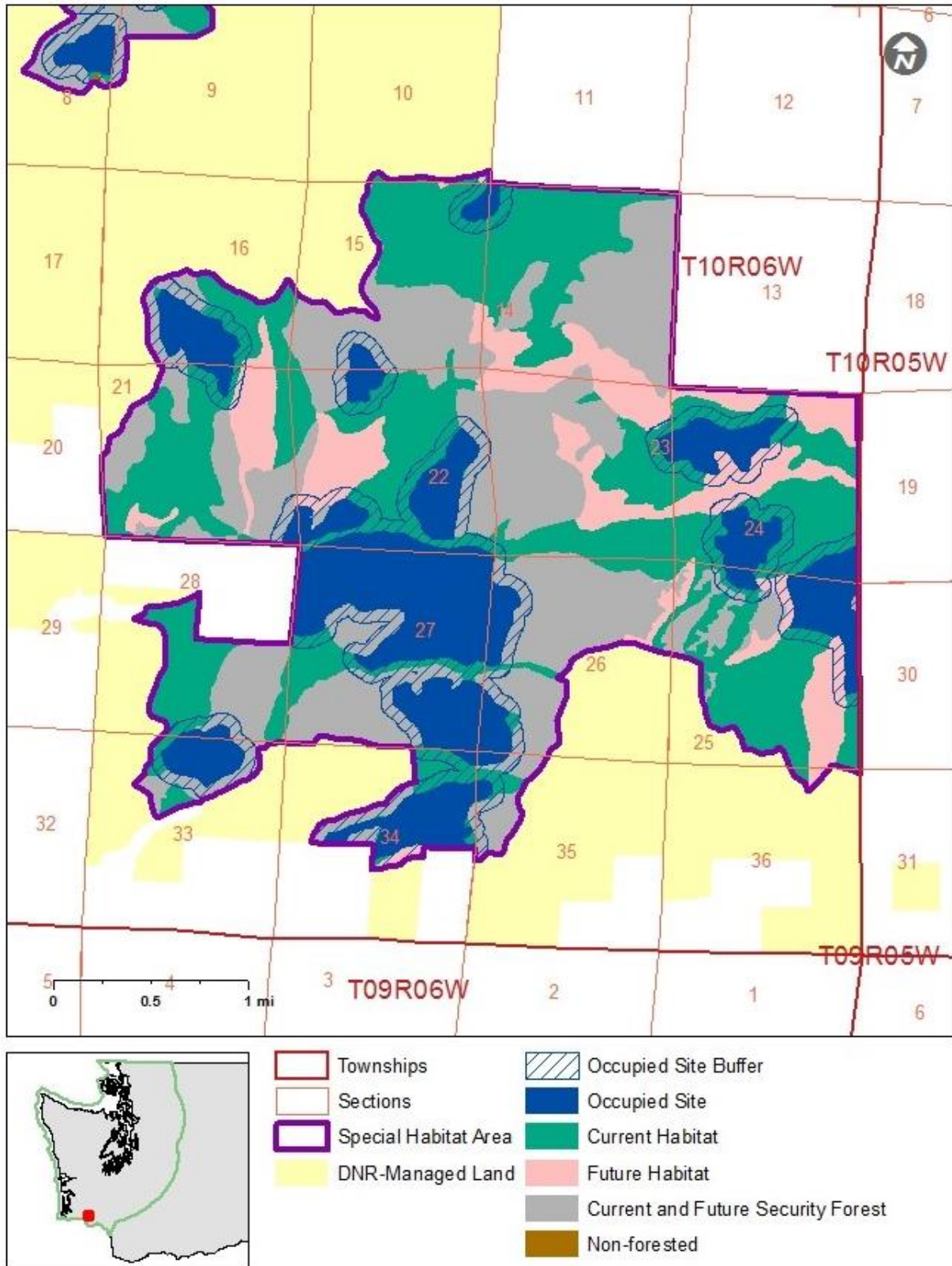
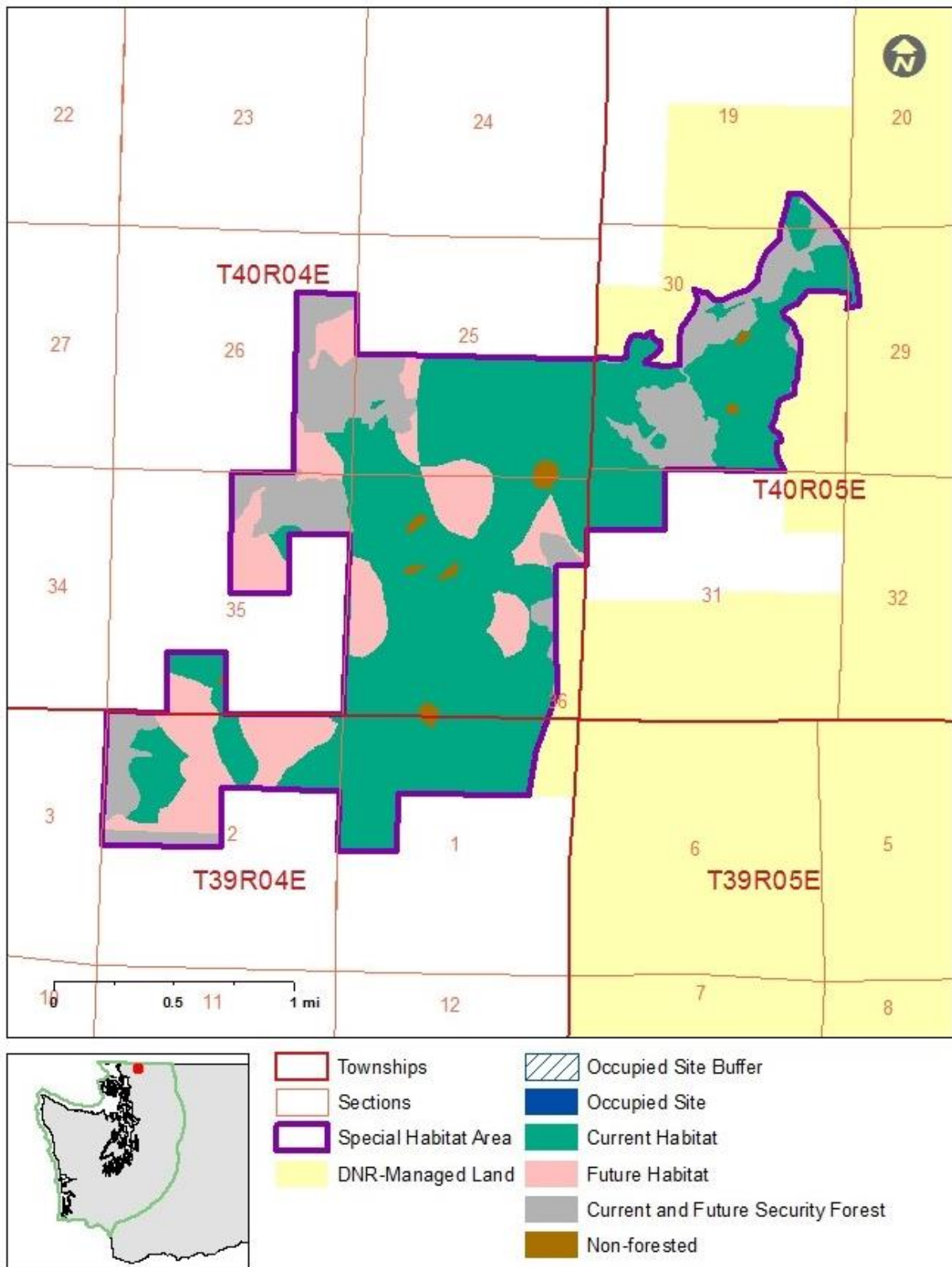


Figure B-22. Sumas Special Habitat Area



# Appendix C

## Background Reports/Supporting Documents

Attachments C-1 through C-4 were prepared as appendices for the *Marbled Murrelet Long-term Conservation Strategy Final Environmental Impact Statement* published in September 2019.

### Attachment C-1

Washington Department of Natural Resources and U.S. Fish and Wildlife Service. 2019. Potential impacts and mitigation focus paper: Potential impacts and mitigation. Wash. Dep. Nat. Resour., Olympia. 26 p.

### Attachment C-2

Peery, M. Z., and G. M. Jones. 2019. Using population viability analyses to assess the potential effects of Washington DNR forest management alternatives on marbled murrelets. Univ. Wisconsin, Madison. 74 p.

### Attachment C-3

Washington Department of Natural Resources and U.S. Fish and Wildlife Service. 2019. P-stage focus paper: Estimating the location and quality of marbled murrelet habitat. Wash. Dep. Nat. Resour., Olympia. 16 p.

### Attachment C-4

Washington Department of Natural Resources and U.S. Fish and Wildlife Service. 2019. Long-term forest cover focus paper: Areas of long-term forest cover. Wash. Dep. Nat. Resour., Olympia. 9 p.

### Attachment C-5

Washington Department of Natural Resources. Uncertainties in the Marbled Murrelet Long-term Conservation Strategy. 2019. Wash. Dep. Nat. Resour., Olympia. 22 p.



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Appendix

# C

## Attachment C-1

### Potential Impacts and Mitigation Focus Paper

Final State Trust Lands Habitat Conservation Plan AMENDMENT • Marbled Murrelet Long-term Conservation Strategy



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# Potential Impacts and Mitigation

## Focus Paper #5

***This focus paper was part of a series presented to the Board of Natural Resources in October and November 2015 to inform development of the marbled murrelet long-term conservation strategy alternatives. The purpose of this paper is to describe how possible impacts to murrelet habitat from harvesting, edge effects, and disturbance activities on DNR-managed lands are assessed and mitigated across conservation alternatives.***

## ■ Introduction

The analytical framework (Refer to Appendix B to the *Marbled Murrelet Long-term Conservation Strategy Final Environmental Impact Statement (FEIS)*, “Analytical Framework Focus Paper”) identifies three sources of possible impacts to marbled murrelets that may incidentally occur on state-managed lands: harvest-related impacts, edge-influenced impacts, and disturbance-related impacts. These impacts can be quantified using repeatable, objective methods based on sound science. By doing so, these impacts can be evaluated against the minimization and mitigation proposed under each alternative being developed for the marbled murrelet long-term conservation strategy.<sup>1</sup>

## ■ Quantifying Impacts and Mitigation

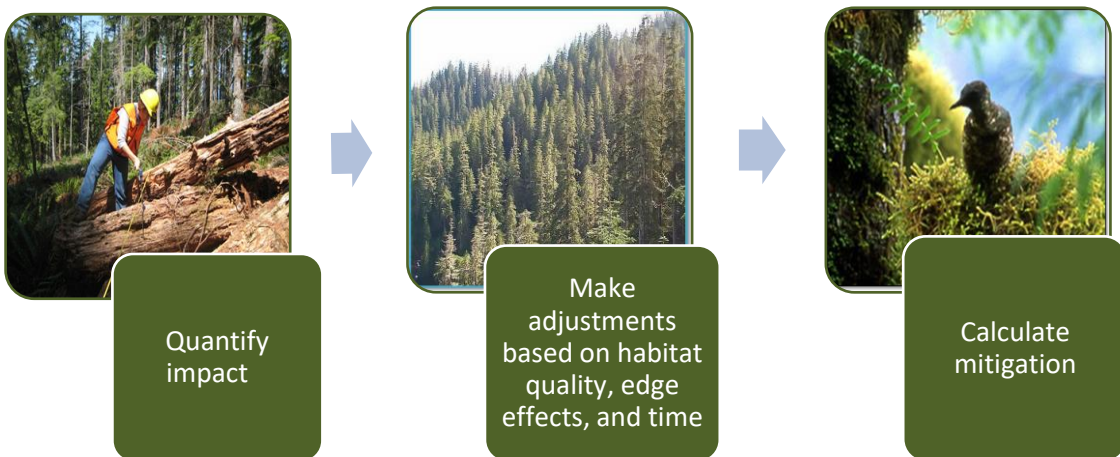
Quantifying impacts to marbled murrelet habitat and determining mitigation hinges upon identifying and assigning value to habitat. The value of habitat is related to its likelihood of use by murrelets, and generally increases with age and structural complexity of the forest.<sup>2</sup> Because not every acre of habitat is of equal value to the murrelet, it is important that the varying weights of impact or mitigation provided by each acre are quantified appropriately.

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<sup>1</sup> As defined in the 1997 HCP, mitigation “includes methods to reduce adverse impacts of a project by (1) limiting the degree or magnitude of the action and its implementation; (2) rectifying the impact by repairing, rehabilitating, or restoring the affected environment; (3) reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action, or; (4) compensating for the impact by replacing or providing substitute resources or environments.”

<sup>2</sup> Refer to Appendix C, Attachment C-3, “P-stage Focus Paper.”

Figure 1. Conceptual Steps in Quantifying Impacts and Mitigation



## ■ Harvest Impacts and Mitigation

Harvest impacts include activities such as timber harvest or road building that result in the removal of marbled murrelet habitat (acres with P-stage values). These activities primarily occur in the managed forest, outside areas of long-term forest cover (LTFC) (refer to Appendix C, Attachment C-4: “Long-term Forest Cover Focus Paper”). Removing habitat can result in the loss of existing nests and reduce future reproductive capability, therefore impacting the species. The analytical framework provides a methodology to assess harvest impacts to potential marbled murrelet habitat over the life of the *State Trust Lands Habitat Conservation Plan (1997 HCP)*.

For analysis purposes, the framework assumes that the loss of habitat from harvest in the managed forest over time will be offset by habitat gains that occur in areas protected by the conservation strategy. Each habitat acre harvested and each acre grown have different habitat *values*, depending on their P-stage value, their location relative to forest edges, distance from other habitat areas, and in which decade they are harvested or develop into habitat.

The equation in Table 1 is simplified. Calculating the value of the habitat is a more complex process that includes the P-stage value plus other factors influencing a forest stand’s value as murrelet habitat. These factors include whether the acres are in an edge condition, where they are located on the landscape, when the harvest and/or new habitat development occurs, and whether the habitat is subject to disturbance. These factors are discussed in detail in the next section.

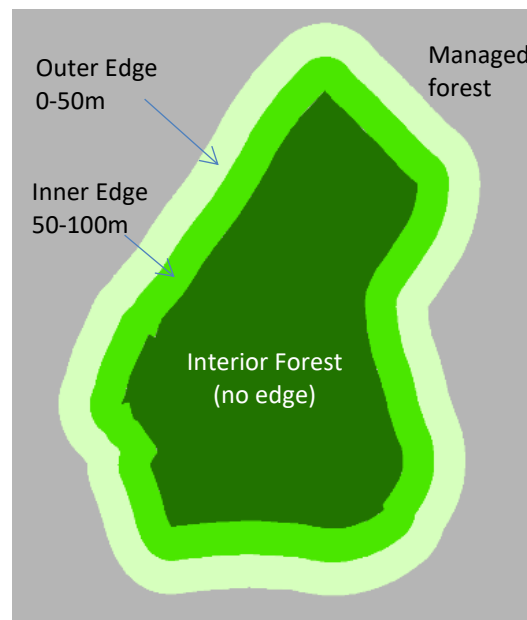
Table 1. Simplified Calculation of Harvest Impacts and Mitigation

Acres Harvested		Habitat Value		Mitigation Acres Needed
500	X	.36	=	180

## ■ Edge Impacts

A forest edge is an abrupt transition between two populations of trees, where the characteristics of the forest on one side are different from the other. Some edges are naturally occurring, created by wetlands, streams, or avalanche chutes, and others are created through human activity. Timber harvesting can create a high-contrast edge along the boundary between the harvested area and the adjacent forested stands. Exposed harvest edges alter microclimate effects (light, moisture, wind, and temperature gradients) in adjacent stands for distances of up to 240 meters (787 feet) (Chen and others 1993, p. 291, 1995, p. 74). For this analysis, a distance of 100 meters (328 ft.) was used to account for the most significant physical and biological effects to murrelet habitat along harvest boundaries due to the loss of trees to windthrow, loss of moss for nesting substrate, reduced canopy cover, altered forest composition, and increased risk of nest predation (Chen and others 1992, p. 390-391; van Rooyen and others 2011, p. 549; Raphael and others 2002; Malt and Lank 2009, p. 1274). For purposes of analyzing edge effects, we distinguish between an outer edge (the first 50 meters from an edge) and inner edge (50 to 100 meters from an edge). Refer to Figure 2.

Figure 2. Illustration of Forest Edges



### How do Edges Impact Murrelet Habitat?

Timber harvest edges can influence adjacent murrelet habitat in two ways: through increased risk of nest predation and habitat degradation resulting from windthrow and microclimate changes. Edge effects resulting from timber harvest may increase the risk of marbled murrelet nest predation in habitat located close to unnatural edges (harvest edges and major road corridors). A review of known murrelet nests found average nest success was 38 percent within 50 meters (164 feet) of a forest edge, and 55 percent at distances greater than 50 meters from an edge. Most nests failed because of predation (60 percent), and predation was higher within 50 meters of an edge than within the forest interior. No murrelet nests greater than 150 meters (492 feet) from an edge

failed because of predation (Manley and Nelson 1999, McShane and others 2004, p. 4-89). Based on these data from actual murrelet nests, the average nesting success rate within 50 meters of an unnatural edge is 69 percent of nests located greater than 50 meters from an edge.

Predator populations are in highest abundance along forest edges bordered by newly initiated stands.

Observations at known nests are affirmed in other research studies that examined the fate of simulated murrelet nests relative to forest edges and stand structure (Raphael and others 2002, Malt and Lank 2009). Simulated murrelet nests located within 50 meters (164 feet) of high contrast edges created by recent timber harvest are 2.5 times more

likely to be disturbed by predators relative to nests located in adjacent interior forest (Malt and Lank 2009, p. 1274). The increased predation risk is associated primarily with Steller’s jays (*Cyanocitta stelleri*) because they are habitat generalists that respond positively to forest fragmentation and preferentially use forest edges due to the abundance of berries and insects in young regenerating forests (Malt and Lank 2009, pp. 1283-1284). Predation risk associated with harvest edges declines over time (20 to 40 years after timber harvest) as young forests regenerate and become dense, simple-structured stands with no understory (Malt and Lank 2009, p. 1282).

Edge effects also increase windthrow and alter microclimate regimes, both of which impact murrelet habitat. Van Rooyen and others (2011) analyzed platform abundance, epiphyte growth, and microclimate at forest edges to understand edge effects on murrelet habitat. In “outer edge forest,” which the authors define as 0 to 50 meters from an edge, they found platform abundance adjacent to regenerating forest (a “hard edge,” approximately 0 to 20 years old) was reduced by 75 percent in comparison with interior forest. Platform abundance at “soft edges” (young forest stands approximately 21 to 40 years old) was only 60 percent of the abundance found in interior forests.<sup>3</sup> Reductions in platform abundance at these various-aged edges were attributed to the loss of platform-bearing trees from windthrow and other mortality sources, and to microclimatic effects that diminished epiphytic growth important to development of potential nesting platforms. The lesser effects at soft edges suggests that epiphyte growth is recovering from the hard edge impacts and is contributing more towards platform development.

### How Far Into the Forest do the Edge Effects Occur?

The extent of influence regarding microclimate and epiphyte effects into stand interiors has not been well studied, but evidence from a study in western Washington and Oregon old-growth forests that looked at 0, 30, 60, 120, 180, and 240 meters suggests appreciable tree mortality decreased substantially beyond 120 meters from edges (Chen and others 1992). Edge effects diminish with increasing distance from a hard edge. A distance of 100 meters was selected to represent the suite of edge effects (predation, habitat degradation, and windthrow). Recognizing

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<sup>3</sup> Table 4 in van Rooyen and others 2011; authors found a mean of  $16.02 \pm 5.14$  platform trees at soft edges, as opposed to  $26.8 \pm 6.60$  platform trees in interior forests (16.02 divided by 26.8 equals 60%).

that effects diminish with distance from the edge, it is assumed that "inner edge" effects are half relative to those in the outer edge.

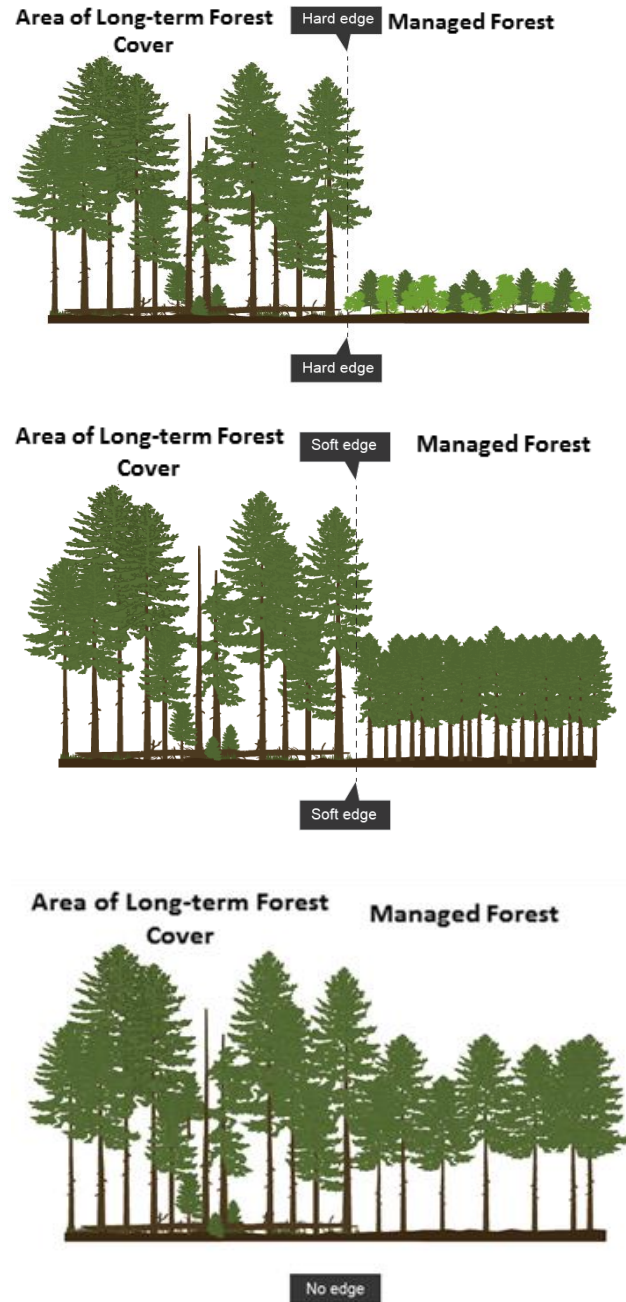
### How Does Forest Succession Influence Edge Effects?

Studies have shown that forest edge effects diminish over time, as harvest areas regenerate and develop into mature forest stands (Matlack 1993, Harper and others 2005, cited in Van Rooyen 2011; refer to Figure 3). Early stages of stand development following harvest, referred to as *ecosystem initiation*, are characterized by actively growing young trees and other herbaceous vegetation (DNR 2007). With their rapidly growing vegetation and increasing forage base (for example, insects, berries), ecosystem initiation stands provide a wide range of food sources and more opportunities for foraging to predators, particularly Steller's jays, a known predator of marbled murrelets (McShane and others 2004).

Over time, the vegetation in the ecosystem initiation stand fills the available growing space and the stand develops into a *competitive exclusion* stage, characterized by more than 70 percent canopy cover and simple stand structure. Stands in these stages have the lowest biodiversity and the least favorable conditions for wildlife when compared to all the stand development stages (DNR 2007). In competitive exclusion, fewer microhabitats for foraging are available for the predators (McShane and others 2004). As predation decreases, however, microclimate effects and windthrow continue to impact adjacent habitat by allowing sunlight and wind into the adjacent marbled murrelet habitat. Once stands on DNR-managed lands reach a height of 40 feet, it is estimated that they have reached the beginning stages of competitive exclusion.

When adjacent forests reach 80 feet in height, they are assumed to ameliorate edge effects for the purposes of this analysis (Malt and Lank 2009, Van Rooyen and others 2011). Once stands

Figure 3. Edges Change with Forest Succession



achieves this height, the crowns begin to overlap with those of the stand containing murrelet habitat, diminishing the impacts resulting from altered climatic regimes and windthrow.

### *How Does the Analytical Framework Address Edge Effects?*

The analytical framework adjusts the mitigation value of habitat located in the edges of long-term forest cover to account for the edge effects that will impact that habitat over the life of the 1997 HCP. The adjustment factors are based on proximity to habitat (inner or outer edge) and edge condition (hard, soft, or no edge).

Both edge location (inner or outer) and edge condition (hard, soft, or no-edge) play a role in determining edge effects.

The analytical framework also adjusts the impact value of habitat located in P-stage slivers to account for edge effects, using the same adjustment factors used for calculating mitigation. P-stage slivers are areas of murrelet habitat that are less than 656 (200 meters) wide and are outside of long-term forest cover. Because of their size and shape, P-stage slivers have no inner edge or interior forest; therefore, only discounts for outer edge are applied.<sup>4</sup>

**Figure 4. Example of Hard Forest Edge Created by Harvest**



The analytical framework categorizes edge conditions into three groups: hard, soft, and no edge.

Newly initiated stands adjacent to the mature forest containing murrelet habitat are considered to create “hard edge” when their height is 40 feet or less (refer to Figure 3 and Figure 4). Stands in competitive exclusion adjacent to a mature forest containing murrelet habitat are considered to create “soft edge” when their height is between 40 and 80 feet. Finally, stands with a height greater than 80 feet adjacent to a mature forest containing habitat are not considered to be “edge-creating;” as they have a diminished effect on the adjacent habitat compared to hard edges.

Edge conditions are not static over time; they change as forests regenerate. The relative percentages of edge across DNR-managed lands will, however, remain generally similar throughout the life of the 1997 HCP. The reason is that DNR will continue to manage its forest consistent with its policies, continuing the pattern of sustainable harvest in portions of the

<sup>4</sup> This paragraph about P-stage slivers was not part of the original focus paper presented to the Board of Natural Resources in October and November of 2015. It was added to explain a change in the computation of impacts and mitigation for the FEIS. Refer to Appendix O to the marbled murrelet FEIS for more information.

**Table 2. Outer Edge Effect**

Forest Inventory Data-Derived Edge Condition <sup>a</sup>			Discount Multiplier		Outer Edge Factor
Hard	21%	x	.83 <sup>b</sup>	=	.174
Soft	33%	x	.40 <sup>c</sup>	=	.132
No-Edge	46%	x	0 <sup>d</sup>	=	0
<b>Sum</b>				=	<b>.31</b>

<sup>a</sup> Percentages are presented here and in Table 3 as examples. Each alternative conservation proposal will have different percentages, due to differences in the amount and configuration of LTFC.

<sup>b</sup> Van Rooyen and others (2011) found that platform tree density at hard edges is 25 percent of the density found in interior forests. McShane and others (2004) summarized from different sources that nests at hard edges are 69 percent as successful as nests in interior forests. When combined (.25 x .69 = .17), an 83% discount results for this edge condition.

<sup>c</sup> Microclimate conditions in soft, outer edges result in only 60 percent of the platform density relative to interior forests (Van Rooyen and others 2011). Therefore, a 40 percent discount is applied.

<sup>d</sup> No edge discounts are assumed.

analysis area while leaving the LTFC portion to develop mostly without direct management intervention.

### **How Are Edge Effects Quantified?**

Two adjustment factors are used in the analytical framework to address edge effects, one that is applied to outer edge and another applied to inner edge. When applied, these factors adjust the value of habitat *down*, reflecting the edge effect.

First, discounts are applied to habitat in a particular edge condition based on the scientific information about how that condition impacts murrelet nest success. No discounts are assumed for interior forests (forests in a “no-edge” condition).

For forests in the outer edge (Table 2), these impacts are:

- Hard, outer edges: predation, microclimate, and windthrow;
- Soft, outer edges: microclimate only.

For forests in the inner edge (Table 3), only microclimate impacts (not predation), are considered, as follows:

- Hard, inner edges: microclimate (not predation)
- Soft, inner edges: microclimate, but at half the intensity as a hard edge.

**Table 3. Inner Edge Effect**

Forest Inventory Data-Derived Edge Condition			Discount Multiplier		Inner Edge Factor
Hard	21%	x	.415 <sup>a</sup>	=	.09
Soft	33%	x	.20 <sup>b</sup>	=	.07
No-Edge	46%	x	0 <sup>c</sup>	=	0
<b>Sum</b>				=	<b>.15</b>

<sup>a</sup> Only microclimate, not a combination of predation and microclimate, is assumed to be a factor in inner, hard edges. So half of the discount applied to outer edges (.83/2).

<sup>b</sup> Microclimate conditions in soft, inner edges are assumed to be half of those in outer edges (.40/2).

<sup>c</sup> No edge discounts are assumed.

The resulting edge factors are then multiplied against the number of P-stage acres in each edge condition to derive the total potential take from edge effects. Because each alternative for the long-term conservation strategy has a different amount of long-term forest cover, and in different configuration on the landscape, the resulting calculations and edge factors differ slightly across the alternatives.

## ■ Disturbance Impacts

In addition to harvest and edge impacts, forest management activities can impact murrelets by creating unfamiliar sights and sounds that may disturb them. This can be disruptive to murrelets during their nesting season when they are incubating eggs and caring for their young. The analytical framework refers to impacts that result from activities that create these audio and visual stimuli as *disturbance impacts*. Quantifying disturbance impacts requires a different approach, because unlike harvest or edge impacts, the vegetation within habitat is not altered through removal or degradation. Instead the environments within habitat are temporarily altered, with the impact of possibly interrupting murrelet nesting behavior. In addition, some activities occur repeatedly during the nesting period. To quantify potential disturbance impacts, the analytical framework estimates the magnitude and frequency of all activities with the potential to disturb murrelets during the nesting season.



## ***What Are Disturbance Impacts?***

A disturbance event is considered significant when an activity causes a murrelet to delay or avoid nest establishment, flush away from an active nest site, or abort a feeding attempt during incubation or brooding of nestlings. A flush from a nest site includes movement out of an actual nest, off of the nest branch, and away from a branch of a tree within suitable habitat during the nesting season. Such events are considered significant because they have the potential to result in reduced reproduction, hatching success, fitness, or survival of juveniles and adults (USFWS 2012a).

## ***What Activities can Disturb Murrelets?***

When evaluating the potential for audio-visual disturbance of nesting murrelets, DNR and USFWS grouped activities into three categories: 1) aircraft, 2) ground-based activities, and 3) impulsive noise-generating activities such as blasting and pile-driving. Aircraft activities includes any forest management activity that requires the use of low-flying, small fixed-wing planes and small helicopters, such as aerial spraying of herbicide treatments. Examples of ground-based activities include timber harvest and hazard tree removal, and road and trail maintenance. Activities generating impulsive noise include blasting to generate rock for forest roads.

## ***How Are Disturbance Events Evaluated?***

It is very difficult to separately analyze an animal's response to either auditory or visual stimuli alone (Pater and others 2009), and most studies have not been designed to adequately control for those factors separately. As such we evaluate both the audio and visual component of potentially disturbing activities together.

The body of knowledge on bird response to disturbance indicates that human activity can potentially impact nesting success and can be energetically costly to individual birds. Disturbance can have effects throughout the nesting season, including the nest establishment, incubation, and chick rearing phases. Marbled murrelet response to disturbance is variable and appears related to the developmental stage of the individual bird exposed to stimuli, degree of habituation existing prior to exposure, and whether there is a visual component to the stimuli. Murrelets have responded behaviorally to disturbance in ways that create a reasonable likelihood of injury to the adult, the chick, or both.

## ***How far From Murrelet Habitat can Activities Disturb Murrelets?***

In a review of best available information on avian ecology, disturbance, and acoustics, USFWS determined that significant disturbances to murrelets can occur within a distance of 100 meters of suitable habitat throughout the murrelet nesting season (USFWS 2012a). Exceptions include blasting, (0.25 mile-radius disturbance distance), and large aircraft (for example, military jets)

where the disturbance distance is defined by where the sound exposure level (SEL) from the aircraft meets or exceeds 92 dBA (A-weighted decibels).

### ***What Time of Year can Murrelets be Disturbed?***

The USFWS has previously determined that murrelets can be disturbed during their nesting season, which occurs between April 1<sup>st</sup> and September 23<sup>rd</sup>, 176 days out of the year. There is enough overlap in nest establishment, incubation and nestling periods to assume there is equal risk of murrelet exposure to disturbances occurring throughout the nesting season (USFWS 2012b).

### ***How do Murrelets Respond to These Disturbances?***

Murrelet responses are expected to vary according to the type of activity in combination with the timing, duration, and frequency of the exposure. Many forest dwelling birds (including raptors, golden eagles, and Mexican spotted owls) exhibit increased flush rates due to noise. Chicks and adults are expected to vary in their response. Observations by murrelet researchers in the field indicate that murrelet chicks may not have a noticeable response to noise and visual stimulant all, or may respond by becoming very still, lying flat on the branch (Hebert and others 2006). As such, murrelet chicks are not expected to prematurely leave a nest in response to these types of noise and visual stimuli. However, adult murrelets may abandon or delay nest establishment, or abort or delay feedings in response to exposure to these stimuli. Adults that are incubating an egg are not expected to flush (USFWS 2012a).

### ***How Does the Analytical Framework Evaluate the Significance of Each Activity?***

The 1997 HCP permits a range of forest management activities. The analytical framework relies upon an analysis of all activities permitted to occur on DNR-managed lands to determine whether they have the potential to cause disturbance to marbled murrelets. The framework identifies 36 activities that may cause disturbance. Examples include:

Disturbance is quantified by determining the the birds' likely response given the duration and intensity of a stressor and converting that information into acres impacted.

- Recreational site use
- Sand and gravel sales
- Electronic site maintenance
- Road use and maintenance
- Collection of western greens, Christmas greens, and mushrooms.

In order to quantify the potential impacts that result from these activities, the analytical framework assigns values for the following qualities that are used to measure the significance of

the disturbance activities: stressors, duration, and response. Disturbance is quantified by determining the birds' likely response given the duration and intensity of a stressor and converting that information into acres of habitat exposed.

**Stressors** are physical, chemical, or biotic phenomenon or a circumstance that constitutes a real or perceived challenge or threat to an organism's physical health, homeostasis, or homeostatic mechanisms. Stressors include:

- Ground-based noise (examples: chainsaws that are harvesting trees, removing hazard trees from campgrounds, or heavy equipment maintaining roads);
- Visual disturbance (example: human presence around nest trees, such as someone hiking around or near a nest tree);
- Human activity that attracts predators (example: campgrounds close to murrelet habitat, because the human activity draws the predators to the habitat);
- Impulsive noise (example: blasting in rock pits to generate crushed rock for forest roads)
- Aircraft noise (example: sounds generated by helicopters and small planes).

**Duration** represents the length of time an activity is present within close proximity of murrelet habitat. Duration measures how long the habitat would it be exposed to that activity. Duration categories include:

- <1 day
- <7 days
- >7 days and < 30 days
- >30 days

**Response** represents the murrelet's possible behavioral reaction to various auditory and/or visual disturbances. Responses include:

- No significant response
- Aborted feedings
- Adults flushing
- Mortality or loss of productivity from removal of nest tree
- Mortality from predation
- Hearing damage

### ***How Does the Analytical Framework Evaluate Disturbance?***

Once each activity is assigned stressor, duration and response the activities are allocated into six groups based on similar combinations of these three categories (refer to Table 4). For each group, the analytical framework estimates the total habitat area within the appropriate distance bands of each activity (100 meters of each ground-based and small aircraft activity and ¼ mile for blasting) and then adjusts the acreage for habitat quality, time of year that the activity occurs, and then by the total years remaining in the 1997 HCP.

POTENTIAL IMPACTS AND MITIGATION

Table 4. Activity Groups by Stressor, Distance, Duration, and Response

Group Assignment	Stressor	Disruption Distance	Duration	Response/Impact
<b>Group 1</b> (includes green collecting, precommercial thinning, non-motorized trail use, minor road maintenance)	Ground-based Noise and Visual Disturbance	≤100 m	< 1 Day	No significant response based on duration; minimal to no impacts
<b>Group 2</b> (includes firewood collection, road reconstruction, major road and trail maintenance, communications facilities)	Ground-based Noise and Visual Disturbance	≤100 m	< 7 Day	Aborted feedings, Adults flushing; potential harassment <sup>1</sup>
<b>Group 3</b> (campground use and maintenance)	Ground-based Noise and Visual Disturbance  Predator Attraction	≤100 m	< 1 Month	Increased predation risk, Aborted feedings, Adults flushing; potential harm <sup>2</sup>
<b>Group 4</b> (includes timber harvest, motorized trail use, new road and bridge construction)	Ground-based Noise and Visual Disturbance	≤100 m	>7 Days < 1 Month	Aborted feedings, Adults flushing; potential harassment
<b>Group 5</b> (sand and gravel extraction, blasting)	Ground-based Noise and Visual Disturbance	≤.25 mi	>7 Days < 1 Month	Hearing damage from blast noise (within 100m), Aborted feedings, Adults flushing; potential harm or harassment
<b>Group 6</b> (aerial herbicide application)	Aircraft Noise	≤100 m	< 7 Days	Aborted feedings, Adults flushing; potential harassment

<sup>1</sup>Harass is defined as an act which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly impair normal behaviors, including breeding, feeding, or sheltering (50 CFR 17.3).

<sup>2</sup>Harm is defined as act which actually kills or injures wildlife, and can include habitat modification that significantly impairs essential behaviors such as breeding, feeding, or sheltering (50 CFR 17.3)

When estimating possible responses of the marbled murrelet to human activity, it is important to note that empirical data are lacking for the range of activities represented in Table 4. Studies evaluating the effects of noise on various animals frequently use different metrics, and often fail to report which metrics they use, making comparisons and interpretation difficult. For the purposes of this analysis, we do not expect that short-term exposures to low intensity stimuli that

last less than 1 day will adversely affect marbled murrelets. However, any reduction in feedings has the potential to physiologically effect a murrelet chick, depending on how many feedings are received in one day, and presumably, the energy content of the food that is delivered. Further, aborted or delayed feedings have the potential to increase energy demands and predation risk on adult murrelets. Conversely, when weighing these risks, we must also consider that many of these short duration activities are intermittent and low intensity (e.g. mushroom pickers walking through a stand of suitable habitat) and pose little risk. After considering these factors, we expect that exposure of juvenile and adult murrelets to these low-intensity activities, when lasting <1 day are not expected to result in measureable effects, and are therefore insignificant.

### ***Adjusting Disturbance Impacts for Habitat Area, Quality, and Time***

Using DNR's GIS and other data, including annual activity reports and summaries, the analytical framework identifies the *footprint* of each activity within each group, as it occurs on DNR-managed lands within the range of the murrelet. Using a distance buffer with a width equivalent to the area of disturbance around the footprint, the framework sums the total area of P-stage habitat for each activity. These totals are then summed for each group.

The analytical framework only quantifies disturbance for the habitat located within LTFC. This is because we assume that habitat located outside of LTFC will be removed over time, therefore the expected disturbance impacts in managed areas are accounted for in the harvest impact estimates. The P-stage acreage is multiplied by the proportion of DNR-managed lands within LTFC to reflect the habitat acres disturbed within LTFC by each group.

As with edge effects, the effects of disturbance vary based on the *quality* of habitat (P-stage value). Therefore, in evaluating disturbance take, acres of disturbed habitat are multiplied by their P-stage value. (Refer to Attachment 1 for an example of how this works.).

The magnitude of disturbance impacts are also influenced timing; by *when* they occur in a particular year and *how often* throughout the year. This is because activities that disturb marbled murrelets impact their reproductive activities, such as nest incubation, caring for young, which only occur during the nesting season. This analysis is limited to the time period of the murrelet nesting season, when impacts to reproduction are most likely to result.

Timing is considered in two dimensions: the time of year (i.e., marbled murrelet nesting season or not; and if so, how many days) and the duration of the activity during the week (i.e., occasional versus everyday occurrence, or a 5-day workweek occurrence).

To factor time adjustments into the estimate of disturbance impact, the framework multiplies the weighted habitat acres in LTFC by the number of days the activities within each group overlaps with the nesting season. The number of days the activities overlap with the nesting season is influenced by how often an activity occurs during the week. For example, road maintenance on DNR lands is expected to only occur 5 days a week, whereas campground use may occur on weekdays or weekends throughout the summer. The result is an adjusted number of acres potentially affected by disturbance activities during the nesting season.

Some of these habitat acres will be disturbed repeatedly over the life of the 1997 HCP. To account for this, the framework takes the time-adjusted weighted habitat acres and multiplies them by the years remaining in the 1997 HCP (52 years), for a final amount of statewide time-adjusted acres of P-stage habitat in LTFC disturbed during the nesting season. This final acreage calculation is an estimate of DNR's potential disturbance impact. An example of how these adjustments work is provided as Attachment 1.

## ■ Where Will Mitigation Occur?

DNR's conservation strategy uses areas of long-term forest cover (LTFC) to provide both minimization and mitigation for the types of impacts described previously.<sup>5</sup> Areas of LTFC are established to meet a variety of conservation objectives, but within the murrelet conservation strategy they serve three major purposes:

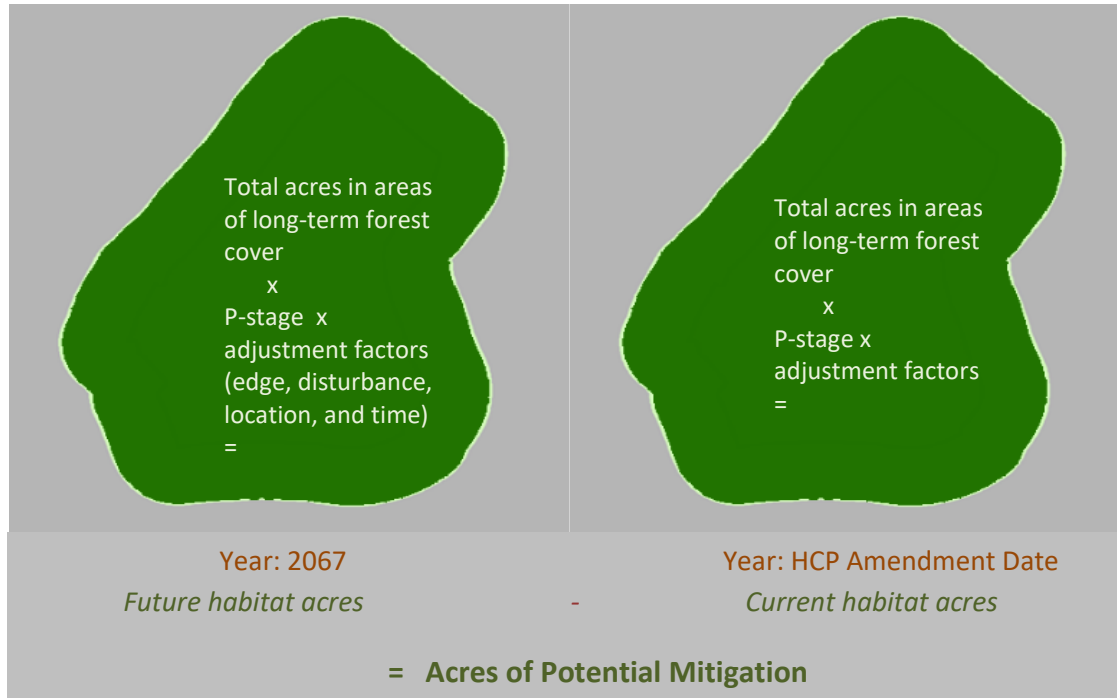
- To conserve most marbled murrelet habitat on DNR-managed forest lands;
- To minimize overall impacts to that habitat and increase its quality by including additional contiguous area to increase the area of interior forest habitat;
- To mitigate impacts from activities in the managed forest by allowing new and higher quality murrelet habitat to develop through time.

Similar to how impacts are adjusted for edge conditions and other factors, adjustments must be made to the mitigation value of habitat grown over the life of the 1997 HCP. Mitigation provided by LTFC can be expressed as the number of acres of marbled murrelet habitat grown within those areas through the end of the 1997 HCP. Mitigation value is determined by subtracting "current habitat acres" from "future habitat acres." Refer to Figure 5. The total acres of P-stage habitat located inside and out of areas of long-term forest cover varies across conservation alternatives, depending on what is included LTFC (size of the conservation areas, occupied site buffer widths, and other landscape components). For each alternative, this habitat can be quantified. Total "raw" acres of habitat with P-stage values are estimated using DNR's inventory information of forest lands. The total "raw" acres within each P-stage category (.25, .36, .47, .62, .89, 1.0) are then multiplied by their respective values. These raw acres are converted to "weighted habitat acres," which incorporates habitat quantity and quality, including edge effects, into one unit. All of the totals are summed, producing the total "current habitat" for each alternative.

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<sup>5</sup> Refer to Appendix C, Attachment C-4, "Long-term Forest Cover Focus Paper."

Figure 5. Calculating Mitigation in Areas of Long-Term Forest Cover



When the acres of habitat are multiplied by their respective P-stage value and other adjustment factors, the total acres in that category that can be used as mitigation is reduced, according to quality. For example, if 100,000 acres of LTFC only has a P-stage value 0.25, this is valued as 25,000 acres for purposes of calculating mitigation.

### ***Not all Habitat Is Considered for Mitigation***

An *interim strategy* for marbled murrelet conservation has been operating since the 1997 HCP was adopted. This strategy included protections for occupied sites and reclassified habitat (refer to Appendix D to the marbled murrelet FEIS, “Occupied Sites Focus Paper,” for a brief description of the interim strategy). USFWS issued an incidental take permit for impacts to the murrelet occurring on DNR’s managed forest lands over this time period, and DNR has complied with that permit. Habitat has also been growing and developing for the murrelet during this time. However, no mitigation credit will be given for that interim habitat development because this analysis starts with current conditions. The analytical framework is forward-looking. It begins in “Decade 0” (current year until 2025) and focuses on potential impacts and mitigation occurring out to 2067 (“Decade 5”). Habitat is expected to increase within areas of long-term forest cover through that time period.

In addition, the analytical framework does not give credit to forest stands within LTFC that do *not* have a P-stage value; stands that are too young to count toward total acres of habitat. These stands may still have conservation value for the murrelet by reducing fragmentation.

### Adjusting Mitigation Values for Time

Adjustments to the mitigation value of habitat are necessary to accommodate edge and disturbance effects, as described previously. However, a different kind of adjustment is needed to address another modifier of habitat quality: time. Habitat that exists today currently provides nesting opportunities to murrelets and is therefore more valuable than habitat that will be developed further into the future (as forests mature). If an impact to that habitat happens today, the offsetting mitigation (the same value of habitat becoming available to the murrelet) may not happen for several years. The analytical framework takes this into account by adjusting the value of mitigation through time, which is expressed by decade to the end of the 1997 HCP.

The decadal adjustment factor is based on how much habitat develops in a particular decade, as well as which decade that habitat is realized. For example, the total habitat that develops in long-term forest cover from the present into the first decade receives full mitigation credit to offset harvest in the managed forest within that first decade; all of the acres are counted. However, the total habitat that develops between the first and second decades receive only 80% of the total credit. This is because the habitat that grows during this decade will contribute to murrelet conservation for less time, four out of the five total decades ( $4/5 = 80\%$ ). Growth occurring between the second and third decades receives 60% credit (three out of five decades of growth), and so forth through to the end of the 1997 HCP. (Refer to Table 6).

**Table 6. Adjusting Future Habitat in Mitigation Value. Numbers are for illustration purposes only. They are not a representation of DNR-managed lands.**

Decades	Habitat Acres	Difference Between Decades	Decade Adjustment Factor	Acres of Mitigation Credit
0	1000			
1	2000	1000	1.00	1000
2	3000	1000	0.80	800
3	4000	1000	0.60	600
4	5000	1000	0.40	400
5	6000	1000	0.20	200
<b>Total Mitigation Credit:</b>				<b>3000</b>



## *Adjusting Mitigation Values Based on Location*

Across the analysis area, some landscapes are less valuable, or “marginal” for long-term marbled murrelet conservation due to a lack of suitable habitat, isolation from known occupied sites, and low-capability for developing future habitat based on forest types. An example of a marginal landscape for marbled murrelets is the Capitol Forest, located in the South Puget Planning Unit. The Capitol Forest is a large landscape that encompasses more than 95,000 acres of DNR-managed lands, but currently contains relatively little murrelet nesting habitat (< 2,000 acres). DNR conducted marbled murrelet surveys at more than 450 survey stations located within the Capitol Forest. Murrelet presence was detected at only one survey station, and no murrelet occupancy behaviors were detected during any of the surveys. The Capitol Forest has been intensively managed for timber production for many decades, and is comprised of forest dominated by second-growth Douglas-fir plantations which have a low capability to develop into murrelet habitat during the life of the 1997 HCP. Due to the limited and fragmented nature of potential nesting habitat in this landscape, and no known occupied murrelet sites, we consider the Capitol Forest to be a marginal landscape for murrelet conservation.

To define marginal murrelet landscapes we considered multiple factors:

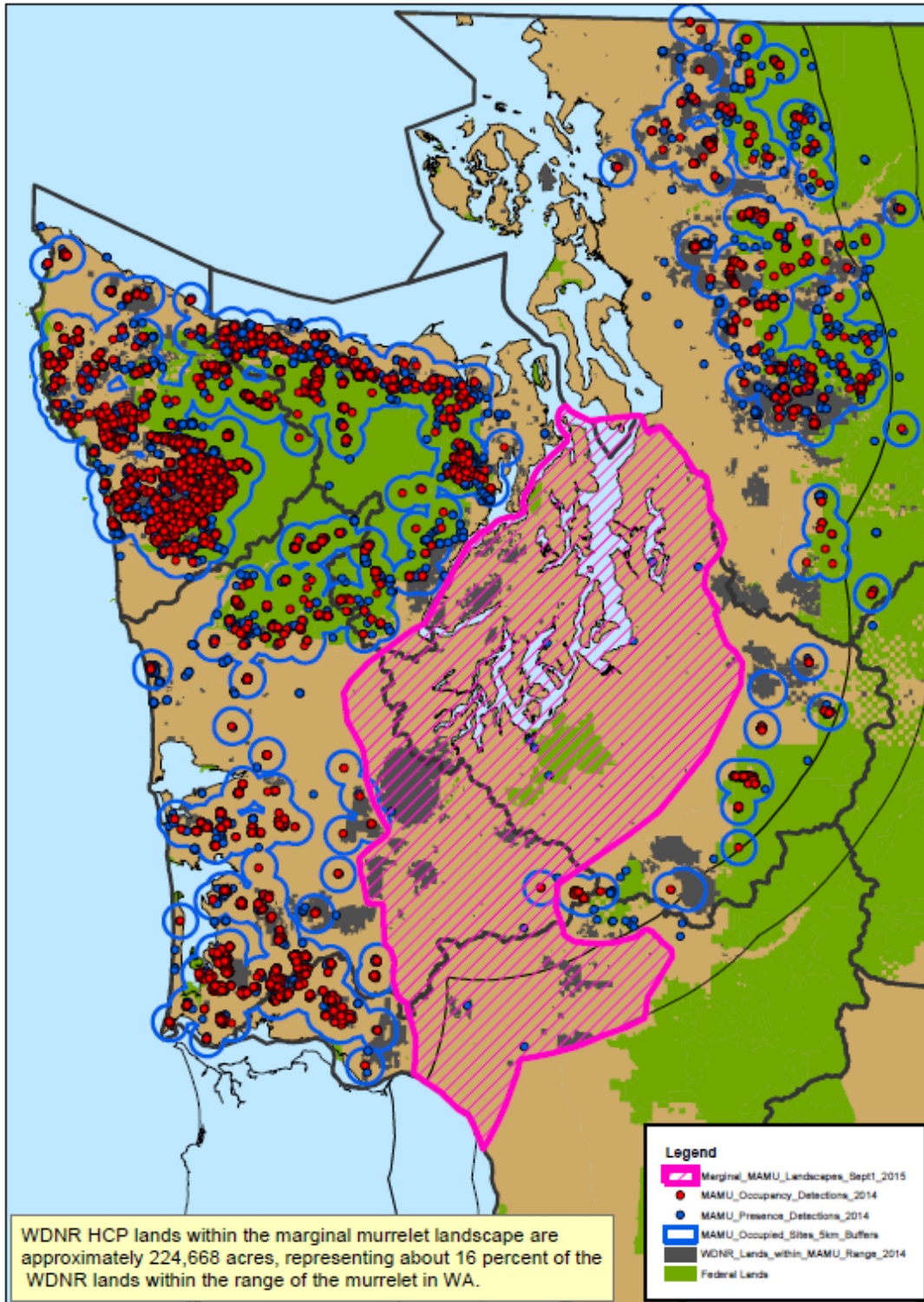
- proximity to known occupied sites (within a distance of 5 km from known occupied sites<sup>6</sup>),
- results of marbled murrelet survey information,
- proximity to murrelet critical habitat on federal lands,
- current habitat distribution, and
- capability for developing future habitat.

Our delineation of marginal murrelet landscapes includes more than 224,000 acres of DNR-managed lands located primarily in the Puget Trough lowlands from the Kitsap Peninsula south to the Columbia River (refer to Figure 6). These landscapes currently contain low amounts of murrelet habitat (about two percent) in small scattered patches, are located further than 5 km from any known occupied murrelet sites, and have a relatively low capacity for developing future habitat within the life of the 1997 HCP.

---

<sup>6</sup> The 5 km proximity distance is derived from research in southern Oregon and northern California that found that murrelets are less likely to occupy habitat if it is isolated (> 5 km) from other nesting murrelets (Meyer and others 2002).

Figure 6. Map of Marginal Landscapes for Murrelet Conservation



### *Calculating Take and Mitigation in Marginal Landscapes*

In the marginal murrelet landscapes, we reduce all P-stage habitat values by 75 percent. In other words, P-stage habitat acres are given 25 percent of the P-stage habitat value for the purposes of calculating take and mitigation. In this way, we still account for potential take of murrelets associated with any habitat loss that may occur in these landscapes. We think the potential for take of murrelets in these areas is very low, but recognize that murrelet occupancy in these areas is not entirely discountable because they are located within the range of the species in Washington. Likewise, we apply mitigation credit for habitat conserved in areas of long-term forest cover, but at a reduced rate relative to other areas within the DNR-managed lands that are more likely to contribute to long-term murrelet conservation.

### **■ Putting it all Together: Take and Mitigation**

Calculating the extent and intensity of potential impacts through the life of the 1997 HCP, and ensuring that a long-term conservation strategy minimizes and mitigates these impacts, is complex. The alternative long-term strategies being developed provide a range of approaches to how and where habitat is conserved. But this analytical framework ensures that the same metrics to calculate take and mitigation will be to evaluate every alternative in an environmental impact statement. That way, comparisons can be made among the alternatives to determine how well they work to minimize and mitigate impacts.

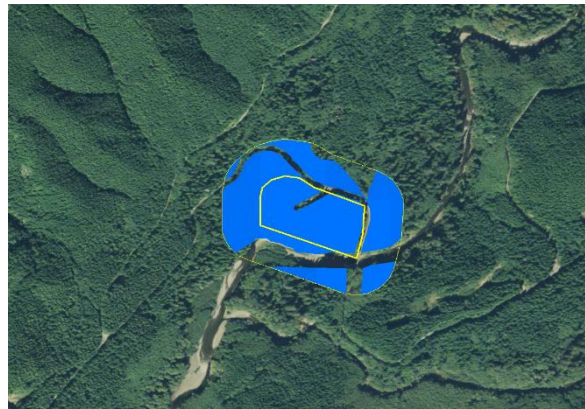
## Attachment 1

# Calculating the Mitigation for Disturbance

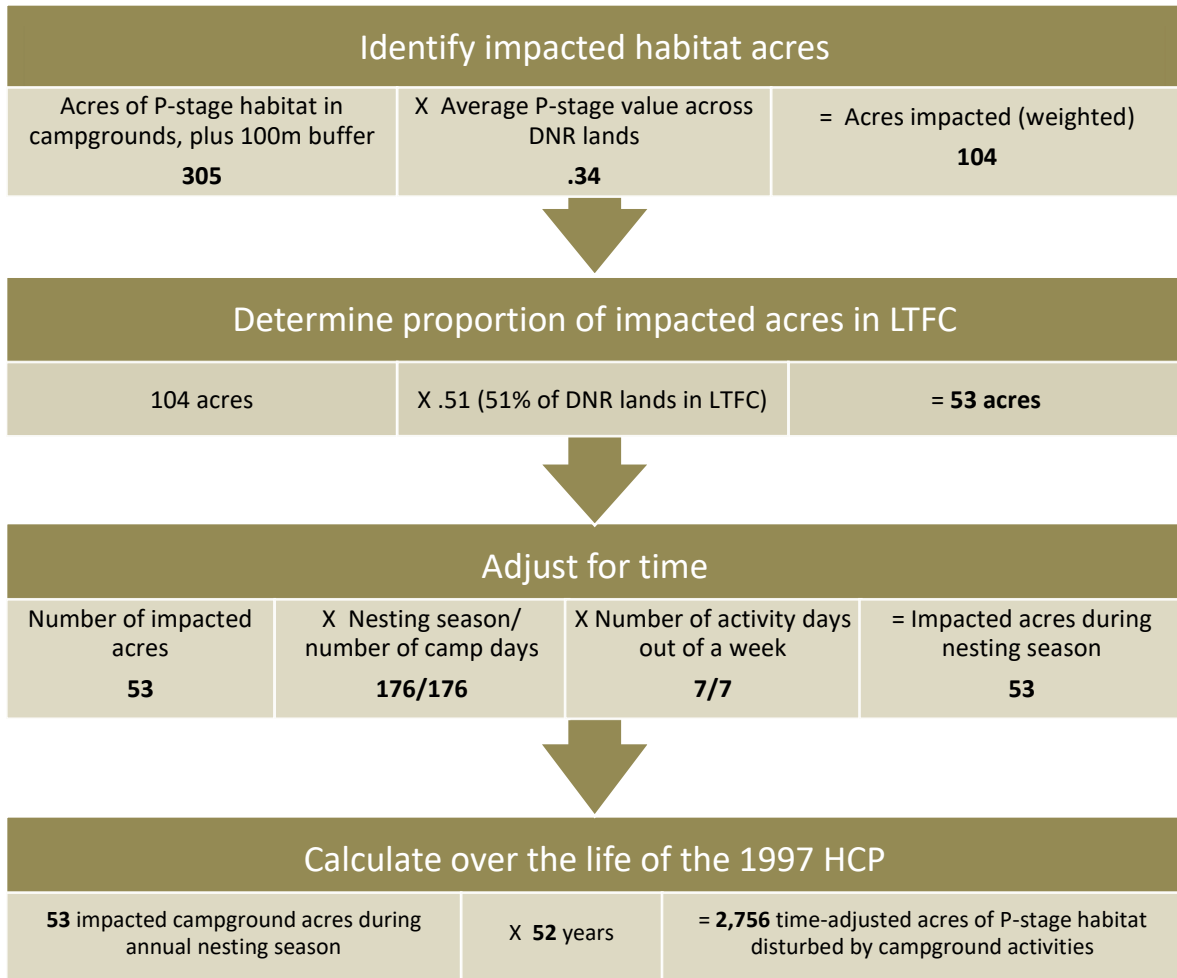
## ■ Example: Campground Operations

Potential stressors from the use and management of campgrounds are ground-based noise and visual disturbance. These can occur during the 176 day nesting season, every day of the week. The chart on the following page walks through the calculations for determining the total acres impacted by this disturbance activity through the life of the 1997 HCP. The first step is using GIS to identify the potential acres of campground-disturbed habitat (Figure 1); DNR conducted this analysis for all its campgrounds in the analysis area. After the GIS analysis, a series of calculations are made to determine the number of impacted acres in LTFC that must be mitigated for this activity. The numbers provided are for illustration only.

**Figure 1. Footprint, Buffer, and P-stage Habitat for One Campground, in Blue Shading; For Illustration Purposes Only**



POTENTIAL IMPACTS AND MITIGATION



## Attachment 2

## Roads as Edges

### ■ How do Forest Roads Impact Murrelet Habitat?

Forest roads associated with timber harvests act as edges, which in turn affect the success of murrelet nests as discussed earlier in this paper. There is little information about the specific intensity of the edge effect that forest roads alone have on marbled murrelet nests. Some studies using artificial nests near logging roads did not show an increased predation effect (Yahner and Mahan 1997; Ortega and Capen 2002), but these studies were not conducted for canopy-nesting birds in Pacific Northwest forests. In a study from British Columbia using artificial murrelet nests near clearcuts, roads and other forest edges indicated increased corvid abundance and potential predation near artificial edges (Burger and others 2004). Steller's jays in particular are found in greater abundance at edges created by roads and clearings (Masselink 2001; Burger and others 2004; Vigallon and Marzluff 2005). Roads constructed close to or within murrelet habitat are assumed to attract Steller's jays closer into the forest interior (Masselink 2001). As discussed previously, predation impacts have been found to be greatest within 50 meters of a forest edge.

Forest roads initially act as hard edges, and soften over time as they transition back to forest. Many roads are not being actively used, but are a relic of a previous management activity. As roads transition back into forest over the course of several decades, they have corresponding changes in the intensity of their edge effects. There is no accurate method for determining exactly where and how many new forest roads may be needed to access timber harvest sites through 2067. For purposes of analyzing how roads impact the habitat, it is assumed that the current density of DNR forest roads will remain stable through the life of the 1997 HCP. In other words, roads will be abandoned and new roads built, but the overall density will remain unchanged.

### ■ How Is the Road Edge Effect Calculated?

The analytical framework adjusts the value of habitat located within 50 meters of a forest road to reflect potential increases in predation effects. The reduction in habitat value assumed attributable to roads can then be added to the other edge effect factors discussed in this paper. The level of a road's impact, and therefore its "share" of the edge effect, depends on where the road is located relative to habitat. For example, a road located within an outer, hard edge created by a timber harvest has a concomitant edge effect with that of the harvest area. The road brings no additional predation impacts. But a road bisecting an inner edge is assumed to contribute a portion of the predation edge effect (which for inner, hard edge forests is a 31% reduction in nest success; McShane and others 2004). DNR applied a road edge effect factor throughout the landscape as 15.5% (half of 31%) to reflect these variations.

## POTENTIAL IMPACTS AND MITIGATION

This road edge effect only applies to a small portion of the analysis area. DNR conducted a spatial analysis to identify how much marbled murrelet habitat is located within 50 meters of active roads. Roads located more than 50 meters from an interior forest were not counted as an edge. Approximately 4.8% of habitat was estimated to be subject to a road edge effect. The number of acres of habitat in different edge conditions, adjusted by other edge factors, can be multiplied by 4.8%, and then multiplied by the road edge factor of 15.5% to determine the road edge effect across the analysis area.

$$\begin{array}{ccccccc} \text{Percent of habitat} & & \text{Acres of habitat in each} & & & & \\ \text{in interior, or inner-} & & \text{edge condition, adjusted by} & & \text{Road edge factor} & & \text{Acres of} \\ \text{edge LTFC assumed} & & \text{other edge factors (varies} & & \text{(15.5\%)} & = & \text{habitat} \\ \text{to be within 50 m of} & \times & \text{depending on the} & \times & & & \text{impacted by} \\ \text{a road (4.8\%)} & & \text{conservation alternative)} & & & & \text{roads} \end{array}$$

The acres of road edge-impacted habitat are added to the total acres that are impacted by harvest and other edge factors. This methodology assumes that as new roads are built, older roads are abandoned, and new habitat grows, keeping the road edge effect consistent through the end of the 1997 HCP. Overall, the portion of the overall impacts from harvest and edges that are attributable to road edges alone is very small. However, this factor is incorporated into the analytical framework and reflected in the formulas used to determine how much mitigation is needed to offset potential impacts from forest management.

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## POTENTIAL IMPACTS AND MITIGATION

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# Appendix C

## Attachment C-2 Population Viability Analysis

Final State Trust Lands Habitat Conservation Plan AMENDMENT • Marbled Murrelet Long-term Conservation Strategy



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# Population Viability Analysis Preface

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A population viability analysis approaches was used to evaluate the potential future (50-year) effects of proposed management alternatives (A through H) on marbled murrelets in Washington for the *Marbled Murrelet Long-term Conservation Strategy Final Environmental Impact Statement* (FEIS). A stochastic, two-population model was developed that linked murrelet demographic rates to forest conditions on DNR-managed and non-DNR-managed lands. The model was used to evaluate each proposed alternative's relative potential to lead to *risk* or *enhancement* of murrelet populations.

## Note on Data Used to Parameterize the Population Viability Model

The marbled murrelet meta-population model and population viability analysis presented in this attachment was parameterized using at-sea survey data from Zones 1 and 2 (Washington) over the period 2001 through 2015. However, more recent at-sea survey data are now available for 2017 through 2018 (McIver and others 2019). (At the initiation of the contract between DNR and Peery/Jones, the 2001 through 2015 data were the most recently available data.) This note briefly describes why more recent data were not included in the model.

1. **Re-parameterizing the model was not possible in time for the FEIS.** The at-sea survey data feeds into a number of components of the model, including (a) initial population size in “year 0” of the simulation, (b) variance in survival and fecundity rates used in the projections (the coefficient of variation, or CV, of simulated populations should be similar to process CV in recent at-sea survey estimates), (c) and the carrying capacity scaling used within the model to help simulated declines match observed recent declines. Changing the input data would require adjusting all of these components, each of which requires time-consuming analyses. There was not adequate time to engage in these analyses and make subsequent adjustments to the model.
2. **2001 through 2015 survey data are more robust because they are complete and contain no missing survey years.** The at-sea survey data in Zones 1 and 2 over the period 2001 through 2015 are complete, but contain missing data for these zones in years 2016 through 2018 (McIver and others 2019). Specifically, Zone 1 is missing data from 2017, and Zone 2 is missing data from 2016 and 2018. This missing data increases the uncertainty in the actual count of murrelets in the state of Washington from 2016 through 2018. In population viability analyses, it is important to minimize the uncertainty in the components that feed into the population model. Using data from 2001 through 2015 makes that possible.
3. **Continued observed/estimated declines in the Washington murrelet population (McIver and others 2019) fall within the range predicted by the population viability model.** In effect, the first three years of forward projection presented in this attachment should represent the projected female murrelet population in Washington during 2016 through 2018. Estimates for these years

(assuming 1/2 the population is female, and under the *Risk* parameterization where mean adult survival = 0.87), compared to the empirical data, are as follows:

- a. 2016: mean = 6695 (95% range = 5713-7590) (McIver = 7494)
- b. 2017: mean = 6335 (95% range = 5144-7450) (McIver = 7095)
- c. 2018: mean = 6024 (95% range = 4731-7312) (McIver = 5984)

As one can see, the empirical data reported by McIver and others (2019) fall within the 95 percent predicted range of the population viability model for all three years. This leads to the conclusion that (a) the model is performing well and (b) does not need to be re-parameterized with more recent data.

4. **Re-parameterizing the model would be unlikely to produce different qualitative results.** The power in population viability analyses is the ability to distinguish *among* plausible management scenarios. If the parameterization of the model was fiddled with to incorporate 2016 through 2018 at-sea survey data (refer to point #2), and the corresponding slight decrease in the rate of population decline in Washington, the result may be a change in the absolute number of projected murrelets in any given year of the scenario; however, it would be unlikely to produce changes in the *relative comparisons among scenarios*. That is, Alternative F would likely still produce the highest murrelet numbers after 50 years, and Alternative B the lowest, and so on.

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**Using population viability analyses to assess the potential effects of  
Washington DNR forest management alternatives on marbled murrelets**

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## EXECUTIVE SUMMARY

The marbled murrelet (*Brachyramphus marmoratus*) was listed as threatened in Washington, Oregon, and California under the Endangered Species Act in 1992 due to commercial logging of nesting habitat, oil spills, and gill net entanglement. In 2012, the Washington Department of Natural Resources (DNR) initiated the development of a statewide, long-term conservation strategy for marbled murrelets to replace the 1997 Habitat Conservation Plan implemented after initial listing. We used population viability analysis (PVA) approaches to evaluate the potential future (50-year) effects of proposed management alternatives (A – H) on marbled murrelets in Washington. To do so, we developed a stochastic, two-population model linking murrelet demographic rates to forest conditions on DNR and non-DNR lands, and used this model to evaluate each proposed alternative’s relative potential to both lead to *Risk* and *Enhance* murrelet populations. Proposed alternatives F and G generally resulted in the greatest number of murrelets and lowest quasi-extinction probabilities, whereas alternative B always resulted in the lowest murrelet population size and highest quasi-extinction probabilities, in both the *Risk* and the *Enhancement* scenarios and at the two spatial scales considered (DNR lands versus state of Washington). Thus, alternative B posed the greatest risk to murrelet populations and alternatives F and G provided the greatest capacity to enhance murrelet populations. For example, at the state scale alternative F was projected to lead to 60 and 280 more murrelets than alternative B under the *Risk* and *Enhancement* scenarios, respectively. All alternatives except B were projected to lead to larger murrelet population sizes at year 50 than alternative A (the “no action” alternative), regardless of the spatial scale or scenario (one exception was alternative D in the *Risk* analysis, which resulted in slightly lower murrelet population sizes than alternative A). The same pattern



was generally observed for quasi-extinction probabilities. In a separate sensitivity analysis, we found that, acre-for-acre, murrelet population growth was most sensitive to changes in higher-quality nesting habitat (Pstage 0.89 and 0.62), and while still sensitive, less so to changes in the raw acreage of nesting habitat or nesting habitat configuration (i.e., edge conditions). While we believe our model is sufficiently robust and well-parameterized to help assess how the proposed management alternatives may impact murrelet populations, our results must be considered in light of uncertainty about the effects of future changes in climate and stressors in the marine environment. Future efforts would benefit from using spatially-explicit models that provide (i) geographically-targeted (local) estimates of risk, (ii) prioritize stands for conservation and management, and (iii) generate more realistic insights into how changes in the spatial arrangement of nesting habitat may influence regional murrelet population viability. However, spatially-explicit population models are relatively complex in structure and would benefit from additional research designed to fill key information gaps in our understanding of murrelet ecology and environmental factors influencing murrelet populations.

# Table of Contents

<b>INTRODUCTION.....</b>	<b>1</b>
<b>METHODS .....</b>	<b>7</b>
<b>Model Structure and Parameterization .....</b>	<b>7</b>
Matrix Model Structure .....	7
Parameterizing Survival Rates .....	8
Parameterizing Breeding Probabilities .....	9
Modeling Transition Probabilities .....	10
Parameterizing Dispersal Rates .....	11
Initial Population Sizes .....	13
<b>Evaluating “Risk” and “Enhancement” .....</b>	<b>14</b>
<b>Modeling the Impact of Nesting Habitat Change on Marbled Murrelet Populations .....</b>	<b>15</b>
Effects of Forest Conditions on Carrying Capacity .....	16
Effects of Forest Conditions on Nest Success .....	19
<b>Forest Management Alternatives .....</b>	<b>19</b>
<b>Model Projections, Stochasticity, and Estimating Risk.....</b>	<b>25</b>
Model Projections.....	25
Incorporating Environmental Stochasticity.....	26
Quantifying Population Risk.....	27
<b>Sensitivity Analysis .....</b>	<b>28</b>
<b>RESULTS .....</b>	<b>29</b>
<b>Forest Management Scenarios.....</b>	<b>29</b>
<b>Population Viability Analysis.....</b>	<b>30</b>
Risk analysis, DNR population.....	30
Risk analysis, Washington population.....	31
Enhancement analysis, DNR population .....	32
Enhancement analysis, Washington population .....	33
Exploratory analyses with variant of alternative H.....	34
<b>Sensitivity Analysis .....</b>	<b>35</b>
<b>DISCUSSION .....</b>	<b>35</b>
<b>Implications for Population Risk and Enhancement.....</b>	<b>35</b>
<b>Comparison of Individual Alternatives .....</b>	<b>37</b>
<b>Sensitivity of Marbled Murrelet Populations to Habitat Change .....</b>	<b>39</b>
<b>Caveats and Future Directions .....</b>	<b>39</b>
<b>LITERATURE CITED .....</b>	<b>42</b>
<b>TABLES AND FIGURES .....</b>	<b>46</b>
<b>APPENDIX.....</b>	<b>68</b>

## **INTRODUCTION**

The U.S. Endangered Species Act of 1973 (hereafter “ESA”) prohibits the “take” of species listed as threatened or endangered (U.S. Congress 1973). In 1982 the ESA was amended to provide flexibility to non-federal land owners with endangered species on their property by granting an “incidental take permit” if they developed a Habitat Conservation Plan (HCP). Under Section 10 of the ESA, HCPs represent planning documents intended to ensure that anticipated take of a listed species will be minimized and mitigated to the maximum extent practicable by conserving the habitat upon which the species depend. Since issuance of an incidental take permit is a federal action, consultation under Section 7 of the ESA must also occur. Through the consultation process the U.S. Fish and Wildlife Service (FWS) determines if the proposed action is likely to lead to “jeopardy” which, according to the regulations implementing the ESA, is when an action “...reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species” (50 CFR §402.02). Although not a statutory requirement, another component of HCP development is addressing whether proposed management alternatives contribute to the recovery of the species as a whole, which is considered to be “an integral product of an HCP...” (USFWS 1996).

HCP negotiations and Section 7 consultations typically consider a wide range of information pertinent to the threatened or endangered species including, but not limited to, current habitat distribution and population trends as well as projections of future habitat and population status. Modeling approaches such as Population Viability Analyses (PVA) are frequently used as part of Section 7 consultations and HCP negotiations to evaluate the potential effects of proposed activities on threatened and endangered species (Harding et al. 2001, Morris

et al. 2002). While the ability of PVA approaches to evaluate absolute levels of risk has been questioned, they remain well-suited to compare the relative effects of alternative management strategies on species of concern (Beissinger and Westphal 1998). However, addressing how well different management alternatives both lead to risk and support recovery raises conceptual and practical challenges, even when projections are limited to relative comparisons. Many, if not most, endangered species are declining in numbers and face extirpation due to the cumulative effects of multiple environmental stressors over broad geographic areas that extend beyond the effects of local habitat management within the HCP planning area. In these cases, understanding an alternative's capacity to support recovery may require additional, optimistic assumptions about, for example, improvements to other stressors that impact vital rates. Thus, simultaneously addressing these two questions—namely risk of extirpation/extinction and potential for recovery— as part of Section 7 consultations for endangered species, may require two distinct, yet parallel, modeling efforts. Further, modeling results must often be coupled with consideration of other factors such as geographic distribution for a complete jeopardy analysis.

The marbled murrelet (*Brachyramphus marmoratus*) is a small seabird endemic to the west coast of North America that generally nests in coastal old-growth forests and forages in marine nearshore environments (Meyer et al. 2002). The murrelet was listed as a federally threatened species in Washington, Oregon, and California under the ESA in 1992 primarily because of the loss of older, complex-structured forests to timber harvest, and edge effects from ongoing forest fragmentation (USFWS 1997). However, a host of other factors unrelated to forest management likely impact murrelet populations including marine foraging conditions, disease, oil spills, and by-catch from gill net fishing (Peery et al. 2004, Raphael 2006). Nevertheless, the relative importance of each of these factors in driving recent population

declines is not well understood (Falxa and Raphael 2016).

The Washington Department of Natural Resources (DNR) manages forests on “state trust lands” as fiduciary trusts to provide revenue to specific trust beneficiaries, such as schools, universities and other public institutions. In accordance with Section 10 of the ESA, the DNR developed a Habitat Conservation Plan in the late 1990’s (WDNR 1997) which was an ecosystem-based forest management plan intended to help the DNR develop and protect habitat for at-risk species, including several federally threatened species (e.g., marbled murrelet and northern spotted owl *Strix occidentalis caurina*), while carrying out forest management and other activities on the state trust lands it manages. In 2012, the DNR formally began a process to amend the 1997 HCP to include a long-term conservation strategy for the marbled murrelet that incorporated a more recent body of scientific information on murrelet biology and habitat needs. The revision of the DNR’s HCP seeks to simultaneously address the question of risk and contribution to recovery, a question complicated by the fact that by our analytical framework, habitat on DNR lands contains only about 15% of the estimated carrying capacity for murrelets in Washington (and less in the tri-state area) and multiple, poorly understood environmental stressors likely impact murrelet populations regionally.

To provide insight as to whether forest management alternatives proposed as DNR’s long-term conservation strategy may lead to risk or support significant contributions to recovery of murrelet populations in Washington, we used two parallel modeling frameworks—a “*Risk*” and an “*Enhancement*” analysis—that differed in assumptions about future impacts of environmental factors on murrelets beyond habitat change on DNR lands. In the *Risk* analysis, we assumed that current population declines were, in part, a function of recent loss of nesting habitat, and that the current population exceeded the nesting carrying capacity and was expected

to decline further because of density-dependent effects. However, we also assumed that undetermined, chronic environmental stressors have contributed to population declines by reducing vital rates (reproduction and survival) such that the population was expected to continue to decline even after the population reached carrying capacity, albeit at a slower rate. While there is uncertainty in the environmental and anthropogenic factors responsible for recent population declines, parameterizing the model such that projected populations declined at approximately the same rate as recent estimates provided some biological realism to the model. This analysis was thus intended to provide a relative comparison of future state-level risk among management alternatives and to provide a general assessment of how risk can be modulated by forest management alternatives on DNR lands, particularly in light of recent population declines (Miller et al. 2012).

While the first analysis provides perspective on risk, estimating differences in risk among alternatives superimposed on expected future, substantial (ca. 5% annual) population declines does not necessarily provide a basis for assessing the extent to which the alternatives may support murrelet recovery. Put simply, we had an *a priori* expectation that potential increases in nesting habitat on DNR-managed lands are unlikely, by themselves, to provide a substantial contribution to the recovery of the considerably larger state-wide population experiencing significant declines likely owing to a host of factors in addition to the nesting habitat on state lands. From the perspective of evaluating a forest management plan, the question of recovery might be cast as: “if other stressors are ameliorated, how do the alternatives differ in their ability of DNR managed-lands to increase local breeding populations?” Therefore, in the *Enhancement* analysis, we developed an alternative parameterization of the model where we assumed that (i) the availability of nesting habitat was the primary cause of recent population declines and the

most important factor limiting future population growth, and (ii) that other environmental stressors would not appreciably limit potential future recovery. Thus, as with the *Risk* analysis, murrelets were expected to decline initially at approximately the same rate as estimated with at-sea monitoring, but at some point in the future, the population would reach equilibrium with nesting carrying capacity and that the intrinsic population growth rates were sufficient for the population to increase in response to potential increases in nesting habitat. This second approach, then, provided a more direct means to “credit and debit” the DNR by evaluating potential population response to expected increases and decreases in nesting habitat on DNR lands using population metrics, under the important assumption that other chronic stressors in the environment will not impede recovery.

We implemented this dual modeling approach using a stochastic meta-population model that provided a framework for projecting expected changes in the abundance of murrelets in the state of Washington under various forest management alternatives currently under consideration by DNR and FWS. The model links changes in murrelet population dynamics to expected changes in the quantity, quality, and configuration of nesting habitat on DNR lands over time (that varied among management alternatives) through ecological processes that were reasonably well-supported by the literature and that were agreed upon by DNR and FWS (WDNR 2016). It included two subpopulations linked demographically by dispersal, where the subpopulations represented murrelets nesting on DNR and non-DNR lands. In our model, the dispersal process was spatially implicit; we did not explicitly consider the complex, landscape-scale distribution of murrelet nesting habitat on different landownerships in the state of Washington because many of these processes are not well understood and fully addressing these complexities was deemed beyond the scope of the Conservation Strategy negotiations by the involved resource agencies.

The metapopulation model made a number of additional simplifying assumptions as the secretive behavior and marine habitats of marbled murrelets challenges field studies needed to parameterize the model described below. Thus, and as is the case with all PVA exercises, projections of risk should not be considered as absolute estimates, and only be interpreted as a way to compare the relative consequences of different scenarios (Beissinger and Westphal 1998). However, our objective was to develop a population model where differences in projected risk among management alternatives were sufficiently robust to violations of assumptions and uncertainty that the involved agencies could identify which alternative best met joint objectives. More broadly, we sought to understand how using parallel *Risk* and *Enhancement* analyses could facilitate management decisions and endangered species conservation while meeting legal obligations of the Endangered Species Act and DNR’s policy goal of making a “significant contribution” to murrelet conservation. *In doing so, we recognize it is beyond our purview to provide recommendations as to whether individual alternatives impact murrelets such that “...survival and recovery in the wild is appreciably reduced” or whether they benefit murrelet populations to the point that they “contribute to the recovery of the species as a whole”.* While we do highlight when, and under what circumstances, an individual alternative might increase/decrease risk or may increase the likelihood of recovery via population gains, we make no judgments as to whether modeled impacts on populations are sufficient to meet specific FWS regulatory criteria related to jeopardy or population recovery. While this distinction is subtle, we believe it is an important one.



## METHODS

### Model Structure and Parameterization

*Matrix Model Structure.* We developed a female-based, stochastic meta-population model that employed a one-year time step in accordance with the annual breeding cycle of marbled murrelets (Nelson 1997). Each of the two subpopulations (DNR and non-DNR lands) contained five stages classes: juveniles, 1-year old subadults, 2-year old subadults, adult ( $\geq 3$ -year olds) nonbreeders that did not breed because of insufficient nesting habitat, and adult breeders ( $\geq 3$ -year olds; Figure 1). The five stage classes were indexed  $x = 1, 2, \dots, 5$  in the order presented above, and DNR and non-DNR lands were indexed as  $L = 1$  and 2, respectively. Note that, at times, the  $\geq 1$ -year-old stage classes (non-juveniles) are collectively referred to as after-hatch-year (AHY) individuals for convenience. Model parameters are defined in Table 1, and the rationale for assumptions behind the selected model structure and parameter values are described throughout the next several sections.

The life-cycle diagram can be expressed mathematically as a matrix model that determines the number of individuals in each stage class at time  $t + 1$  based on the number of individuals in each stage class in year  $t$  (Caswell 2001, Morris and Doak 2002). The murrelet meta-population model  $\mathbf{A}_t$  consisted of four submatrices that defined local demographic and dispersal processes (Hunter and Caswell 2005):

$$\mathbf{A}_t = \begin{bmatrix} \mathbf{A}_{1,t} & \mathbf{M}_{2,t} \\ \mathbf{M}_{1,t} & \mathbf{A}_{2,t} \end{bmatrix}$$

The two submatrices on the main diagonal ( $\mathbf{A}_{L,t}$ ) governed local demographic processes on DNR

and non-DNR lands, denoted  $\mathbf{A}_{1,t}$  and  $\mathbf{A}_{2,t}$ , respectively. The two submatrices in the off-diagonal determined murrelet dispersal between the two landownerships where the submatrix governing dispersal from DNR lands to non-DNR lands was  $\mathbf{M}_{1,t}$  and the submatrix governing dispersal from non-DNR to DNR lands was  $\mathbf{M}_{2,t}$  (the dispersal matrices are described in more detail below). The demography submatrices were structured as follows:

$$\mathbf{A}_{L,t} = \begin{bmatrix} 0 & 0 & s_{3,L,t}g_{3,L,t}bf_{L,t} & s_{4,L,t}g_{4,L,t}bf_{L,t} & s_{5,L,t}(1-g_{5,L,t})bf_{L,t} \\ s_{1,L,t} & 0 & 0 & 0 & 0 \\ 0 & s_{2,L,t} & 0 & 0 & 0 \\ 0 & 0 & s_{3,L,t}(1-g_{3,L,t})(1-d_{L,t}) & s_{4,L,t}(1-g_{4,L,t})(1-d_{L,t}) & s_{5,L,t}g_{5,L,t} \\ 0 & 0 & s_{3,L,t}g_{3,L,t}(1-d_{L,t}) & s_{4,L,t}g_{4,L,t}(1-d_{L,t}) & s_{5,L,t}(1-g_{5,L,t}) \end{bmatrix}$$

In these matrices,  $s_{x,L,t}$  represented the annual survival rates,  $g_{x,L,t}$  represented the probability of transitioning (transition rate) from stage class  $x$  (conditional on survival and population fidelity),  $d_{L,t}$  was the annual dispersal rate,  $b$  was the breeding probability, and  $f_{L,t}$  was nest success. Note that  $g_{1,L,t}$  and  $g_{2,L,t}$  were always equal to 1 and are therefore not presented in either the life cycle diagram or the matrix model.

*Parameterizing Survival Rates ( $s_{x,L,t}$ ).* The model was parameterized with an annual survival rate of 0.87 and 0.90 in the *Risk* and *Enhancement* analyses, respectively, for after-hatch-year females ( $s_{2,L,t}$  to  $s_{5,L,t}$ ) based on a mark-recapture study of 331 individual marbled murrelets in central California (Peery et al. 2006b) (Table 1). A pooled survival rate was used for these four stages classes because it was not possible to distinguish beyond juvenile versus after-hatch-year at the time of the mark-recapture study. We assumed the annual juvenile survival ( $s_1$  and  $s_6$ ) was 70% of after-hatch-year survival based on differences in survival rates between these stage

classes in other alcid species (insufficient juveniles were captured to estimate juvenile survival directly; Peery et al., 2006a).

*Parameterizing Breeding Probabilities ( $b, f_{L,t}$ ).* We treated the parameter  $b$  as the expected proportion of individuals in the breeding stages (i.e., that were “in possession” of a nest site) that actually nested in each year. We assumed that some fraction of breeders did not nest each year because, in seabirds, some individuals typically forgo nesting due to, for example, poor foraging conditions (Peery et al. 2004). The proportion of breeders has been estimated using radio-telemetry in the state of Washington, but estimates are likely biased low as a result of transmitter effects (Peery et al., 2006b, M. G. Raphael *pers. comm.*). A similar study in central California (Peery et al. 2004) used assays of plasma calcium (an indicator of eggshell deposition) and vitellogenin (an egg yolk precursor) to identify radio-marked individuals that did not nest but were physiologically in breeding condition at the beginning of the breeding season (indicating they likely would have nested in the absence of radio-tagging). Peery et al. (2004) found that 77% of sampled murrelets either initiated nesting or were physiologically in breeding condition. However, some individuals that were not detected nesting and were not in breeding condition may have nested and failed prior to radio-tagging. Thus, we used  $b = 0.90$  as a reasonable estimate for the proportion of breeders in the state of Washington. Note that we assumed  $b$  was constant across years and equal 0.90 in both landownerships. However, we incorporated the effects of environmental variability on  $b$  implicitly by treating expected fecundity ( $m_{L,t}$ : the product of the proportion of breeders,  $b$ , and nest success,  $f_{L,t}$ , divided by two; see below) as a random beta-distributed variable in the population projection model as described above.

*Modeling Transition Probabilities* ( $g_{x,L,t}$ ). Transition rates ( $g_{x,L,t}$ ) provided the primary mechanism linking the demographic model to potential changes in the availability of nesting habitat resulting from forest management activities. Transition rates for the 2-year subadult and nonbreeding stages into the breeding stage class ( $g_{3,L,t}$  and  $g_{4,L,t}$ , respectively) were calculated based on the number of individuals seeking nests sites relative to the number of available nests in year  $t + 1$  in landownership  $L$ . For example, if the number of murrelets seeking nest sites (i.e., 2-year old subadults plus nonbreeders) was less than the number of available nest sites, then  $g_{3,L,t}$  and  $g_{4,L,t} = 1$ , such that all murrelets found nest sites. If the number of murrelets seeking nest sites exceeded the number of available nest sites, then  $g_{3,L,t}$  and  $g_{4,L,t} < 1$  such that not all 2-year old subadults and nonbreeders in the population become breeders in year  $t + 1$ . Thus, if the number of nest sites in a given landownership ( $K_{L,t}$ ) declined, for example as a result of timber harvesting, transition rates into the breeding class would also decline and fewer individuals would reproduce (effectively reducing the expected population growth rate). Conversely, if the number of nest sites increased (for example, as a result of forest growth and maturation), transition rates into the breeding class would tend to increase and more individuals would reproduce (effectively increasing the expected population growth rate). Mathematically, transition probabilities for landownership  $L$  in year  $t$  and were calculated as follows:

$$g_{3,L,t} = g_{4,L,t} = \frac{K_{L,t+1} - s_{5,L,t}n_{5,L,t}(1 - g_{5,L,t})}{s_{3,L,t}n_{3,L,t} + s_{4,L,t}n_{4,L,t}}$$

The numerator in this equation represented the number of available nest sites (carrying capacity minus the number of surviving breeders from the previous year), whereas the denominator represented the number of potential new breeders seeking nest sites (surviving 2-year subadults

and nonbreeders from year  $t$ ).

Reductions in the number of nests sites ( $K_{L,t}$ ) could also impact population growth by causing some breeders in possession of a nest site in year  $t$  to transition to the nonbreeder stage in year  $t + 1$  ( $g_{5,L,t}$ ):

$$g_{5,L,t} = 1 - \frac{K_{L,t+1}}{K_{L,t}}$$

For example, if half of existing nest sites were lost in year  $t$ , half of the surviving breeders in year  $t$  would transition to the nonbreeder stage in year  $t + 1$ . As described above, nonbreeders could transition back to the breeding stage if nests became available (e.g., through forest growth), but the model assumed that breeders that lost their nest sites as a result of habitat loss became nonbreeders for at least one year.

*Parameterizing Dispersal Rates ( $d_{L,t}$ ) and Modeling Dispersal Processes.* Modeled murrelet populations in the two landownerships were linked demographically by the dispersal of individuals, where the annual dispersal rate from DNR to non-DNR lands, and from non-DNR to DNR lands, was defined as  $d_{1,t}$  and  $d_{2,t}$ , respectively. The submatrix representing dispersal from land ownership  $L$  was structured as follows:

$$\mathbf{M}_{L,t} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & s_{3,L,t}g_{3,L,t}d_{L,t} & s_{4,L,t}g_{4,L,t}d_{L,t} & 0 \end{bmatrix}$$

For example, if  $L = 1$ , then the matrix  $\mathbf{M}_{1,t}$  would represent dispersal from DNR to non-DNR lands in year  $t$ . The model assumed that dispersal movements were made by 2-year subadults and nonbreeders as these individuals transitioned to breeding stages in either landownership; juveniles and 1-year subadults remained in their natal population until they were old enough to breed. Individuals in breeding stages were assumed to remain in their respective populations such that “breeding dispersal” was effectively zero, a reasonable assumption based on anecdotal observations of the re-use of the same nesting site by murrelets in consecutive years (R. T. Golightly *pers. comm.*) as well as generally strong breeding fidelity in alcids (Gaston and Jones 1998). Dispersal rates between DNR and non-DNR lands are unknown, but approximately 85% of existing carrying capacity for murrelets in Washington occurs on non-DNR lands and 15% occurs on DNR lands. Thus, if we assume natal dispersal is random with respect to landownership,  $d_1$  would be 0.85 and  $d_2$  would be 0.15. However, a cap to the number of dispersers, and thus the dispersal rates was imposed by the number of available nest sites in the receiving population. Thus, if the number of dispersers calculated based on the dispersal rate exceeded the number of available nest sites in the receiving population, the “realized” dispersal rate was adjusted as follows for murrelets dispersing from DNR lands:

$$d_{1,t} = \frac{K_{2,t+1} - (s_{3,2,t}n_{3,2,t} + s_{4,2,t}g_{4,2,t}n_{4,2,t} + s_{5,2,t}[1 - g_{5,2,t}]n_{5,2,t})}{s_{3,1,t}(1 - g_{3,1,t})n_{3,1,t} + s_{4,1,t}(1 - g_{4,1,t})n_{4,1,t} + s_{5,1,t}g_{5,1,t}n_{5,1,t}}$$

Here, the numerator represents the number of available nest sites on non-DNR lands in year  $t + 1$  after “local” recruitment by resident 2-year subadults and nonbreeders, whereas the denominator represents the number of available recruits from DNR lands in year  $t + 1$ . The analogous adjustment for dispersal rates from non-DNR lands was made as follows:

$$d_{2,t} = \frac{K_{1,t+1} - (s_{3,1,t}n_{3,1,t} + s_{4,1,t}g_{4,1,t}n_{4,1,t} + s_{5,1,t}[1 - g_{5,1,t}]n_{5,1,t})}{s_{3,2,t}(1 - g_{3,2,t})n_{3,2,t} + s_{4,2,t}(1 - g_{4,2,t})n_{4,2,t} + s_{5,2,t}g_{5,2,t}n_{5,2,t}}$$

As with local recruitment into the breeding stage, the model assumed that dispersing individuals selected nesting habitat in the destination population independent of habitat quality and edge conditions.

*Initial Population Sizes* ( $n_{x,L,0}$ ). We set the population size in year  $t = 0$  of model projections equal to one-half of the mean annual population size (our model was female-based and we assumed a 50% sex ratio) for the state of Washington estimated with at-sea monitoring from 2011 to 2015 ( $n = 3,616$  individuals; Falxa et al. 2016). While more recent surveys for murrelets have been completed in Washington, 2015 was the last year that a state-wide census was completed. The total number individuals (i.e., females) was allocated to DNR and non-DNR lands in proportion to the estimated carrying capacity of nesting habitat that exists on each of the two land ownerships (0.15 and 0.85, respectively), which yielded a total 542 individuals in the DNR subpopulation and 3,074 individuals in the non-DNR subpopulation. Within each subpopulation, we allocated individuals to the stage classes in accordance with the expected stable age distribution associated with a deterministic version of the matrix model structure that was parameterized as described above. Initially, nonbreeding and breeding stages ( $n_{4,L,0}$  and  $n_{5,L,0}$ , respectively) were pooled (both classes treated as “adults”) when determining the stage distribution in year  $t = 0$ . Adults were then allocated to the nonbreeding and breeding stages in year  $t = 0$  as described below such that the number of adults exceeded the carrying capacity to a degree that provided reasonable correspondence between modeled population trajectories and

observed trends in the Washington population.

### **Evaluating “*Risk*” and “*Enhancement*”**

We parameterized the matrix model in both the *Risk* and *Enhancement* analyses using the values described above and listed in Table 1. We assumed that 40% of individuals of breeding age ( $\geq 3$  years old) were in the nonbreeding stages in year  $t = 0$  for each subpopulation and thus that the number of adult-aged individuals exceeded nesting carrying capacity for both analyses (see below). As described above, we made this assumption to reflect nesting habitat loss in the state of Washington that may have resulted in a nonbreeding component of the population. Moreover, associated density dependent effects on population growth allowed projected populations to decline in the initial years of the modeling period in reasonable accordance with recent observed declines (see below). The after-hatch-year annual survival rate was set to 0.87 and 0.90 in the *Risk* and *Enhancement* analyses, respectively. Higher survival rates in the *Enhancement* than *Risk* analysis allowed projected populations in this scenario to increase in response to potential gains in nesting habitat. For the portion of the *Enhancement* analysis focusing on DNR lands only, we assumed no dispersal between subpopulations to highlight “debits” and “credits” of forest management alternatives for losses and gains in nesting habitat, respectively, using population metrics.

Together, these assumptions yielded deterministic projections of population growth under constant habitat conditions that were reasonably consistent with the recent estimates of population trends (5% annual decline) in the initial years of the population projection. As the breeding-age component of modeled populations approached nesting carrying capacity, the rate of population growth increased in both the *Risk* and *Enhancement* analyses. The expected



population growth rate stabilized around year 15 under the *Risk* analysis, but stabilized below 1 (a population growth rate of 1 is indicative of a stable population), and the simulated populations were thus expected, on average to decline (by approximately 1.5% annually) over the projection period. By contrast, population growth stabilized above 1 under the *Enhancement* analysis, and thus we expected small population increases (approximately 1% annually) over the modeling period.

### **Modeling the Impact of Nesting Habitat Change on Marbled Murrelet Populations**

As described above, we modeled the potential effects of forest management alternatives on marbled murrelet population dynamics by linking the maximum number of breeders (carrying capacity,  $K_{L,t}$ ) and nest success rates ( $f_{L,t}$ ) to forest conditions (i.e., nesting habitat) present in the two landownerships in each year  $t$ . We assumed that availability of nesting habitat limits murrelet breeding opportunities and that forest fragmentation reduces nest success via edge effects. Specific measures of nesting habitat considered were nesting habitat (1) area, (2) quality, and (3) configurations (WDNR 2015). These three measures were initially quantified at the forest stand scale using DNR's spatially-explicit forest inventory database which contains information on mapped stands of known acreage such as characteristics of age, origin (natural vs. planted), and composition (Douglas-fir vs. shade-tolerant). Stand-level characteristics were ultimately aggregated to develop estimates of the maximum number of breeders and expected nest success in each landownership. The analytical methods, rationale, and assumptions used to derive estimates of carrying capacity and nest success are described below in conceptual terms. For a more detailed, mathematical explanation, we direct the reader to Appendix A.

*Effects of Forest Conditions on Carrying Capacity ( $K_{L,t}$ ).* The model imposed a limit to the number of breeders ( $K_{L,t}$ ) in each landownership based on the total amount, quality, and configuration of nesting habitat in each year  $t$ . Nesting carrying capacity ( $K_{L,t}$ ) was assumed to be positively related to the amount of nesting habitat present on landownership  $L$  in year  $t$  in a one-to-one manner; for example, a forest stand 100 ha in size would be expected to contain twice as many breeding murrelets as a stand 50 ha in size, all other factors being equal (i.e., nesting habitat quality and configuration). In Washington, a positive association has been observed between radar counts of murrelets flying inland and the amount of late-seral stage forest at the watershed scale, and the slope of this relationship is approximately one (Raphael et al. 2002). Nesting density was assumed to be related to stand-level “habitat quality” based on generalized probabilities of murrelet use that were associated with stages of successional development in DNR-managed forest in southwest Washington (Raphael et al. 2008). Based on DNR’s forest inventory, stands were assigned to one of six nesting habitat quality categories (“Pstage”), non-habitat (Pstage = 0) and five classes of habitat with Pstage values 0.25, 0.36, 0.47, 0.62, 0.89. In the previous version of the report, the Pstage value at sites occupied by murrelets was reassigned to an additional Pstage class, Pstage = 1; in the current version of the report we did not redistribute the Pstage value at occupied sites to 1 but instead used the underlying Pstage value (0.25, 0.36, 0.47, 0.62, or 0.89). This revised approach more precisely reflects estimated habitat quality and permits increases in carrying capacity to occur at occupied sites through forest maturation as forest stands transition into higher Pstage classes. Classification was based on stand age, origin (natural vs. planted), and species composition, where (i) older stands were assumed to have greater nesting densities than younger stands, (ii) naturally-regenerated stands (unlike planted) were assumed to be capable of developing as habitat within the analysis period,

and (iii) stands dominated by western hemlock (*Tsuga heterophylla*) were assumed to develop into suitable habitat and thus greater nesting densities at an earlier age than stands dominated by Douglas-fir (*Pseudotsuga menziesii*). Together these three variables were assumed to represent the development of key murrelet nesting habitat characteristics such as large trees with large limbs and complex canopy structure. In our population model, the Pstage value represented the stand's maximum nesting density where, for example, ~3.5 acres of Pstage 0.25 provide the same nesting opportunities as one acre of Pstage 0.89.

Maximum nesting density was also influenced by edge effects, where availability of nest sites (and thus nesting density), was assumed to be lower in portions of stands adjacent to edges with non-habitat. Wind-throw as well as hotter, drier microclimate at the edge of young stands created by timber harvest can lead to the mortality of platform-bearing trees as well as epiphyte mortality that reduces platform abundance in surviving trees (Chen et al. 1992; van Rooyen et al. 2011). Edge effects were assumed to occur when a stand of suitable habitat (Pstage > 0) occurred adjacent to a stand dominated by trees < 80' (approximated as <40 years old) and were categorized based on the condition of adjacent young forests as "hard" (<40' tall approximated as <20 years old) or "soft" (40'-80' tall). Empirical values of tree density and suitable platform abundance from van Rooyen et al. (2011) formed the basis for adjustments to nesting density (Pstage) for the two edge types, 0.25 adjacent to hard edges and 0.60 at soft edges. Habitat in small, often linear fragments that were entirely edge, called *Strings* was assumed to have no value. Edge effects on larger habitat patches with areas over 100 meters from edge are assumed to be greatest near edges and decline with distance, generalized to "outer" and "inner" edges within 50 meters and between 50 and 100 meters from edge (Chen et al. 1992). Full effects were assumed to occur in outer edges, half-effects were assumed for inner edges, and "interior" habitat

>100 m from edge was assumed to be unaffected. Thus as informed by DNR's spatially-explicit forest inventory, nesting density was estimated for each factorial combination of Pstage (five classes), edge distance (three classes: outer, inner, interior), and edge type (hard and soft). This process resulted in 20 combinations of five Pstage classes by edge-distance (outer, inner) and edge-type (hard, soft) plus five Pstage classes in interior habitat providing 25 different nesting density adjustments applied to current and alternative-specific projected future habitat maps. For example, nesting density was assumed to be 14.2 times greater in Pstage = 0.89, interior forest than in Pstage = 0.25 subject to the hard, outer edge effect of 0.25 ( $14.2 = 0.89 / (0.25 \cdot 0.25)$ ). Pstage and edge adjustments for non-DNR lands followed the assumptions of Raphael et al. (2008) and were held constant over the modeling period.

Original nesting carrying capacity estimates (see Appendix A) based on the number of adult female murrelets based on at-sea surveys failed to yield population trajectories consistent with recent ~5% annual declines in the state (Falxa et al. 2016). Using deterministic simulations, we found that when we set nesting carrying capacity such that 40% of adult murrelets were non-breeders (i.e. the population was above carrying capacity), initial simulated population declines better approximated recent observed ~5% annual declines. Therefore we set initial nesting carrying capacity ( $K_{L,0}$ ) to equal the number of adult breeders on each landownership  $L$  ( $n_{5,L,0}$ ), which was 60% of the number of female adult murrelets in year 0 based on a stable age distribution (Table 1). In each subsequent year ( $t \geq 1$ ), carrying capacity  $K_{L,t \geq 1}$  changed based on projected losses (from harvesting) or gains (through forest growth) in nesting habitat in each Pstage by edge-type and distance combination and the nesting density relationships described above. Moreover, because a single nesting carrying capacity was considered for each landownership that reflected aggregate habitat conditions, we assumed that recruiting murrelets

choose nests sites randomly with respect to edge type and Pstage (i.e., they recruit into habitat in proportion to the abundance of potential nest sites it is assumed to provide).

*Effects of Forest Conditions on Nest Success* ( $f_{L,t}$ ). The model also linked population growth rates to nesting habitat conditions by treating nest success rates (number of female offspring produced per nesting female) in landownership  $L$  and year  $t$  ( $f_{L,t}$ ) as a function of the distribution of interior, inner edge, and outer edge forest in the landownership. Nest success was assumed to be greatest where edge effects were absent and to be reduced where nesting habitat occurred adjacent to a hard edge, with inner edges assumed to promote higher nest success than outer edges. Soft edges were assumed to have no influence in nest success (Raphael et al. 2002, Malt and Lank 2009). Estimates of nest success rates in soft- or non-edge influenced forest (0.550) and outer edge (0.380) were drawn from the upper and lower bounds assumed for this parameter in demographic analyses conducted by McShane et al. (2004). An intermediate value of 0.465 was assumed for nest success in inner edge near hard edges. In sum, greater relative amounts of edge habitat under a given management alternative were expected lead to a greater fraction of the population nesting near edges, lower mean nest success, and lower population growth rates.

### **Forest Management Alternatives**

We considered eight forest management alternatives (A-H), each involving different approaches to timber harvesting and habitat conservation on DNR-managed land in western Washington (WDNR and USFWS 2018). Each alternative was built around *long-term forest cover* (LTFC), areas of existing conservation commitments made under the HCP (e.g., high-quality spotted owl habitat, riparian management zones), DNR's Policy for Sustainable Forests and state law. The

alternatives then variously add LTFC to further conserve and restore murrelet habitat. The abundance, configuration, and location of this murrelet-specific LTFC differs among alternatives, reflecting a range of conservation approaches. All alternatives provide for new habitat growth through the life of the HCP. Common among alternatives, initial ( $t = 0$ ) forest conditions were set to current conditions on DNR-managed lands (DNR database and landscape models of potential murrelet nesting habitat) and other landownerships in Washington (Raphael et al. 2016). Projections of future habitat conditions over the 50-year modeling period were conducted by DNR using the Forest Vegetation Simulator (FVS), where differences in harvest and conservation among the management alternatives led to different expected trajectories in the amount, quality and configuration of murrelet nesting habitat on the landscape, and thus differences in carrying capacity and nest success among the alternatives (Figure 2). The eight alternatives are more thoroughly defined elsewhere ([dnr.wa.gov/mmltcs](http://dnr.wa.gov/mmltcs)), but they, and a baseline scenario (i.e., static forest conditions) are briefly summarized below:

1. **Alternative A** is the “no-action” alternative, approximating continued DNR operations as authorized under the 1997 HCP. This alternative includes approximately 600,000 acres of LTFC, with murrelet-specific conservation including: all occupied sites as delineated by HCP-directed surveys, with a 100-meter buffer; all reclassified habitat in OESF; all reclassified habitat in the Straits, South Coast and Columbia planning units that has not been identified as “released” for harvest under the interim strategy; in the North Puget and South Puget planning units, all suitable habitat that has not been identified as “released” for harvest subject to the 2007 concurrence letters, all newly identified habitat, and all potential habitat that has a Pstage value  $>0$  in decade 0.

2. **Alternative B** focuses on protecting the known locations of marbled murrelet occupied sites on DNR-managed land. Under this alternative, LTFC totals approximately 576,000 acres, and includes occupied sites delineated by the 2008 Science Team recommendations (Raphael et al. 2008). This approach results in approximately 16,000 acres more than the HCP delineations used by Alternative A, as well as occupied sites identified by DNR staff in the North and South Puget planning units. This is the only alternative that does not provide buffers on occupied sites.
3. **Alternative C** is designed to protect occupied sites and current habitat as well as grow new habitat over the life of the HCP. LTFC totals approximately 617,000 acres. This alternative contains both marbled murrelet “emphasis areas” and “special habitat areas.” Seven emphasis areas from 4,100 to 15,600 acres are identified in strategic landscapes for the purpose of protecting and reducing fragmentation around occupied sites, and developing future marbled murrelet habitat. Twenty special habitat areas, 40 to 8,000 acres, are generally smaller than emphasis areas and are designed to increase murrelet productivity by reducing edge and fragmentation around more isolated occupied sites that are not within an emphasis area. Outside of emphasis or special habitat area boundaries, this alternative will also buffer all other existing occupied sites and will maintain all higher quality habitat (Pstage value 0.47 and greater).
4. **Alternative D** concentrates conservation into thirty-two special habitat areas, 40 to 14,400 acres. LTFC totals approximately 618,000 acres. All acreage within special habitat areas is designated as LTFC. Special habitat areas are designed to increase the productivity of existing occupied sites by increasing habitat abundance and reducing edge effects. They include: strategically located occupied sites with 100-meter buffers;

adjacent Pstage habitat (both existing and expected to develop through 2067); adjacent, non-habitat areas intended to provide security to existing and future habitat (security forests). The boundaries of the special habitat areas were identified based on existing landscape conditions (management history, watershed boundaries, natural breaks or openings). Because of its focus on reducing fragmentation around existing, occupied sites, Alternative D would allow more acres of potential habitat (habitat that has or will develop a Pstage value) to be harvested throughout the analysis area than Alternative C. However, the overall amount of LTFC is similar under Alternatives C and D.

5. **Alternative E** combines the conservation approaches of Alternatives C and D, for a total of approximately 621,000 acres of long-term forest cover. This alternative includes the following murrelet-specific conservation: occupied sites, with 100 meter buffers; all habitat with a Pstage value of 0.47 and greater throughout the analysis area; emphasis areas as designated under Alternative C; special habitat areas as designated under Alternative D (where emphasis areas and special habitat areas overlap, emphasis area will be the designation).
6. **Alternative F** proposes to apply the conservation recommendations presented in the 2008 Science Team report (Raphael et al. 2008), which evaluated conservation opportunities in the four coastal HCP planning units and recommended the establishment of 45 marbled murrelet management areas of up to 15,500 acres. It also applied the principles of Raphael et al. (2008) to establish 20 similar areas of up to 47,400 acres in the North and South Puget planning units. In total approximately 743,000 acres of LTFC is designated under this alternative. All occupied sites would be protected with a 100-meter buffer. Additionally, all Old Forest in the OESF would receive a 100-meter buffer.



Existing, mapped low quality northern spotted owl habitat in designated owl conservation areas (nesting/roosting/foraging, dispersal and OESF) is included as LTFC (Alternatives A through E only include high quality owl habitat as LTFC).

- 7. Alternative G** is a new alternative, added between the DEIS and RDEIS. This alternative was developed based on comments received on the DEIS from federal and state agencies, environmental groups, and various individuals. Alternative G includes approximately 642,000 acres of LTFC. This alternative includes, emphasis areas, special habitat areas, and marbled murrelet management areas and applies 100 meter buffers to all occupied sites. Alternative G includes the following murrelet specific conservation lands: all habitat with a Pstage value of 0.47 and greater throughout the analysis area; in the OESF, all habitat with a Pstage greater than zero in decade zero; Emphasis Areas as designated under Alternative C; special habitat areas as designated under Alternative D (where emphasis areas and special habitat areas overlap, an emphasis area will be the designation); areas where the Pstage model did not identify potential existing habitat or applied a lower Pstage value than thought appropriate based on expert opinion (WDFW Polygons); the marbled murrelet management area in the Elochoman block, as drawn for Alternative F, managed as an Emphasis Area; and the following marbled murrelet management areas in the North Puget Planning Unit: Spada Lake/Morningstar, Whatcom, Middle Fork Hazel/Wheeler Ridge, Marmot Ridge.
- 8. Alternative H** is DNR's preferred alternative. Alternative H is based on direction from the Board of Natural Resources to minimize impacts, offset impacts and address uncertainty, and reduce disproportionate financial impacts to trust beneficiaries. Alternative H minimizes impacts by conserving all existing occupied sites, capturing

existing habitat within special habitat areas, and metering harvest of habitat outside conservation areas in strategic locations. Metering delays harvest of a portion of habitat until the second decade of the modelling period. Metering is designed to maintain nesting carrying capacity on DNR-managed lands such that capacity always equals or exceeds baseline conditions. Alternative H offsets impacts and addresses uncertainty by applying 100-meter buffers on all occupied sites, locating special habitat areas in strategic locations, and increasing the amount of interior forest habitat in LTFC. This alternative reduces disproportionate financial impacts identified in the DEIS in Pacific and Wahkiakum counties under Alternatives C through F by placing less conservation on State Forest lands in these counties. Alternative H includes approximately 604,000 acres of LTFC.

9. **Baseline** represents a static habitat scenario, where the raw amount of murrelet nesting habitat that presently exists on DNR lands excluding habitat located in “strings” (162,592 acres) remains constant over the 50-year modeling period. Carrying capacity ( $K_{1,t} = 217$ ) and nest success ( $f_{1,t} = 0.5343$ ) also remain fixed. Although it is biologically unrealistic, the baseline scenario offers a useful benchmark by which to compare scenarios with changing habitat conditions.

In addition to the eight proposed alternatives, the DNR and USFWS proposed an additional analysis which would show how the modeled murrelet population on DNR lands might respond to Alternative H *without* the delayed harvest implementation (**Alternative H – ‘no meter’**) under both *Risk* and *Enhancement* scenarios. This additional exploratory scenario sought to gauge how a more rapid rate of habitat decline (but less prolonged decline) might influence

projected murrelet populations.

For the eight primary alternatives and one exploratory alternative, forest conditions on non-DNR lands were assumed to be stationary over the modeling period. While we recognize that habitat conditions on non-DNR lands are not static, we lacked sufficient information for non-DNR lands to project habitat changes over time. Because our modeling objective was to evaluate how changes in habitat conditions on DNR lands may influence murrelet populations over time, it was appropriate to evaluate the range of alternatives in the context of the current conditions on non-DNR lands. Although this assumption is clearly unrealistic, some habitat will be lost to harvest and natural disturbances, and habitat will develop on federal lands reserved from harvest under the Northwest Forest Plan (Raphael et al. 2016), it was adopted because it simplified presentation and interpretation of population responses to changes on DNR-managed land which contain about 15% of murrelet nesting carrying capacity in Washington according to our analytical model.

### **Model Projections, Stochasticity, and Estimating Risk**

*Model Projections.* We projected the model forward in time as follows:

$$\mathbf{n}_{t+1} = \mathbf{A}_t \cdot \mathbf{n}_t$$

where  $\mathbf{n}_t$  was a 10 by 1 vector of murrelet abundance in the five stage classes  $x = 1, 2, \dots, 5$  and two landownerships  $L = 1, 2$  in year  $t$ , and  $\mathbf{A}_t$  was the matrix of vital rates (described above). The vector of population sizes  $\mathbf{n}_1$  was:

$$\mathbf{n}_1 = \begin{bmatrix} 83 \\ 52 \\ 46 \\ 145 \\ 217 \\ 472 \\ 293 \\ 260 \\ 819 \\ 1229 \end{bmatrix}$$

where the first five elements represent the number of juveniles, 1-year subadults, 2-year subadults, and adults (nonbreeders and breeders) on DNR lands assuming a stable age distribution. The second five elements would be the number of individuals in each of these stage classes on non-DNR lands under the same sets of assumptions. The number of adults in the nonbreeding and breeding classes (the fourth and fifth elements for each landownership) were allocated based on deterministic carrying capacity simulations (see above).

*Incorporating Environmental Stochasticity.* The model incorporated the effects of stochasticity by allowing survival and reproductive rates to vary randomly from year to year. After-hatch-year survival rates in year  $t$  were selected randomly from a beta distribution. Selecting survival rates from a beta distribution ensured that survival rates fell between 0 and 1. As discussed above, we set the mean value for annual survival for after-hatch-year murrelets to 0.87 and 0.90 in the *Risk* and *Enhancement* analyses, respectively, based on mark-recapture studies in California (Peery et al. 2006b). Annual variability in survival has not been estimated rigorously for marbled murrelets, but setting the variance in annual survival [ $var(s)$ ] to 0.004 resulted in few years with survival  $< 0.75$ , and thus provided a reasonable degree of biological realism. Frequent survival rates below 0.75 seemed implausible given the modest annual variability in population size estimated from at-sea surveys (Falxa et al. 2016). Juvenile survival in year  $t$  was set to 70% of

after-hatch-year survival such that these two rates are assumed to co-vary perfectly. Stochasticity in reproduction was modeled by first calculating expected fecundity (the number of female juveniles per female adult denoted  $m_{1,t}$  and  $m_{2,t}$  for DNR and non-DNR lands, respectively) which is simply the product of the expected proportion of females that breeders ( $b$ ) and nest success ( $f_{L,t}$ ) divided by 2 (because approximately half of fledging juveniles are female). Fecundity was then randomly selected in year  $t$  from a beta distribution with an expected value of  $m_{L,t}$  and a variance [ $var(m)$ ]. An attempt was made to use the variance in reproductive data from central California, but simply using a value of 0.016 for [ $var(m)$ ] yielded more realistic projections. Fecundity on DNR and non-DNR lands was assumed to be perfectly correlated and vary with the same magnitude. Survival and fecundity were assumed to co-vary independently among years since these vital rates appear to be driven by different environmental processes (Peery et al. 2006b, Becker et al. 2007). The variances of [ $var(s)$ ] = 0.004 for survival and [ $var(m)$ ] = 0.016 for reproduction resulted in a mean coefficient of variation (CV) in simulated populations over the first 15 years (CV = 0.201) that aligned with expectations based on the process variance observed in murrelet at sea counts in WA from 2001 to 2015 (CV = 0.203), when we used demographic values and nesting carrying capacity that led to approximately 5% annual declines ( $s_{\geq 2,L,t} = 0.87$  and  $d_{L,t} = 0$ ).

*Quantifying Population Risk.* For each of the management alternatives (see below), we projected 10,000 simulated populations forward in time for  $t = 50$  years (where  $t = 0$  represented present conditions). To assess patterns of risk, we estimated (i) the mean change in population size between  $t = 0$  and 50 and (ii) the “quasi-extinction probability”, defined as the proportion of simulated populations where  $\sum_{i=1}^x n_{x,L,50}$  was lower than subjectively defined quasi-extinction

thresholds. Quasi-extinction thresholds were set to one half, one quarter, one eighth, and one sixteenth of the starting population size (i.e.,  $\sum_{i=1}^x n_{x,L,0}$ ).

### **Sensitivity Analysis**

While the scenario-based analysis of murrelet population viability allowed us to compare potential effects of proposed forest management alternatives, the relative influence of changes in individual habitat classes (e.g., inner edge vs. interior forest) on murrelets was confounded because the alternatives included simultaneous changes in many or all habitat classes each year throughout the 50-year modeling period. We developed a sensitivity analysis to explore the relative influence of each the nine habitat classes (the three edge types and five Pstage categories) on murrelet populations by simulating a change in one habitat class while controlling for effects of other classes. Specifically, we simulated an immediate loss of 10,000 acres of murrelet habitat in year  $t = 0$  within either (i) one edge class (e.g., inner edge), where Pstage classes were reduced in proportion to their availability within the focal edge class, or (ii) one Pstage class, where edge classes were reduced in proportion to their availability within the focal Pstage class. We created one additional scenario (“acreage”) in which the simulated 10,000-acre loss in habitat occurred proportionally across all 15 edge-Pstage combinations as a basis for comparing the relative influence of habitat amount (raw acreage) vs. habitat quality (e.g., edge conditions, Pstage) on murrelet populations.

Using 10,000 acres (~5.9% of total raw acreage) ensured that proportional losses to certain habitat classes did not exceed their availability on the landscape. For each of the 10 scenarios in the sensitivity analysis we simulated the 10,000-acre loss of habitat in year 0, ran the population model for 50 years under the *Enhancement* parameterization, and repeated 10,000

simulations using SAS 9.3. We then compared the average percent population change on DNR lands after 50 years for all scenarios and compared these changes to a baseline scenario in which no habitat loss occurred. Results of the sensitivity analysis should be interpreted as the relative (as opposed to absolute) influence of different habitat classes (raw acreage, edge, Pstage) on murrelet population growth in the region.

## **RESULTS**

### **Forest Management Scenarios**

Four of the eight management alternatives (C, E, F, and G) were projected to result in a net gain in total acres of nesting habitat on DNR lands at the end of the 50-year modeling (Figure 2a), while the remaining four management alternatives (A, B, D, and H) were projected to result in less total acres of nesting habitat (Figure 2a). All eight management alternatives were projected to result in higher nesting carrying capacity and expected nest success on DNR lands at the end of the 50-year modeling period (Figure 2b-c). Nevertheless, some alternatives differed from one another considerably with respect to all three metrics (Figure 2a-c). The most optimistic scenario for change in raw murrelet habitat was alternative F, in which net habitat increased by 30% over the 50-year modeling period. In contrast, the most pessimistic scenario for change in raw habitat was alternative B, which ended with a net 13% loss in habitat after 50 years. In terms of raw habitat change, the remaining alternatives fell between B and F (Figure 2a). Similarly, differences in nesting carrying capacity (K) among the eight alternatives were bounded on the upper end by alternative F and on the lower end by alternative B. Carrying capacity increased by 149% under alternative F, while alternative B ended with a net 36% increase in nesting carrying

capacity despite a net loss in nesting habitat. Carrying capacities for the remaining alternatives always fell between B and F (Figure 2b). Mean nest success, which contributed to estimates of annual fecundity, generally increased in all scenarios over the first 30 years of the simulation then gradually decreased for the final 20 years (Figure 2c). In contrast to the eight management alternatives, the baseline scenario did not vary temporally but was structured such that the amount of raw habitat, nesting carrying capacity, and mean nest success remained constant over the 50-year modeling period.

Changes to raw habitat, nesting carrying capacity, and nest success for the exploratory variant of alternative H (H – ‘no meter’) can be found in Figure 2d-f. Alternative H – ‘no meter’ tracked alternative H closely except over the first two decades for raw habitat and carrying capacity, because alternative H – ‘no meter’ was not designed to implement the delayed harvesting strategy as in alternative H (Figure 2d-e). Nest success for alternatives H and H – ‘no meter’ was identical (Figure 2f).

### **Population Viability Analysis**

*Risk analysis, DNR population.* In the *Risk* analysis, we observed considerable variation in the probability of the murrelet population on DNR lands reaching quasi-extinction thresholds across the eight management alternatives and baseline scenario (Figure 3). The probability of murrelet populations on DNR lands reaching 1/2 their initial size after 50 years ranged from 0.7805 (alternative F) to 0.9387 (alternative B). Likewise, alternative F defined the lower boundary and alternative B defined the upper boundary of quasi-extinction probabilities for smaller thresholds: at 1/4 of initial N, quasi-extinction probability ranged from 0.3494 (alternative F) to 0.6618 (alternative B); at 1/8 of initial N, quasi-extinction probability ranged from 0.0670 (alternative F)



to 0.2434 (alternative B); and at 1/16 of initial N, quasi-extinction probability ranged from 0.0043 (alternative F) to 0.0387 (alternative B). A complete list of quasi-extinction probabilities for all alternatives is provided in Table 2.

Mean female population size on DNR lands declined from 542 individuals to 200.9 (most optimistic) and 124.8 (most pessimistic) under alternatives F and B representing a 62.9% and 77.0% decline in population size, respectively, after 50 years. Mean female population size for the remaining alternatives (as well as the baseline scenario) fell between that of alternatives F and B after 50 years (Figure 4). A complete list of mean female population sizes at 10-year intervals across the 50-year modeling period is provided in Table 3.

*Risk analysis, Washington population.* In the *Risk* analysis, quasi-extinction probabilities for the Washington murrelet population were much more tightly clustered among the management alternatives (Figure 5). Projections of risk were presumably relatively uniform because modeled management actions were limited to DNR lands, which contained a relatively small portion (~15%) of carrying capacity for murrelets nesting in the state. The probability of the Washington murrelet population reaching 1/2 of its initial size after 50 years ranged from 0.7804 (alternative F) to 0.8150 (alternative B). For the remaining quasi-extinction thresholds, alternative F generally formed the lower bound and alternative B formed the upper bound. At 1/4 of initial N, quasi-extinction probability ranged from 0.2993 (alternative F) to 0.3406 (alternative B); at 1/8 of initial N, quasi-extinction probability ranged from 0.0476 (alternative F) to 0.0534 (alternative B). At 1/16 of initial N, quasi-extinction probability ranged from 0.0024 (alternative E) to 0.0038 (alternative B), although the difference between these probability estimates represents only 14 of 10,000 simulations. A complete list of quasi-extinction probabilities for all alternatives is

provided in Table 2.

Mean female population size on all lands in Washington declined from 3,616 to 1,125 (most optimistic) and 1,065.5 (most pessimistic) under alternatives F and B representing a 68.9% and 70.5% decline in population size, respectively, after 50 years. Mean female population size among the remaining alternatives (as well as the baseline scenario) fell between that of alternatives F and B after 50 years (Figure 6). A complete list of mean female population sizes at 10-year intervals across the 50-year modeling period is provided in Table 3.

*Enhancement analysis, DNR population.* In the *Enhancement* analysis, quasi-extinction probabilities were lower on DNR lands than in the *Risk* analysis (Figure 7). The probability of murrelet populations on DNR lands reaching 1/2 their initial size after 50 years (in the absence of dispersal among land ownerships) ranged from 0.0470 (alternative F) to 0.1863 (alternative B). At 1/4 of initial N, quasi-extinction probabilities among alternatives ranged from 0.0027 (alternative G) to 0.0122 (alternative B); at 1/8 and 1/16 of initial N, quasi-extinction probability was nearly equal to zero across all alternatives (i.e. three or fewer of 10,000 simulations reached quasi-extinction thresholds for all alternatives). A full table of quasi-extinction probabilities for all alternatives is found in Table 2.

With the exception of the baseline scenario, in which female population size continued to decline over the 50-year modeling period, all management alternatives resulted in a murrelet population trajectory characterized by an initial decline for the first 10-20 years followed by a gradual and sustained increase through the end of the modeling period (Figure 8). Female population size on DNR lands increased from 542 individuals to 650.1 (most optimistic) and declined to 388.4 (most pessimistic) under alternatives F and B representing a 20% increase and

28.3% decline in population size, respectively, after 50 years. Mean female population size among the remaining alternatives fell between that of alternatives F and B after 50 years (Figure 8). A complete list of mean female population sizes at 10-year intervals across the 50-year modeling period is provided in Table 3.

*Enhancement analysis, Washington population.* Quasi-extinction probabilities among alternatives for the Washington murrelet population were considerably lower in the *Enhancement* than the *Risk* analysis (Figure 9). The probability of the Washington murrelet population reaching 1/2 of its initial size after 50 years ranged from 0.0488 (alternative F) to 0.0737 (alternative B). Quasi-extinction probability was nearly equal to zero for all other thresholds among all alternatives (i.e. fewer than 25 of 10,000 simulations reached quasi-extinction thresholds for all alternatives). A complete list of quasi-extinction probabilities for all alternatives is provided in Table 2.

In contrast to the *Risk* analysis, in which the Washington murrelet population followed a relatively steep and steady decline throughout the 50-year modeling period, female population size in the *Enhancement* analysis declined for 20-30 years but then remained approximately stable for the remainder of the modeling period across all alternatives (Figure 10). Female population size in the state of Washington declined from 3,616 individuals to 2,734.2 (most optimistic) and 2,454.2 (most pessimistic) individuals under alternatives F and B representing a 24.4% and 32.1% decline in population size, respectively, after 50 years. Mean female population size among the remaining alternatives fell between that of alternatives F and B after 50 years (Figure 10). A complete list of mean female population sizes at 10-year intervals across the 50-year modeling period is provided in Table 3.

*Exploratory analyses with variant of alternative H.* We evaluated the exploratory variant of alternative H under the *Risk* and *Enhancement* scenarios for DNR lands only. In the *Risk* analysis, quasi-extinction probabilities were always higher for alternative H – ‘no meter’ compared with alternative H (Figure 3, Table 2). The probability of the murrelet population on DNR lands reaching 1/2 its initial population size after 50 years was 0.8864 for alternative H – ‘no meter’ and 0.8467 for alternative H. At 1/4 of initial N, the quasi-extinction probability was again higher for alternative H – ‘no meter’ (0.5326) compared to alternative H (0.4282) and the same pattern continued at 1/8 and 1/16 of initial N (Figure 3, Table 2). Female population size declined from 542 individuals to 153.0 and 176.5 individuals under alternatives H – ‘no meter’ and H, respectively, after 50 years (Figure 4). A complete list of quasi-extinction probabilities is provided in Table 2, and mean female population sizes at 10-year intervals is provided in Table 3.

Similar to the *Risk* analysis, quasi-extinction probabilities in the *Enhancement* analysis were higher for alternative H – ‘no meter’ than for alternative H. At 1/2 of initial N, quasi-extinction probability was 0.1057 for alternative H – ‘no meter’ followed by alternative H (0.0870). This pattern persisted at 1/4 of initial N but the differences among scenarios was smaller; quasi-extinction probability was 0.0056 for alternative H – ‘no meter’ and 0.0043 for alternative H. At 1/8 and 1/16 of initial N, quasi-extinction probability was nearly zero for both alternatives (Figure 7, Table 2). Mean female population size declined from 542 individuals to 476.3 and 487.6 individuals under alternatives H – ‘no meter’ and H, respectively, after 50 years (Figure 8, Table 3). A complete list of quasi-extinction probabilities is provided in Table 2, and mean female population sizes at 10-year intervals is provided in Table 3.

## **Sensitivity Analysis**

Murrelet population growth was most sensitive to changes in the highest Pstage (habitat quality) classes 0.89 and 0.62; reducing the prevalence of these habitat classes on the landscape by 10,000 acres resulted in population estimates that were 18.7% and 13.4% lower than the baseline (static habitat) scenario after 50 years, respectively. Removing 10,000 acres of murrelet habitat across the 18 Pstage-edge class combinations in proportion to their availability ('acreage') resulted in a population estimate 10.4% lower than the baseline, which had a slightly weaker effect on murrelet population growth than removing 10,000 acres of interior forest (11.6% lower than baseline). Removing inner edge and outer edge resulted in final populations 9.1% and 8.1%, lower than the baseline scenario, respectively. Removing 10,000 acres of Pstages 0.47, 0.36, and 0.25 resulted in final populations 10.2%, 8.0%, and 5.9% lower than the baseline scenario, respectively (Figure 11).

## **DISCUSSION**

### **Implications for Population Risk and Enhancement**

We developed a stochastic, demographic meta-population model to compare the relative differences among alternative forest management strategies for DNR lands on the viability of marbled murrelet populations in the state of Washington. Moreover, we carried out parallel *Risk* and *Enhancement* analyses to help assess the relative manner in which proposed management actions were projected to increase population risk or the likelihood of population recovery given that it was not possible to assess both of these HCP considerations with a single analysis. Two

alternatives (B and D) were projected to reduce murrelet population size compared to alternative A (“no-action”; i.e., continued management under the 1997 HCP guidelines) on DNR lands if murrelet populations continue to decline as a result of environmental factors unrelated to changes in nesting habitat quality and quantity (i.e., under the *Risk* analysis), but only alternative B reduced murrelet population size compared to alternative A when all lands were considered (Table 3). Conversely, our findings suggest that all other alternatives (C, E-H) are expected to lead to larger murrelet populations than alternative A should the population continue to decline as a result of these factors. Alternative B appeared to provide less capacity for murrelet populations to increase in size than alternative A, whereas alternatives C through H led to larger murrelet populations than alternative A, under the assumption that environmental stressors likely impacting murrelets are ameliorated (i.e., in the *Enhancement* analysis). The same patterns were generally observed for quasi-extinction probabilities.

Differences in ending population size among the proposed alternatives were greater when inference was limited to the “DNR population” as opposed to the entire state of Washington, particularly when differences were considered on a percentage basis. Compared to the “no-action” alternative (A), ~1.3 times as many murrelets were expected to occur on DNR lands under alternative F after 50 years according to both *Risk* and *Enhancement* analyses (i.e., a 30% difference). While percentage differences in ending population sizes among alternatives were greater for the DNR “population” than they were for the entire Washington population, differences in the number of individuals among alternatives were more similar at the two spatial scales. For example, the difference in mean ending population size between alternative F and “no-action” (alternative A) alternatives was 48.3 for DNR lands and 36.3 individuals for the state of Washington in the *Risk* analysis. Thus, differences in abundance among the alternatives at the

state level were largely the result of changes in abundance on DNR lands, which were included in state level projections of population sizes.

### **Comparison of Individual Alternatives**

For both *Risk* and *Enhancement* analyses, alternative B consistently resulted in the lowest projected murrelet numbers after the 50-year simulation period, and generally had the highest quasi-extinction probabilities. Alternative B was the only proposed alternative that resulted in lower murrelet numbers than the “no-action” alternative (alternative A) in all analyses; both *Risk* and *Enhancement* analyses at the scale of DNR lands and the state of Washington. This finding was, to a certain extent, consistent with the fact that alternative B would include the least (576,000 acres) LTFC among all alternatives. By comparison, the “no-action” alternative (A) would involve the protection of 600,000 acres of LTFC. Compared to the “no-action” alternative (see above for details), alternative B focused only on protecting the known locations of marbled murrelet occupied sites on forested state trust lands, and was the only alternative that did not provide buffers on occupied sites. Similar to alternative B although to a lesser extent, alternative D sometimes also yielded lower projected murrelet numbers than alternative A after 50 years for both DNR lands and the state of Washington under the *Risk* analysis, but yielded slightly higher numbers than alternative A under the *Enhancement* analysis (Table 3).

In contrast, alternative F consistently resulted in the highest projected murrelet numbers after the 50-year simulation period for both *Risk* and *Enhancement* analyses. At the state level, alternative F was projected to lead to an average of 59.5 and 280 more female murrelets than alternative B under the *Risk* and *Enhancement* scenarios, respectively. Alternative F also generally had the lowest quasi-extinction probabilities. Under alternative F, 101,000 more acres

(743,000 acres total) of LTFC than any other alternative (alternative G being the second most conservative, involving the protection of 642,000 acres).

In sum, alternative B posed the greatest risk to murrelet populations and alternative F (often closely followed by alternative G) provided the greatest capacity to enhance murrelet populations. Importantly, our population simulations suggested that alternatives F and B were generally the “best” and “worst”, respectively, with respect to murrelet population viability for DNR lands and the state of Washington in both the *Risk* and *Enhancement* analyses. This result is useful from a forest management perspective, because whether or not unrelated chronic environmental stressors are alleviated (i.e., the major difference in model assumptions between *Risk* and *Enhancement* analyses), alternative F is predicted to have the most positive effect on murrelet populations over the next 50 years because it provides the greatest amount of habitat and carrying capacity with the least edge effects.

Alternative H with delayed harvest suggested that harvesting over two decades as opposed to one decade (Figure 2d) ultimately translates to greater murrelet numbers and lower quasi-extinction probabilities (Tables 2 and 3). The delayed pace of harvest appears to balance with forest growth and development such that although harvesting under H results in a decline of overall habitat in the first 20 years of the simulation (Figure 2d), nesting carrying capacity remains steady and begins to increase over the same period (Figure 2e). This steady and increasing carrying capacity in the initial years of alternative H alleviates the downward pressure that projected murrelet populations experience when harvest is more rapid, resulting in greater capacity for population growth and therefore greater murrelet numbers.



## **Sensitivity of Marbled Murrelet Populations to Habitat Change**

The sensitivity analysis suggested that murrelet populations were most sensitive to changes in the amount of higher-quality nesting habitat (Pstages 0.89 and 0.62), which exerted a stronger influence on modeled trajectories than changes in either the raw amount of nesting habitat or edge conditions (habitat configuration). Murrelet nests are typically located in large, decadent platform-bearing trees which, because of their age and economic value are relatively uncommon across the landscape and likely represent a limiting factor with respect to murrelet population densities (Burger 2001, Raphael et al. 2002). Because the highest Pstage classes represent forest stands with greater densities of platform-bearing trees suitable for nesting and presumably higher levels of murrelet use, it is therefore unsurprising that murrelet population growth appeared to be more sensitive to loss of the highest-quality habitat which, acre-for-acre, has a disproportionate influence on the population density of breeding-age murrelets. While change in habitat configuration (edge) was linked to nest success as well as nesting density in our analytical model, it nevertheless had a relatively modest influence on murrelet population growth presumably because the proportion of interior forest is considerably higher for the highest Pstages than the other categories on DNR-managed land (WDNR and USFWS 2018).

## **Caveats and Future Directions**

Our model was parameterized with published demographic information collected for marbled murrelets from intensive field studies and structured based on a reasonable understanding and interpretation of murrelet ecology and nesting habitat needs. Moreover, the reproductive component of the model was informed by detailed assessments forest conditions in the state of Washington, and particularly on DNR lands. However, changes in climate and other

environmental factors, particularly in the marine environment, that were not considered explicitly here likely also impact murrelet population dynamics and will continue to do so in the future. For example, unanticipated increases in marine stressors could further diminish murrelet populations regardless of projected increases to the amount and quality of nesting habitat. Nevertheless, the scope of this analysis was to estimate the potential and relative effect of habitat management alternatives using parameters largely under the control of land management agencies. Future areas of research could involve the development of a population model that more explicitly links risk to, for example, potential future changes in climate, oil spills, fisheries interactions, and predators.

As is always the case in PVA analyses, our model required a number of simplifying assumptions. We assumed that murrelets recruiting into the breeding population (e.g., 2-year subadults) selected nesting habitat independent of quality. Rather, individuals recruited into habitat types “proportionally” such that if, for example, three murrelets recruited into the breeding population, ~2 would do so into  $P_{\text{stage}} = 0.47$  habitat and ~1 would recruit into  $P_{\text{stage}} = 0.25$  habitat, even if additional nests were available in  $P_{\text{stage}} = 0.47$  habitat. Second, we assumed that breeders remained in the same landownership unless they were displaced by habitat loss, and thus assumed that only nonbreeding individuals recruiting into the breeding population dispersed among landownerships. In other words, natal dispersal was permitted but, in the absence of habitat loss, breeding dispersal was not. Third, we assumed that displaced breeders (by habitat loss) could become nonbreeders for at least one year (for analytical tractability) and that displaced breeders could become breeders again if nesting habitat was available the year after they became nonbreeders. All of these aspects of murrelet breeding ecology are not well understood, and violations of associated assumptions could influence inferences regarding risk to

the population.

Population viability analyses range from simple count-based approaches to more complicated spatially-explicit demographic meta-population approaches (Morris and Doak 2002). Here, we used a two-population model (DNR vs non-DNR lands) as a simplification of the complex spatial arrangement of murrelet nesting habitat in Washington given time and budgetary constraints, this simplification being agreed upon by DNR and FWS. However, the spatial arrangement of murrelet nesting habitat likely plays an important role in murrelet movement and dispersal processes throughout the state. Future efforts using spatially-explicit models could provide geographically-targeted (local) estimates of risk, prioritize stands for conservation and management, and generate more realistic insights into how changes in the spatial arrangement of nesting habitat may influence regional murrelet population viability. However, uncertainty about the landscape ecology of murrelet habitat selection and use as well as dispersal processes could obscure inference from such an effort. Finally, we note that results from PVA analyses such as ours typically constitute one of many sources of information (e.g., habitat mapping, expert opinion, etc.) that can inform species conservation and land management decisions and we recommend that they be treated as such.

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## TABLES AND FIGURES



**Table 1.** Parameter values used in the marbled murrelet meta-population model.

Parameter	Analysis	DNR	non-DNR	Reference/Justification
Initial (female) population size ( $n_{x,L,0}$ )	Both	$\sum_{i=1}^x n_{x,1,0} = 542$	$\sum_{i=1}^x n_{x,2,0} = 3,074$	Falxa <i>et al.</i> (2016); Lance and Pearson (2016)
Initial (female) adult non-breeders ( $n_{4,L,0}$ )	Both	$n_{4,1,0} = 145$	$n_{4,2,0} = 819$	40% of adult females begin as non-breeders because the population is above carrying capacity
Initial (female) adult breeders ( $n_{5,L,0}$ )	Both	$n_{5,1,0} = 217$	$n_{5,2,0} = 1,229$	
Mean 1-year old survival rate ( $s_{1,L,t}$ )	Both	$s_{1,1,t} = s_{2,1,t} \cdot 0.7$	$s_{1,2,t} = s_{2,2,t} \cdot 0.7$	Peery <i>et al.</i> (2006a, b)
Mean >1-year old survival rates ( $s_{2,L,t}$ )	Risk	$s_{2,1,t}, \dots, s_{5,1,t} = 0.87$	$s_{2,2,t}, \dots, s_{5,2,t} = 0.87$	Peery <i>et al.</i> (2006a, b)
Variance in survival rates	Enhancement	$s_{2,1,t}, \dots, s_{5,1,t} = 0.90$	$s_{2,2,t}, \dots, s_{5,2,t} = 0.90$	Peery <i>et al.</i> (2006a, b)
Maximum dispersal rate ( $d_{L,t}$ )	Risk, Enhancement (WA population)	$d_{1,t} = 0.85$	$d_{2,t} = 0.15$	Equal to proportion of murrelet habitat on DNR and non-DNR lands, lower if

only)				number of dispersers exceeds availability of nest sites in other landownership
<i>Enhancement</i> (DNR population only)		$d_{1,t} = 0$	$d_{2,t} = 0$	Assumes DNR and non-DNR populations are demographically independent
Proportion of breeders (possess a nest site) that breed per year ( $b$ )	Both	$b = 0.90$	$b = 0.90$	Peery <i>et al.</i> (2004)
Mean nest success rate ( $f_{L,0}$ )	Both	$f_{1,0} = 0.5347$	$f_{2,0} = 0.5418$	See Appendix A
Fecundity rate ( $m_{L,t}$ )	Both	$f_{1,\geq 1}$ varies by management alternative	$f_{2,\geq 1}$ remains constant	
Variance in fecundity rate	Both	$m_{1,t} = \frac{b \cdot f_{1,t}}{2}$	$m_{2,t} = \frac{b \cdot f_{2,t}}{2}$	
Carrying capacity (number of nests) ( $K_{L,t}$ ), scaled	Both	$var(m) = 0.016$	$var(m) = 0.016$	Yields coefficient of variation (CV) in simulated populations similar to process CV in population estimates from at-sea surveys
		$K_{1,0}=217$	$K_{2,0} = 1,229$	See Appendix A
		$K_{1,\geq 1}$ varies by management alternative	$K_{2,\geq 1}$ remains constant	

**Table 2.** Quasi-extinction probabilities for proposed forest management alternatives (A – H) under the *Risk* and *Enhancement* analyses. Note that a quasi-extinction probability of 0.0001 represents 1 out of 10,000 simulations.

Alternative	<i>Risk - DNR lands</i>				<i>Risk - Washington</i>			
	Fraction of Initial Population Size				Fraction of Initial Population Size			
	1/16	1/8	1/4	1/2	1/16	1/8	1/4	1/2
A	0.0220	0.1581	0.5292	0.8879	0.0029	0.0506	0.3214	0.8039
B	0.0387	0.2434	0.6618	0.9387	0.0038	0.0534	0.3406	0.8150
C	0.0131	0.1230	0.4644	0.8458	0.0026	0.0493	0.3158	0.7950
D	0.0253	0.1652	0.5449	0.8869	0.0036	0.0526	0.3274	0.7985
E	0.0099	0.1059	0.4423	0.8330	0.0024	0.0507	0.3215	0.7880
F	0.0043	0.0670	0.3494	0.7805	0.0029	0.0476	0.2993	0.7804
G	0.0055	0.0725	0.3709	0.7914	0.0034	0.0496	0.3132	0.7827
H	0.0061	0.0895	0.4282	0.8467	0.0033	0.0528	0.3187	0.7916
H (no meter)	0.0217	0.1653	0.5326	0.8864	-	-	-	-
Baseline	0.0086	0.1022	0.4637	0.8970	0.0032	0.0529	0.3237	0.8034

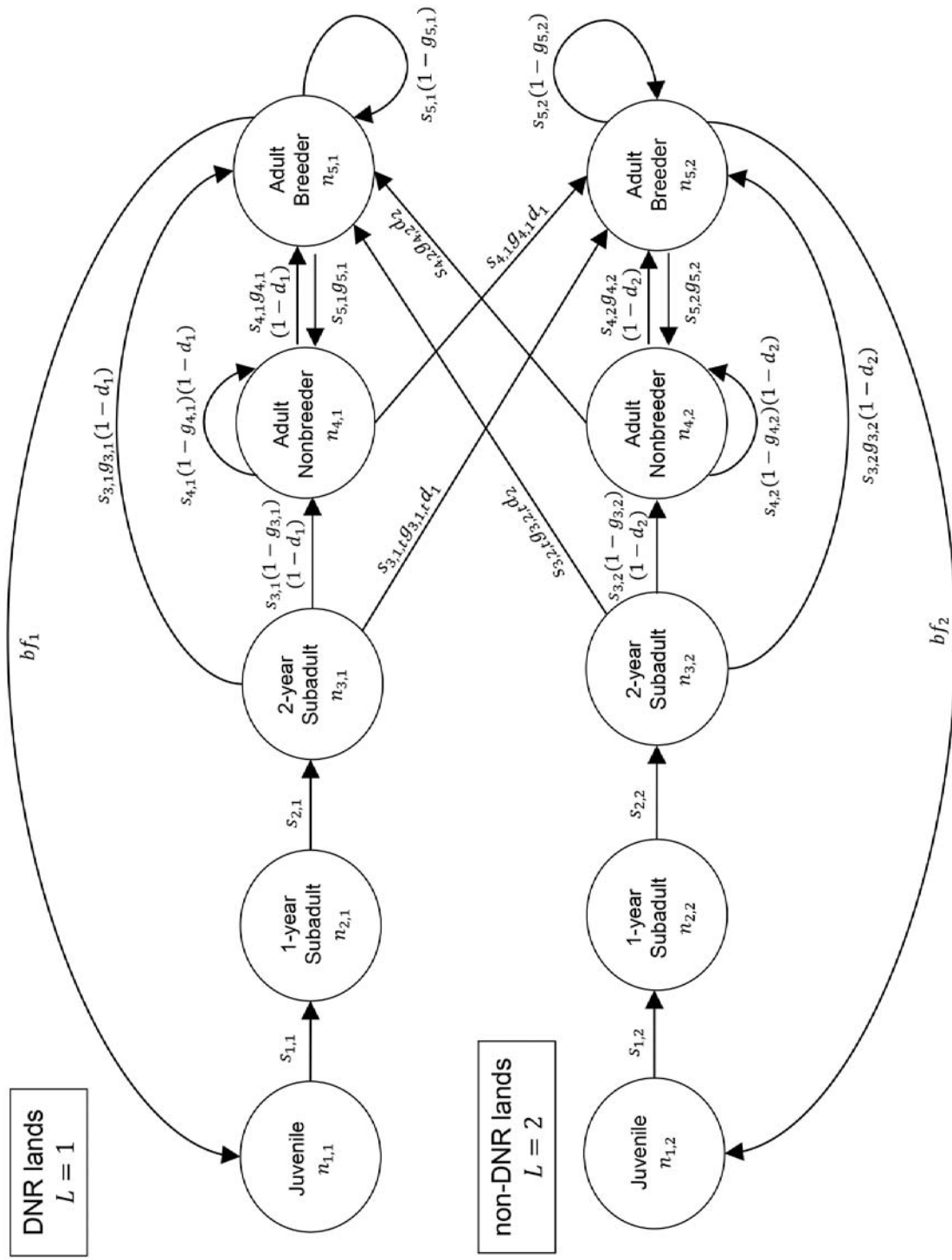
Alternative	<i>Enhancement - DNR lands</i>				<i>Enhancement - Washington</i>			
	Fraction of Initial Population Size				Fraction of Initial Population Size			
	1/16	1/8	1/4	1/2	1/16	1/8	1/4	1/2
A	0	0.0001	0.0059	0.0981	0	0	0.0017	0.0664
B	0	0.0003	0.0122	0.1863	0	0	0.0016	0.0737
C	0	0.0003	0.0053	0.0682	0	0.0001	0.0024	0.0600
D	0	0.0003	0.0058	0.1030	0	0.0002	0.0022	0.0627
E	0	0	0.0040	0.0732	0	0.0001	0.0020	0.0574
F	0	0	0.0035	0.0470	0	0	0.0019	0.0488
G	0	0	0.0027	0.0545	0	0	0.0014	0.0584
H	0	0.0001	0.0043	0.0870	0	0	0.0026	0.0583
H (no meter)	0	0.0001	0.0056	0.1057	-	-	-	-
Baseline	0	0.0001	0.0055	0.1616	0	0.0001	0.0029	0.0676

**Table 3.** Projected mean population sizes (average of 10,000 simulations) at each 10-year interval for proposed forest management alternatives (A – H) in the *Risk* and *Enhancement* analyses.

Alternative	<i>Risk - DNR lands</i>					<i>Risk - Washington</i>						
	0	10	20	30	50	0	10	20	30	50		
A	542	306.4	240.5	208.1	179.2	152.6	3616	2320.3	1837.3	1533.0	1291.5	1088.7
B	542	277.6	194.8	168.5	145.6	124.8	3616	2294.2	1806.2	1500.2	1260.3	1065.5
C	542	326.9	272.4	233.5	201.7	172.5	3616	2338.3	1873.4	1549.7	1311.9	1110.1
D	542	302.2	237.1	205.7	176.7	152.1	3616	2310.5	1837.3	1530.7	1287.3	1096.5
E	542	336.7	280.0	242.0	207.7	177.9	3616	2345.8	1869.6	1557.7	1312.0	1114.0
F	542	371.9	318.8	274.8	235.3	200.9	3616	2362.3	1892.0	1576.7	1327.5	1125.0
G	542	366.4	310.1	266.6	228.5	196.0	3616	2355.3	1875.9	1562.2	1316.9	1119.5
H	542	350.0	279.0	238.1	205.2	176.5	3616	2345.0	1862.5	1551.1	1310.5	1114.1
H (no meter)	542	305.6	239.7	206.3	178.3	153.0	-	-	-	-	-	-
Baseline	542	348.6	275.9	227.1	188.2	157.5	3616	2340.0	1863.2	1545.2	1291.0	1088.8

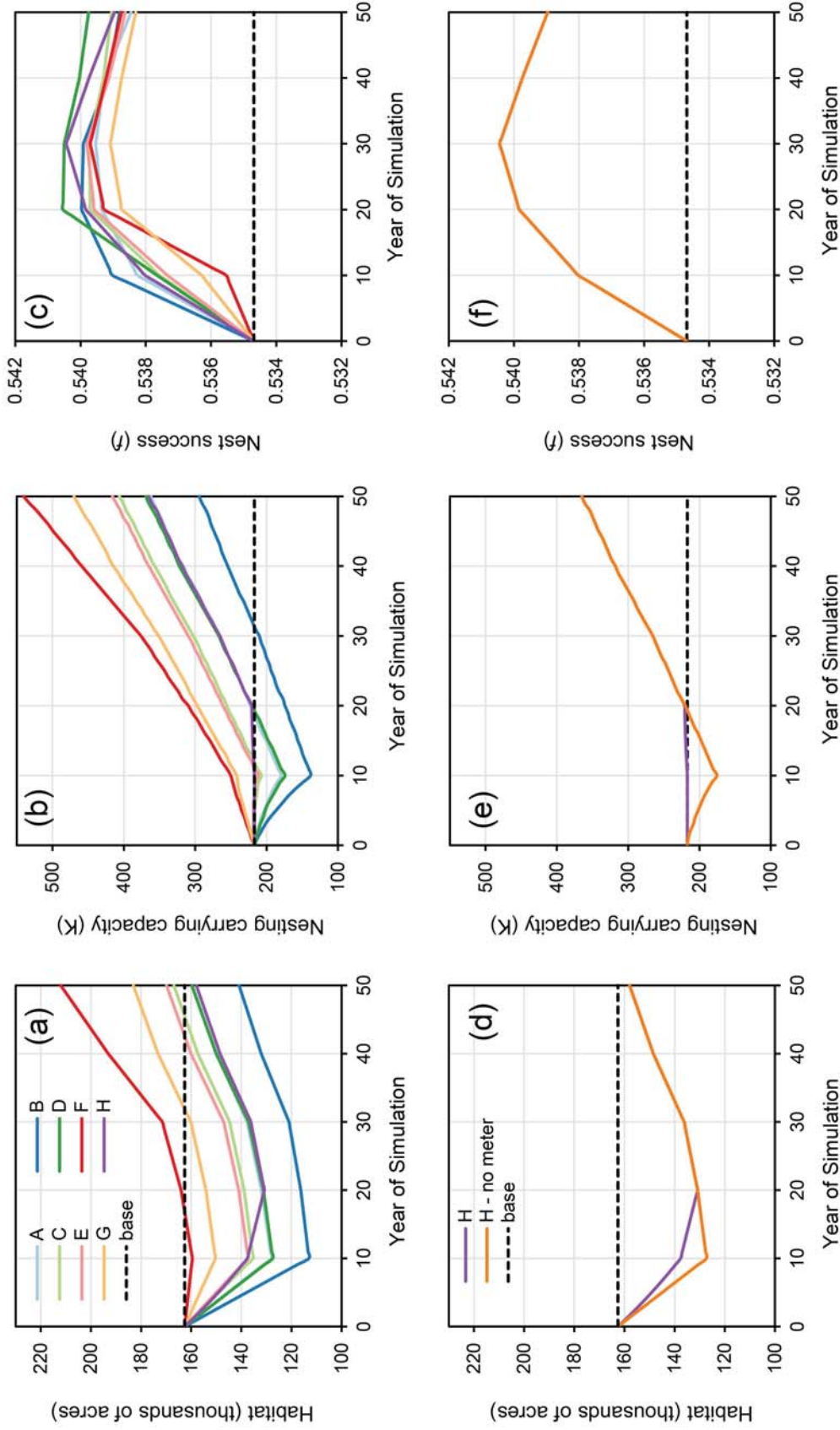
  

Alternative	<i>Enhancement - DNR lands</i>					<i>Enhancement - Washington</i>						
	0	10	20	30	50	0	10	20	30	50		
A	542	407.4	374.1	394.1	432.9	478.5	3616	2868.3	2616.6	2522.4	2514.4	2531.8
B	542	379.2	315.2	324.1	352.4	388.4	3616	2842.8	2558.0	2472.4	2452.8	2454.2
C	542	427.7	413.6	442.4	485.2	534.8	3616	2885.0	2647.5	2582.6	2578.5	2599.8
D	542	403.9	370.7	393.7	434.2	482.2	3616	2863.2	2613.3	2540.2	2530.6	2541.0
E	542	430.8	419.7	449.0	495.2	544.2	3616	2886.9	2658.6	2585.1	2576.5	2598.4
F	542	458.0	470.2	516.1	575.3	650.1	3616	2918.2	2715.3	2661.2	2681.0	2734.2
G	542	451.4	457.4	495.1	547.3	608.0	3616	2913.7	2701.3	2635.2	2632.8	2671.3
H	542	431.8	397.5	407.3	444.4	487.6	3616	2893.2	2649.2	2557.9	2537.3	2557.7
H (no meter)	542	405.5	371.0	391.1	430.6	476.3	-	-	-	-	-	-
Baseline	542	431.1	392.3	374.1	365.4	357.5	3616	2890.0	2640.1	2526.3	2466.8	2427.8



**Figure 1.** Life-cycle diagram for the demographic meta-population model used to evaluate the potential effects of Washington DNR's

management alternatives on marbled murrelets.  $n_{x,L}$  represents the number of female murrelets;  $s_{x,L}$  represents the survival probability;  $g_{x,L}$  represents the transition probability;  $d_L$  represents the dispersal probability;  $b$  represents the breeding probability;  $f_L$  represents nest success rate; the subscript  $x = 1, 2, \dots, 5$  represents stage classes juvenile, 1-year subadult, 2-year subadult, adult nonbreeder, and adult breeder, respectively; the subscript  $L = 1, 2$  represents DNR and non-DNR lands, respectively. Note that time  $t$  was not included in the diagram for simplicity.

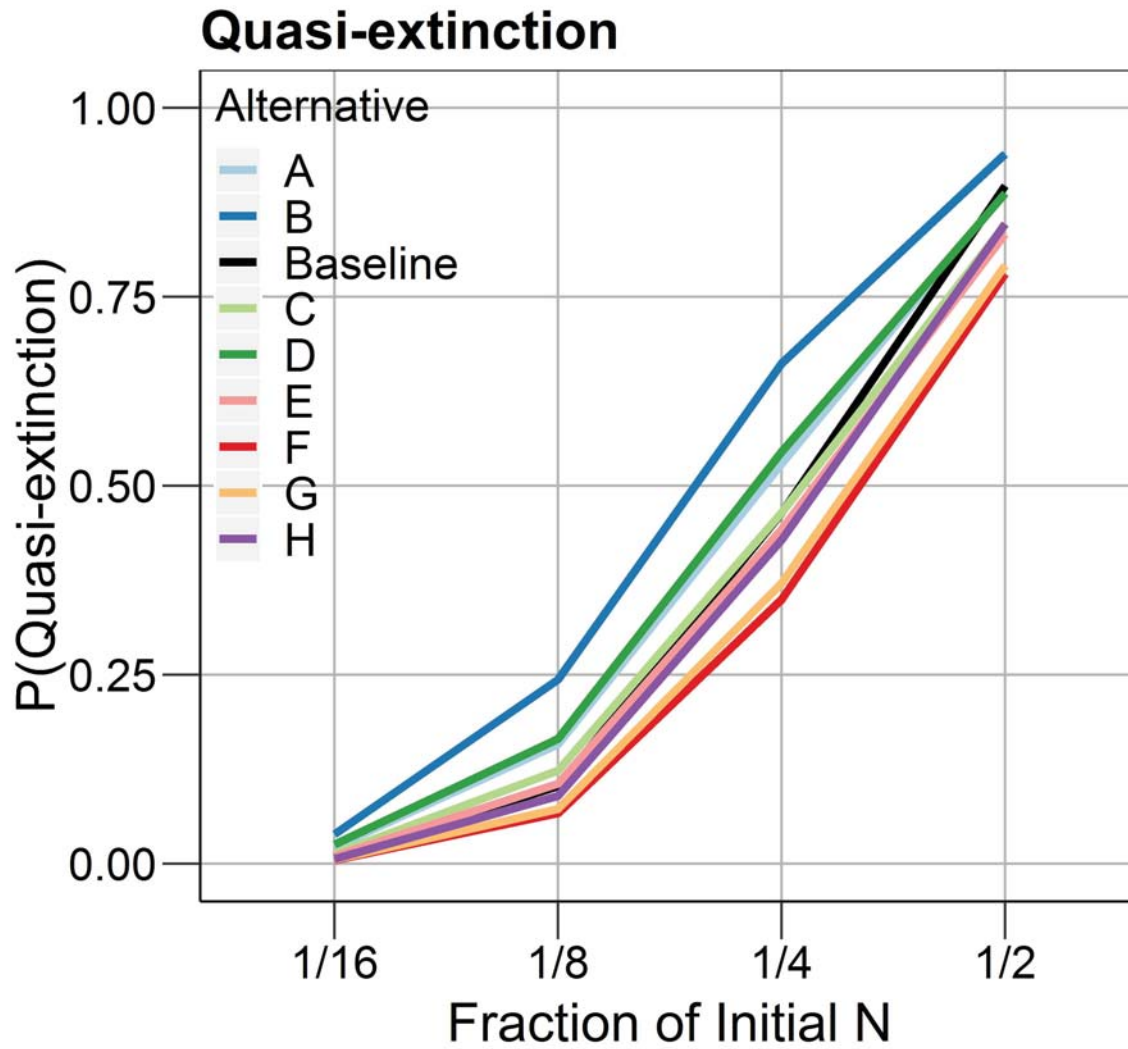


**Figure 2.** Forest management alternatives proposed by the Washington DNR and the U.S. Fish and Wildlife Service. The raw amount of nesting habitat, carrying capacity, and nest success on DNR-managed lands for each of the primary alternatives (A – H) over the modeling period are presented in panels a – c, respectively. Habitat “strings” are not included in these estimates. The same measures

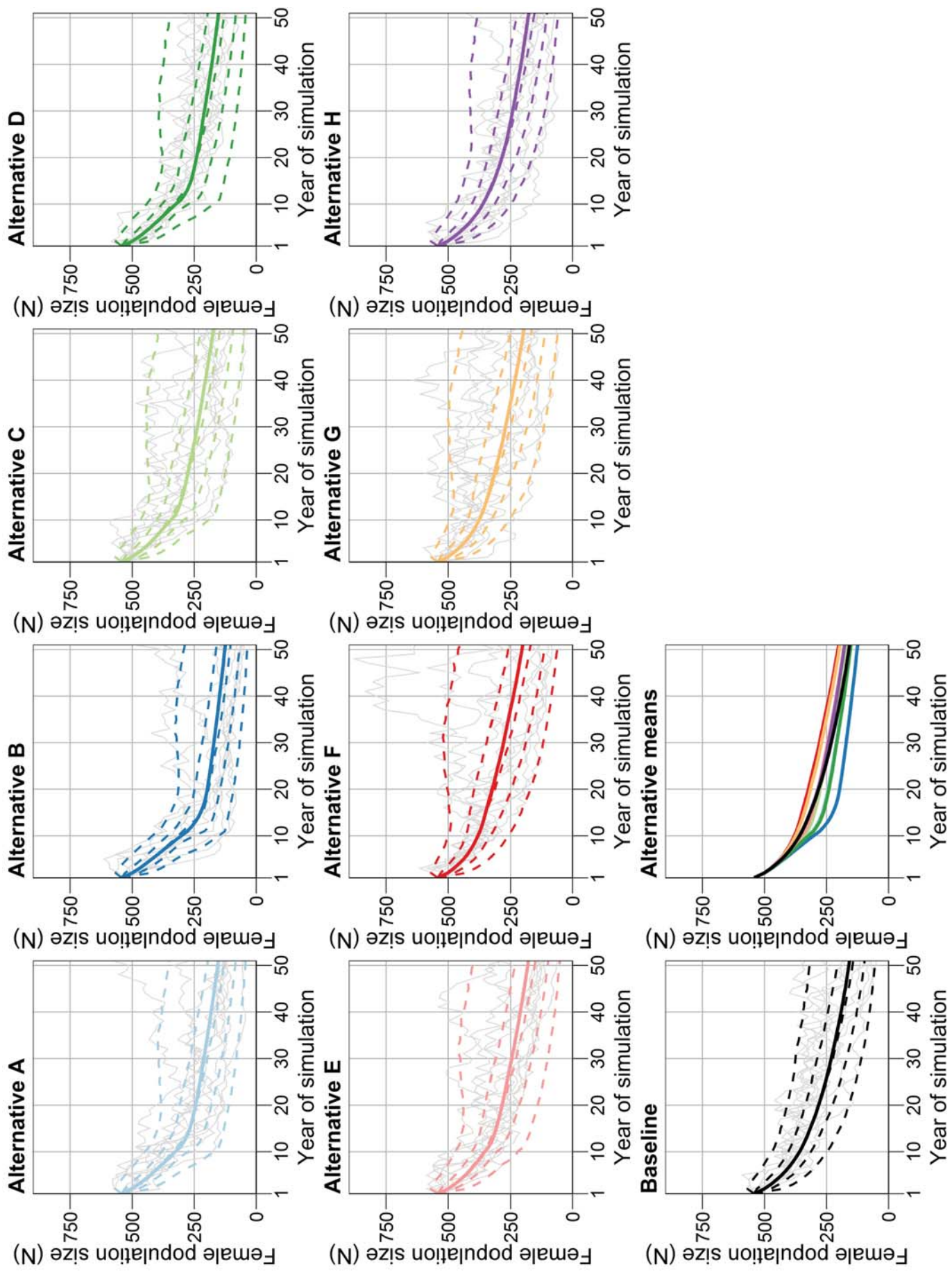
for the exploratory alternative (H – ‘M’) is shown in panels d – f, and includes alternative H for the purposes of comparison.

Note: The lines showing nest success for alternatives H and H-M are on top of one another.

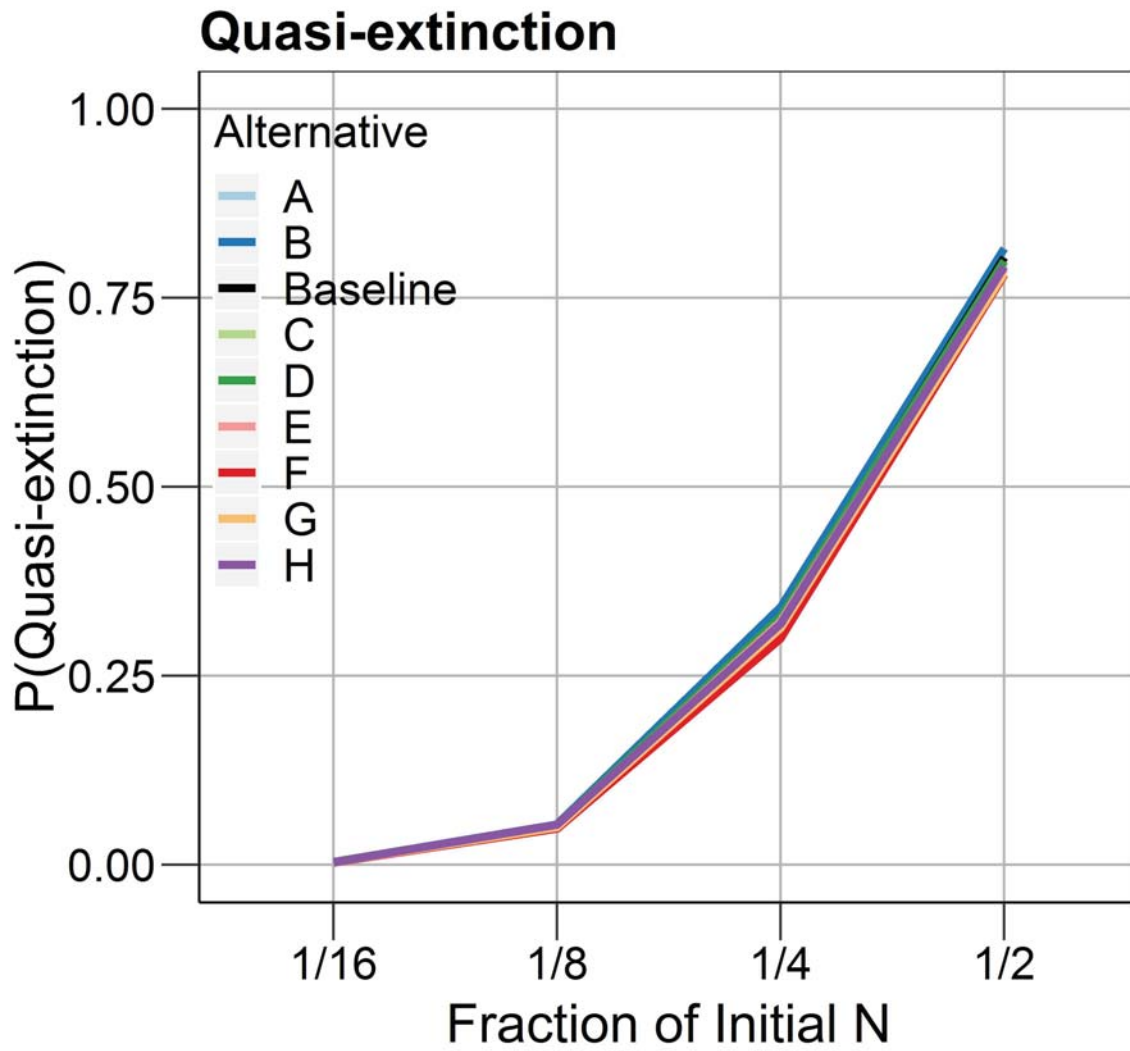




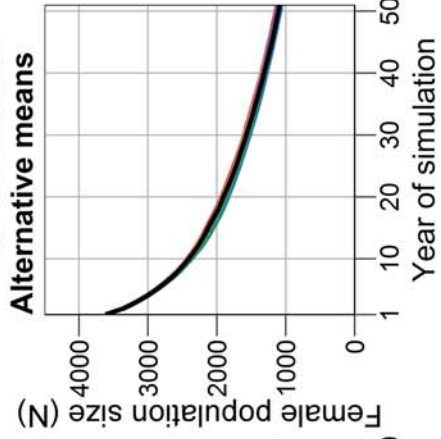
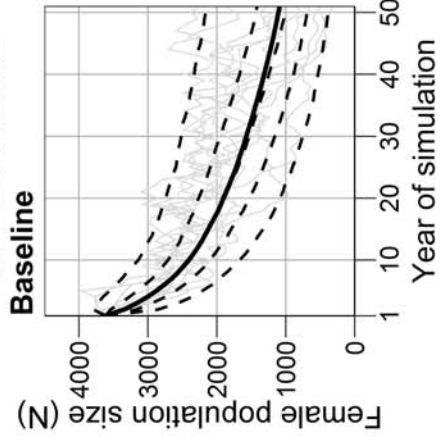
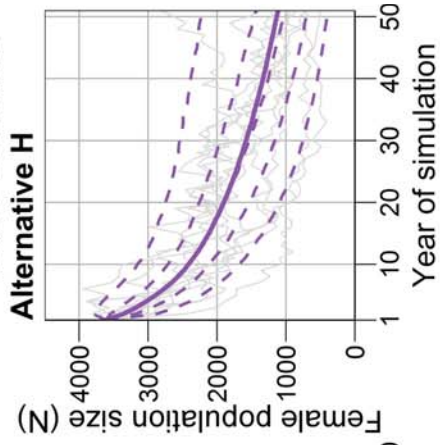
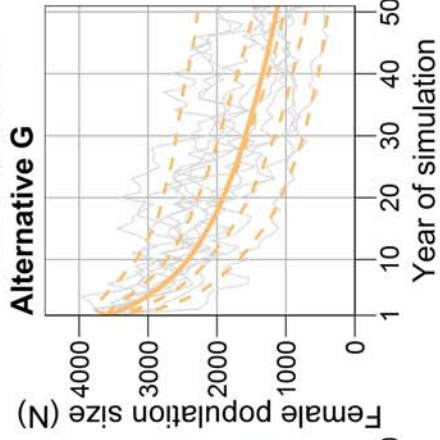
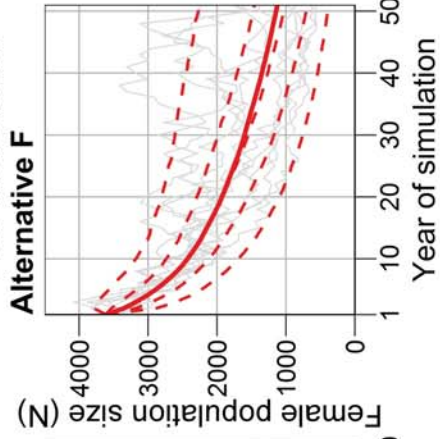
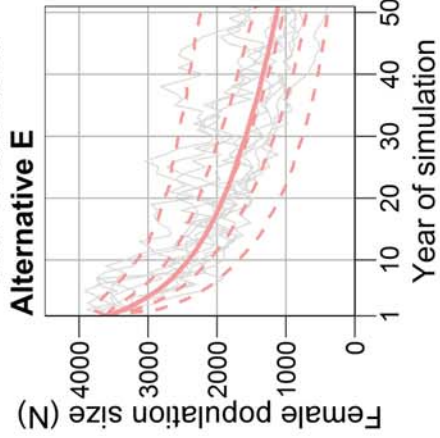
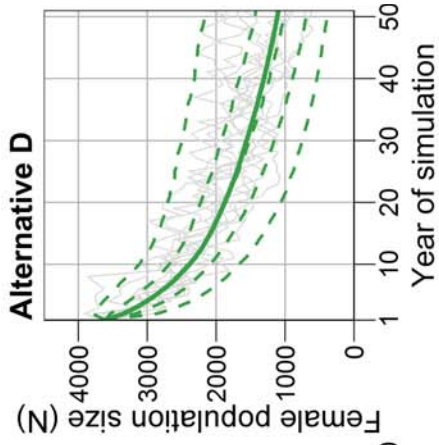
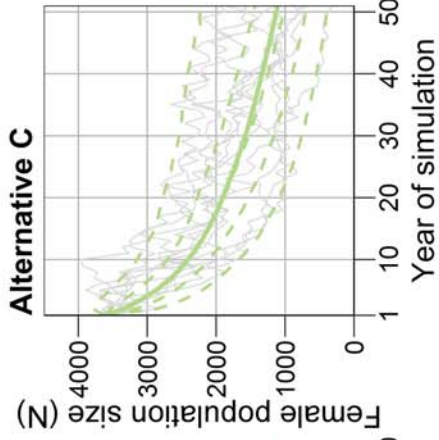
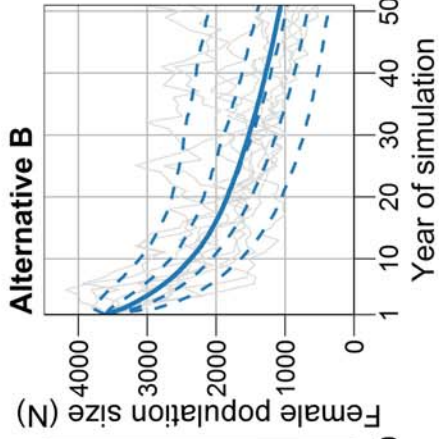
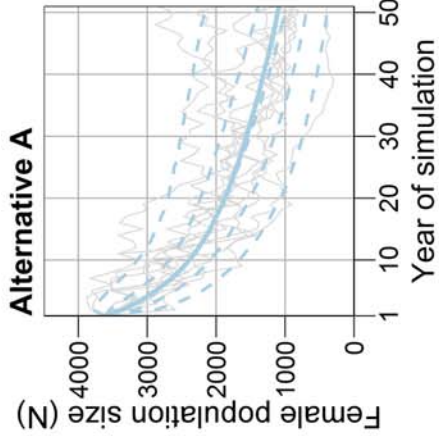
**Figure 3.** Risk analysis – DNR lands. Quasi-extinction probabilities (proportion of 10,000 simulations that reached a specified fraction of initial population size) for the proposed management alternatives.



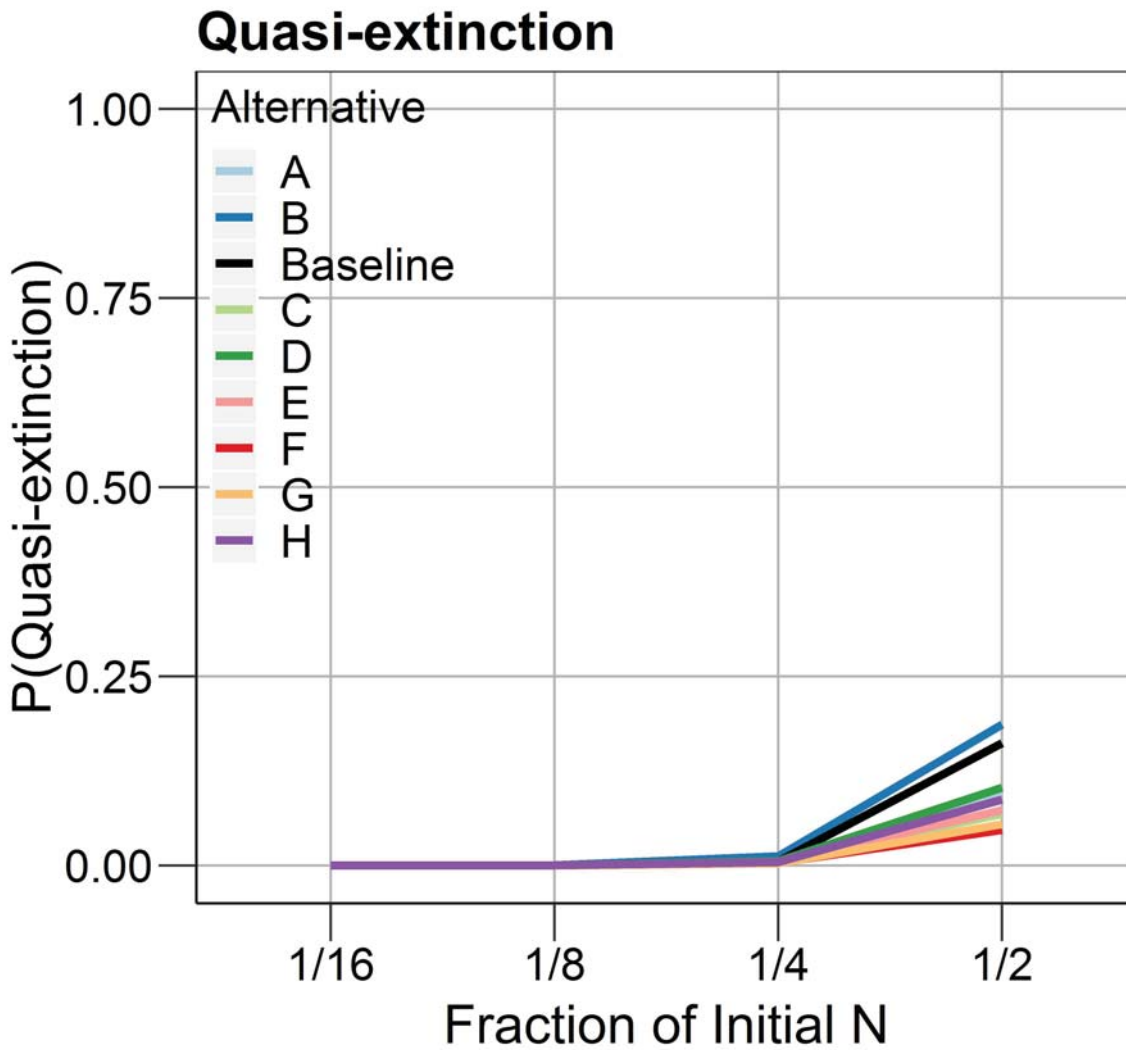
**Figure 4.** *Risk analysis – DNR lands.* Projected murrelet population sizes as a function of proposed management alternatives. In each panel the solid colored line represents the mean annual population size averaged over 10,000 simulations, the dashed colored lines represent the 5%, 25%, 50% (median), 75%, and 95% quantiles, and the grey lines represent a random subsample ( $n = 10$ ) of individual simulation outcomes. The bottom-right panel (“Alternative means”) plots the mean from each alternative on a single graph for the purposes of comparison.



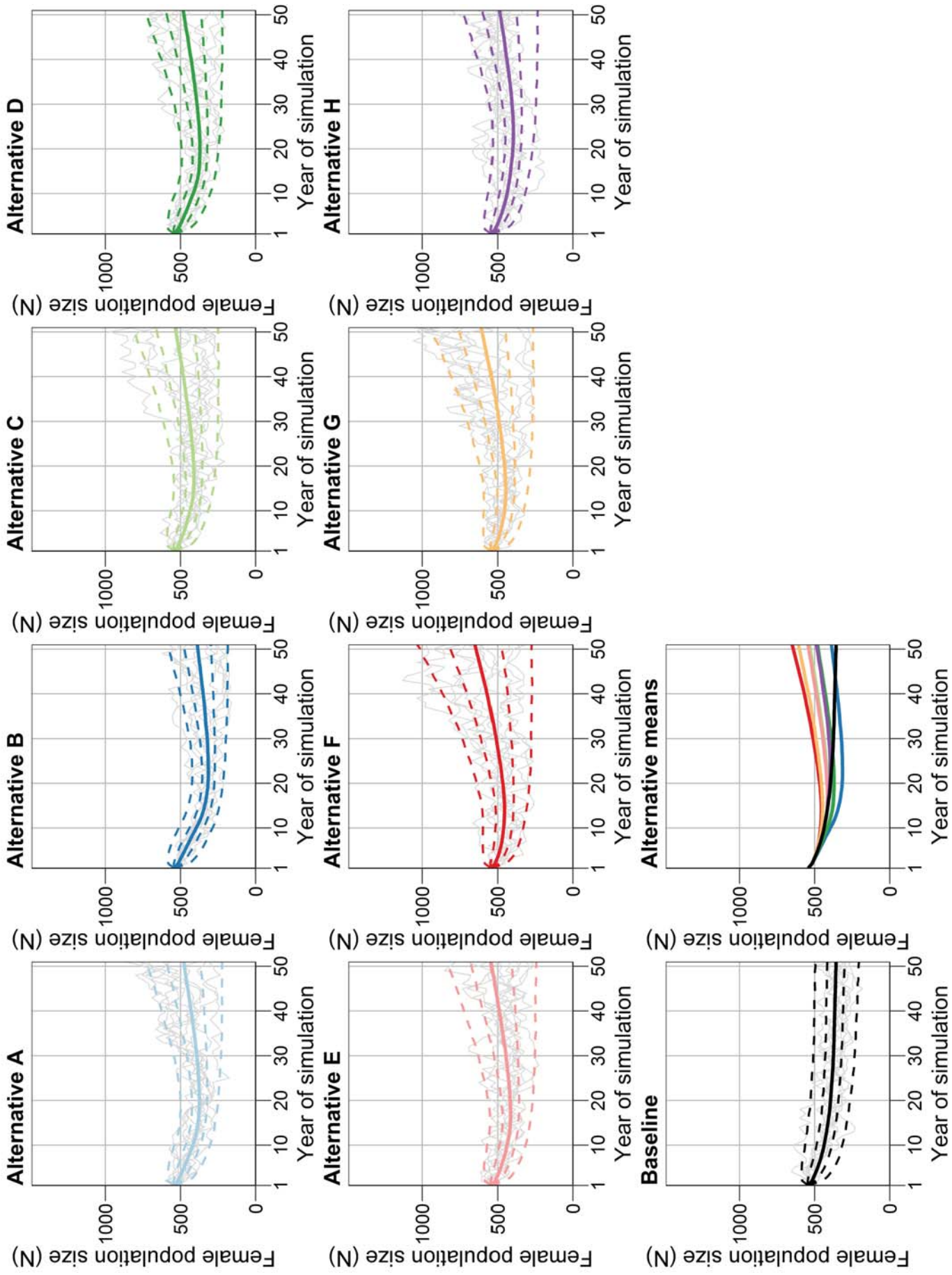
**Figure 5.** *Risk analysis – Washington.* Quasi-extinction probabilities (proportion of 10,000 simulations that reached a specified fraction of initial population size) for the proposed management alternatives.



**Figure 6.** *Risk analysis – Washington.* Projected murrelet population sizes as a function of proposed management alternatives. In each panel the solid colored line represents the mean annual population size averaged over 10,000 simulations, the dashed colored lines represent the 5%, 25%, 50% (median), 75%, and 95% quantiles, and the grey lines represent a random subsample ( $n = 10$ ) of individual simulation outcomes. The bottom-right panel (“Alternative means”) plots the mean from each alternative on a single graph for the purposes of comparison.

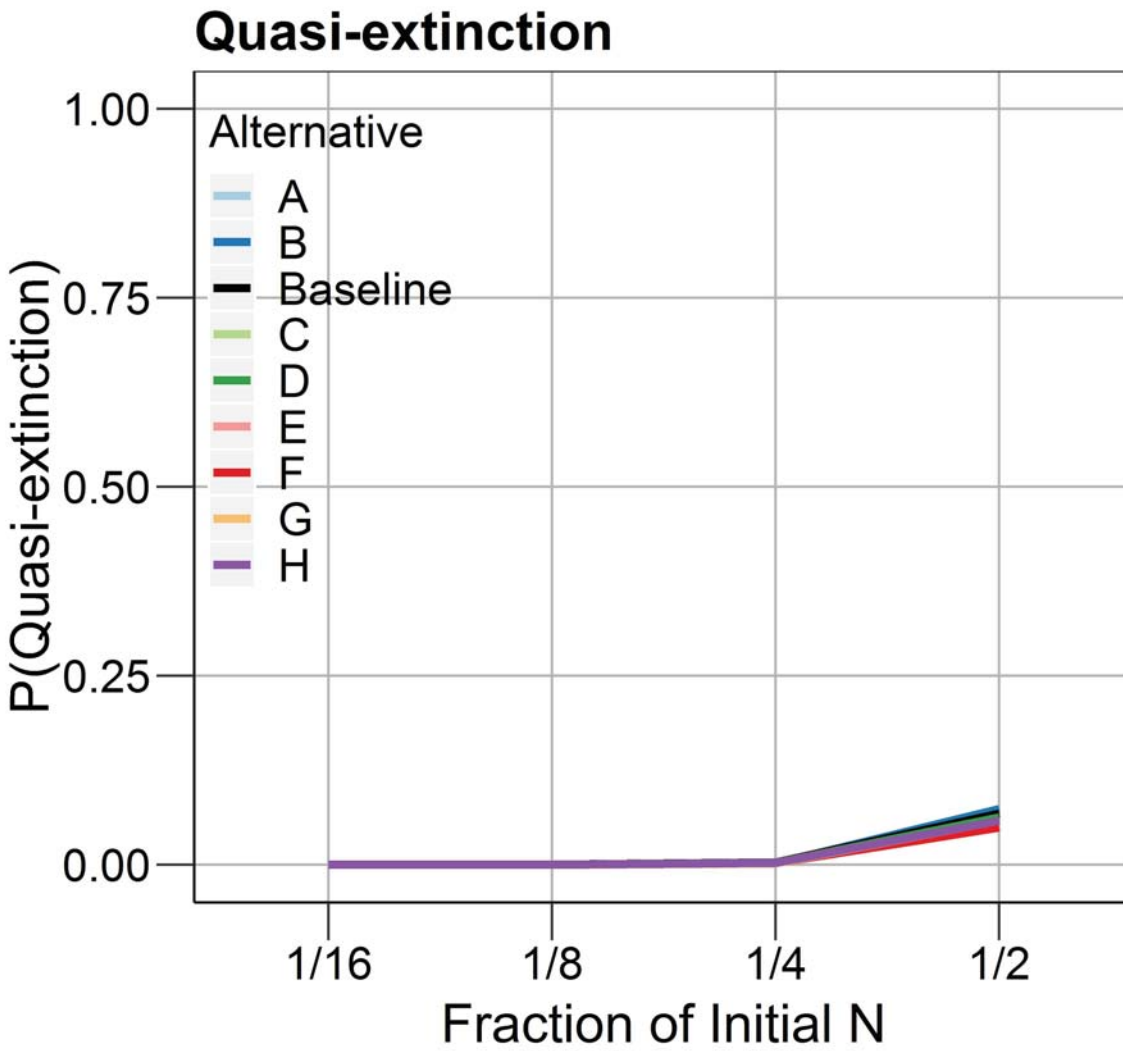


**Figure 7.** *Enhancement* analysis – DNR lands. Quasi-extinction probabilities (proportion of 10,000 simulations that reached a specified fraction of initial population size) for the proposed management alternatives.

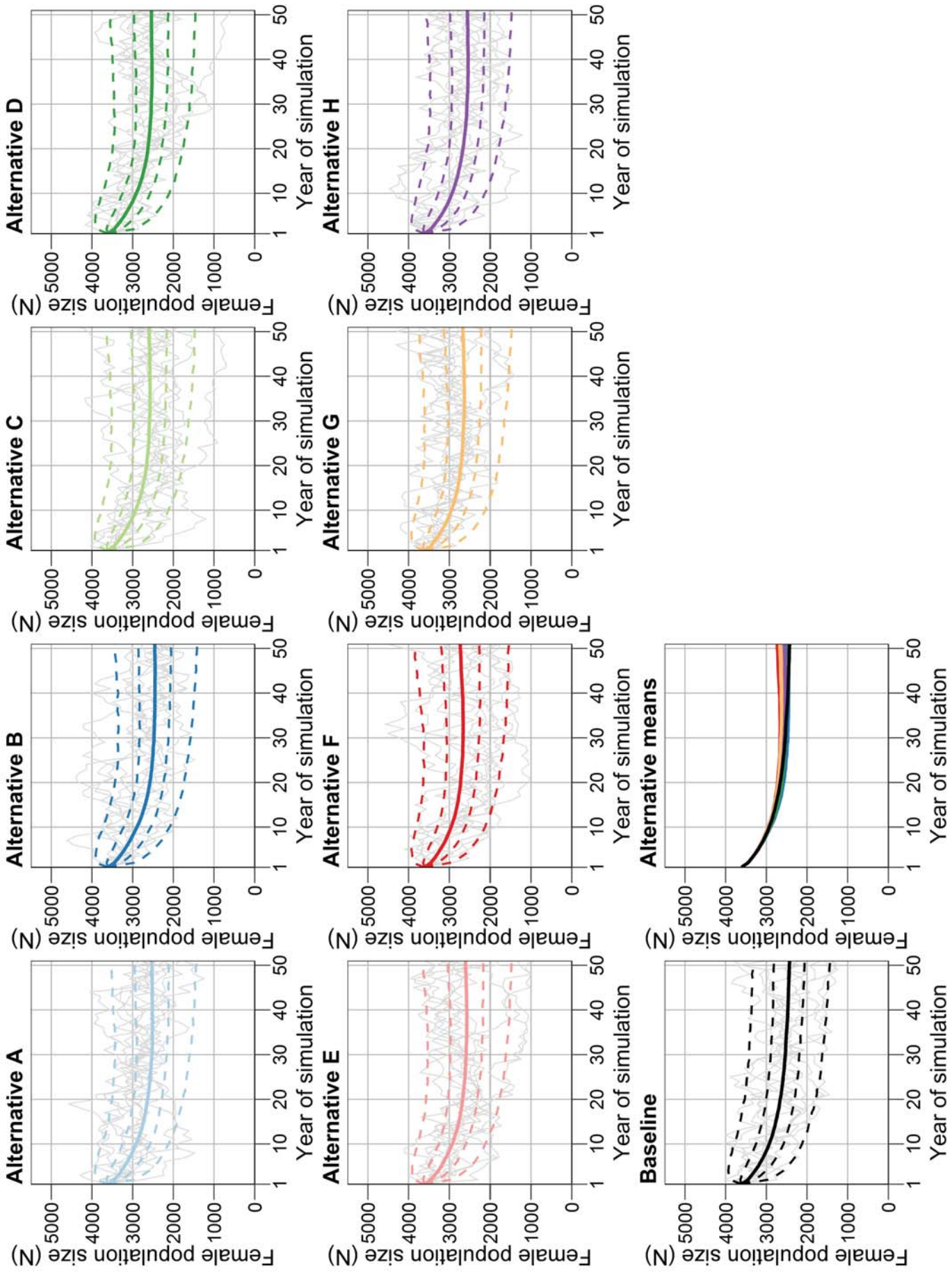




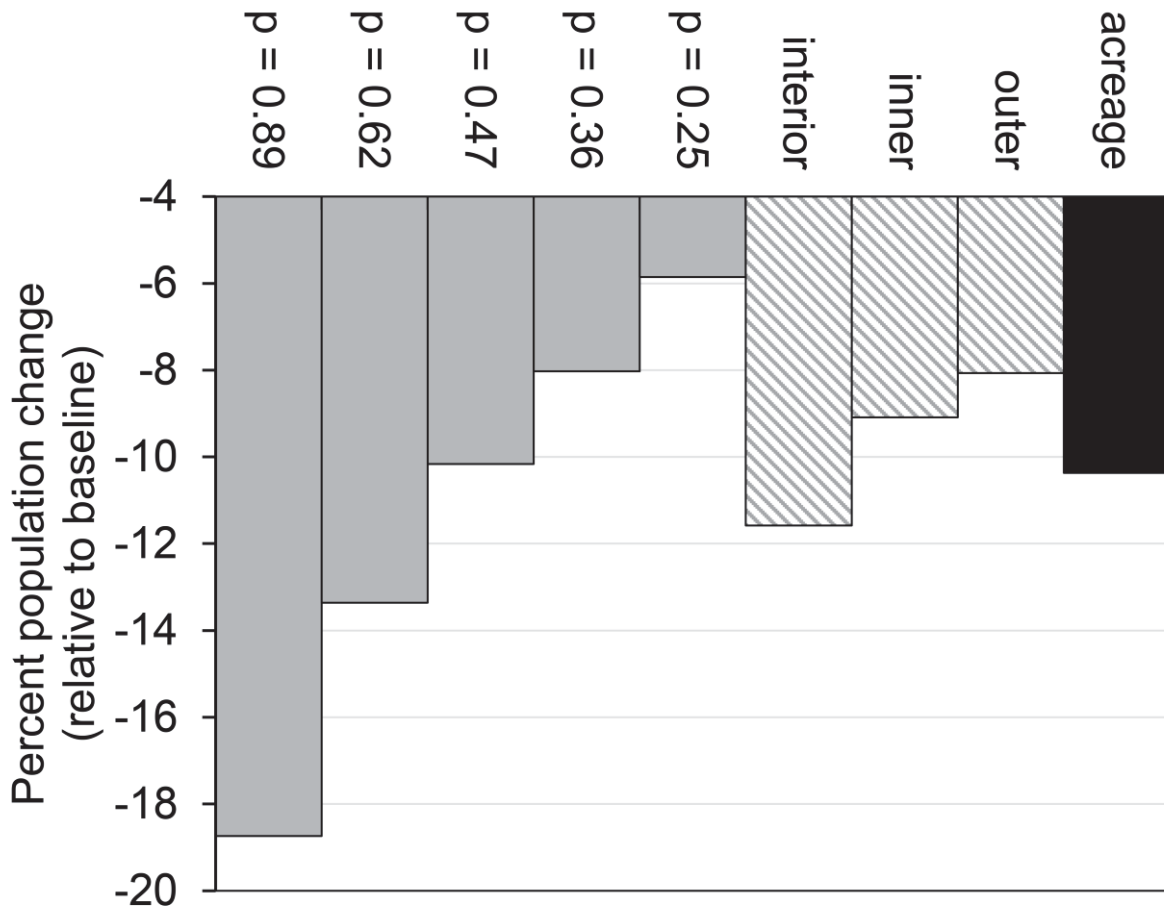
**Figure 8.** *Enhancement analysis – DNR lands.* Projected murrelet population sizes as a function of proposed management alternatives. In each panel the solid colored line represents the mean annual population size averaged over 10,000 simulations, the dashed colored lines represent the 5%, 25%, 50% (median), 75%, and 95% quantiles, and the grey lines represent a random subsample ( $n = 10$ ) of individual simulation outcomes. The bottom-right panel (“Alternative means”) plots the mean from each alternative on a single graph for the purposes of comparison. Note that in this set of graphs the line representing the 50% quantile (median) is not visible because it is obscured by the line representing the mean.



**Figure 9.** *Enhancement* analysis – Washington. Quasi-extinction probabilities (proportion of 10,000 simulations that reached a specified fraction of initial population size) for the proposed management alternatives.



**Figure 10.** *Enhancement* analysis – Washington. Projected murrelet population sizes as a function of proposed management alternatives. In each panel the solid colored line represents the mean annual population size averaged over 10,000 simulations, the dashed colored lines represent the 5%, 25%, 50% (median), 75%, and 95% quantiles, and the grey lines represent a random subsample ( $n = 10$ ) of individual simulation outcomes. The bottom-right panel (“Alternative means”) plots the mean from each alternative on a single graph for the purposes of comparison.



**Figure 15.** Sensitivity analysis. Grey solid bars represent habitat quality (Pstage), grey hatch-marked bars represent habitat configuration (edge conditions), and the black bar represents habitat amount (raw acreage).

## APPENDIX A

**Nest Density** – Based on the assumptions that a threshold acreage of habitat is required to provide one nest site and that nesting habitat is limited so that there is just enough for the current statewide population, i.e., the population is at the carrying capacity,  $K$ , of its forest habitat. WA state habitat estimates are from Raphael et al. (2016) and the murrelet population is estimated as the average WA at-sea population over a 5 year monitoring period, 2011-2015. Due to reduced-sampling efforts implemented in 2014, state-scale estimates for Washington are not currently available for the 2016 or 2017 monitoring years (Lynch et al. 2016). Habitat quality, and consequently the availability of potential nest sites, is assumed to be influenced by stand condition, edge effects including lack of habitat capability in strings, and geography (see below). Adjusted acreages for non-DNR land are based on Science Team (Raphael et al. 2008) assumptions for habitat quality and accessory assumptions for edge conditions and strings (i.e., assume federal habitat consists of half as much edge and strings while private habitat consists of 50% more edge and strings than DNR-managed land). Adjusted acreages for DNR land are based on assumptions regarding the influence of stand development, edge effects, and geography on habitat quality (see below) applied to estimated habitat acreage (Raphael et al. 2016). Nest density,  $D$ , is estimated as the total number of murrelets in WA divided by the total adjusted habitat acreage,  $A$ .

**Raw Habitat (DNR)** – Acreage of habitat ( $P_{stage>0}$ ) symbolized as  $H$ , based on interpretation and projection of DNR's spatially-explicit forest inventory. This estimate of current habitat ( $P_{stage>0}$ ), 211,700 acres, differs slightly from that of Raphael et al. (2016) which was used to estimate nest density, 187,100 acres.

**Adjustment for Habitat Quality (DNR)** – This incorporates three influences on habitat quality as it relates to function in providing nesting opportunities and  $K$ : stand condition, edge effects,

and geography. DNR’s spatially-explicit forest inventory summarizes acreage ( $H$ ), composition, and structure for stands, contiguous forest patches with sufficiently uniform composition and structure to be distinguishable units. Each stand has a current and projected future  $Pstage$  value (0, 0.25, 0.36, 0.47, 0.62, 0.89) which reflects habitat quality, thus its capacity to provide nest sites as  $H * Pstage$ . Edge effects,  $E$ , are influenced by two factors, distance from edge and edge type as summarized in the table below. Edge type and distance were estimated with spatial analyses of DNR forest inventory and the proposed conservation alternatives. Geographic influence,  $G$ , was incorporated by mapping habitat over 5 km from the nearest occupied murrelet site where the diminished attractiveness and/or availability of nest sites was assumed to have a further effect, 0.25, on habitat quality at these isolated habitat patches. Less than 5% of DNR-managed habitat,  $H$ , is so isolated, thus  $G = 1$  for the large majority of habitat.

		Interior ( $t$ )	Inner Edge ( $r$ )	Outer Edge( $o$ )	String
Edge Type	None ( $n$ )	1	1	1	0
	Soft ( $s$ )	1	0.8	0.6	0
	Hard ( $h$ )	1	.585	.17	0

Stands of current and projected future habitat ( $Pstage > 0$ ) were spatially partitioned by multiple factors important to DNR forest management including edge distance and geography (approximately 1,000,000 partitions varying by time-step and alternative), so that each partition,  $i$ , had an unique acreage  $H_i$ , and was in one of twenty-four  $Pstage/Edge$ -distance categories. Habitat was configured either in small, often fairly linear fragments called *strings* that contained



no interior forest, or in larger blocks that contained habitat in outer (*o*) and inner (*n*) edges as well as in interior forest (*t*), >100 meters from edge. Edge effects were assumed to negate the value of habitat in strings. Depending on alternative, 13% - 24% of habitat was in strings. Edge effects on inner and outer edge habitat was estimated with spatial methods based on the location of p-stage, and estimates of forest growth in LTFC based on site index values from DNR's forest inventory. Edges outside of LTFC were assumed to be equal to current proportions of edge types due to the balance of growth and harvest across the land base. Thus, projected future edge effects to inner and outer edge forests varied by alternative over the 50 year modeling period.

Six of the eighteen, non-string *Pstage*/Edge-distance categories are interior (*t*) and not subject to edge effects. The habitat quality adjustments described above were applied to all *j* spatial partitions within the interior categories and estimate the “functional capability” of murrelet habitat over 100 meters from potential edge as the sum of adjusted habitat acreage:

$$A_t = \sum_{i=1}^j H_i * Pstage_i * G_i * E_t$$

where  $E_t = 1$ . The adjusted habitat acreage within inner and outer edge categories are calculated as:

$$A_r = \sum_{i=1}^j H_i * Pstage_i * G_i * ((E_{nr} * p_n) + (E_{sr} * p_s) + (E_{hr} * p_h))$$

and

$$A_o = \sum_{i=1}^j H_i * Pstage_i * G_i * ((E_{no} * p_n) + (E_{so} * p_s) + (E_{ho} * p_h)),$$

respectively. The sum of adjusted acreages in interior and the two edge categories estimates  $A_{DNR}$ ,

$$A_{DNR} = A_t + A_r + A_o.$$

**K (DNR)** – The estimated number of nest sites on DNR-managed land, calculated as  $K_{DNR} = D * A_{DNR} * 0.5$  to reflect a population that is half female.

**Nest Success (DNR)** – Based on the assumption that edge effects are a primary influence on nest success,  $f$ . High nest success,  $f_{high}$  is assumed to be 0.55 and low success,  $f_{low}$ , 0.38 (McShane et al. 2004), with intermediate success,  $f_{int}$ , halfway between. Edge effects are influenced by two factors, distance from edge and edge type as summarized in the table below (Malt and Lank 2009). Edge type and distance from edge were estimated with spatial analysis of DNR forest inventory.

		Interior	Inner Edge	Outer
Edge Type	None ( $n$ )	0.55	0.55	0.55
	Soft ( $s$ )	0.55	0.55	0.55
	Hard ( $h$ )	0.55	0.465	0.38

Similar to adjustments for habitat quality, nest success was estimated by a combination of spatial and non-spatial analyses. Seven of the nine Edge-distance/Edge-type categories are interior or influenced by no or soft edge and are not subject to edge effects. Their influence on nest success,  $f$ , was estimated for all  $j$  spatial partitions within those categories as

$$f_{t,n,s} = \sum_{i=1}^j H_i * f_{high}$$

The influence of inner and outer hard edges on nest success was estimated as

$$f_{hr} = \sum_{i=1}^j H_i * f_{int}$$

and

$$f_{no} = \sum_{i=1}^j H_i * f_{low}$$

thus

$$f_{DNR} = f_{t,n,s} + f_{hr} + f_{no}$$

**Raw Habitat (Other)** – Estimates from Raphael et al. (2016).

**Adjustment Factor (Other)** – Based on the same logic and edge effects described for the DNR adjustment factor but using Science Team (Raphael et al. 2008) assumptions for habitat quality and the assumptions for edge conditions and strings summarized above, i.e., federal habitat consists of half as much edge and strings while private habitat consists of 50% more edge and strings than DNR-managed land.

**K (Other)** – The estimated number of nest sites on federal and other non-federal land, calculated as described above.

**Nest Success (Other)** – Estimated as above, based on the assumptions about edge on non-DNR lands (federal habitat consists of half as much edge while private habitat consists of 50% more edge than DNR-managed land).

**Additional references**

Lynch, D. Falxa, G., J. Baldwin, M. M. Lance, S.K. Nelson, S.F. Pearson, M.G. Raphael, C. Strong, and R. Young. 2016. Marbled murrelet effectiveness monitoring, Northwest Forest Plan: 2015 summary report. 19 pp.

Appendix **C**

**Attachment C-3**

Estimating the Location and Quality of  
Marbled Murrelet Habitat Focus Paper  
(P-stage)

Final State Trust Lands Habitat Conservation Plan AMENDMENT • Marbled Murrelet Long-term Conservation Strategy



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# Estimating the Location and Quality of Marbled Murrelet Habitat

## Focus Paper #3

*This focus paper was part of a series presented to the Board of Natural Resources in October and November 2015 to inform development of the marbled murrelet long-term conservation strategy alternatives. The purpose of this paper is to describe how DNR and USFWS identify and classify marbled murrelet habitat for purposes of developing the long-term conservation strategy.*

## ■ Identifying Marbled Murrelet Nesting Habitat

Marbled murrelets were proposed for listing under the Endangered Species Act in part because their habitat in older, complex-structured forests was thought to be so diminished by timber harvest that nesting opportunities were limiting the population (USFWS 1992). Contemporary research continues to support the importance of both *quantity* and *quality* of nesting habitat to murrelet distribution and abundance (for example, Raphael and others 2015). For the development of a long-term conservation strategy, DNR and USFWS required a credible method, a “habitat model,” to identify the current and potential future location and quality of marbled murrelet habitat across DNR-managed lands. Specific objectives for a habitat model were that it be:

- Consistent with contemporary scientific findings on the relationships of murrelet nesting biology with forest characteristics,
- Applicable to DNR-managed lands within the analysis area,
- No more complex than necessary,
- Of a geographic scale and resolution consistent with DNR forest inventory,
- Appropriately consistent with independent habitat assessments on DNR-managed land, and

- Consistent with data and models for forest structure and composition, growth, habitat quality and development.

## Using Forest Inventory Data

Murrelet nesting habitat is widely considered to have four components that interact to attract nesting murrelets and support their successful nesting: potential nest sites (platforms), flight access to the platforms, nest site- and neighborhood-level security from nest predators, and location within commuting distance of marine habitat (considered to be 55 miles inland). The presence and abundance of platforms and canopy complexity that enables flight access and provides site-level security are characteristics of forest stands<sup>1</sup> that can be evaluated using DNR’s comprehensive forest inventory. This inventory includes data for stands across all DNR-managed forest lands. A variety of inventory measurements of live and dead trees, other plants, and site conditions are used to provide stand-level estimates of timber volume and value, growth potential, habitat potential, and other important attributes. These forest inventory data also provide the basis for identifying the location and quality of current and future murrelet habitat according to methods agreed upon by DNR and USFWS and described here. The resulting estimates are essential for purposes of conservation planning. Forest stands with high value as nesting habitat, or with the potential to develop nesting habitat characteristics within the tenure of the 1997 HCP, can be identified and incorporated in conservation strategies.<sup>2</sup> Likewise, these estimates can provide an objective basis for evaluating and adjusting forest management to arrive at a conservation strategy that meets the mandates of both DNR and USFWS.

Marbled murrelet nesting habitat key components:

- Nest platforms
- Flight access to platforms
- Security from predators
- Located within 55 miles of marine habitat

## What Habitat Classification Models Are Available?

Since the marbled murrelet was listed under the Endangered Species Act in 1992, DNR and USFWS have used various methods to define and identify murrelet habitat.

### HABITAT MODELING UNDER THE HCP INTERIM STRATEGY

The 1997 HCP includes an interim strategy that directs DNR to follow a stepwise process of increasingly focused identification and protection of habitat. The interim strategy has led to deferrals of harvest of the most important habitat (and some harvest deferrals in less important habitat) while DNR continues to gather knowledge about how and where marbled murrelets use habitat on DNR-managed lands. (Refer to Appendix D to *the Marbled Murrelet Long-term Conservation Strategy Final Environmental Impact Statement* (FEIS), “Occupied Sites Focus Paper,” for a detailed description of the interim strategy.) The

<sup>1</sup> A forest stand is a contiguous group of trees sufficiently uniform to be a distinguishable unit. Definition provided by Society of American Foresters, Dictionary of Forestry 1998.

<sup>2</sup> Refer to Appendix C, Attachment C-4, “Long-term Forest Cover Focus Paper,” for a description of how the strategy delineates these areas; refer to Appendix C, Attachment C-1, “Potential Impacts and Mitigation Focus Paper,” for a discussion of activities that may impact the murrelet.



first step of the interim strategy is to identify “suitable habitat blocks,” which requires intensive fieldwork and has therefore mostly been applied to screening site-specific timber harvest proposals, rather than comprehensive habitat inventory and conservation planning. This first step was followed by the development of habitat relationship models, which are planning-unit-specific statistical models that used a suite of stand and neighborhood-level characteristics to predict the likelihood of murrelet use (occupancy) based on 1997 HCP-directed murrelet research in a sample of 54 forest stands in each planning unit (Prenzlów Escene 1999).<sup>3</sup> Based on these models, habitat mapping (“reclassification”) was done across DNR-managed lands in four HCP planning units, and audio-visual murrelet surveys were conducted in that habitat to determine the extent of marbled murrelet occupancy and further refine implementation of the interim strategy. Habitat relationship modeling was not successful in the North and South Puget HCP planning units; the interim strategy continues to use suitable habitat blocks to identify and protect habitat in those planning units.

## NORTHWEST FOREST PLAN MODELING

Other comprehensive, region-wide habitat models have been developed for habitat inventory and monitoring to support the federal *Northwest Forest Plan* (1994). The “Biomapper” model was published in the ten-year review of the plan (Raphael 2006) and was used by the Science Team (Raphael and others 2008) in their analysis of murrelet conservation opportunities. (The Science Team will be described in the next section of this attachment.) Further work by the *Northwest Forest Plan* team led to updates using a different habitat modeling technique, “*Maxent*,” the results of which were published in the fifteen-year and 20-year reviews of the *Northwest Forest Plan* (Raphael and others 2011, Falxa and Raphael 2016). The 20-year review provides the best available landscape scale estimate of the amount and location of murrelet habitat across all lands in Washington. It is not specific to DNR-managed lands.

## SCIENCE TEAM MODELING

In 2004, DNR convened a team of scientists to assess the state of knowledge on murrelets and their habitat on DNR-managed lands in order to provide recommendations on conservation opportunities. This “Science Team” published a report that included a habitat model that used DNR’s forest inventory to predict current and future locations and quality of murrelet habitat (Raphael and others 2008).

## ***Why Was the Science Team’s Classification Model Selected to Estimate Marbled Murrelet Habitat for the Long-term Conservation Strategy?***

For the long-term conservation strategy, DNR and USFWS sought a habitat classification model that would use DNR’s spatially-explicit forest inventory data to credibly estimate the current and future location and quality of habitat. To be credible, the model needed to generally identify habitat where it exists, avoid and minimize “false positives” (identifying non-habitat as habitat), avoid and minimize “false negatives” (model not predicting habitat where it actually exists), and distinguish lower-quality habitat in structurally simple stands from higher-quality habitat in older, complex-structured stands. Additionally, model predictions needed to be reasonably consistent with observed patterns of murrelet

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<sup>3</sup> Refer to Appendix D to the marbled murrelet FEIS, “Occupied Sites Focus Paper,” for a description of this survey and modeling work.

habitat use. The model known as “P-stage” was developed by the Science Team to meet these criteria and is modified slightly here to reflect updated information and understanding. Development of the P-stage habitat model was described in detail by Raphael and others (2008, pp. 4.1 – 4.19) and is briefly summarized here, as are the current modifications.

## What Is P-stage?

P-stage is based on a conceptual model of marbled murrelet nesting habitat (for example, Nelson 1997) as it relates to stand development in natural forests (for example, Franklin and Spies 2002). It attempts to generalize and classify levels of habitat quality as it relates to forest stand characteristics.

The model was developed by the Science Team using information from DNR-commissioned murrelet surveys, forest inventory, and forest growth modeling as well as general murrelet and silvicultural science.

Probability of occupancy increased with stand development from the simple-structured, large-tree exclusion stage through the complex-structured, “fully-functional” stage.

## Developing the P-stage Model

The P-stage model was developed by the Science Team in order to estimate murrelet habitat quality based on DNR’s forest inventory. DNR commissioned murrelet surveys<sup>4</sup> to screen forest stands for murrelet use, resulting in their binary classification as occupied or not. Forest inventory data from 355 murrelet survey sites in southwest Washington were used in logistic regression analysis to estimate the probability of occupancy based on two forest attributes widely acknowledged to be important components of nesting habitat: platform abundance and canopy complexity. Platform abundance was estimated with the model used by Washington State Forest Practices (Duke 1997), which was developed with data from private forest lands in southwest Washington and is based on the relationships of platform presence and abundance with tree size. An algorithm that estimated canopy layering based on gaps in tree-height distribution (Crookston and Stage 1999) provided an index to canopy complexity. Platform abundance, canopy layering, and their interaction (platforms \* layers) were found to be associated with higher probabilities of occupancy, but were not perfect predictors. However, model predictions clearly supported that probability of occupancy (habitat quality) increased with stand successional development (DNR 2004) from the simple-structured “large-tree exclusion” stage at least through the complex-structured “fully-functional” stage (which provides functions of “old-growth”), as represented in the 355 sites in southwest Washington.

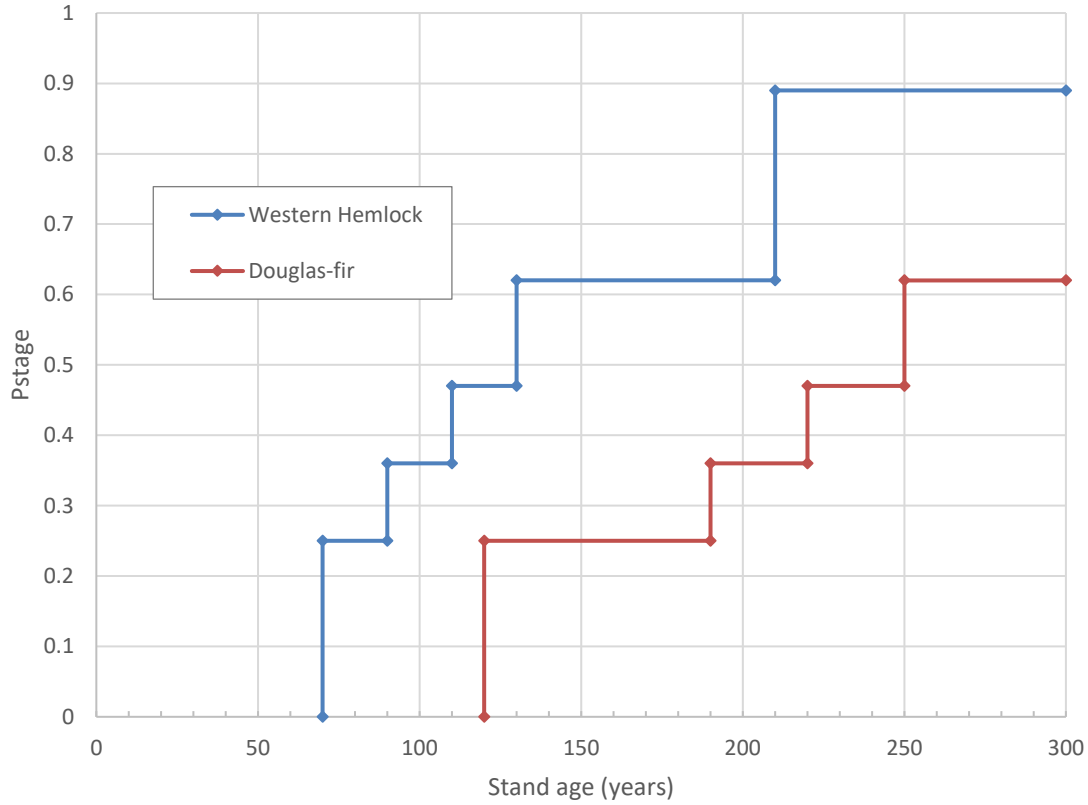
The Science Team examined this relationship of habitat quality increasing with platform abundance and canopy layering, observing that it paralleled patterns of stand successional development. The Team generalized a set of assumptions that quantified habitat quality as a function of stand age and dominant tree species composition (Raphael and others 2008). Five stand development stages (DNR 2004) were assumed to have some value as murrelet habitat, and forest growth models were used to generalize the relationship of these five stages with stand age.<sup>5</sup> Stands were classified into stages based on forest

<sup>4</sup> Refer to Appendix D to the marbled murrelet FEIS, “Occupied Sites Focus Paper,” for more details about occupancy surveys.

<sup>5</sup> Refer to Figures 4-2 and 4-3 in the Science Team Report (Raphael and others, 2008).

inventory estimates of age and species composition, which also predicted the age at which a stand would transition into a higher quality stage (Figure E-1).

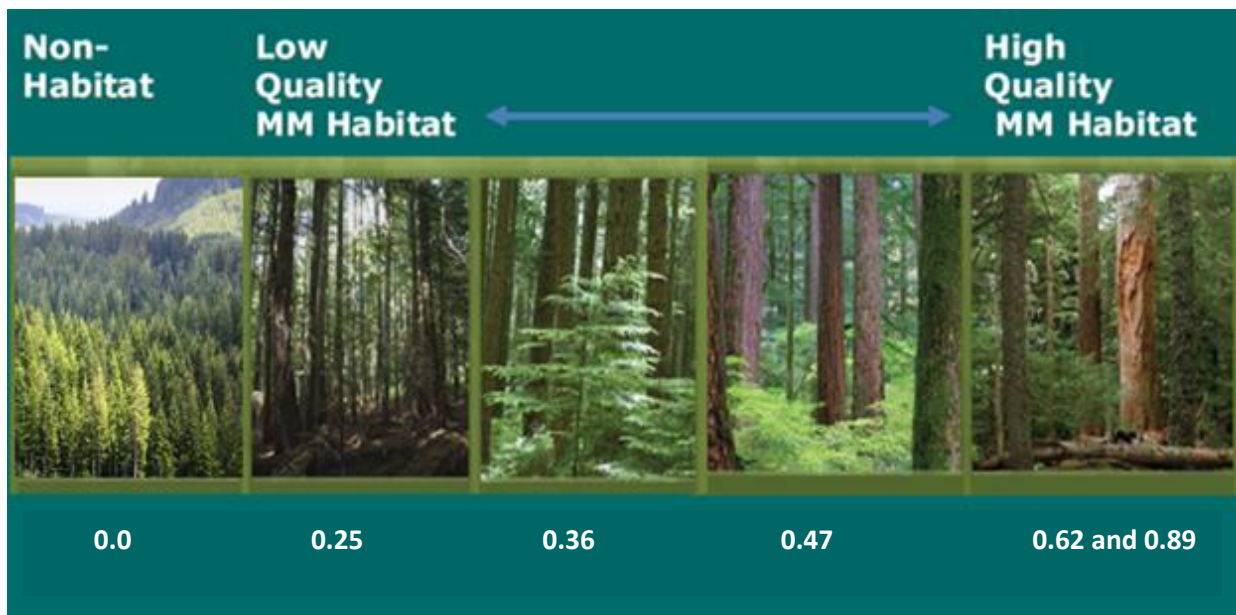
**Figure E-1. Ages at Which Naturally-Regenerated Forest Stands Transition Among P-stage Categories According to the P-stage Model**



Stands dominated by Douglas-fir rather than western hemlock or other shade-tolerant species were predicted to develop habitat quality more slowly (Raphael and others, 2008). The value that indexed “habitat potential” based on stand development stage was called P-stage to reflect its origins in the logistic regression analysis that predicted “P,” the probability of use. Stands were classified as non-habitat (P-stage 0) or as one of five stages of increasing quality (.25, .36, .47, .62, .89), from the lowest-quality stage that had consistent use (large tree exclusion) to the stage with the highest usage rates (fully-functional) (Figure E-2). Those assumptions were used to evaluate conservation opportunities on DNR-managed lands in southwest Washington and the Olympic Peninsula (Raphael and others 2008).

The value that indexed “habitat potential” based on stand development stage was called “P-stage” to reflect its origins in the logistic regression analysis that predicted “p,” the probability of use.

**Figure E-2. How the P-stage Model Associates Key Stand Characteristics With Stepwise Development of High Theorized Marbled Murrelet Habitat**



### Updates to the P-stage Model

The P-stage model of Raphael and others (2008) was modified slightly to apply more broadly across all DNR-managed forests in western Washington and to incorporate updated information and understanding of murrelet habitat and stand development. The most significant update was to the plan area, which was expanded beyond the four coastal HCP planning units analyzed by the Science Team to include the North Puget and South Puget planning units. This update approximately doubled the analysis area. Stand origin categories of naturally regenerated versus planted stands were included to avoid predicting that late 20<sup>th</sup> century plantations with few or no legacy trees would develop into habitat during the 50-year analysis projections. This requirement would allow model predictions of habitat development in naturally-regenerated stands that often include considerable biological legacies due to historic timber harvest

methods. Small adjustments were also made to the predicted rates of transition among P-stage classes (Table E-1). The Science Team applied P-stage values to forest habitat within 40 miles of high-use marine habitat (Raphael and others 2008) and discounted those values by 0.25 at greater distances; the current approach applies P-stage values to all habitat within 55 miles of marine water, with discounts applied to some regions with little or no documented murrelet use (refer to Appendix C, Attachment C-1, “Potential Impacts and Mitigation Focus Paper,” for a description of how P-stage values are adjusted for geography and edge effects across the landscape). An additional adjustment acknowledged the demonstrably high value of known *occupied* habitat, which was classified as P-stage 1 (a value not represented in the Science Team report).

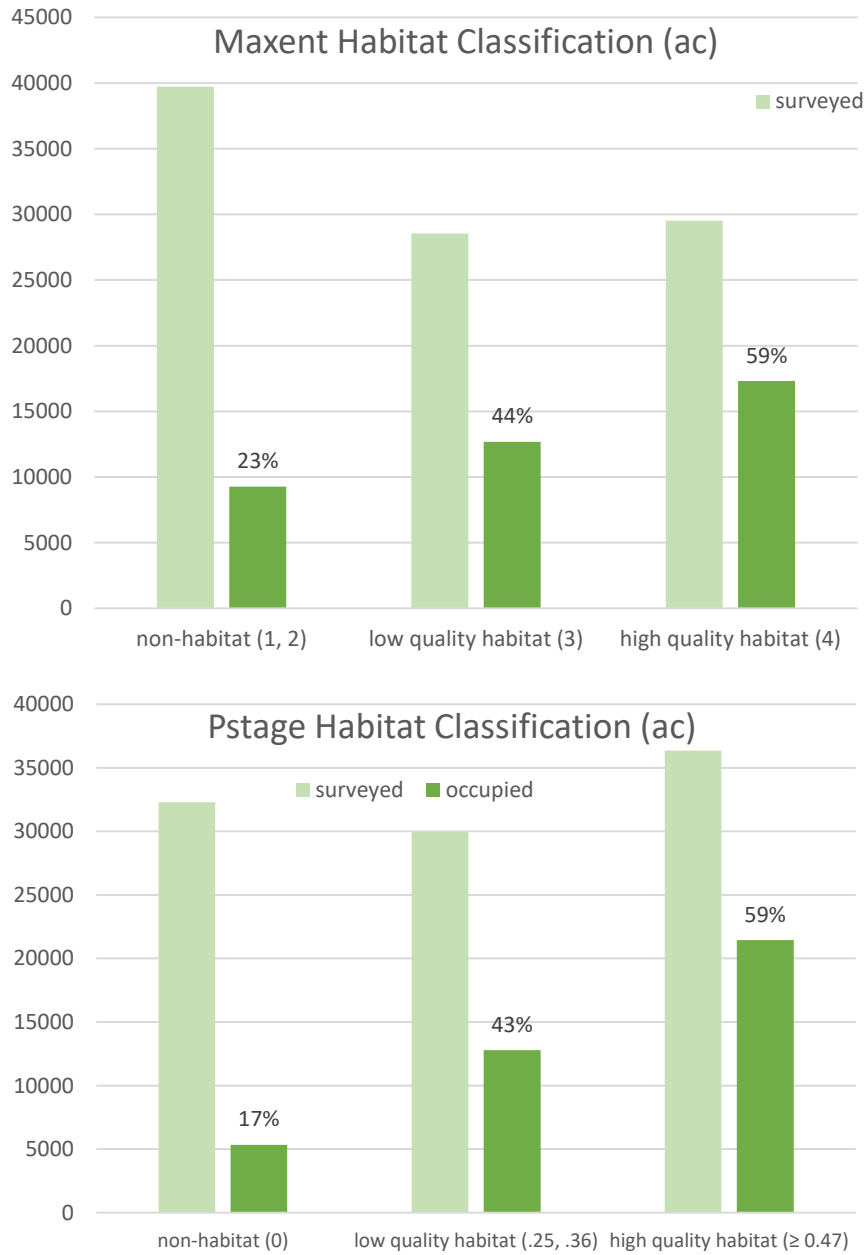
**Table E-1. Ages at Which Stands Transition Among P-stage Categories, by Dominant Tree Species, for Modelling Decisions**

P-stage (value)	Relative Stand Age (years)	
	Western hemlock	Douglas-fir
0.25	70	120
0.36	90	190
0.47	110	220
0.62	130	250
0.89	210	NA

### How Does P-stage Compare to Other Models in Estimating Habitat?

To evaluate a model’s performance, the normal procedure is to compare predicted results with an observed set. The ratio of observed over predicted results provides a measure of the model’s performance. Because there are no agreed-upon biological definitions of murrelet habitat or habitat quality, it is not possible to have an observed data set that captures varying habitat quality. Instead, evidence regarding the accuracy of Maxent and P-stage predictions was gathered by examining model predictions at DNR murrelet survey sites comprising nearly 100,000 acres (refer to Appendix D to the marbled murrelet FEIS, “Occupied Sites Focus Paper,” for a description of these surveys). Given the hypothesis that murrelets avoid non-habitat and preferentially occupy higher-quality habitat, the ratio of occupied to surveyed acreage (occupied ÷ surveyed) should be near zero for non-habitat, and increase as model-predicted habitat quality increases. Falxa and Raphael (2016) summarize Maxent categories 3 and 4 as habitat and categories 1 and 2 as non-habitat. They also consider categories 3 and 4 to represent a gradient in habitat quality. Figure E-3 suggests that both P-stage and Maxent predictions are in accordance with the murrelet’s hypothesized pattern of habitat use, although both models identify significant portions of occupied sites as non-habitat.

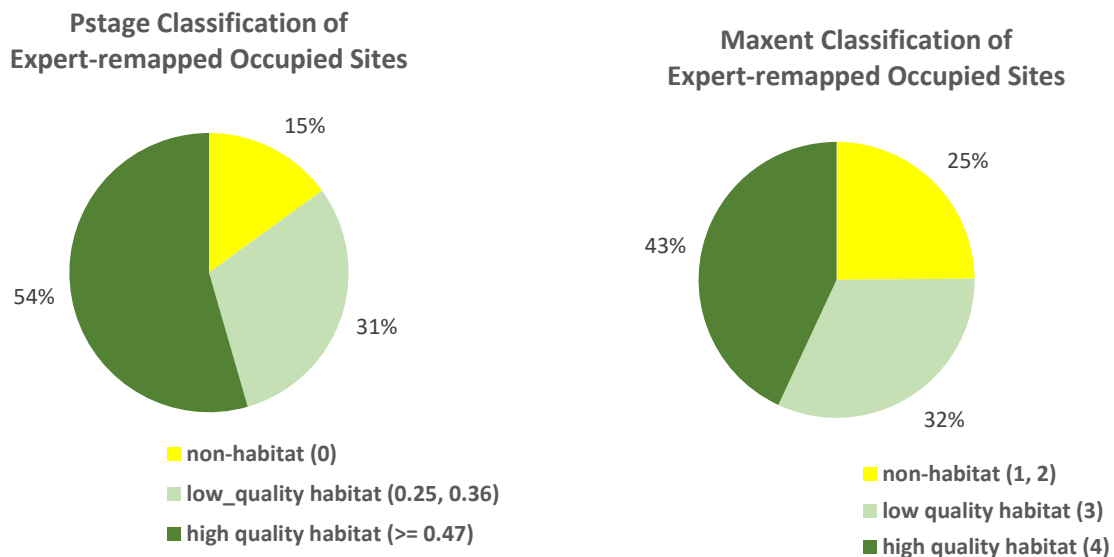
**Figure E-3. Habitat Classification by the Maxent and P-stage Models for DNR-Managed Land Surveyed for Murrelets and for Occupied Sites Located With Those Surveys (Percentages Reflect Occupied/Surveyed Acres Within Classes)**



Expert review (Raphael and others 2008) of occupied sites as they were originally mapped under the 1997 HCP resulted in the delineation of approximately 16,000 more acres (including surveyed and unsurveyed areas) as occupied habitat. Assuming that this expert re-mapping provides a more biologically appropriate delineation of murrelet habitat, Maxent and P-stage habitat classifications of those re-mapped occupied sites also can be evaluated. Model-based estimates of the composition of those areas should conform to the prediction that occupied murrelet sites are predominantly higher quality habitat, with lesser amounts of low quality habitat and little non-habitat.

As illustrated in Figure E-4, both models identify that predicted distribution, with higher quality habitat comprising the most abundant group under Maxent (43%) and P-stage (54%) classifications. However, both models identify significant amounts of occupied sites as non-habitat, Maxent 25% and P-stage 15%.

**Figure E-4. Maxent and P-stage Classifications of 61,000 Acres of Expert-mapped Occupied Murrelet Sites on DNR-Managed Land (Percentages Are Class/Total Area of Occupied Sites)**



It appears that both Maxent and P-stage provide reasonably consistent habitat estimates for areas surveyed for murrelets and for areas found to be occupied. Model predictions of habitat classes at occupied sites provide information on the ability of the respective models to identify habitat where it exists and suggest that while both models perform “reasonably,” neither model can identify all habitat. While evidence is less direct, some of the model-predicted habitat by either model that was found unoccupied with surveys may actually be non-habitat. However, the general alignment of both models with predictions based on murrelet biology, the gradient of occupancy rates found with murrelet surveys, and the composition of occupied sites suggests that either model provides appropriate estimates of the current location and quality of habitat.

Although no conclusive comparisons of model performance can be made, habitat predictions of the P-stage model align slightly better with hypothesized murrelet habitat relationships, with a lower occupancy rate in non-habitat (Figure E-3) and higher proportions of habitat and high-quality habitat composing occupied sites (Figure E-4). P-stage appears to be the best available stand-level murrelet habitat model for

DNR-managed land because it is the only model that meets all requirements of USFWS and DNR for development and assessment of the long-term conservation strategy (Table E-2).

**Table E-2. Criteria-based Comparison of Three Habitat Classification Models**

Model criteria	P-stage	Maxent	Interim strategy (reclassified model)
1. Based on relationship between nesting biology and forest composition	✓	✓	
2. Applicable to all DNR-managed lands in the analysis area	✓	✓	
3. Simple rather than complex	✓		
4. Scale and resolution consistent with DNR forest inventory	✓		
5. Habitat classifications demonstrably consistent with contemporary murrelet science	✓	✓	✓
6. Consistent with DNR forest modeling	✓		

### How Are Uncertainties in P-stage Model Predictions Addressed?

Hilborn and Mangel (1997) describe two broad types of uncertainty that influence the ability to make inference from ecological models: 1) uncertainty in generalizing and quantifying ecological *processes*, and 2) uncertainty in ecological data gathered from *observations*. Both process and observation uncertainty affect conclusions derived from the P-stage habitat model. Murrelet biological responses (processes like habitat selection, nesting rates, and nest success) are more variable and unpredictable than can be acknowledged within a simplistic model of habitat quality, or in the binary classification of murrelet habitat as “occupied” or not. Likewise, forest structure, composition, and growth are processes that are more complex and subject to many more influences than can be incorporated into the P-stage model. Findings from sample-based forest inventory and murrelet surveys can be influenced by sampling and measurement error and other forms of observation uncertainty.

Predictions of the P-stage model cannot be perfectly accurate; the model classifies habitat quality by discrete groups, while habitat quality in nature is more likely a continuous gradient. Murrelets likely select habitat based on a more complex suite of environmental cues than platform abundance and canopy layering, and further specificity is lost in the generalization of those elements of stand structure by age-class. Because of these and other uncertainties, some habitat will be overlooked and some non-habitat will be mistakenly identified as habitat. Some habitat also will be mistakenly classified as higher or lower quality than its actual state, and transitions among habitat quality classes will not perfectly follow predictions. Some of these uncertainties and their possible influences on evaluating and selecting a conservation strategy are summarized and discussed later in this attachment.



If P-stage predictions were consistently biased, there likely would be a directional effect on outcomes of the long-term conservation strategy. For example, if model predictions consistently under-estimated habitat quality, habitat conservation would likely be less effective because some current habitat and forests that would grow into habitat would be overlooked. If habitat quality were consistently over-estimated, habitat conservation would likely be less efficient because some non-habitat would be assigned to conservation pathways but would not serve its intended purpose. Unbiased error also can affect conservation outcomes with effects of under- and over-estimates as noted in this section, but if those errors were approximately balanced, their effects would be manifest but diluted compared to consistent, directional error. Key components of the P-stage model are examined for theory and/or evidence that could suggest its predictions are biased.

## SCALE AND RESOLUTION

The scale at which murrelets select nesting habitat is not known. Clearly, these seabirds need an appropriate nest platform in a context that provides stability and security during the nesting season. Across the nearly 3,000 miles of coast they inhabit in North America, those fine-scale elements of nesting habitat are rather constant, but as the view expands beyond the immediate nest site, the environment becomes increasingly indistinguishable from its surroundings (McShane and others 2004). This uncertainty over the scale at which habitat is distinguished from non-habitat, and how to distinguish among levels of habitat quality, likely is responsible for much of the uncertainty in all habitat modeling and delineation exercises. Raphael and others (2015) discuss this source of uncertainty in their Maxent model. The Maxent model predicts and maps murrelet habitat across three states at the scale of 30-meter square pixels (the resolution of their satellite imagery), generalized from characteristics of the target pixels and their immediate neighbors (9 pixels total, approximately 2 acres), although their multivariate habitat model also incorporates broader-scale influences from the surrounding 50 hectares (147 acres). The P-stage model predicts and maps habitat over DNR-managed land at the scale of forest inventory units (in other words, forest stands) which average 48.7 acres in western Washington, with 82 percent of nearly 19,000 stands between 5 and 100 acres. Stand-level metrics are developed from on-ground measurements at a network of sample plots located at approximately one plot per five acres. The “suitable habitat block” model, which has been mainly used for project-level planning and implementation, identifies and delineates habitat based on tree-by-tree inspection and arbitrary thresholds for the density of platforms observed (two per acre), the inter-tree distance between platform-bearing trees (300 feet, 92 meters), and minimum patch size (five acres).

Wiens (1976) cautioned researchers to avoid our human preconceptions and focus habitat research at scales important to the organisms of interest. Absent knowledge of the scale or scales at which murrelets recognize and select nesting habitat, the habitat models noted in this section mainly focus around human perceptions of forest habitat at scales appropriate to the geographic scope of their unique applications (range-wide, estate-wide, project-level) using the resolution of available data. Thus even if each model classified habitat similarly, their mappings would differ because small habitat areas or inclusions of non-habitat would be variously overlooked, depending on resolution. If murrelet habitat consistently occurred in habitat patches too small to be recognized with DNR’s forest inventory, P-stage would fail to identify much habitat. However, the consistent broad-scale relationship of murrelet numbers with habitat area as identified with a variety of habitat models (Burger 2002, Raphael and others 2002, Raphael and others 2015) and the consistent patterns of murrelet inland habitat use in identifiable habitat patches (in other

words, “stands”) as identified with a variety of methods (for example, McShane and others 2004) suggest that the scale and resolution of P-stage predictions are appropriate to identify most murrelet habitat.

## FOREST STANDS

Forest stands, by definition, are a construct of human perception. DNR’s current forest inventory is collected at sample plots, which comprise approximately one percent of stand area for overstory trees (where potential murrelet nest sites occur). Thus, even though stands were delineated from high-resolution aerial photography based on apparent similarity of vegetation and topography, considerable fine-grained heterogeneity within stands is obscured when stand-level averages are compiled from plot data. Consequently, discrete areas of habitat could be missed within stands with average characteristics of non-habitat or vice-versa. Some murrelet nests have been located in what appear to be unsuitable forest conditions (Bradley and Cooke 2001, Bloxton and Raphael 2009) although they were generally in landscapes dominated by older forest. These discoveries probably reflect the inability of coarse-grained, stand-level classifications to recognize rare structural elements or small patches of murrelet habitat. However, the great majority of murrelet nests have been located within forests more broadly recognizable as murrelet habitat (for example, McShane and others 2004), lending confidence that stand-level habitat classification can identify most murrelet habitat.

## FOREST GROWTH, STAND CHARACTERISTICS, AND HABITAT DEVELOPMENT

The P-stage model simplifies the relationship of murrelet habitat quality with stand development to three stand characteristics: origin, dominant species, and age. But forest growth and the development of murrelet habitat that accompanies it are much more complex and unpredictable processes than represented by that simple model. Observation uncertainty in the forest inventory-based estimates of stand characteristics adds to the uncertainty that accompanies P-stage predictions of habitat quality. However, comparison of P-stage classifications with murrelet survey findings (Figure E-3) and habitat mapping at occupied sites (Figure E-4) do not suggest that P-stage provides biased estimates of murrelet habitat quality.

## FIELD OBSERVATIONS

Some areas predicted as murrelet habitat by P-stage appear to lack abundant trees with platforms and/or individual trees with abundant platforms. Likewise, some predicted non-habitat contains trees with platforms and some of the area mapped as occupied is classified by P-stage as non-habitat. These observations can be proposed as evidence that P-stage mistakenly classifies some non-habitat as habitat and overlooks other habitat. However, some areas mapped as occupied were found to lack platforms as well, lending an additional dimension of uncertainty to comparisons of expert- and model-based habitat predictions. While some habitat is certainly overlooked just because of the scale issues summarized here, it is more difficult to contend that non-habitat is mistakenly classified as habitat because of the probabilistic nature of P-stage predictions. For example, P-stage 0.25 is so classified because stands with that general suite of characteristics are occupied about one-fourth as frequently as the highest quality habitat. The generalized probability of use that P-stage classes represent encompasses within-class, among-stand variability in habitat quality, behavioral variability among murrelets, and other sources of variability. Thus the lack of observable habitat characteristics in some P-stage habitat can be considered

to be within the scope of model predictions. The overall patterns of “selection” among P-stage classes found with DNR murrelet surveys (Figure E-3) and the classification of habitat identified as belonging to occupied sites (Figure E-4) demonstrates the general applicability of the model, even though some predictions do not conform to field observations.

## *Planning With Uncertainty*

USFWS and DNR conclude that there is an unknown level of uncertainty in P-stage predictions of current and future habitat. However, the general applicability of the P-stage model predictions outweigh their uncertainty for this conservation planning effort. Uncertainty can be acknowledged and development and implementation of the long-term conservation strategy can proceed using P-stage habitat predictions for three basic reasons: 1) the apparent prevalence of reliable model predictions relative to those clouded by uncertainty, 2) the need to develop and implement a long-term conservation strategy with this uncertainty in mind, and 3) existing policies and management procedures, as well as conservation planning approaches, that safeguard against high levels of risk associated with this uncertainty. Those additional cautions include the following:

USFWS and DNR concluded that there is an unknown level of uncertainty in P-stage predictions of current and future habitat, but also that the general applicability of P-stage model predictions outweigh their uncertainty.

- Habitat conservation is geographically extensive in all alternatives.
- Occupied sites were expanded to include sites where above-canopy circling was observed, and to include expert-identified contiguous habitat regardless of survey findings or previous habitat classification. Protection of expanded occupied sites and buffers are a component of all but one alternative.
- All alternatives propose to retain the majority of identified current and potential future habitat.
- Current and future habitat is abundant in long-term forest cover. It is likely that much of the “overlooked habitat” is prevalent in long-term forest cover and already is in conservation status.
- Some alternatives propose the retention of all “higher quality” habitat.
- Under most alternatives, the majority of habitat conservation and development occurs nearby but outside of occupied sites.
- Estimation of impacts and mitigation are based on the same assumptions, so there is an intrinsic balance.

## *How Is P-stage Applied in the Development of the Long-term Conservation Strategy?*

P-stage is being used for the long-term conservation strategy as a baseline for determining habitat quantity and quality on DNR-managed lands over the life of the 1997 HCP. P-stage values are used to

identify key areas to focus conservation, as well as in the calculation of take and mitigation. It is important to recognize that there are other factors that influence the probability of occupancy of a forest stand by murrelets, including proximity to high-quality marine habitat, proximity to other occupied sites, and habitat fragmentation. The P-stage model does not, by itself, account for these factors when evaluating habitat. However, the analytical framework adjusts P-stage values to reflect edge effects, geographic location, and other important factors affecting habitat quality (refer to Appendix C, Attachment C-1, “Potential Impacts and Mitigation Focus Paper”). In addition, the conservation alternatives being developed account for these factors when designating potential habitat for long-term protection under the 1997 HCP.

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# Appendix C

## Attachment C-4

### Long-term Forest Cover Focus Paper

Final State Trust Lands Habitat Conservation Plan AMENDMENT • Marbled Murrelet Long-term Conservation Strategy



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# Areas of Long-Term Forest Cover

## Focus Paper #2

*This focus paper was part of a series presented to the Board of Natural Resources in October and November 2015 to inform development of the marbled murrelet long-term conservation strategy alternatives.*

### ■ Introduction

Evidence from most research on marbled murrelet nesting ecology supports the murrelets' requirement for complex-structured forests with large trees. These trees provide large, moss-covered limbs that become nesting platforms. Other research identifies impacts from timber harvest on the availability of nest sites, and on nest success due to increased predation on eggs and nestlings near forest edges. Murrelets therefore rely on conifer-dominated forest stands with large interior areas and high numbers of large, old trees. Forest stands with these characteristics provide nesting opportunities, contain limited amounts of edge, and provide cover from predators and adverse weather (Ralph and others 1995, cited in McShane and others 2004). These types of forest stands can be found on DNR-managed lands within the range of the marbled murrelet. In many cases, these stands are already designated by existing DNR policy to provide conservation benefits. The marbled murrelet long-term conservation strategy identifies forest lands that will be managed as areas of long-term forest cover (LTFC), which may have current murrelet habitat or have the capability to develop into the types of structurally complex forests needed for nesting by the murrelet. These areas will be managed to maintain forest cover over the life of the *State Trust Lands Habitat Conservation Plan* (1997 HCP).

### ■ How Do DNR-managed Forest Lands Contribute to Marbled Murrelet Conservation?

DNR-managed forest lands are subject to several laws and DNR policies guiding their management. The following documents have the most direct impact on how forests are managed for purposes of marbled murrelet conservation:

- The 1997 HCP, a 70-year agreement between the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Services (the Federal Services) and DNR, describes a set of management strategies that DNR employs to offset any incidental take caused to individual listed animals, and

promotes conservation of the species as a whole. The 1997 HCP was amended in 2004 for the Klickitat HCP planning unit to better implement northern spotted owl habitat conservation strategies.<sup>1</sup> The 1997 HCP included an interim strategy for marbled murrelet conservation. In addition, concurrence letters between DNR and USFWS further specified procedures for identifying and protecting marbled murrelet habitat in the North Puget (2007) and South Puget (2009) HCP planning units.

- The 2006 *Policy for Sustainable Forests* contains the vision of the Board of Natural Resources and DNR for the management of current and future forests on state trust lands. Policies are specifically designed to achieve DNR's fiduciary responsibilities by generating revenues for trust beneficiaries, while meeting DNR's obligations under the 1997 HCP.

The analysis area for the marbled murrelet long-term conservation strategy includes just over 1.38 million acres of DNR-managed lands.<sup>2</sup> These lands are managed for multiple objectives including timber production, conservation, and recreational and resource land uses. With such a large area and variety of land types and land uses, the development of a long-term conservation strategy takes advantage of a landscape-planning approach to conservation.

DNR collects and maintains information on the forest lands it manages. These data are used to determine where, when, and how timber harvest is likely to happen, as well as where on the landscape forests are likely to be maintained and/or conserved over time. For example, some forest stands may be deferred from harvest because they are designated as existing old-growth forests, or serve as gene pool reserves for native trees species. Areas also may be deferred from harvest due to slope stability issues or other local knowledge of ecologically, socially, or culturally important areas. Other forest areas may be managed to maintain forest cover or certain forest structural conditions to achieve wildlife habitat objectives for species covered by the 1997 HCP (including the northern spotted owl, salmonids, and other aquatic and riparian-obligate species). DNR also manages lands under the state Natural Areas Preserves Act, which dedicates natural areas (including natural resource conservation areas and natural area preserves) in perpetuity for education, scientific research, and conservation of native biological diversity. Together, these lands are managed to maintain forest cover<sup>3</sup> for conservation and provide the building blocks for a landscape approach to the marbled murrelet long-term conservation strategy.

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<sup>1</sup> Washington State Department of Natural Resources. 2004. HCP Amendment No. 1, Administrative Amendment to the Northern Spotted Owl Conservation Strategy for the Klickitat HCP Planning Unit, April 2004.

<sup>2</sup> Refer to Appendix B to the *Marbled Murrelet Long-term Conservation Strategy Final Environmental Impact Statement (FEIS)*, "Analytical Framework Focus Paper," which describes the analysis area in more detail.

<sup>3</sup> "Forest cover" as used here refers to a relatively closed canopy structure, which may provide cover, security and potential nesting habitat to marbled murrelets.

The long-term conservation strategy defines these areas as LTFC, which may provide potential nesting habitat for marbled murrelet or insulate that habitat from impacts from forest management activities, both now and in the future. This approach implements a key objective of the long-term conservation strategy.<sup>4</sup>

## ■ What Are Areas of LTFC?

Areas of LTFC can be found throughout DNR’s managed forest landscape. These areas are defined and mapped using GIS information from DNR’s databases.<sup>5</sup> Areas of LTFC come in various shapes and sizes, and when in a strategic location and suitable habitat condition, provide nesting opportunity for the marbled murrelet.<sup>6</sup> LTFC includes the following types of lands:

- Natural area preserves
- Natural resource conservation areas
- High quality<sup>7</sup> northern spotted owl habitat (all alternatives), high *and* low quality northern spotted owl (Alternative F only)
- Riparian management zones
- Wetlands
- Areas of slope stability concern
- Gene pool reserves
- Old-growth forests
- Local knowledge of ecological/social and culturally important areas
- Marbled murrelet occupied sites<sup>8</sup>
- Areas specifically designated for marbled murrelet conservation in strategic locations under each of the alternatives

Layered together (as illustrated in Figure G-1), these areas create blocks of land that contribute to marbled murrelet conservation, if the structure and complexity of the forest within provides nesting habitat and security from predation.<sup>9</sup>

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<sup>4</sup> Refer to Objective #2 of the long-term conservation strategy: “Provide forest conditions in strategic locations on forested state trust lands that minimize and mitigate incidental take of marbled murrelets resulting from DNR’s forest management activities. In accomplishing this objective, DNR and USFWS expect to make a significant contribution to maintaining and protecting marbled murrelet populations.”

<sup>5</sup> DNR large data overlay, 2015.

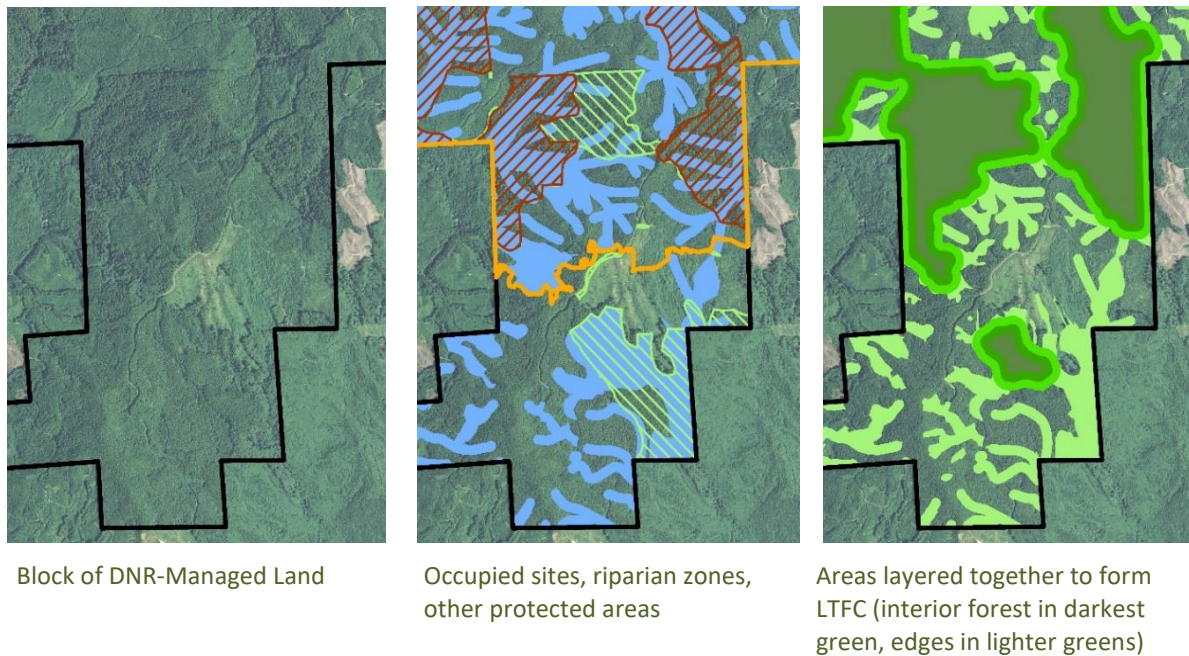
<sup>6</sup> Refer to Objective #2 of the long-term conservation strategy: “Provide forest conditions in strategic locations on forested state trust lands that minimize and mitigate incidental take of marbled murrelets resulting from DNR’s forest management activities. In accomplishing this objective, we expect to make a significant contribution to maintaining and protecting marbled murrelet populations.”

<sup>7</sup> Existing northern spotted owl high-quality habitat refers to the following DNR mapped habitat classes as of 2018: old forest, high-quality nesting habitat, and A and B habitat per the definitions in the 1997 HCP (DNR 1997, p. 12).

<sup>8</sup> Refer to Appendix D to the marbled murrelet FEIS, “Occupied Sites Focus Paper.”

<sup>9</sup> The varying quality of the habitat found within LTFC is analyzed using a mathematical model, described in Appendix C, Attachment C-3, “P-stage Focus Paper.”

Figure G-1. Layering Data to Map Areas of LTFC



The boundaries of some categories of LTFC are precisely mapped in DNR databases. Examples include gene pool reserves, natural area preserves, and natural resource conservation areas. These boundaries are not expected to change throughout the life of the 1997 HCP. Other categories of LTFC are not precisely mapped but are approximated until field inspections can more accurately define correct boundaries. LTFC associated with riparian areas, wetlands, and unstable slopes are examples for which the boundaries may be adjusted when site-specific information becomes available. Although the exact location of LTFC associated with riparian areas can change with field verification, the total acres of LTFC associated with these deferrals is a reasonably accurate estimate of the total LTFC expected to be retained on the landscape.

## ■ How Does LTFC Provide Nesting Security to Murrelets?

LTFC is assumed to conserve habitat by protecting current and potential nest sites from harvest and other land uses in the managed forest. The shape and amount of interior forest patches within LTFC is a critical factor in nesting success and security. Forest edges created from harvest or other types of openings (for example, roads) impact this security. LTFC can be classified into one of three forest zones that support varying levels of marbled murrelet conservation. These zones are influenced by the condition of the adjacent managed forest, which is characterized as “hard-edged,” “soft-edged,” or “no-edge.” In addition, some areas, referred to as “stringers” (described later in this section), are linear in nature and do not include any interior forest. Beyond these areas is the actively managed forest, where most of the harvest and related activities occur.

## Interior Forest

The interior forest (Figure G-2) is comprised of forested area (patch) that is at least 100 meters from any type of edge. These interior areas are protected from effects associated with harvest edges. Edge effects include changes in microclimate (such as decreasing humidity), windthrow, changes in vegetative species such as reduction in epiphyte<sup>10</sup> presence, and increased risk of predation (Nelson and Hamer 1995, McShane and others 2004, Van Rooyen and others 2011). Further, impacts to murrelets from disturbance (loud noise and activity that can interrupt breeding and nesting behaviors) is reduced in the interior forest portions of LTFC. (Refer to Appendix C, Attachment C-1, “Potential Impacts and Mitigation Focus Paper,” for a detailed description of edge effects.)

## Outer Edge

The outer edge of the interior forest patch is located between 0 to 50 meters from the edge of an actively managed forest (Figure G-2). Because this area is adjacent to the actively managed forest, edge effects are more pronounced in the outer edge.

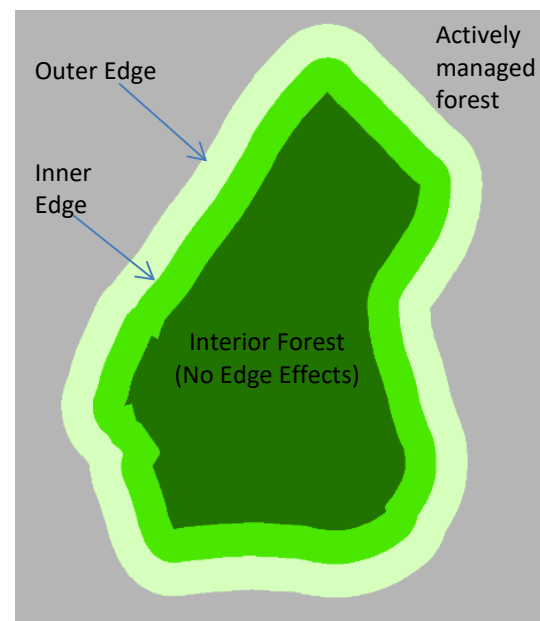
## Inner Edge

The inner edge (Figure G-2) is a forested area located 51 to 100 meters from the edge of the actively-managed forest and adjacent to the interior forest patch. The literature indicates that the edge effects from the actively managed forest extend further than 50 meters into the stand, but diminish until there is minimal effect after 100 meters from the managed area (Burger and others 2004).

## Hard, Soft, and no Edges

Depending on the age and height of the trees in the actively managed forest, edges can be characterized as either “hard” or “soft.” Hard edge effects extend through the outer and inner edges, and occur when the actively managed forest is comprised of young stands (0 to 20 years old) that are expected to be generally less than 40 feet high. Higher risk of nest predation, and increased microclimate and windthrow effects are all associated with hard edges.

**Figure G-2. Conceptual Illustration of an Area of LTFC and Edges**



<sup>10</sup> Plants that grow on the surface of other plants, such as moss.

Soft edges are characterized by managed forest stands that are expected to be generally 20 to 40 years old and 40 to 80 feet high adjacent to long-term forest cover.<sup>11</sup> At this stage, interior forest and the outer and inner edges are less affected by predation risk, and microclimate and windthrow effects still factor into edge impacts, but to a lesser degree. Trees in the managed forest that are beyond 40 years of age and 80 feet in height are assumed to have minimal edge effects to the interior forest patch, and therefore are not counted as edge under the analytical framework.

DNR can assess the edge conditions of managed forest lands in the analysis area using forest inventory and GIS data. This information is used to determine potential impacts to murrelet habitat from forest edges, and to calculate necessary mitigation (refer to Appendix C, Attachment C-1, “Potential Impacts and Mitigation Focus Paper”).

### *Roads as Edges*

New and existing forest roads (logging roads) also create edges. Depending on their location relative to murrelet habitat, and whether they are actively used or are undergoing transition back to forest, roads have effects similar to other hard or soft edges. Roads can attract corvids and affect microclimate. (Refer to Appendix C, Attachment C-1, “Potential Impacts and Mitigation Focus Paper” for a discussion on how roads and other edges impact habitat and mitigation values.)

### *Stringers*

Areas mapped as long-term forest cover using GIS will show large and small blocks of LTFC, as well as some narrow strips of land. These narrow strips are termed “stringers.” Stringers are defined as areas less than 200 meters wide (predominately riparian management zones) where adjacent uplands have not been designated as long-term forest cover. Stringers do not have interior forest. Stringers are considered part of LTFC; however, they are not assigned credit for mitigation under the conservation alternatives.

### *Areas Outside LTFC*

Forest lands outside of LTFC are managed for harvest to meet DNR’s fiduciary responsibilities to the trust beneficiaries. These forest lands are part of the actively managed forest.

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<sup>11</sup> The tree height and age associations described here are generalized, and may vary somewhat across the landscape depending on site conditions.

## ■ How Does LTFC Differ Across the Conservation Alternatives?

DNR and USFWS developed alternative approaches to long-term marbled murrelet habitat conservation. These alternatives are evaluated using a common analytical framework.<sup>12</sup>

Designating areas of LTFC under each alternative allows potential impacts to be quantified, mitigation to be calculated,<sup>13</sup> and conservation benefits to be evaluated. The amount and composition of LTFC varies among alternatives (refer to Figure G-3 for an example). The proportion of interior forest to outer and inner edges may vary, or the conservation areas that are included may be different.

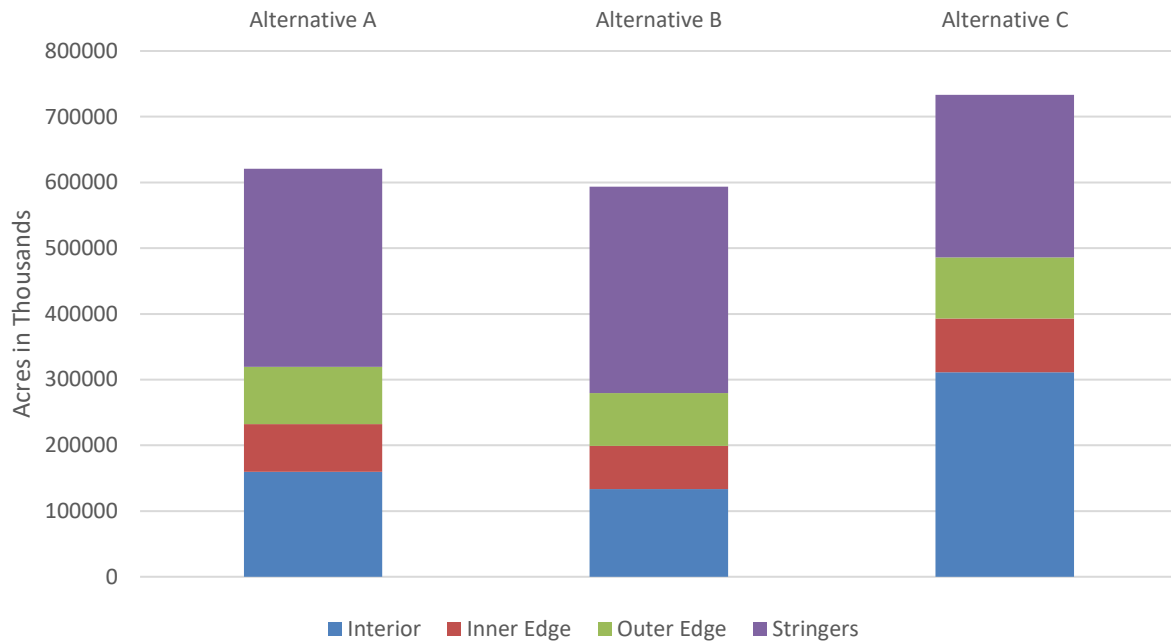
These differences in composition mean that the geographic extent of LTFC (how much of, and where, on the landscape it is located) will differ among alternatives. All LTFC is intended to provide conservation benefit to the murrelet. However, the conservation value of one area of LTFC may be higher or lower than another, depending on its relative habitat quality, its location relative to occupied sites or marine populations, and other factors. The analytical framework takes these factors into account when calculating potential impacts and mitigation through the life of the 1997 HCP.

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<sup>12</sup> Refer to Appendix B to the marbled murrelet FEIS, “Analytical Framework Focus Paper.”

<sup>13</sup> Refer to Appendix C, Attachment C-1, “Potential Impacts and Mitigation Focus Paper.”

Figure G-3. How the Amount and Composition of LTFC May Differ Across Alternatives; Data for Illustration Purposes Only (does not reflect the actual alternatives)



## How Will Areas of LTFC be Managed for Purposes of Marbled Murrelet Conservation?

Although the exact make-up of LTFC may differ among conservation alternatives, the management objective of LTFC is the same under every alternative: to provide LTFC. Forest stands within areas of LTFC that have murrelet habitat characteristics, or that have the potential to develop murrelet habitat characteristics, will be conserved over the life of the 1997 HCP. No major harvest activities will be allowed within LTFC. The conservation alternatives being developed may allow some thinning or habitat enhancement within areas of LTFC, consistent with the underlying conservation objectives. For example, riparian areas within LTFC may be thinned consistent with DNR’s Riparian Forest Restoration Strategy. Management of non-timber harvest land uses will also be addressed under the alternatives.

Stands within interior areas of LTFC that have marbled murrelet habitat characteristics, or that have the potential to develop those characteristics, will be protected from potential impacts from harvest, edge effects, and other types of disturbance.

Management will be consistent with the conservation objective that the quality and quantity of habitat within areas of LTFC is expected to improve as forest stands mature. Mature stands that do not currently have murrelet habitat characteristics will also have the potential to develop into habitat over the life of the 1997 HCP.



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# Appendix C

## Attachment C-5

### Uncertainties in the Marbled Murrelet Long-term Conservation Strategy

Final State Trust Lands Habitat Conservation Plan AMENDMENT • Marbled Murrelet Long-term Conservation Strategy



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# Uncertainties in the Marbled Murrelet Long-Term Conservation Strategy

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## Introduction

This amendment to the *State Trust Lands Habitat Conservation Plan* (1997 HCP) details a long-term conservation strategy (Long-term Strategy) for marbled murrelets on lands managed by the Washington State Department of Natural Resources (DNR). The Long-term Strategy was developed through a 22-year, rigorous analytical process undertaken by DNR in consultation with U.S. Fish and Wildlife Service (USFWS) that began with implementation of habitat relationship studies and a survey program to identify occupied sites on DNR-managed HCP lands. This process has been complemented by extensive public input. The Long-term Strategy described in this HCP Amendment is scientifically robust, relying on current science, extensive data sets, well-documented analysis methods, and biologically-based conservation principles.

As part of this analytical process, DNR and USFWS developed seven action alternatives for the Long-term Strategy that are consistent with DNR's trust obligations and provide conservation for the marbled murrelet to fulfill the requirements of the Endangered Species Act. These alternatives were analyzed in the *Marbled Murrelet Long-term Conservation Strategy Final Environmental Impact Statement* (FEIS).

As it did for the interim marbled murrelet conservation strategy (Interim Strategy), DNR (in consultation with USFWS) has made management decisions for the Long-term Strategy in the face of uncertainties. Areas of uncertainty identified during this analytical process include (but are not limited to) murrelet biology and nesting behavior and DNR's methods for estimating and locating habitat accurately on DNR-managed HCP lands. In many cases, the decisions made result in DNR-managed HCP lands providing **more habitat protection, for longer periods of time, than reflected in the mitigation credit quantified for this HCP Amendment**<sup>1</sup>. DNR believes that this additional conservation provides mitigation for current and potential, future uncertainties.

This attachment is in three sections:

- **Uncertainties Identified Under the Interim Strategy:** This section describes the Interim Strategy and how conservation was used to address uncertainties while still fulfilling DNR's trust responsibilities.

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<sup>1</sup> DNR estimates that mitigation will exceed impacts by 706 adjusted acres under this HCP Amendment. Refer to Uncertainty #18 in this document for more information.

- **Uncertainties Identified in the Analytical Framework:** This section includes uncertainties identified from 2011 to the present and how they were addressed. These uncertainties are incorporated as scientifically based assumptions in the analytical framework and are well documented in the FEIS.
- **Additional Conservation of the HCP Amendment:** This section discusses components of the Long-term Strategy that provide additional conservation benefits for the marbled murrelet that do not receive mitigation credit.

## *Uncertainties Identified Under the Interim Strategy*

The 1997 HCP conservation objective for marbled murrelets is to develop a long-term conservation strategy for the habitat of the marbled murrelet that will provide minimization and mitigation for any incidental take of the species. At the time the 1997 HCP was written, not enough was known about marbled murrelet habitat use to develop a long-term conservation strategy. For example:

- Where is murrelet habitat located on DNR-managed HCP lands?
- Where are occupied sites located on DNR-managed HCP lands?
- Are all occupied sites equally important, or do some function more effectively than others?
- What should be done to ensure an occupied site’s longevity?
- Must the occupied site be a “no entry” area or can some management occur within it?
- Does the occupied site need a buffer and, if so, how large?

Due to the lack of information about murrelet habitat use, both generally and specific to DNR-managed HCP lands, DNR developed the Interim Strategy. In brief, the Interim Strategy consists of three steps: (1) a habitat relationship study, (2) marbled murrelet inventory surveys, and (3) development of the Long-term Strategy. A description of the Interim Strategy can be found in Appendix D of the marbled murrelet FEIS.

In 2004, DNR convened a team of professionals called the “Science Team” to compile expert opinion, data, and research on marbled murrelet habitat conservation and to develop a set of recommendations<sup>2</sup> for DNR to consider when developing the Long-term Strategy (Raphael and others 2008). In their four-year process, the Science Team scrutinized DNR’s efforts to date in implementing its habitat relationship studies and murrelet inventory surveys. Their work, in

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<sup>2</sup> Represented as Alternative F in the marbled murrelet FEIS.

combination with DNR’s work and consultation from other agencies and entities, identified uncertainties regarding the adequacy of the habitat relationship study in identifying high-quality habitat, DNR’s efforts to survey those acres, and the reliability of the extent of occupied sites identified. These uncertainties are discussed in detail in this section.

► **How these uncertainties were addressed:** With the exception of relying on intensive surveys by Washington Department of Fish and Wildlife (WDFW) in Southwest Washington, DNR resolved all of the following uncertainties by conserving, until the development of the Long-term Strategy, any areas that were questioned.

### Uncertainty #1: Incomplete Murrelet Inventory Surveys

DNR did not complete murrelet inventory surveys in two of the six HCP planning units: Olympic Experimental State Forest (OESF) and North Puget. Not completing these surveys created uncertainty about how unsurveyed acres would be classified and considered for conservation.

#### OESF

The OESF HCP planning unit murrelet inventory surveys were 75 percent complete in 2002, with 40,687 acres of reclassified habitat surveyed and approximately 13,621 acres of reclassified habitat unsurveyed. DNR discontinued surveys due to a high murrelet detection rate. Instead, DNR deferred all remaining reclassified habitat and decided with USFWS to convene the Science Team, which would assess these areas for their contribution to the biological requirements of the murrelet. The Science Team recommended that all but 1,698 acres of unsurveyed, reclassified habitat be conserved in a type of conservation area called a “marbled murrelet management area.”

► **How this uncertainty was addressed:** In 2004, DNR deferred all of these areas (15,200 acres) from harvest until the adoption of the Long-term Strategy.

#### NORTH PUGET

In 2009, DNR suspended murrelet inventory surveys in the North Puget HCP planning unit due to budget shortfalls. Biologists from DNR, USFWS, and WDFW worked together to identify areas of potential habitat and defer them from harvest. There was uncertainty about whether those areas were actually occupied by murrelets.

To address this uncertainty, DNR and USFWS developed an alternate methodology to identify murrelet habitat in the North Puget HCP planning unit. This methodology is described in the “Final North Puget Planning Unit Marbled Murrelet Concurrence Letter”

dated February 23, 2007. North Puget staff field check potential murrelet habitat areas to determine if they meet the HCP definition of suitable habitat under the Interim Strategy.

► **How this uncertainty was addressed:** Field-delineated, suitable habitat was deferred from harvest until a Long-term Strategy is adopted. For more information on the Interim Strategy and occupied sites, refer to Appendix D of the marbled murrelet FEIS.

## Uncertainty #2: Incomplete Habitat Relationship Study in South Puget HCP Planning Unit

Although the South Puget HCP planning unit is within the breeding range of the marbled murrelet, the adjacent offshore population of murrelets is extremely small. Low population numbers and limited suitable habitat within this HCP planning unit indicate that the probability of inland detections of murrelets is very low. This suspicion is corroborated by the fact that there have been few detections on either DNR-managed HCP or adjacent lands. Without an adequate number of inland detections, the habitat relationship study outlined in the 1997 HCP is ineffective, which leads to uncertainty about how to identify potential murrelet habitat in this HCP planning unit.

In response to this uncertainty, DNR and USFWS developed an alternate methodology to identify murrelet habitat in the South Puget HCP planning unit. This methodology is described in the “Final South Puget Planning Unit Murrelet Habitat Identification Concurrence Letter” dated July 16, 2009. As in the North Puget HCP planning unit, South Puget staff field check potential murrelet habitat areas to determine if they meet the HCP definition of suitable habitat under the Interim Strategy.

► **How this uncertainty was addressed:** DNR deferred from harvest all suitable, unsurveyed habitat and all potential suitable (not field verified) habitat until it was either field verified, surveyed, or addressed in the Long-term Strategy. For more information on the Interim Strategy and occupied sites, refer to Appendix D of the marbled murrelet FEIS.

## Uncertainty #3: Changing Survey Protocols

DNR’s marbled murrelet inventory survey efforts spanned nine years (1994 through 2003) and were completed under various versions of the Pacific Seabird Group’s marbled murrelet inland survey protocol (Ralph and others 1994, 1995, 1996, 1997, and 1998; Evans Mack and others 2003). Because of variation in the number of survey visits required to detect occupancy between the different protocols, some sites that are considered surveyed and unoccupied may actually be “occupied but undetected,” meaning that these sites may be found to be occupied through additional field visits (Evans Mack and others 2003). The Science Team conducted a retrospective evaluation of DNR’s survey effort for sites that were potentially misclassified as



“not occupied” in the South Coast, Columbia, OESF, and Straits HCP planning units (Raphael and others 2008).

### **OESF HCP PLANNING UNIT**

Out of 767 sites surveyed in OESF, DNR found 306 occupied sites. The Science Team estimated that 55 additional sites may have been misclassified as “not occupied.” They recommended that all forests in which inventory surveys were conducted be deferred from harvest to completely mitigate the risk of not protecting misclassified sites in the OESF (Raphael and others 2008).

► **How this uncertainty was addressed:** As a result of this recommendation, DNR included existing high-quality northern spotted owl habitat<sup>3</sup> in existing conservation in long-term forest cover (LTFC) for the Long-term Strategy (refer to Chapter 2 in the marbled murrelet FEIS). In addition, special habitat areas were designated in the OESF. Special habitat areas provide marbled murrelet habitat and security forest, in addition to occupied sites and existing conservation in LTFC.

### **SOUTH COAST AND COLUMBIA HCP PLANNING UNITS**

Following the 1991 Tenyo Maru oil spill roughly 20 miles west of Cape Flattery, a trustee committee was formed to develop a restoration plan for resources harmed by the spill. Among the resources identified were marbled murrelets. An estimated seven to eleven percent of the total outer coast marbled murrelet population was killed by the spill.

One component of the restoration plan was to identify and permanently protect marbled murrelet inland habitat. In response to this restoration plan, WDFW conducted intensive surveys on the Olympic Peninsula and in southwest Washington in 2001 and 2002. These surveys resulted in several sites that had been classified as either unsurveyed, surveyed with no detections, or surveyed and presence detected to be re-classified as occupied. This intensive survey effort likely reduced the potential for error in classifying sites based on less intense survey efforts under earlier protocols. For more information on the Tenyo Maru oil spill, refer to Raphael and others 2008.

In their subsequent review of occupied sites (refer to Uncertainty #4), the Science Team estimated that a total of 17 occupied sites in Southwest Washington were misclassified as “not occupied.”

► **How this uncertainty was addressed:** Under the Long-term Strategy, special habitat areas were designated across western Washington in areas that were strategically important

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<sup>3</sup> Existing high-quality northern spotted owl habitat refers to the following DNR mapped habitat classes as of 2015: old forest, high-quality habitat, and A and B habitat per the definitions in the 1997 HCP (DNR 1997, p. 12).

to marbled murrelets, including southwest Washington. Special habitat areas include habitat that is in addition to the occupied sites in southwest Washington, which mitigates the risk of not protecting misclassified occupied sites in this area.

#### **Uncertainty #4: Habitat Relationship Study Did Not Identify All Higher Quality Habitat**

This uncertainty was identified by the Science Team regarding the implementation of the Interim Strategy. To address this issue, the Science Team evaluated the delineation of occupied sites and the condition of murrelet non-habitat, marginal habitat, and reclassified habitat using color orthophotos (dated 2005 for the OESF and 2003 for southwest Washington). This effort was supplemented by limited field verification. Based on this work, the Science Team added and subtracted areas from occupied sites and recommended that total occupied site protection be increased from 42,975 acres to 59,331 acres, a 38 percent increase (Raphael and others 2008)

► **How this uncertainty was addressed:** The HCP Amendment protects these “Science Team-delineated” occupied sites. Because the Science Team did not examine North Puget HCP planning unit, occupied sites in North Puget were delineated by DNR staff in the field based on platform-bearing trees or through the inspection of color orthophotos.

#### **Uncertainties Identified in the Analytical Framework**

As DNR began working jointly with USFWS, the two agencies developed an “analytical framework” to provide objective, repeatable, science-based estimates of potential impacts and mitigation to marbled murrelet habitat from DNR’s land management activities. In the analytical framework, the value of habitat is adjusted based on time, edge effects, and other factors, including geographic location. These adjustments help ensure that harvested habitat is mitigated with habitat that provides similar or better function to the murrelet. For more information on the analytical framework, refer to Appendix B of the marbled murrelet FEIS. Refer to Appendix D of the marbled murrelet FEIS for more information on occupied sites. For more information on impacts and mitigation, P-stage, and LTFC, refer to Appendix C, attachments C-1, C-3, and C-4, respectively.

The following section discusses uncertainties that were identified by the Science Team, DNR or USFWS staff, or members of the public during the development of alternatives for the FEIS, and how those uncertainties were addressed by the analytical framework based on scientifically supported assumptions.

## Uncertainty #5: Identification of Murrelet Habitat

Marbled murrelets were proposed for listing under the Endangered Species Act in part because their habitat in older, complex-structured forests was thought to be so diminished by timber harvest that nesting opportunities were limiting the population (USFWS 1992). Contemporary research continues to support the importance of both *quantity* and *quality* of nesting habitat to murrelet distribution and abundance (for example, Raphael and others 2015). However, the Science Team identified “considerable uncertainty about how the amount, stand-level characteristics, and configuration of forest habitat influence key elements of population biology, nesting rates, nest success, and adult survival of marbled murrelets” (Raphael 2006 as cited in Raphael and others 2008).

► **How these uncertainties were addressed:** DNR and USFWS used a habitat model to identify the current and potential future location and quality of marbled murrelet habitat across DNR-managed lands. The model they used is called “P-stage.” The P-stage model was first developed by the Science Team using information from DNR-commissioned murrelet surveys, forest inventory, and forest growth modeling as well as general murrelet and silvicultural science. P-stage is based on a conceptual model of marbled murrelet nesting habitat (for example, Nelson 1997) as it relates to stand development in natural forests (for example, Franklin and Spies 2002). It generalizes and classifies levels of habitat quality as they relate to forest stand characteristics. (Refer to Appendix C, Attachment C-3 for more information on the P-stage habitat model.)

The P-stage model of Raphael and others (2008) was modified slightly for the analysis of the Long-term Strategy to apply more broadly across all DNR-managed forests in western Washington and to incorporate updated information and understanding of murrelet habitat and stand development. The most significant update was to the plan area, which was expanded beyond the four coastal HCP planning units analyzed by the Science Team to include the North and South Puget HCP planning units. This change approximately doubled the plan area. The P-stage model differentiates between stands that were naturally regenerated and those that were planted to avoid predicting that late 20th century plantations with few or no legacy trees would develop into habitat during the 50-year analysis projections. As a result, the model predicts habitat development in naturally regenerated stands that often include considerable biological legacies due to historical timber harvest methods.

## Uncertainty #6: Relationship Between Occupancy and Marbled Murrelet Nesting

Plissner and others (2015) identified five behaviors that regularly occur in the vicinity of known marbled murrelet nest sites. These are sub-canopy flights, landings, stationary vocalizations, jet dives, and circling. They found “studies providing evidence that all five types of occupied behaviors occurred at active nest sites and that four of the five types of occupied behaviors (i.e.,

all except jet dives) occurred at inactive nest sites. These data indicate that occupied behaviors occur not only at active nesting sites, but also suggest that they might be associated with past nesting attempts and potentially with future nesting attempts.”

In 2019, Oregon Department of Forestry (ODF) noted uncertainty regarding the relationship between occupied behaviors and actual nesting: “There are still key unanswered questions regarding the relationship of these behaviors to active nesting and this topic has not been systematically examined using a rigorous study design. We do not fully understand how often these behaviors occur in suitable habitat not actually used for nesting (e.g., by non-nesting birds prospecting for nest sites or by incidental flights below the canopy).”

► **How this uncertainty was addressed:** DNR and USFWS addressed this uncertainty by assuming that all occupied sites are being used for nesting and by deferring them from harvest and protecting them with buffers. Despite uncertainty, occupied sites represent the best information available to DNR and USFWS about where murrelets might be nesting.

## Uncertainty #7: Scale and Resolution of the P-stage Model and its Possible Misidentification of Stands

### RESOLUTION AND SCALE

The scale at which murrelets select habitat is not known. Clearly, murrelets need an appropriate nest platform in a context that provides stability and security during the nesting season. Uncertainty about the scale at which habitat is distinguished from non-habitat, and how to distinguish among levels of habitat quality, is likely responsible for much uncertainty in all habitat modeling and delineation exercises. However, the scale and resolution of P-stage predictions are appropriate to identify most murrelet habitat, as suggested by the consistent, broad-scale relationship of murrelet numbers with habitat area as identified with a variety of habitat models (Burger 2002, Raphael and others 2002, Raphael and others 2015) and the consistent patterns of murrelet inland habitat use in identifiable habitat patches (in other words, “stands”) as identified with a variety of methods (for example, McShane and others 2004).

DNR’s current forest inventory is collected from sample plots, which comprise approximately one percent of stand area for overstory trees (where potential murrelet nest sites occur). Even though stands were delineated from high-resolution aerial photography based on apparent similarity of vegetation and topography, considerable fine-grained heterogeneity within stands can occur because heterogeneity can be obscured when stand-level averages are compiled from plot data. Consequently, discrete areas of habitat can be missed within stands with average characteristics of non-habitat or vice-versa. However, the great majority of murrelet nests have been located within forests that are broadly

recognizable as murrelet habitat (for example, McShane and others 2004), lending confidence that stand-level habitat classification can identify most murrelet habitat.

### **MISIDENTIFICATION OF HABITAT**

Public comments received through public meetings, written comments and other forms of stakeholder outreach indicated concern about P-stage misidentifying stands that contain murrelet habitat. Refer to Appendix S of the marbled murrelet FEIS for more information on comments provided to DNR and USFWS after the release of the DEIS and RDEIS and responses to those comments.

► **How this uncertainty was addressed:** In order to improve the accuracy of P-stage, the joint agencies corrected the underlying inventory data by applying a more accurate inventory to forest stands without inventory data, including habitat identified by USFWS and WDFW, and correcting mapping errors. For more information on these and other data updates, refer to Appendix O to the marbled murrelet FEIS. The HCP Amendment relies on this updated P-stage data layer. For more information on P-stage, refer to Attachment C-3 to this HCP Amendment.

### **Uncertainty #8: Future Occupancy**

Public comments received through public meetings, written comments, and other forms of stakeholder outreach indicated concern about the potential for occupancy to occur in the future. The HCP Amendment does not protect occupied sites identified after the amendment is adopted.

► **How this uncertainty was addressed:** Acres with current and future P-stage values are protected within LTFC, which means that the HCP Amendment conserves areas where occupancy is unknown, but the stand development stage indicates a probability of nesting.

### **Uncertainty #9: Influence of Edge on Occupied Sites**

This uncertainty was identified by the Science Team and both DNR and USFWS staff. The scientific literature indicates that edge effects from an actively managed forest extend further than 164 feet (50 meters) into the stand but diminish until there is minimal effect after 328 feet (100 meters) from the managed area (Burger and others 2004).

► **How this uncertainty was addressed:** A 328-foot (100-meter) buffer was applied to all occupied sites. Additional rules designed to avoid and minimize the impacts on specific activities permitted under the 1997 HCP are reported in Appendix A, Table A-4. Refer to Chapter 2 in the marbled murrelet FEIS for more information on edges and murrelet habitat configuration.

## Uncertainty #10: Influence of Edge on Murrelet Habitat

Uncertainties about the influence of edge on murrelet habitat were first identified by the Science Team. DNR and USFWS later built strategies to address these uncertainties as part of the analytical framework. The analytical framework adjusts the mitigation value of habitat located in the edges of LTFC to account for edge effects that will impact that habitat over the life of the 1997 HCP. The adjustment factors are based on proximity to habitat (inner or outer edge) and edge condition (hard, soft or no edge). The resulting edge factors are then multiplied against the number of habitat acres in each edge condition to derive the total potential impacts from edge effects.

► **How this uncertainty was addressed:** Mitigation credit was reduced for habitat that develops within edges. The HCP Amendment also reduces the impact value of habitat located in P-stage slivers to account for edge effects. P-stage slivers are areas of murrelet habitat located outside LTFC that are less than 656 (200 meters) wide. Because of their size and shape, P-stage slivers have no inner edge or interior forest; therefore, only discounts for outer edge are applied. For more information on edges and how they are quantified in the analytical framework, refer to Attachment C-1.

## Uncertainty #11: The Value of Murrelet Habitat in Stringers

Areas mapped as LTFC using GIS will show large and small blocks of LTFC, as well as some narrow strips of land where adjacent uplands are not designated as long-term forest cover. These narrow (less than 200-meter wide) forested strips are called stringers and are predominantly riparian management zones. Stringers do not have interior forest.

Because of edge effects, stringers have the potential to function as biological “sinks” for murrelets. In other words, they may attract murrelets to nest because of their habitat characteristics, but those nests will be exposed to edge effects and therefore unlikely to be successful. A literature review by ODF in 2019 found that the relationship between murrelet nesting success and landscape characteristics is complicated, and available information does not indicate a consistent trend; however, many studies indicate higher nesting success away from hard edges (ODF 2019). Malt and Lank (2009) conducted a study of nesting depredation using artificial nests and demonstrated that predator disturbance was more likely at hard edges than in interior habitats (ODF 2019). Another study has shown that marbled murrelet nesting is likely to be more productive if the habitat is surrounded by simple-structured forest (McShane and others 2004, p. 4-94).

However, stringers may provide some level of support for murrelet nesting. There is conflicting information available regarding whether murrelets tend to locate nests in large interior forest patches (ODF 2019). McShane and others (2004) found that, range-wide, most nests occurred along edges, although in most cases these were natural edges. It was unknown if this tendency

resulted from the prevalence of forest fragmentation and natural edges, or if edges provide murrelets easier access to their nests for both adults and chicks during fledging (McShane and others 2004).

► **How this uncertainty was addressed:** DNR included stringers within LTFC but did not assign mitigation credit to the habitat that develops within them. Table 1 shows acres of current habitat within stringers.

**Table 1. Acres of Current Habitat in Stringers in the Plan and Permit Area**

P-stage	0.25	0.36	0.47	0.62	0.89	1.0	Total
Acres	21,677	5,437	2,055	1,727	2,332	3,744	36,972

### Uncertainty #12: Mitigation Credit for LTFC

A significant question that DNR and USFWS addressed early in the development of the analytical framework was whether and how much mitigation credit DNR should receive for areas conserved under the other HCP conservation strategies. Both agencies recognized that stands with characteristics that could support marbled murrelets can be found on DNR-managed HCP lands within the range of the marbled murrelet and, in many cases, these stands are already designated by existing DNR policy to provide conservation benefits.

The amendment identified forest lands that will be managed as LTFC. LTFC may have current habitat or the capability to develop into the types of structurally complex forests needed for nesting by the murrelet. LTFC will be managed to maintain forest cover over the life of the 1997 HCP. For more information on LTFC, refer to Appendix C, Attachment C-4.

► **How this uncertainty was addressed:** DNR does not receive mitigation credit for all of the acres managed under other HCP conservation strategies. Mitigation credit is only assigned when existing forest cover either becomes murrelet habitat or existing habitat transitions from on P-stage category to another. If existing forest cover does not transition to a higher-quality P-stage category, DNR does not receive mitigation credit. Habitat located in stringers (narrow areas of LTFC [less than 200 meters wide] where adjacent uplands have not been designated as LTFC) is not given mitigation credit. For more information on how impacts and mitigation are calculated, refer to Appendix C, Attachment C-1.

### Uncertainty #13: Data Depicting Existing Conservation

Areas of LTFC can be found throughout the plan and permit area for the HCP Amendment. These areas of LTFC are defined and mapped using GIS information from DNR’s databases. Areas of LTFC come in various shapes and sizes, and when in a strategic location and suitable

habitat condition, provide nesting opportunity for the marbled murrelet. LTFC includes the following types of lands:

- Natural area preserves
- Natural resources conservation areas
- High-quality northern spotted owl habitat
- Riparian management zones
- Wetlands
- Areas of slope stability concern
- Gene pool reserves
- Old-growth
- Local knowledge of ecological/social and culturally important areas
- Marbled murrelet occupied sites
- Areas specifically designated for marbled murrelet conservation in strategic locations

Taken together, these areas create blocks of land that contribute to marbled murrelet conservation if the structure and complexity of the forest within provides nesting habitat and security from predation. The precise boundaries of some categories of LTFC are accurately mapped in DNR databases. Examples include gene pool reserves and natural area preserves. These boundaries are not expected to change throughout the life of the 1997 HCP.

However, other categories of LTFC are not precisely mapped but are approximated until field inspections can more accurately define correct boundaries. LTFC associated with riparian areas, wetlands, and unstable slopes are examples where the boundaries may be adjusted when site-specific information becomes available. Although the exact location of LTFC associated with riparian areas can change with field verification, the total acres of LTFC associated with these deferrals is a reasonably accurate estimate of the total LTFC expected to be retained on the landscape.

► **How this uncertainty was addressed:** The assumption in the analytical framework is that some habitat estimated to be mitigation will fall outside of LTFC boundaries and be impacted. Other habitat estimated to be impacted will be found within LTFC boundaries after field verification and serve as mitigation. The analytical framework assumes that there will be no bias in how these boundaries will be located in the field.



## Uncertainty #14: Development of Future Habitat

It is uncertain how future habitat will function to support murrelets, especially compared with habitat that exists today. However, habitat that exists today currently provides nesting opportunities to murrelets and is therefore more valuable than habitat that will develop in the future (as forests mature). If an impact to that habitat happens today, the offsetting mitigation (the same value of habitat becoming available to the murrelet) may not happen for several years. The analytical framework takes this into account by adjusting the value of mitigation through time, which is expressed by decade to the end of the 1997 HCP.

► **How this uncertainty was addressed:** The analytical framework discounts future habitat based on the length of time that it is predicted to occur on the landscape. The decadal adjustment factor is based on how much habitat develops in a particular decade, as well as the decade in which that habitat is realized. For example, the total habitat that develops in LTFC from the present into the first decade receives full mitigation credit to offset harvest in the managed forest within that first decade; all of the acres are counted. However, the total habitat that develops during the second decade receive only 80 percent of the total credit because the habitat that grows during this decade will contribute to murrelet conservation for less time, four out of the five total decades ( $4/5 = 80$  percent). Growth occurring during the third decade receives 60 percent credit (three out of five decades of growth), and so on through to the end of the 1997 HCP.

For more information on how the analytical framework discounts mitigation for time, refer to Appendix C, Attachment C-1.

## Uncertainty #15: Impacts of Roads on Murrelet Habitat

Forest roads associated with timber harvests act as edges, which in turn affect the success of murrelet nests as discussed earlier in this attachment. Little information is available about the specific intensity of the edge effect that forest roads alone have on marbled murrelet nests. Some studies using artificial nests near logging roads did not show an increased predation effect (Yahner and Mahan 1997; Ortega and Capen 2002), but these studies were not conducted for canopy-nesting birds in Pacific Northwest forests. In a study from British Columbia using artificial murrelet nests near clearcuts, roads and other forest edges indicated increased corvid abundance and potential predation near artificial edges (Burger and others 2004). Steller's jays in particular are found in greater abundance at edges created by roads and clearings (Masselink 2001; Burger and others 2004; Vigallon and Marzluff 2005). Roads constructed close to or within murrelet habitat are assumed to attract Steller's jays closer into the forest interior (Masselink 2001). As discussed previously, predation impacts have been found to be greatest within 164 feet (50 meters) of a forest edge.

► **How this uncertainty was addressed:** The analytical framework reduces the value of habitat located within 164 feet of a forest road to reflect potential increases in predation effects. The reduction in habitat value assumed attributable to roads can then be added to the other edge effect factors discussed in this attachment. However, a road bisecting an inner edge is assumed to contribute a portion of the predation edge effect (which for inner, hard edge forests is a 31 percent reduction in nest success [McShane and others 2004]). DNR applied a road edge effect factor throughout the landscape at 15.5 percent (half of 31 percent) to reflect these variations.

### **Uncertainty #16: Effect of Road Construction and Yarding Corridors on Conservation Areas**

A limited amount of road construction and yarding corridors in conservation areas will be allowed (refer to Appendix A, Table A-4).

► **How this uncertainty was addressed:** Impacts (take) were assigned to these areas. DNR estimated that new road construction in occupied sites, occupied site buffers, and special habitat areas would result in an impact of 104 adjusted acres over the 50 year planning period. Yarding corridors will result in another estimated 10 adjusted acres of impacts.

### **Uncertainty #17: The Value of Marginal Landscapes for Marbled Murrelets**

Across the analysis area, some landscapes are less valuable, or “marginal” for long-term marbled murrelet conservation due to a lack of suitable habitat, isolation from known occupied sites, and low-capability for developing future habitat based on forest types. An example of a marginal landscape for marbled murrelets is Capitol State Forest, located in the South Puget HCP planning unit. Capitol State Forest is a large landscape that encompasses more than 95,000 acres of DNR-managed HCP lands, but currently contains relatively little murrelet habitat (less than 2,000 acres). DNR conducted marbled murrelet surveys at more than 450 survey stations located within Capitol State Forest. Murrelet presence was detected at only one survey station, and no murrelet occupancy behaviors were detected during any of the surveys. Capitol State Forest has been intensively managed for timber production for many decades, and is comprised of forest dominated by second-growth Douglas-fir plantations which have a low capability to develop into murrelet habitat during the life of the 1997 HCP. Due to the limited and fragmented nature of potential habitat in this landscape, and no known occupied murrelet sites, Capitol State Forest is considered to be a marginal landscape for murrelet conservation.

► **How this uncertainty was addressed:** The analytical framework applies a reduced mitigation credit (25 percent of the value) for habitat conserved in areas of LTFC in marginal landscapes, relative to other areas that are more likely to contribute to long-term murrelet conservation. For more on marginal landscapes, refer to Appendix C, Attachment C-1.

## Uncertainty #18: The Effects of Natural Disturbance and Climate Change on Mitigation

Raphael and others (2016) assessed current natural disturbance rates of marbled murrelet habitat and reported that, between 1993 and 2012, 11,116 acres of “higher quality habitat” was lost to natural disturbance across all ownerships in Washington, including federal reserves. This amount represents a loss of about 0.72 percent of murrelet habitat over 20 years, or about 0.36 percent habitat loss per decade across all ownerships due to natural disturbance (wildfire, windthrow, insects, and disease). The analysis by Raphael and others (2016) was done using a “Maxent” marbled murrelet habitat model that USFWS and DNR found to be reasonably consistent with the P-stage model (refer to Appendix C, Attachment C-3). Davis and others (2016) also studied disturbance rates of northern spotted owl habitat and found results similar to those reported by Raphael and others (2016) for all lands in western Washington.

The amount of mitigation currently estimated under the HCP Amendment for all five decades is 11,905 adjusted acres. If the rate of 0.36 percent habitat loss per decade is applied, the total mitigation is 11,680 acres, a reduction of 225 acres (refer to Table 2).

**Table 2. Calculation of time and natural disturbance-adjusted mitigation**

Decade	Unadjusted mitigation (raw acres)	Mitigation value based on decade of development	Disturbance loss rate	Decade and disturbance loss adjustment	Decade and disturbance adjusted mitigation (Unadjusted mitigation x decade and disturbance loss adjustment)
1	4,423	1	0.36%	0.9964	4,408
2	3,119	0.8	0.72%	0.7928	2,473
3	3,601	0.6	1.08%	0.5892	2,122
4	4,884	0.4	1.44%	0.3856	1,884
5	4,361	0.2	1.79%	0.1821	794
<b>Total</b>					<b>11,680</b>

As described in Section 3.2 of the FEIS, rates of different type of natural disturbances are expected to change due to climate change. Some disturbance rates are expected to increase, others decrease, and others to stay about the same as they are currently. For each type of disturbance, there is uncertainty in the magnitude of change. Based on the information in Section 3.2 of the FEIS, DNR estimates that the natural disturbance rate of murrelet habitat may double by the end of the 50-year analysis period due to climate change.

As stated previously, the amount of mitigation currently estimated under the HCP Amendment for all five decades is 11,905 adjusted acres. If the rate of 0.36 percent habitat loss per decade is doubled for climate change, the total mitigation is 11,510 acres, a reduction of 395 acres (refer to Table 3).

**Table 3. Calculation of time and natural disturbance-adjusted mitigation, including an adjustment for climate change**

Decade	Unadjusted mitigation (raw acres)	Mitigation value based on decade of development	Disturbance loss rate	Natural disturbance rate multiplier	Adjusted disturbance loss rate	Decade and disturbance loss adjustment	Decade and disturbance adjusted mitigation (Unadjusted mitigation x decade and disturbance loss adjustment)
1	4,423	1	0.36%	1.2	0.43%	0.9957	4,404
2	3,119	0.8	0.72%	1.4	1.00%	0.7900	2,464
3	3,601	0.6	1.08%	1.6	1.72%	0.5828	2,099
4	4,884	0.4	1.44%	1.8	2.58%	0.3742	1,828
5	4,361	0.2	1.79%	2.0	3.59%	0.1641	716
<b>Total</b>							11,510

► **How this uncertainty was addressed:** The Joint Agencies addressed this uncertainty by ensuring that potential mitigation exceeded potential impacts enough to account for natural disturbance. DNR estimates impacts at 11,085 adjusted acres, which is 425 fewer adjusted acres than potential mitigation under climate change (11,510 adjusted acres).

### Uncertainty #19: Harvest of Marbled Murrelet Habitat

Outside of LTFC, some murrelet habitat will be harvested.

► **How this uncertainty was addressed:** As a “reasonable worst case” scenario, the FEIS analysis assumed that all harvest of this habitat would occur in the first decade of the planning period. (The area of murrelet habitat outside of LTFC is reported in Section 4.6 of the FEIS.) Due to metering and other operational constraints, it is not possible for all murrelet habitat outside LTFC to be harvested in the first decade. Per initial analysis, it is not likely that all of this habitat will be harvested in the second decade either.

### Uncertainty #20: Effect of Forest Management Activities on Marbled Murrelet Habitat

The HCP permits a range of forest management activities. The analytical framework relies upon an analysis of all activities permitted to occur on DNR-managed HCP lands to determine whether they have the potential to cause disturbance to marbled murrelets. The framework identifies 36 activities that may cause disturbance. Examples include:

- Recreational site use
- Sand and gravel sales
- Electronic site maintenance

- Road use and maintenance
- Collection of western greens, Christmas greens, and mushrooms

► **How this uncertainty was addressed:** The HCP Amendment incorporates conservation measures to avoid or minimize the impacts of all activities permitted under the 1997 HCP (refer to Appendix A, Table A-4). Impacts due to these activities are assessed in the marbled murrelet FEIS in Section 4.6. Activities not identified in the 1997 HCP will not be covered under the incidental take permit issued by USFWS.

## ***Additional Conservation Benefits of the Amendment***

### **Habitat Development Within Occupied Sites**

Based on their origin, dominant species type, and age, forest stands on DNR-managed HCP lands are assigned to one of the six categories of P-stage. In ascending order of quality, these categories are 0 (non-habitat), 0.25, 0.36, 0.47, 0.62, and 0.89. Occupied sites, as demonstrated by the survey results, are assigned a value of 1.0 to reflect that the stand is occupied and therefore has a one hundred percent probability of occupancy.

However, stands within occupied sites have an underlying P-stage value between 0 and 0.89, meaning that not all forests within an occupied site are identified as having a P-stage value. Because occupied sites are assigned a value of 1.0, DNR does not receive mitigation credit when non-habitat within an occupied site becomes habitat, or when current habitat transitions to a higher P-stage category. Under the analytical framework, mitigation credit is only assigned when existing forest cover either becomes murrelet habitat or existing habitat transitions from one P-stage category to another. This assumption is recognized in the population viability analysis (Appendix C, Attachment C-2).

► **Additional conservation benefit:** Occupied sites will be conserved for the life of the HCP Amendment. Development of habitat within these sites is a potential increase in habitat capacity for which DNR will not receive specific mitigation credit.

### **Habitat Development Within Low-Quality Northern Spotted Owl Habitat**

DNR's northern spotted owl conservation strategies involves maintaining thresholds of habitat in each spotted owl management unit (SOMU). Most designated nesting, roosting, and foraging and dispersal SOMUs have a 50 percent overall habitat threshold. The OESF and South Puget HCP planning units have two-tiered habitat thresholds which are described later in this section.

Northern spotted owl habitat and murrelet habitat do not have the same characteristics. However, some northern spotted owl habitat also is assigned to a P-stage category, acknowledging its function as both owl and murrelet habitat.

The HCP Amendment does not designate low-quality northern spotted owl habitat<sup>4</sup> as existing conservation within LTFC. Per the northern spotted owl conservation strategy, amounts of low-quality northern spotted habitat in excess of threshold amounts can be harvested, so long as habitat thresholds can be maintained within the SOMU. Therefore, there is no guarantee that low-quality habitat that is also murrelet habitat will persist on the landscape in any given location until the end of the planning period for the HCP Amendment.

According to DNR's 2018 *HCP Annual Report*, in Columbia and North Puget HCP planning units, three of ten dispersal SOMUs have reached their 50 percent thresholds. Four of those SOMUS are above 40 percent but under 50 percent, and the remaining three are below 40 percent.

In the OESF HCP planning unit, DNR's objective is to restore and maintain threshold amounts of northern spotted owl habitat in each of 11 landscape planning units: at least 40 percent of DNR-managed HCP lands as structural habitat<sup>5</sup> and at least 20 percent of DNR-managed HCP lands as Old Forest Habitat. Only two of the eleven landscape planning units have reached the 40 percent threshold, and only two have reached the 20 percent threshold. None have reached both.

The South Puget HCP planning unit has a 50 percent overall habitat threshold for each SOMU. Dispersal management areas have an additional threshold of 35 percent of each SOMU as movement, roosting, and foraging habitat or better. The remaining habitat must be movement habitat or better. In South Puget HCP Planning Unit, no SOMUs have reached the 35 percent threshold.

► **Additional conservation benefit:** Based on the current levels of northern spotted owl habitat within SOMUs and landscape planning units in relation to their thresholds, harvest of low-quality northern spotted owl habitat may not occur at all in some SOMUs and landscape planning units, and may not occur for two or more decades in others. Because this habitat is located outside LTFC, DNR does not receive mitigation credit for it. The lack of mitigation credit for low-quality northern spotted owl habitat demonstrates another way in which DNR-managed HCP lands under the HCP Amendment will likely provide more support for marbled murrelet populations than the mitigation credit reflects. In addition, this northern spotted owl

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<sup>4</sup> Refers to the following DNR-mapped habitat classes as of 2015: sub-mature; movement, roosting, and foraging; movement; young forest marginal; and dispersal habitat per the definitions in the 1997 HCP (DNR 1997, p. 12) and the 2008 South Puget Forest Land Plan.

<sup>5</sup> Sub-mature and young forest marginal habitat.

habitat also provides value to marbled murrelets in the form of security habitat. Security habitat reduces edge and provides security from predators and other edge related disturbances.

### Habitat Development in “Metered” Acres

Under the Long-term Strategy, DNR will delay (“meter”), until the end of the first decade following implementation, the harvest of 5,000 adjusted acres of murrelet habitat that DNR would otherwise be authorized to harvest upon amendment of its incidental take permit.

► **Additional conservation benefit:** The analytical framework does not provide mitigation credit for these acres because it assumes that they will be harvested in the second decade. Nonetheless, these stands will provide conservation benefits to the murrelet for at least the first decade of implementation of the Long-term Strategy.

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# Appendix D

## **Board of Natural Resources Resolution 1559 and Transmittal Letter from U.S. Fish and Wildlife Service for the Incidental Take Permit**

On December 3, 2019, the Board of Natural Resources passed Resolution 1559, which adopts the Marbled Murrelet Long-term Conservation Strategy as an amendment to the 1997 *State Trust Lands Habitat Conservation Plan (HCP)*.

On November 14, 2019, U.S. Fish and Wildlife Service issued DNR an amended incidental take permit for the marbled murrelet and other species covered by DNR's amended 1997 HCP. This letter was signed by Hugh Morrison, Acting Deputy Regional Director.



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**STATE OF WASHINGTON**  
**DEPARTMENT OF NATURAL RESOURCES**  
**BOARD OF NATURAL RESOURCES**

**RESOLUTION NO. 1559**

A RESOLUTION approving the amendment (AMENDMENT) to the 1997 Habitat Conservation Plan (1997 HCP) to replace the interim marbled murrelet conservation strategy described in the 1997 HCP with the long-term marbled murrelet conservation strategy.

**BE IT RESOLVED BY THE BOARD OF NATURAL RESOURCES, DEPARTMENT OF NATURAL RESOURCES, STATE OF WASHINGTON, THAT:**

**SECTION 1.** The Department of Natural Resources staff (DNR) has presented to the Board of Natural Resources (BOARD) the AMENDMENT approved by the United States Fish and Wildlife Service, an agency of the federal government (hereafter "SERVICE"). The AMENDMENT is attached as Resolution Exhibit A.

**SECTION 2.** The AMENDMENT was negotiated by DNR and the SERVICE to address DNR's compliance with the Endangered Species Act of 1973, as amended 16 U.S.C § 1531 - 1544, on approximately 1.38 million acres of DNR-manage lands. The AMENDMENT supports the issuance of an amended incidental take permit (ITP) under section 10 of the Endangered Species Act of 1973, as amended 16 U.S.C § 1539, for the marbled murrelet on the approximately 1.38 million acres within the HCP's five Westside Planning Units and the Olympic Experimental State Forest. The ITP (TE81252 1-1) is attached as Resolution Exhibit B.

**SECTION 3.** The AMENDMENT will remain in effect until the end of the initial 70-year term of the 1997 HCP, ITP, and implementation agreement (IA). This period began on 30 January 1997 and will end on 30 January 2067. The 1997 HCP, ITP, and IA may be extended for up to 30 additional years consisting of three 10-year extensions. This AMENDMENT will remain in effect for the duration of any such approved extensions

**SECTION 4.** The AMENDMENT has been through an extensive public process. DNR and the SERVICE began public scoping for a joint State Environmental Policy Act and National Environmental Policy Act environmental impact statement (EIS) process in 2006. Public scoping continued in 2012 and 2013. Comments received during these scoping periods were included for consideration in the EIS process. DNR and SERVICE published a draft EIS in 2016 and a revised draft EIS in 2018. Publication of each of these EIS's were followed by a series of four public meetings held across western Washington. In addition, a total of over 9,000 written public comment letters were received on the two EIS's. In all, DNR and SERVICE conducted over 20 public meetings, while also meeting separately with stakeholder groups numerous times to explain different aspects of the proposed long-term conservation strategy and supporting environmental analysis, leading to the AMENDMENT. Responses to the written comments received on the draft EIS and revised draft EIS were also included in the final EIS for the long-term conservation strategy, published in September 2019. The marbled murrelet long-term

conservation strategy has also been a topic presented at numerous BOARD meetings between 2013 and 2019.

**SECTION 5.** The AMENDMENT follows the guiding principles provided to DNR staff by the BOARD in November 2017 to minimize impacts to marbled murrelets, offset impacts and address uncertainty, and reduce disproportionate financial impacts to trust beneficiaries.

**SECTION 6.** The AMENDMENT changes the 1997 HCP by replacing the interim marbled murrelet conservation strategy only; it does not change DNR's obligation to any other strategies under the HCP or to the HCP implementation agreement, Appendix B to the 1997 HCP.

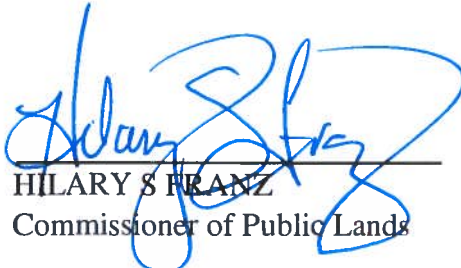
**SECTION 7.** DNR and the BOARD have given full and careful consideration to the EIS. Accordingly, the BOARD finds that the EIS, including comments and responses thereto, adequately identifies and discusses the probable significant adverse impacts on the environment that may result from implementation of the AMENDMENT and the identified alternatives.

**SECTION 8.** DNR and the BOARD have given full and careful consideration to the AMENDMENT, and the economic effects of the AMENDMENT on trust assets. Accordingly, the BOARD, acting consistent with its fiduciary duties and in the exercise of reasonable judgement, determines that on balance, the AMENDMENT is in the best interest of each trust.


**SECTION 9.** In consideration of the findings stated above, the BOARD hereby approves the AMENDMENT and accepts the terms of the ITP.

**APPROVED AND ADOPTED** by the Board of Natural Resources, Department of Natural Resources, State of Washington, this 3 day of December, 2019.

**IN WITNESS WHEREOF**, I have hereunto set my hand and affixed the official seal of the Commissioner of Public Lands.


  
HILARY S FRANZ  
Commissioner of Public Lands

\_\_\_\_\_  
BILL PEACH  
Clallam County Commissioner

  
\_\_\_\_\_  
CHRIS REYKDAL  
Superintendent of Public Instruction

\_\_\_\_\_  
ANDRÉ-DENIS WRIGHT  
Dean, College of Agricultural,  
Human & Natural Resource Sciences  
Washington State University

\_\_\_\_\_  
JIM CAHILL  
Senior Budget Assistant to the  
Governor for Natural Resources,  
Designee for Governor Jay Inslee

  
\_\_\_\_\_  
DAN BROWN  
Director, School of Environmental  
and Forest Sciences, College of the  
Environment, University of  
Washington

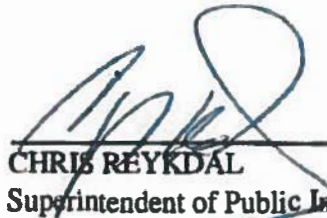
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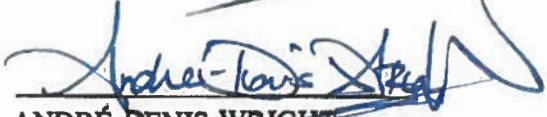
  
Sr. Assistant Attorney General

Date: 12/3/2019






  
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**CHRIS REYKDAL**  
Superintendent of Public Instruction

  
\_\_\_\_\_  
**ANDRÉ-DENIS WRIGHT**  
Dean, College of Agricultural,  
Human & Natural Resource Sciences  
Washington State University

\_\_\_\_\_  
**JIM CAHILL**  
Senior Budget Assistant to the  
Governor for Natural Resources,  
Designee for Governor Jay Inslee

  
\_\_\_\_\_  
**DAN BROWN**  
Director, School of Environmental  
and Forest Sciences, College of the  
Environment, University of  
Washington

Approved as to form:

  
\_\_\_\_\_  
Sr. Assistant Attorney General

Date: 12/3/2019





**DEPARTMENT OF  
NATURAL RESOURCES**

**OFFICE OF THE COMMISSIONER  
OF PUBLIC LANDS**

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**360-902-1000**  
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December 19, 2019

I, Theresa McGuire, declare under penalty of perjury under the law of the State of Washington, that the following is true and correct.

1. I am, and at all times hereinafter mentioned have been, a citizen of the United States over the age of 18 years. I have personal knowledge regarding the matters stated herein, and I am competent to testify as a witness.
2. I am the Board Coordinator for the Washington State Board of Natural Resources (Board). I have been in this position since July 2019.
3. On December 3, 2019, at the regularly scheduled meeting of the Board, a quorum of the members of the Board approved Resolution No. 1559 concerning the amendment to the 1997 Habitat Conservation Plan (1997 HCP) to replace the interim marbled murrelet conservation strategy described in the 1997 HCP with the long-term marbled murrelet conservation strategy.

SIGNED at Olympia, Washington, this 19 day of December, 2019.

\_\_\_\_\_  
THERESA MCGUIRE





## United States Department of the Interior

FISH AND WILDLIFE SERVICE  
911 NE 11<sup>th</sup> Avenue  
Portland, Oregon 97232-4181



In Reply Refer to:  
FWS/R1/AES/TE812521-1

NOV 14 2019

Angus W. Brodie  
Deputy Supervisor for State Uplands  
Washington Department of Natural Resources  
1111 Washington Street SE MS #47001  
Olympia, WA 98504-7000

Dear Mr. Brodie:

Enclosed is your amended Endangered Species Act (ESA) section 10(a)(1)(B) Incidental Take Permit (TE812521-1) for the amendment of the 1997 State Trust Lands Habitat Conservation Plan. The amended permit authorizes take of the federally threatened marbled murrelet (*Brachyramphus marmoratus*) and other covered species caused by covered activities that are implemented in accordance with your amended Habitat Conservation Plan.

By mutual understanding between our respective agencies, this Permit will go into effect if and when the Washington Board of Natural Resources adopts the Permit and all its Terms and Conditions. Until such time, the two agencies agree that Permit TE-812521 remains in effect and the Interim Strategy for the marbled murrelet will continue to be implemented per the 1997 HCP.

Thank you for helping to conserve listed species. If you have any questions regarding this permit, please contact the Field Supervisor of our Washington Fish and Wildlife Office at (360) 753-9440.

Sincerely,

Acting Deputy Regional Director

Enclosures (3)

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