Endangered Species Act - Section 7 Consultation

BIOLOGICAL OPINION

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Washington State Department of Natural Resources Marbled Murrelet Long-term Conservation Strategy Amendment to the 1997 Habitat Conservation Plan

Federal Action Agency: U.S. Fish and Wildlife Service

Consultation Conducted By:

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[signature] 11/7/2019

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Date

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ACRONYMS AND ABBREVIATIONS

CFR	Code of Federal Regulations
CHU	Critical Habitat Unit
CI	confidence interval
dBA	A-weighted decibel level
DNR	Department of Natural Resources (Washington State)
EIS	Environmental Impact Statement
ESA	Endangered Species Act of 1973, as amended (16 U.S.C. l531 *et seq.*)
FEIS	Final Environmental Impact Statement
FR	Federal Register
GIS	Geographic Information System
HCP	Habitat Conservation Plan
HUC	hydrologic unit code
IA	Implementing Agreement
ITP	Incidental Take Permit
LTFC	Long-term forest cover
murrelet	marbled murrelet
OESF	Olympic Experimental State Forest
Opinion	Biological Opinion
PBF	physical or biological features
PCE	Primary Constituent Element
PVA	population viability analysis
SEL	Sound Exposure Level
SHA	Special Habitat Area
USFWS	U.S. Fish and Wildlife Service
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington State Department of Natural Resources

1 INTRODUCTION

This document represents the U. S. Fish and Wildlife Service's (USFWS) Biological Opinion (Opinion) based on our review of a proposed amendment to the 1997 Washington Department of Natural Resources (WDNR) State Trust Lands Habitat Conservation Plan (HCP) (WDNR 1997). The proposed HCP amendment will replace an interim conservation strategy for the marbled murrelet (*Brachyramphus marmoratus*) (murrelet) described in the 1997 HCP with a long-term conservation strategy.

This Opinion evaluates the effects of the proposed HCP amendment on the federally threatened murrelet and designated critical habitat for the murrelet and in accordance with section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*) (ESA). This consultation was initiated concurrent with the publication of a *Final Environmental Impact for a Long-Term Conservation Strategy for the Marbled Murrelet* (FEIS) on September 20, 2019 (WDNR and USFWS 2019).

The USFWS determined that issuance of the proposed HCP amendment "may affect, and is likely to adversely affect" the murrelet and designated critical habitat for the murrelet. This Opinion is based on information provided in the 2019 FEIS and associated appendices, and in the September, 2019, HCP amendment titled: *Washington State Department of Natural Resources State Trust Lands Final Habitat Conservation Plan Amendment – Marbled Murrelet Long-term Conservation Strategy* (WDNR 2019), and other sources of information provided by WDNR. A complete record of this consultation is on file at the USFWS' Washington Fish and Wildlife Office in Lacey, Washington.

1.1.1 Habitat Conservation Plans and Incidental Take Permits

Section 9 of the ESA and federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct. *Harm* is defined by the USFWS as an act which actually kills or injures wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering (50 CFR 17.3). *Harass* is defined by the USFWS as an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering (50 CFR 17.3). *Incidental take* is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity.

To obtain an incidental take permit, an applicant must develop a conservation plan that meets specific requirements identified in section 10(a)(2)(A) of the ESA and its implementing regulations at 50 CFR 17.22 (endangered species) and 17.32 (threatened species), and 50 CFR 222.25, 222.27, and 222.31). Among other requirements, the plan must specify the impacts that are likely to result from the taking, the measures the permit applicant will undertake to minimize and mitigate such impacts, and the funding that will be available to implement such measures.

Conservation plans under section 10(a)(1)(B) are known as "habitat conservation plans" or "HCPs" for short. Section 10(a)(2)(B) of the ESA sets forth the statutory criteria that must be satisfied before an incidental take permit can be issued:

- The taking will be incidental;
- The applicant will, to the maximum extent practicable, minimize and mitigate the impacts of such taking;
- The applicant will ensure that adequate funding for the plan will be provided;
- The take will not appreciably reduce the likelihood of survival and recovery of the species in the wild; and
- Other measures (if any) that the Secretary of the Interior may require as being necessary or appropriate for the purposes of the plan are implemented.

Because the ESA requires the USFWS to establish that "the taking will not appreciably reduce the likelihood of the survival and recovery the species in the wild" as a pre-condition for issuing an incidental take permit, a permit that satisfies this criterion should also satisfy the first requirement of section 7(a)(2) of the ESA ["... insure that any action authorized, funded, or carried out by (a federal agency) is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species…"].

2 CONSULTATION HISTORY

In January, 1997, the USFWS completed an Opinion (USFWS 1997) and issued an Incidental Take Permit (PRT-812521) to WDNR pursuant to section 10(a)(1)(B) of the ESA for the *Washington State Department of Natural Resources State Trust Lands Final Habitat Conservation Plan* (WDNR 1997). That permit exempts the incidental take of northern spotted owl (*Strix occidentalis caurina*), murrelet, and other federally-listed species within the range of the northern spotted owl in Washington associated with forest and non-forested resource management on state lands managed by WDNR in accordance with the 1997 HCP.

The 1997 HCP included an Interim Conservation Strategy (Interim Strategy) for the murrelet because at the time the 1997 HCP was developed (mid 1990s), information about murrelet habitat use, both generally and specific to WDNR-managed HCP lands, was not sufficient to design and implement a long-term conservation strategy. From 1997 to present, WDNR has implemented land management activities within western Washington in compliance with the Interim Strategy as described in the 1997 HCP, and consistent with concurrence letters issued by USFWS in 2007 and 2009 regarding modifications to the Interim Strategy (FEIS Appendix I).

A summary of murrelet surveys, habitat relationship studies, and other efforts undertaken by WDNR to implement the interim murrelet strategy and develop a long-term conservation strategy for murrelets is described in the *Final HCP Amendment* (FEIS Appendix Q), the

Occupied Sites Focus Paper (FEIS Appendix D), and in the *Recommendations and Supporting Analysis of Conservation Opportunities for the Marbled Murrelet Long-term Conservation Strategy* (Raphael et al. 2008).

Public scoping to inform development of alternatives for a long-term strategy was completed in 2006, 2012, and in 2013 as described in the *Scoping Report* (FEIS Appendix A). From 2013 through 2019, USFWS staff provided technical assistance to WDNR in the development of alternatives considered for a long-term strategy including the final proposed HCP Amendment.

The USFWS and WDNR jointly published a draft Environmental Impact Statement (EIS) in December, 2016, and a revised draft EIS and draft HCP amendment in September, 2018. Following a comment period ending December 8, 2018, the USFWS and DNR published a final EIS and proposed final HCP amendment on September 20, 2019 (USFWS and WDNR 2019) (FEIS).

The focus of this analysis is the effect of the proposed HCP amendment on the murrelet. The USFWS has determined that the proposed HCP amendment "may affect, and is likely to adversely affect" the murrelet and designated murrelet critical habitat. The proposed HCP amendment will result in effects to murrelets that were not previously considered in the 1997 Opinion. For example, the proposed HCP amendment will release some existing murrelet habitat that has otherwise been deferred from timber harvest under the Interim Strategy and establishes conservation areas in some locations that would otherwise be available for timber production. The long-term conservation strategy had not been developed in 1997, and therefore its implementation was not evaluated in the 1997 Opinion.

The proposed HCP amendment for a murrelet long-term conservation strategy does not alter the existing conservation commitments or objectives of the 1997 HCP for the northern spotted owl, aquatic species, and uncommon habitats. With regard to the proposed HCP amendment, the USFWS evaluated whether or not the proposed HCP amendment has the potential to result in effects to a federally-listed species and/or designated critical habitats that were not previously considered either in the 1997 HCP, the 1997 Opinion, or in subsequent Incidental Take Permit amendments. With the exception of two species, the murrelet and the Taylor's checkerspot butterfly (*Euphydryas editha taylori*), the USFWS determined that the proposed HCP amendment will have no effect on all other federally-listed species and designated critical habitats. Federally-listed species and designated critical habitats that potentially occur within or adjacent to WDNR-managed lands, and the rationale for the USFWS effect determination for each species is provided in the administrative record for this Opinion (USFWS 2019a).

3 CONCURRENCE

3.1 Taylor's Checkerspot Butterfly

The Taylor's checkerspot butterfly (*Euphydryas editha taylori*) occurs on WDNR-managed lands at a location known as Dan Kelly Ridge, in Clallam County, Washington. Taylor's checkerspot butterfly occurs in natural grassy openings called "balds" and in early-seral habitats adjacent to the natural balds that were created by past clear-cut timber harvesting at Dan Kelly Ridge. The proposed long-term conservation strategy will establish 328-ft (100 m) buffers around mapped murrelet occupied sites. At Dan Kelly Ridge, there is a murrelet occupied site, and the 328-ft buffer surrounding the occupied site overlaps with early-seral habitats that support Taylor's checkerspot butterfly. Management activities within the occupied site buffers established under the Long-Term Strategy will be limited, and are intended to protect existing forest, or promote the development of forest cover within the buffer area to protect the integrity of the murrelet habitat within occupied sites. Therefore, the establishment of a murrelet occupied site buffer for the long-term conservation strategy establishes additional conservation under the HCP to provide long-term forest cover in an area that is currently being managed to maintain early-seral habitat for the Taylor's checkerspot. Because the proposed amendment has the potential to affect how early-seral habitat is managed for the Taylor's checkerspot butterfly in the future, the USFWS determined that the proposed HCP amendment "may affect, but is not likely to adversely affect" the Taylor's checkerspot butterfly. Critical habitat for the Taylor's checkerspot butterfly has been designated at Dan Kelly Ridge, but the proposed Long-Term Strategy will have "no effect" on the designated critical habitat. The designated critical habitat for Taylor's checkerspot butterfly occurs entirely outside of the proposed murrelet occupied site buffer.

The grassy balds that occur within the murrelet occupied site buffer are natural features that have limited capability for growing trees or supporting forest cover. Habitat maintenance or restoration within natural balds for Taylor's checkerspot butterfly will not be precluded in these areas by the establishment of a murrelet occupied site buffer. Management activities such as pre-commercial thinning in young forest will be allowed within occupied site buffers (WNDR 2019, Table A-4). Therefore, the effect of the proposed HCP amendment to Taylor's checkerspot butterfly is insignificant. WDNR, in cooperation with the Washington Department of Fish and Wildlife (WDFW) have engaged in habitat restoration and maintenance efforts at Dan Kelly Ridge under an existing recovery permit issued to WDFW under section 10(a)(1)(A) of the ESA. The effects of ongoing early-seral habitat management and restoration to benefit Taylor's checkerspot butterfly under the recovery permit program has been evaluated by the USFWS under section 7 of the ESA and is consistent with the conservation needs of the Taylor's checkerspot butterfly (USFWS 2015).

4 BIOLOGICAL OPINION

5 DESCRIPTION OF THE PROPOSED ACTION

A federal action means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by federal agencies in the United States or upon the high seas (50 CFR 402.02).

The federal action agency is the USFWS and the program is the issuance of an amended Incidental Take Permit (ITP) under section 10(a)(1)(B) of the ESA. Specifically, the USFWS proposes to amend WDNR's 1997 ITP for the proposed long-term conservation strategy for the murrelet. The Applicant (WDNR) has prepared and submitted a Permit application based on the proposed long-term conservation strategy for the murrelet. Specifically, the proposed Amendment will replace the interim murrelet conservation strategy (Interim Strategy) described in the 1997 HCP with a long-term murrelet conservation strategy (Long-Term Strategy) envisioned in the 1997 HCP (WDNR 1997). The proposed HCP amendment includes specific measures WDNR will implement to minimize and mitigate the impact of the taking of murrelets to the maximum extent practicable.

The proposed Long-Term Strategy is similar to Alternative H, which is described in the FEIS (WDNR and USFWS 2019). The Long-Term Strategy described focuses murrelet-specific conservation into 20 special habitat areas (SHA) that are distributed across strategically important locations for the murrelet and establishes 328-ft wide buffers around mapped murrelet occupied sites. The only difference between the Long-Term Strategy as described in the FEIS and Alternative H is that the Long-Term Strategy includes 441 more acres of long-term forest cover (LTFC[1]) 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.

5.1 Plan 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) (WDNR 1997, pp. B1-B19). The plan area encompasses all WDNR-managed HCP lands in the range of the northern spotted owl and include approximately 1.9 million acres of primarily forested lands. 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. The Plan area analyzed for the Long-Term

[1] Long-term forest cover (LTFC) is WDNR-managed lands on which WDNR maintains and grows forest cover for conservation purposes, including habitat conservation for the marbled murrelet, through the life of the 1997 HCP. Areas of long-term forest cover may have existing conservation commitments under the 1997 HCP (e.g., riparian areas), Policy for Sustainable Forests, Natural Heritage Program, and/or are identified as marbled murrelet conservation areas.

Strategy in the FEIS includes all WDNR-managed lands within the inland range of the murrelet (approximately 1.38 million acres) located within 55 miles of marine waters in western Washington.

5.2 Plan Duration

Upon amendment of WDNR's ITP, the Amendment will remain in 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 (WDNR 1997, pp. B1-B19). This period began on 30 January 1997 and will end on 30 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 consisting of three, 10-year extensions. This Amendment will remain in effect for the duration of any such approved extensions.

5.3 Covered Activities

Covered activities are the same as those described in 1997 HCP (WDNR 1997, pp. IV-191 to IV-212). No activities have been added or deleted. These activities include:

a. Timber Harvest and Silviculture:

- Variable retention timber harvest[2] (felling, yarding, rigging, hauling etc.).
- Commercial thinning timber harvest (roads, yarding, rigging, etc.).
- Salvage harvest of trees damaged by wind, fire, insects (roads, yarding, etc.)
- Reforestation (tree planting, fertilization, weed control, spraying).
- Forest health treatments (harvest, thinning, aerial spraying, replanting, etc.).
- Pre-commercial thinning.
- Forest resource inventory & monitoring, experimental treatments, research activities.
- Fire suppression (including aerial operations).

b. Transportation Network (existing and new facilities):

- New road construction.
- Road reconstruction or maintenance.
- Road decommissioning or abandonment.
- Use and development of rock quarries (existing, new, blasting, crushing).

[2] Variable retention harvest: A type of regeneration or stand-replacement timber harvest in which elements of the existing stand, such as down wood, snags, and leave trees (trees that are not harvested), are left for incorporation into the new stand. Variable retention harvest is different from a clearcut, in which all of the existing stand is removed.

c. Recreation Activities (existing and new facilities developments):

- Developed campgrounds.
- Day-use areas, trailheads, parking lots, restroom facilities.
- Recreation trails (motorized and non-motorized).

d. Non-Timber Resources:

- Rights-of-way (roads, transmission lines, etc.).
- Special forest products (floral greens, mushrooms, firewood).
- Communications leases.
- Mineral/Prospecting leases.
- Oil/Gas leases.

e. Land Disposition and/or Acquisitions

5.4 Long-Term Strategy Conservation Measures

The Long-Term Conservation Strategy builds upon an existing network of long-term forest cover (LTFC) that is established by 1997 HCP and other WDNR policies. This network of existing conservation comprises approximately 567,000 acres of WDNR-managed forest lands that are deferred from variable-retention timber harvest. The existing LTFC represents about 41 percent of the 1.38 million acres of WDNR-managed lands in western Washington. Not all areas within existing LTFC contain murrelet habitat, but many areas of existing LTFC currently provide murrelet habitat or are capable of developing suitable murrelet habitat in the future.

The Long-Term Strategy consists of three major components: occupied sites and occupied site buffers, special habitat areas in strategic locations, and other areas of existing LTFC (e.g., Natural Area Preserves, Natural Resource Conservation Areas, etc.). Additional conservation and minimization measured include additional restrictions and "metering" of habitat released for harvest over the first two decades of implementation of the Long-Term Strategy.

5.4.1 Occupied Sites and Occupied Site Buffers

Occupied sites are locations where audio/visual surveys for murrelets have documented one of the following:

- A murrelet nest is located.
- Downy murrelet chicks or eggs or egg shell fragments are found.
- Murrelets are detected flying below, through, or into or out of the forest canopy.
- Murrelets are heard calling from a stationary location within habitat.
- Murrelets are seen circling above a stand within one tree height of the top of the canopy.

Because of the difficulty in finding the specific tree within a forest stand that a murrelet might be using as a nest tree, most occupied sites are determined through observations of murrelets flying below, through, or into or out of the forest canopy, and/or murrelets circling above a forest stand within one tree height of the top of the canopy. This type of observation is documented as an occupancy behavior. A majority of the occupied sites mapped on WDNR-managed lands were identified through detection of occupancy behaviors rather than locating an actual nest location.

WDNR will protect murrelet habitat and restrict management activities and recreation in all murrelet occupied sites on WDNR-managed HCP lands as of the date on which the ITP is amended. "Occupied sites" for the proposed amendment means those sites that were delineated by the Science Team (Raphael et al. 2008) within the Straits, Olympic Experimental State Forest (OESF), South Coast and Columbia HCP planning units. Occupied sites in the North and South Puget HCP planning units were delineated by WDNR staff in the field based on the presence of platform-bearing trees or through the inspection of color orthophotos as described in the FEIS (2019) Appendix D and Appendix O.

"Protect murrelet habitat" means exclude variable retention harvest. "Restrict management and recreation activities" means restricting activities that may remove or damage trees, cause audio or visual disturbances, or attract predators to nest sites. WDNR will conserve 59,331 acres within 388 mapped murrelet occupied sites polygons. Most of these acres (85 percent) are within areas that have multiple conservation objectives as existing LTFC. WDNR 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.

WDNR will apply a 328-ft (100-m) buffer to the outer boundary of all recorded occupied sites on WDNR-managed HCP lands as of the date on which the ITP is amended. Within occupied site buffers, WDNR will exclude variable retention harvest and restrict management and recreation activities that may remove or damage trees, or disrupt murrelet nesting (WDNR 2019, Table A-4). Based on the currently recorded occupied sites, WDNR 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 as existing LTFC. WDNR will not buffer any occupied sites that are discovered after its ITP has been amended.

Under the proposed HCP amendment, some commercial thinning in young forest (non-murrelet habitat) will be allowed within the outer 164 ft (50 m) to enhance or maintain windfirmness of security forest in compliance with restrictions described in WDNR 2019 (Table A-4).

5.4.2 Special Habitat Areas in Strategic Locations

Additional murrelet-specific conservation is proposed through the designation of 20 Special Habitat Areas (SHAs) in strategic locations (Figure 1). Strategic locations are geographic areas within Washington that have a disproportionately high importance for murrelet conservation (FEIS Chapter 2).

Three strategic locations were identified by WDNR and USFWS: Southwest Washington, the OESF and Straits (west of the Elwha River), and North Puget. WDNR-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. WDNR-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. WDNR-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.

5.4.2.1 Special Habitat Areas

SHAs are conservation areas designed to reduce edge and fragmentation and increase the area of interior forest around occupied sites and existing murrelet habitat in specific geographic areas to benefit the species (FEIS Chapter 2) (Figure 2). SHAs consist of various habitat conditions, including occupied sites, areas of existing murrelet habitat not associated with occupied sites, modeled future murrelet habitat, and non-habitat areas that may function as security forest[3] now or in the future. Over the long term, additional murrelet habitat is expected to develop in SHAs as forests mature over the term of the HCP.

WDNR proposes to establish a network of 20 SHAs that encompass a total of 46,925 acres. Most (19) SHAs contain at least one occupied site (WDNR 2019, Table A-6). SHAs range in size from 338 acres to 7,549 acres (WDNR 2019, Table A-6). Habitat categories in SHAs are occupied sites, current habitat, future habitat, security forest, future security forest, and non-forested. Habitat means WDNR forest inventory units that have been assigned a habitat P-stage[4] value of at least 0.25. Future habitat means areas that are currently assigned a habitat P-stage value of 0, 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 areas that will not develop a P-stage value of at least 0.25 over the term of the HCP but have a closed canopy and trees greater than 80-ft tall. Future security forest means areas that do not yet meet the definition of security forest but are projected to reach that threshold over the term of the HCP. 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. All but 1,014 acres of the remaining acreage is either security forest or future security forest (WDNR 2019, Table A-6). Within SHAs, WDNR will exclude variable retention harvest and restrict management and recreation activities that may remove or damage trees, or disrupt murrelet nesting (WDNR 2019, Table A-4). Under the proposed HCP amendment, some commercial thinning in young forest (non-murrelet habitat) will be allowed within SHAs that are located in northern spotted management areas or in the OESF HCP planning unit in compliance with restrictions described in WDNR 2019 (Table A-4).

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[3] Security forest: A closed-canopy forest stand over 80-feet tall that is located adjacent to marbled murrelet nesting habitat and provides security from windthrow, predation, and other disturbances.

[4] The P-stage model classifies WDNR-managed HCP forestlands based on their relative value for murrelet use, represented as probability of occupancy, using WDNR'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 the FEIS Appendix E.

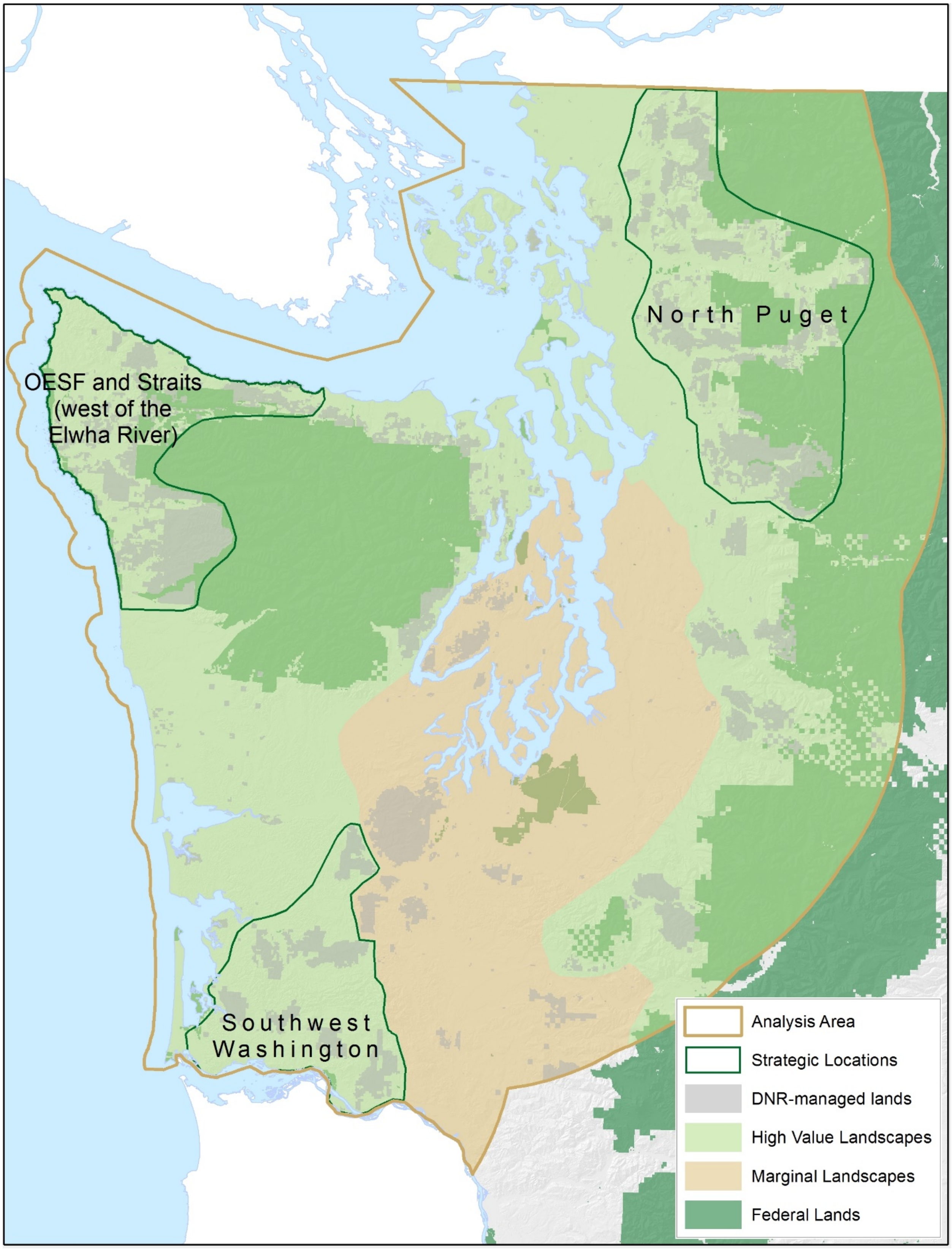

Figure 1. Landscapes and strategic locations for the murrelet.

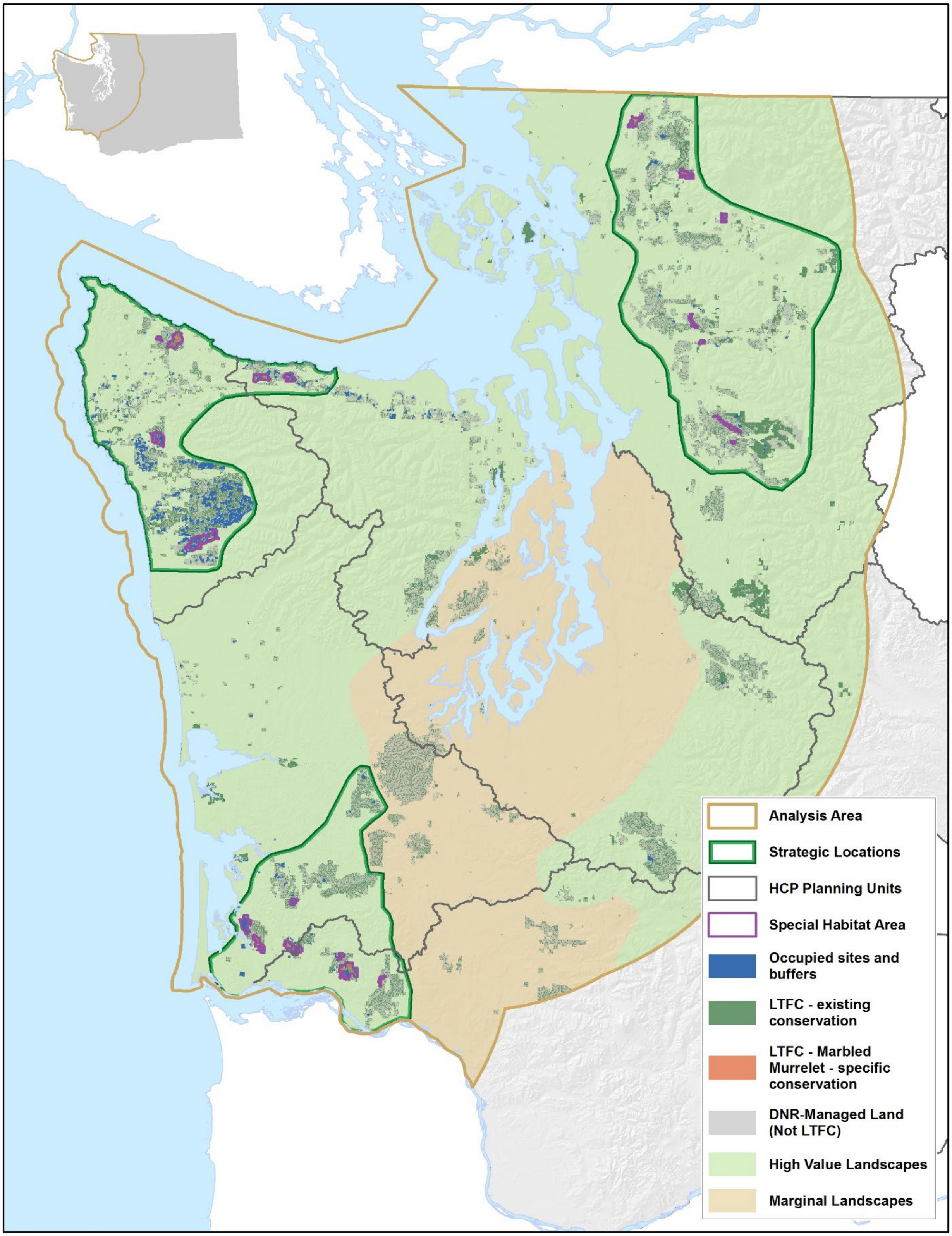

Figure 2. Strategic locations and proposed Special Habitat Areas.
Source: FEIS Figure 2.3.17.

5.4.3 Non-murrelet Specific Conservation

Within the murrelet's Washington range, variable retention harvest is excluded from 567,451 acres of WDNR-managed HCP lands, but may be allowed in limited areas identified as "other long-term forest cover" under specific conditions (e.g., hardwood conversion under the *Riparian Forest Restoration Strategy* (WDNR 2006). These conserved areas are being managed under strategies and prescriptions designed for other purposes of 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 WDNR-managed HCP lands.
- Existing northern spotted owl high-quality habitat, which includes the following WDNR 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. IV-11).
- 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 WDNR's *Policy for Sustainable Forests* (WDNR 2006a).
- Inoperable areas and inaccessible areas.

Murrelet habitat quality on these lands is variable. Not all contain murrelet habitat, and some areas are not forested or are not habitat capable (e.g., natural balds, alpine areas, etc.). In aggregate, these lands provide conservation for the murrelet in the form of existing habitat, future habitat, and security forest. Existing LTFC contain 85 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 (Table 1). These lands compliment the Long-Term Strategy's murrelet-specific conservation components, and are projected develop additional habitat capacity around occupied sites and SHAs over the term of the HCP.

Table 1. Acres of murrelet-specific and existing conservation managed as LTFC under the proposed Long-Term Strategy.

Conservation component	Acres of LTFC		
	Murrelet-specific conservation added	Existing LTFC	Total
Occupied sites	8,900	50,431	59,331
Occupied site buffers	15,871	16,906	32,777
Special habitat areas (SHAs)	12,685	33,952	46,637
Other LTFC	n/a	~	~
Total	37,456	~	~

Notes: Total conservation acres cannot be totaled due to overlap between existing conservation areas, and the total acres within SHAs reported here (46,637 acres) is 288 acres less than the total acres included within SHAs. Source: WDNR 2019, Table A-3.

In total, there are currently 567,541 acres designated as LTFC on WDNR-managed lands within the range of the murrelet. This represents 41 percent of the 1.38 million acres WDNR-managed lands within the range of the murrelet in Washington. The Long-Term Strategy will add 37,456 acres of murrelet-specific conservation to the existing LTFC, resulting in a total of 604,997 acres of LTFC within the range of the murrelet. This represents 43.7 percent of the WDNR-managed lands in western Washington (Table 2).

Table 2. Designations of existing conservation areas on WDNR-managed lands within the range of the murrelet.

Type of conservation	Source	Approximate acres of long-term forest cover
Forested natural areas (natural area preserves and natural resources conservation areas)	RCW 79.70, 79.71	89,000
Long-term conservation commitments for multiple species	1997 HCP, *Policy for Sustainable Forests*	469,000
Existing northern spotted owl habitat—high-quality	1997 HCP	8,000
Sub-total:		**567,541**
Murrelet-specific conservation acres added within occupied sites, occupied site buffers, and SHAs	Proposed long-term conservation strategy (WDNR 2019)	37,456
Total estimated conservation with adoption of the proposed Long-Term Strategy:		**604,907**

Sources: FEIS, Table 2.2.1 values are rounded; WDNR 2019, Table A-3).

The Long-Term Strategy will add murrelet-specific restrictions on certain management and recreation activities in areas of LTFC (WDNR 2019, Table A-4). For example, restoration thinning in riparian management zones that is consistent with the *Riparian Forest Restoration Strategy* (WDNR 2006) will not be allowed in areas of LTFC that are classified as murrelet habitat (P-stage value of 0.25 or higher). Management and recreation activities in areas of LTFC must comply with both existing restrictions and, where applicable, new, murrelet-specific restrictions (WDNR 2019, Table A-4).

5.4.4 Restrictions on Forest Management and Recreation Activities

To avoid and/or minimize effects to nesting murrelets (e.g., habitat change or audio/visual disturbances), the proposed Long-Term Strategy will apply additional restrictions to activities that occur within or adjacent to occupied sites and buffers, SHAs, and other areas of LTFC. These will include the application of seasonal restrictions to avoid implementing certain management activities during the murrelet nesting season;[5] or, the application of daily limited operating periods during the murrelet nesting season to avoid implementing activities during the murrelet's daily peak activity periods.[6] The proposed restrictions or limitations vary by type of activity, and whether or not the activity is within or adjacent to occupied sites and buffers, SHAs, and other areas of LTFC as detailed in the proposed HCP amendment (WDNR 2019, Table A-4). Seasonal restrictions will be addressed in more detail in the *Effects of the Action* section.

5.4.5 Metering

WDNR will delay ("meter") harvest of 5,000 adjusted acres[7] 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 WDNR's discretion. These metered acres will become available for harvest at the beginning of the second decade following implementation of the Long-Term Strategy.

Metering is an important conservation measure that is intended to maintain existing habitat capacity while additional habitat develops under the Long-Term Strategy. The population viability analyses commissioned by WDNR indicate that metering will improve projected (modeled) viability of the murrelet population on WDNR-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 (FEIS 2019 Appendix C).

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[5] The USFWS defines the nesting season for the marbled murrelet in Washington as April 1 to September 23 (USFWS 2012).

[6] Marbled murrelet daily peak activity periods are defined by the USFWS as 1 hour before official sunrise, to two hours after official sunrise, and 2 hours before official sunset to 1 hour after official sunset (USFWS 2012).

[7] Adjusted acres: A quantity of marbled murrelet habitat (in acres) that has been discounted or "adjusted" for P-stage habitat value and other factors that can reduce the quality of that habitat for murrelets (FEIS Appendix B and FEIS Appendix H).

5.5 Habitat Released for Harvest

Existing murrelet habitat that is not located within occupied sites, occupied site buffers, SHAs, and other areas of LTFC will be released for harvest. Habitat released for harvest will not be seasonally-restricted to avoid harvest during the murrelet nesting season. The amount of habitat that will be released for harvest is estimated at 38,744 raw acres,[8] which equates to 11,085 adjusted acres of habitat (WDNR 2019, p. 10). This habitat will be harvested over the 48 years that remain in the initial 70-year term of the HCP. In order to evaluate a reasonable worst case scenario, this analysis assumes that all habitat released for harvest will be harvested in the first two decades following implementation of the Long-Term Strategy. Under the proposed HCP amendment, WDNR will delay (meter), harvest of 5,000 adjusted acres (approximately 15,000 raw acres) of murrelet habitat that WDNR otherwise would be authorized to harvest upon amendment of its ITP. These metered acres will become available for harvest at the beginning of the second decade. Habitat released for harvest will be addressed in more detail in the *Effects of the Action* section.

The potential exists for new road construction to occur within occupied sites, occupied site buffers, and SHAs, as well as limited impacts associated with logging systems such as yarding corridors and the use of tailhold trees to facilitate timber harvesting in areas not designated as LTFC (WDNR 2019, Table A-4). Under the proposed amendment, new road construction and/or logging system impacts will occur only when no other options are feasible. If a proposed new road or yarding corridor is located in an occupied site, buffer, or SHA, WDNR will consult with USFWS to minimize impacts. The proposed HCP amendment estimates 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) (WDNR 2019, p.11).

5.6 Habitat Gains

Murrelet habitat on WDNR-managed lands is projected to increase from the current amount of approximately 207,000 raw acres to 272,000 raw acres over the term of the HCP. Habitat within areas conserved under the proposed HCP amendment is expected to increase in amount and quality over time. By the final decades of the 1997 HCP, initial habitat losses outside LTFC during the first two decades of implementation will be replaced by habitat conserved within areas of LTFC. The increase in adjusted acres of habitat over time is the basis for the mitigation of the impact associated with habitat acres released for harvest. Habitat losses and gains will be addressed in detail in the *Effects of the Action* section.

[8] Raw acres: Acres of marbled murrelet habitat that have not been adjusted for P-stage value or other factors such as forest edges and location that can reduce the quality of the habitat (FEIS Appendix B and Appendix H). The amount of raw acres released for harvest (38,774 acres), is greater than what was reported in the FEIS for Alternative H (2019, p. 4-37) (38,047 acres), however, the amount of adjusted acres (11,085) is the same.

5.7 Action Area

The action area is defined as all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR 402.02). In delineating the action area, we evaluated the farthest reaching physical, chemical, and biotic effects of the action on the environment.

The action area for this proposed federal action is based on the geographic extent of the WDNR-managed lands within 55 miles of marine waters in Washington. (1,383,187 acres) (Figure 3). The 55-mile line used for the proposed HCP amendment is the same geographic area that is used in the Northwest Forest Plan monitoring program to assess trends in murrelet habitat in Washington (Raphael et al. 2016, p.72).

The terrestrial limits of the action area are defined based on estimated edge effects from timber harvest on WDNR lands to adjacent ownerships; and on the general extent of above-ambient sound levels and/or smoke associated with HCP-covered activities including timber harvesting, forest roads, aircraft use, blasting, and prescribed burning activities, which can extend for distances of up to one mile from WDNR lands. The terrestrial action area also includes all road systems used to transport forest products from WDNR-managed lands to highways managed by the Washington State Department of Transportation, at which point the traffic from HCP covered activities will not be discernable from other public traffic on the highway system.

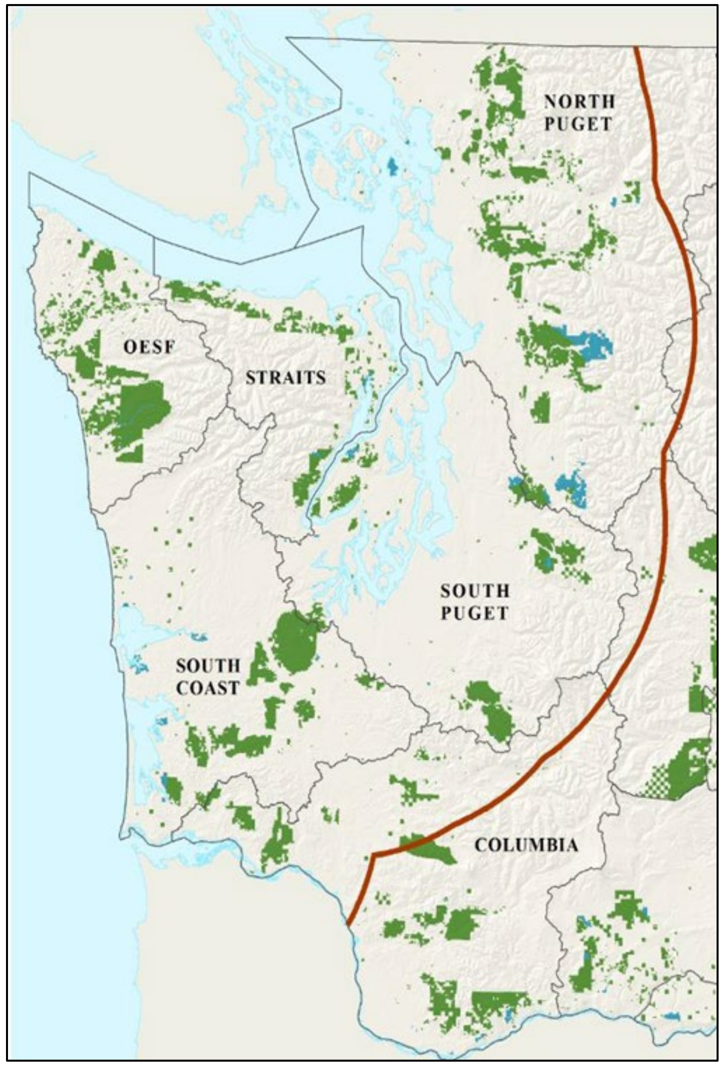

Figure 3. WDNR-managed lands (green/blue areas on map) and HCP planning units within the range of the murrelet in Washington.

Physical effects to water-quality (e.g., temperature, turbidity, etc.,) include all waters that occur on WDNR-managed lands, and all river and/or stream waters that occur downstream from WDNR-managed lands to marine waters and/or the lower Columbia River. Carbon emissions associated with timber harvest and wood processing have the potential contribute to accumulation of atmospheric greenhouse gases. The analysis completed in the FEIS (Chapter 4.2 - Climate) concluded that increasing the area of forested land conserved in LTFC will result in a net increase in total carbon sequestration on WDNR-managed lands, and the amount of carbon sequestered (either in forests or in stable wood products) over a five-decade period is greater than the estimated carbon emitted from WDNR-managed lands (FEIS 2019, p. 4-13).

6 ANALYTICAL FRAMEWORK FOR THE JEOPARDY AND ADVERSE MODIFICATION DETERMINATIONS

6.1 Jeopardy Determination

The following analysis relies on four components: (1) the *Status of the Species*, which evaluates the rangewide condition of the listed species addressed, the factors responsible for that condition, and the species' survival and recovery needs; (2) the *Environmental Baseline*, which evaluates the condition of the species in the action area, the factors responsible for that condition, and the relationship of the action area to the survival and recovery of the species; (3) the *Effects of the Action*, which determines the direct and indirect impacts of the proposed federal action and the effects of any interrelated or interdependent activities on the species; and (4) *Cumulative Effects*, which evaluates the effects of future, non-federal activities in the action area on the species.

In accordance with policy and regulation, the jeopardy determination is made by evaluating the effects of the proposed federal action in the context of the species' current status, taking into account any cumulative effects, to determine if implementation of the proposed action is likely to cause an appreciable reduction in the likelihood of both the survival and recovery of listed species in the wild.

The jeopardy analysis in this Opinion emphasizes the rangewide survival and recovery needs of the listed species and the role of the action area in providing for those needs. It is within this context that we evaluate the significance of the proposed federal action, taken together with cumulative effects, for purposes of making the jeopardy determination.

6.2 Adverse Modification Determination

Section 7(a)(2) of the ESA requires that federal agencies insure that any action they authorize, fund, or carry out is not likely to destroy or to adversely modify designated critical habitat. A final rule revising the regulatory definition of "destruction or adverse modification of critical habitat" was published on August 27, 2019 (84 FR 45016). The final rule became effective on October 28, 2019. The revised definition states: "Destruction or adverse modification means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species."

Designations of critical habitat prior to 2016 used the terms "primary constituent elements" (PCEs), "physical or biological features" (PBFs) or "essential features" to characterize the key components of critical habitat that provide for the conservation of the listed species. The 2016 critical habitat regulations (81 FR 7414) discontinue use of the terms "PCEs" or "essential features," and rely exclusively on use of the term "PBFs" for that purpose because that term is contained in the statute. However, the shift in terminology does not change the approach used in conducting a ''destruction or adverse modification'' analysis, which is the same regardless of whether the original designation identified PCEs, PBFs, or essential features. For those reasons, in this Opinion, references to PCEs or essential features should be viewed as synonymous with PBFs. All of these terms characterize the key components of critical habitat that provide for the conservation of the listed species.

Our analysis for destruction or adverse modification of critical habitat relies on the following four components: (1) the Status of Critical Habitat, which evaluates the range-wide condition of designated critical habitat for the murrelet in terms of essential features, PCEs, or PBFs, depending on which of these terms was relied upon in the designation, the factors responsible for that condition, and the intended recovery function of the critical habitat overall; (2) the Environmental Baseline, which evaluates the condition of the critical habitat in the action area, the factors responsible for that condition, and the recovery role of the critical habitat in the action area; (3) the Effects of the Action, which determines the direct and indirect impacts of the proposed federal action and the effects of any interrelated or interdependent activities on the essential features, PCEs, or PBFs and how those effects are likely to influence the recovery role of affected critical habitat units; and (4) Cumulative Effects, which evaluates the effects of future, non-federal activities in the action area on the essential features, PCEs, or PBFs and how those effects are likely to influence the recovery role of affected critical habitat units.

For purposes of making the destruction or adverse modification finding, the effects of the proposed federal action, together with any cumulative effects, are evaluated to determine if the critical habitat rangewide will remain functional (or retain the current ability for the PBFs to be functionally re-established in areas of currently unsuitable but capable habitat) to serve its intended conservation/recovery role for the murrelet.

7 STATUS OF THE SPECIES: Marbled Murrelet

7.1.1 Summary of the Status of Murrelets

The marbled murrelet was listed as a threatened species in Washington, Oregon, and California in 1992 under the federal ESA. The primary reasons for listing included extensive loss and fragmentation of old-growth forests which serve as nesting habitat for murrelets and human-induced mortality in the marine environment from gillnets and oil spills (57 FR 45328 [Oct. 1, 1992]). Although some threats such as gillnet mortality and loss of nesting habitat on federal lands have been reduced since the 1992 listing, the primary threats to species persistence continue (USFWS 2019b, p. 65).

The 1997 *Recovery Plan for the Marbled Murrelet* (USFWS 1997) identified six Conservation Zones throughout the listed range of the species: Puget Sound (Conservation Zone 1), Western Washington Coast Range (Conservation Zone 2), Oregon Coast Range (Conservation Zone 3), Siskiyou Coast Range (Conservation Zone 4), Mendocino (Conservation Zone 5), and Santa Cruz Mountains (Conservation Zone 6). The Recovery zones are considered to be the functional equivalent of recovery units as defined by Service policy (USFWS 1997, p. 115). Monitoring of murrelet habitat and population trends is reported by Conservation Zones and by state (Table 3).

The most recent population estimate for the entire Northwest Forest Plan area in 2017 was 23,000 murrelets (95 percent confidence interval [CI]: 18,500 to 27,600 birds) (McIver et. al 2019, p. 3). The long-term trend derived from marine surveys for the period from 2001 to 2017 indicate that the murrelet population across the Northwest Forest Plan area has increased at a rate of 0.34 percent per year (McIver et. al 2019, p. 3). While the overall trend estimate across this time period is slightly positive, the evidence of a detectable trend is not conclusive because the confidence intervals for the estimated trend overlap zero (95% -0.9 to 1.6 percent) (McIver et. al 2019, p. 3) (Table 3).

Table 3. Summary of murrelet population estimates and trends (2001-2017/2018) at the scale of Conservation Zones and states.

Zone	Year	Estimated number of murrelets	95% CI Lower	95% CI Upper	Average density (at sea) (murrelets /km^2)	Average annual rate of population change (%)	95% CI Lower	95% CI Upper
1	2018	3,837	1,911	6,956	1.097	-4.9	-7.3	-2.4
2	2017	1,758	1,041	2,623	1.065	-3.0	-6.8	+0.9
3	2018	8,414	5,866	12,183	5.274	+1.4	-0.4	+3.3
4	2017	8,574	6,358	11,155	7.397	+3.7	+1.4	+6.1
5	2017	868	457	1,768	0.983	+7.3	-4.4	+20.3
Zones 1-5	2017	23,040	18,527	27,552	2.623	+0.34	-0.9	+1.6
Zone 6	2018	370	250	546	na	na	na	na
WA	2017	5,984	3,204	8,764	1.16	-3.9	-5.1	-2.0
OR	2017	10,945	8,018	13,872	5.28	2.0	0.5	3.6
CA Zones 4 & 5	2017	6,111	4,473	7,749	3.90	4.5	2.2	6.9

Sources: (McIver et al. 2019, pp. 8-17, Felis et al. 2019, p. 7).

Murrelet population size and marine distribution during the summer breeding season is strongly correlated with the amount and pattern (large contiguous patches) of suitable nesting habitat in adjacent terrestrial landscapes (Falxa and Raphael 2016, p. 109). The loss of nesting habitat was a major cause of murrelet decline over the past century and may still be contributing as nesting habitat continues to be lost to fires, logging, and wind storms (Miller et al. 2012, p. 778).

Currently, only about 11 percent of habitat-capable lands contain potential nesting habitat for the murrelet (Table 4). About 60 percent of the estimated habitat is located within federal reserves (e.g., National Parks, Late-successional Reserves, Wilderness, etc.), while about 34 percent of habitat is located on state or private ownerships (Table 4).

Table 4. Estimates of higher-quality murrelet nesting habitat by State and major land ownership within the area of the *Northwest Forest Plan* – derived from 2012 data.

State	**Habitat capable lands** (1,000s of acres)	**Habitat on federal reserved lands** (1,000s of acres)	**Habitat on federal non-reserved lands** (1,000s of acres)	**Habitat on non-federal lands** (1,000s of acres)	**Total potential nesting habitat (all lands)** (1,000s of acres)	**Percent of habitat capable land that is currently in habitat**
WA	10,851.1	822.4	64.7	456	1,343.1	12 %
OR	6,610.4	484.5	69.2	221.1	774.8	12 %
CA	3,250.1	24.5	1.5	82.9	108.9	3 %
Totals	20,711.6	1,331.4	135.4	760	2,226.8	11 %
Percent		60 %	6 %	34 %	100 %	-

Source: (Raphael et al. 2016, pp. 66-69).

Monitoring of murrelet nesting habitat within the Northwest Forest Plan area indicates nesting habitat has declined from an estimated 2.53 million acres in 1993 to an estimated 2.22 million acres in 2012, a total decline of about 12.1 percent (Falxa and Raphael 2016, p. 72) (Table 5)

Table 5. Distribution of murrelet nesting habitat (acres) by Conservation Zone, and summary of net habitat changes from 1993 to 2012 within the Northwest Forest Plan area.

Conservation Zone	**1993**	**2012**	**Change (acres)**	**Change (percent)**
Zone 1 - Puget Sound/Strait of Juan de Fuca	829,525	739,407	-90,118	-10.9 %
Zone 2 - Washington Coast	719,414	603,777	-115,638	-16.1 %
Zone 3 - Northern to central Oregon	662,767	610,583	-52,184	-7.9 %
Zone 4 - Southern Oregon - northern California	309,072	256,636	-52,436	-17 %
Zone 5 - north-central California	14,060	16,479	+2,419	+17.2 %
Totals	2,534,838	2,226,882	-307,956	-12.1 %

Source: (Raphael et al. 2016, p. 80).

The largest and most stable murrelet subpopulations now occur off the Oregon and northern California coasts, where the population trends are positive, while subpopulations in Washington declined at a rate of approximately -3.9 percent per year for the period from 2001 to 2017 (McIver et al. 2019, p. 3) (Table 3, above). Rates of nesting habitat loss have also been highest in Washington, primarily due to timber harvest on non-federal lands (Falxa and Raphael 2016, p. 37), which suggests that the loss of nesting habitat continues to be an important limiting factor for the recovery of murrelets.

Factors affecting murrelet fitness and survival in the marine environment include: reductions in the quality and abundance of murrelet forage fish species, harmful algal blooms, toxic contaminants; murrelet by-catch in net fisheries; murrelet entanglement in derelict fishing gear; oil spills, and human disturbance in marine foraging areas (USFWS 2019b, pp. 29-61). While these factors are recognized as stressors to murrelets in the marine environment, the extent that these stressors affect murrelet populations is unknown. As with nesting habitat loss, marine habitat degradation is most prevalent in the Puget Sound area where anthropogenic activities (e.g., shipping lanes, boat traffic, shoreline development) are an important factor influencing the distribution and abundance of murrelets in nearshore marine waters (Falxa and Raphael 2016, p. 106).

For a detailed account of murrelet biology, life history, threats, demography, and conservation needs, refer to Appendix A: Status of the Species: Marbled Murrelet.

8 STATUS OF CRITICAL HABITAT: Marbled Murrelet

The final rule designating critical habitat for the marbled murrelet (murrelet) (61 FR 26256 [May 24, 1996]) became effective on June 24, 1996. In the 1996 final rule, the USFWS designated critical habitat for the murrelet within 32 Critical Habitat Units (CHUs) encompassing approximately 3.9 million acres across Washington, Oregon, and California. In 2011, the Service issued a revised final rule which removed approximately 189,671 acres in northern California and southern Oregon from critical habitat designated under the 1996 final rule based on new information indicating that these areas did not meet the definition of critical habitat (76 FR 61599:61604 [October 5, 2011]). No changes were made for critical habitat designations in Washington.

The revised critical habitat designation for murrelets encompasses over 3.69 million acres in Washington, Oregon, and California (76 FR 61599 [Oct. 5, 2011]). In Washington, the critical habitat designation includes over 1.2 million acres, located primarily in Late-Successional Reserves on National Forests. The PCEs of critical habitat represent specific physical and biological features that are essential to the conservation of the species and may require special management considerations or protection. The PCEs of murrelet critical habitat include (1) individual trees with potential nesting platforms and (2) forested areas within 0.8 kilometer (0.5 mile) of individual trees with potential nesting platforms that have a canopy height of at least one-half the site potential tree height. This includes all such forest, regardless of contiguity (76 FR 61604).

In 2016, the USFWS issued a final determination which confirmed that critical habitat for the murrelet as designated in 1996 and revised in 2011, meets the statutory definition of critical habitat under the ESA of 1973, (81 FR 51348 [August 4, 2016]). This final determination did not propose any changes to the boundaries of the specific areas identified as critical habitat in the 2011 final rule. The current designation includes approximately 3,698,100 acres of critical habitat in Washington, Oregon, and California.

The critical habitat designation in Washington also includes approximately 426,800 acres of state lands (26 percent) managed under the WDNR 1997 HCP (WDNR 1997). Because these lands are managed under an approved HCP issued under section 10(a) of the ESA, these lands are excluded from critical habitat by description in the final rule. However, should their permit be revoked, terminated, or expire, WDNR lands would revert back to designated critical habitat. WDNR lands, therefore, continue to remain mapped and accounted for in the total designation acreage (81 FR 51365 [August 4, 2016]).

The conservation role of critical habitat is to support successful nesting and reproduction of murrelets, and to maintain viable murrelet populations that are well distributed across the listed range of the species (76 FR 61609). Much of the area included in the critical habitat designation includes young forest and previously-logged areas within Late-Successional Reserves that are expected to provide buffer habitat to existing old-forest stands, and future recruitment habitat to create large, contiguous blocks of suitable murrelet nesting habitat.

For a detailed account of the status of the designated murrelet critical habitat, refer to Appendix B: Status of Designated Critical Habitat: Marbled Murrelet.

9 ENVIRONMENTAL BASELINE: Marbled Murrelet and Designated Marbled Murrelet Critical Habitat

Regulations implementing the ESA (50 CFR 402.02) define the environmental baseline as the condition of the listed species or its designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the proposed action. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process. The consequences to listed species or designated critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline (45016 FR 84 [Aug. 27, 2019]).

9.1 Murrelet Habitat in Washington

Timber harvest prior to the listing of the murrelet as a threatened species in 1992 removed most of the late-successional forest from within the historic range of the species in Washington. Currently only about 12 percent of habitat-capable lands in Washington contain potential nesting habitat (Table 4, above). Based on the Maxent[9] habitat model developed for the Northwest Forest Plan, most murrelet habitat in Washington occurs on federal lands (66 percent) while approximately 14 percent of the potential habitat occurs on WDNR-managed lands (187,000 acres) (FEIS p. 3-32) (Table 6).

Table 6. Estimated acres of suitable murrelet nesting habitat by major land ownership in Washington based on *Northwest Forest Plan* habitat monitoring.

Ownership	Land Area in Washington	Percent of Land Area in Washington	Estimated Murrelet Habitat	Percent of Habitat	Percent of land area in habitat
Federal	4,249,495	31%	887,100	66%	21%
WDNR HCP	1,383,187	10%	187,200	14%	14%
Other ownerships	7,921,713	58%	268,800	20%	3%
Totals	13,554,395	100%	1,343,100	100%	10%

Source: Murrelet habitat estimates and federal land area represent approximate conditions in 2012, derived from GIS data for the *Northwest Forest Plan 20-Year Monitoring Report* (Raphael et al. 2016). Total land area includes forested and non-forested lands.

9.1.1 <u>Murrelet Conservation Zones in Washington</u>

There is a relationship between the current condition and conservation role of the action area and murrelet recovery units. In Washington, there are two Conservation Zones: Puget Sound (Conservation Zone 1) and Western Washington Coast Range (Conservation Zone 2) (USFWS 1997, p. 114). The action area for the proposed HCP amendment includes portions of both Conservation Zones 1 and 2.

9.1.1.1 Conservation Zone 1

Conservation Zone 1 includes all the waters of Puget Sound and most waters of the Strait of Juan de Fuca south of the United States-Canadian border and extends inland 55 miles from the Puget Sound, including the north Cascade Mountains and the northern and eastern sections of the Olympic Peninsula. Forest lands in the Puget Trough have been predominately replaced by urban development (USFWS 1997, p. 125).

[9] Maxent is a habitat-modelling program use to estimate marbled murrelet habitat across all ownerships for the Northwest Forest Plan 20-year monitoring report (Raphael et al. 2016, p. 38).

The loss of late-successional forest habitat, coupled with its replacement by urban development in throughout the Puget Trough, means the remaining suitable nesting habitat for murrelets on the eastern shore of Puget Sound is a considerable distance from the marine environment (more than 20 miles). This lends special importance to the remaining suitable nesting habitat that is closest to Puget Sound and the Strait of Juan de Fuca. Conservation recommendations in the *Marbled Murrelet Recovery Plan* in Zone 1 are directed toward increasing the size and distribution of murrelet populations in this area, and not further contracting their distribution (USFWS 1997, p. 125). The high level of urbanization, shoreline development, habitat fragmentation, and the "marine human footprint" and low rates of reproduction are major factors influencing the number and distribution of murrelets in Zone 1 (Falxa and Raphael 2016, p. 106).

WDNR and USFWS identified two strategic locations that occur primarily within Conservation Zone 1 – the North Puget strategic location, and the OESF and Straits west of the Elwha River (Figure 4). Both strategic locations are in areas where WNDR lands are located in closer proximity to marine waters than adjacent federal lands, and both areas contain clusters of occupied sites and other habitat that is considered essential for conservation of the murrelets in Zone 1.

Monitoring of murrelet nesting habitat and population trends under the Northwest Forest Plan indicate continued declines in both nesting habitat and numbers of murrelets within Conservation Zone 1 (Table 7).

9.1.1.2 Conservation Zone 2

Conservation Zone 2 includes marine waters within 1.2 miles of the Pacific Ocean shoreline south of the U.S.-Canada border off Cape Flattery, extending south to the mouth of the Columbia River, and inland to the midpoint of the Olympic Peninsula and 55 miles inland in southwestern Washington. Most of the forested lands in the northwestern portion of Conservation Zone 2 occur on public (federal and state) lands, while most of the forested lands in the southwestern portion are privately owned. Extensive timber harvest has occurred throughout Conservation Zone 2 in the last century, but the greatest losses of suitable nesting habitat occurred in the southwest portion of Conservation Zone 2 (USFWS 1997, p. 127).

To maintain a well-distributed murrelet population, conservation recommendations in the *Marbled Murrelet Recovery Plan* are directed toward increasing the size and distribution of murrelet populations and not furthering the gap in distribution between the Olympic Peninsula and the small populations in southwestern Washington. Non-federal lands in Zone 2 currently provide a limited amount of murrelet nesting habitat and have the potential to be managed to increase the amount of suitable nesting habitat in the future (USFWS 1997, p. 127).

WDNR and USFWS identified two strategic locations that occur primarily within Conservation Zone 2 – the OESF and Straits west of the Elwha River, and Southwest Washington (Figure 4). In the OESF/western Straits area, WNDR-managed lands are closer to marine waters than adjacent federal lands. In southwest Washington, federal ownership is extremely limited, and the majority of known habitat and occupied sites are located on WDNR-managed lands. Due to the limited habitat area and lack of federal lands, habitat on WDNR-managed land is considered essential for the conservation of murrelets in Zone 2.

Monitoring of murrelet nesting habitat and population trends under the Northwest Forest Plan indicate continued declines in both nesting habitat and numbers of murrelets within Conservation Zone 2 (Table 7). Habitat loss, habitat fragmentation, and low rates of reproduction appear to be the major cause of population decline in Zone 2.

Table 7. Summary of murrelet nesting habitat and population trends in Washington.

Murrelet Conservation Zone	**Acres of habitat in 1993**	**Acres of habitat in 2012**	**Habitat change** (acres)	**Habitat change** 1993 – 2012 (percent)	**Estimated murrelet population** and 95 % confidence intervals	**Annual rate of population change** (2001-2017)
Zone 1 – Puget Sound and Strait of Juan de Fuca	829,525	739,407	-90,118	-10.9 %	**3,837** (1,911 – 6,956) 2018 estimate	-4.9 %
Zone 2 – Washington Coast	719,414	603,777	-115,638	-16.1 %	**1,758** (1,041 – 2,623) 2017 estimate	-3.0 %
Totals	1,548,939	1,343,184	205,756	-13.3 %	**5,984** (3,204 – 8,764) 2017 estimate	-3.9 %

Source: Murrelet habitat estimates are from Raphael et al. (2016, p. 80). Murrelet population and trend estimates for the years 2017-2018 are from McIver et al. (2019).

While the Conservation Zones in Washington represent large geographic regions that the USFWS uses to describe recovery areas for murrelets, the Conservation Zones do not represent discrete populations of murrelets. Radio-telemetry studies conducted in Washington have documented movements of individual murrelets using marine foraging areas in both Zones 1 and 2 during the same season suggesting all of Washington could be considered a single Zone for conservation planning purposes (Bloxton and Raphael 2006, p. 162). Telemetry studies conducted in Oregon and California have documented long-distance movements of non-breeding murrelets along the Pacific coast between California, Oregon, and Washington (Rivers et al. 2018, p. 169, Hebert and Golightly 2006, p.159). The extent to which murrelets move between Conservation Zones is unknown.

Because murrelets are known to exhibit fidelity to specific nesting areas, murrelet populations are monitored at sea during the summer nesting season, and birds counted in nearshore areas are generally assumed to be associated with nesting habitat in the adjacent upland areas within the Conservation Zones (Raphael et al. 2015, p. 21). Even though the marine distribution of murrelets is generally correlated with the amount of nesting habitat in adjacent landscapes, the degree to which the at-sea numbers reflect the local populations of birds that are actually breeding in a given season is unknown, because murrelets counted at sea during the summer can be comprised of breeding, non-breeding, and transient individuals (McIver et al. 2019, p. 4). Because murrelets in Washington are known to move across large areas of marine habitat during the summer breeding season (Lorenz et al. 2017, p. 313), we do not attempt to attribute murrelets counted in a specific marine area to specific areas of inland nesting habitat.

9.2 Murrelet Numbers and Reproduction in Washington

Annual population estimates of murrelet in Washington are derived from marine surveys. Marine surveys in 2016 and 2017 yielded an estimate of approximately 6,000 murrelets in Washington in 2017, but the confidence intervals around this estimate are large, indicating the Washington population is in the range of 3,200 to 8,700 murrelets (McIver et al., 2019) (Table 7, above). The overall population trend in Washington indicates an average annual population decline of about -3.9 percent per year, with a higher annual rate of decline (-4.9 percent per year) indicated for Zone 1 (Table 7, above). Similar rates of population decline have been observed in southern British Columbia where murrelet populations are estimated to have declined -8.6 percent/year at east Vancouver Island, and -3.1 percent/year at the south mainland coast for the period from 1996 – 2013 (Bertram et al. 2015, p. 16). As in Washington, the murrelet population declines in southern British Columbia are attributed to reductions in forest nesting habitat and changes in marine conditions that have caused reductions in prey fish species (Bertram et al., 2015, p. 17).

Murrelet populations are declining in Washington because the annual rate of reproduction does not compensate for annual death or immigration rates. Annual survival rates in murrelets have been estimated at 83 to 92 percent (McShane et al. 2004, p. 3-41), meaning about 8 to 17 percent of adult murrelets die each year. Adults murrelet are preyed upon by raptors at sea and inland (e.g., peregrine falcons, bald eagles) and many die during the fall or winter months due to unknown causes (Nelson 1997, p. 20). Murrelet nesting rates are highly variable, (the proportion of murrelets that attempt to nest each year) , and nesting success is highly variable. Range-wide, murrelets are estimated to have an average nesting success rate of about 33 percent (range: 0 to 69 percent) (Raphael et al. 2018, p. 322). In Washington, a small sample of nesting murrelets tracked with radio telemetry had very low breeding rates (5 to 20 percent of tagged adults attempted to nest), and nest success ranged from 0 to 50 percent, with an average success rate of 20 percent (Lorenz et al. 2017, p. 312). None of the nests in this study with a known fate failed due to predation. Nests failed because eggs failed to hatch, eggs were abandoned during incubation, or the chick died at the nest due accidental death or other causes (Lorenz et al. 2019, p. 160).

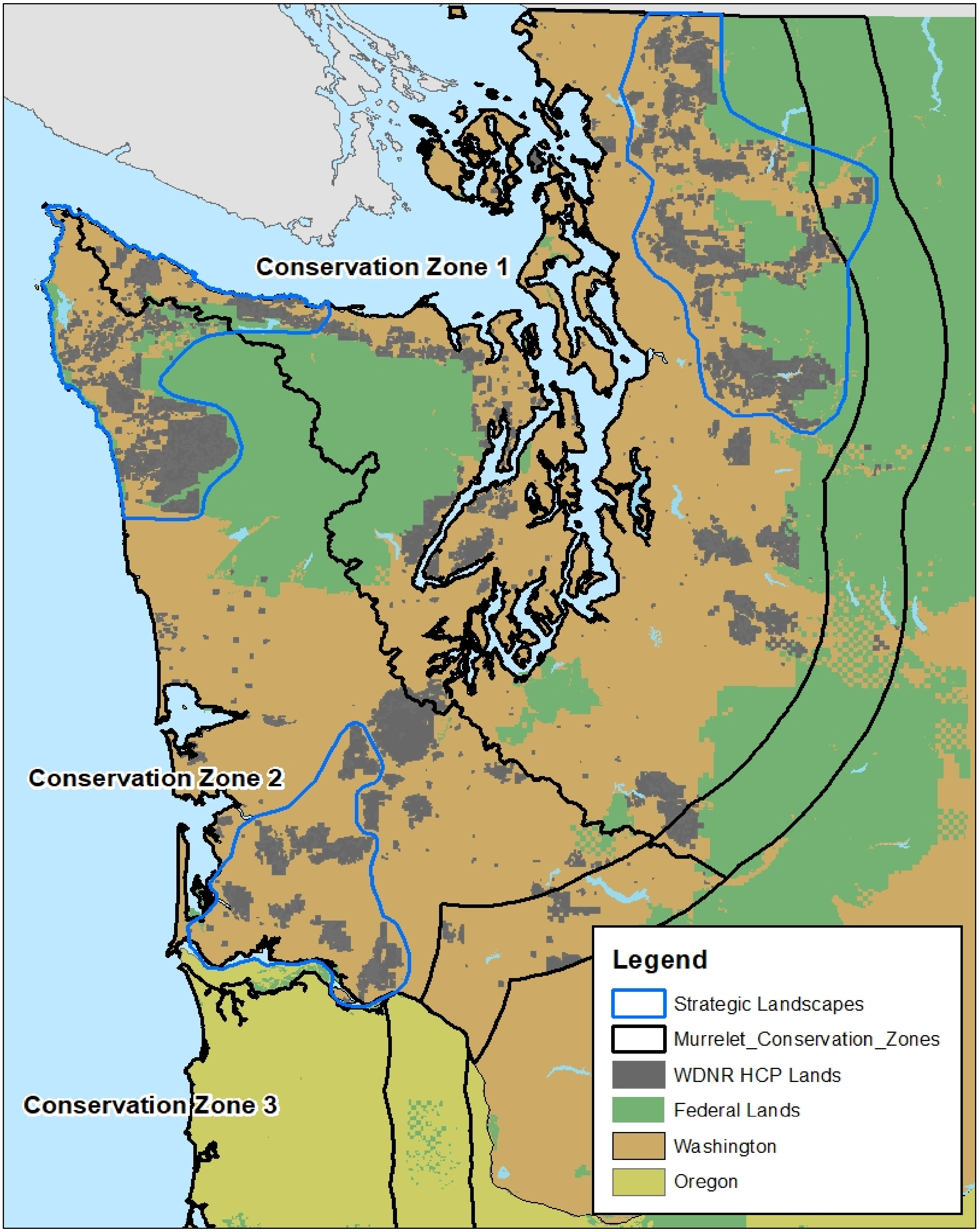

Figure 4. Murrelet Conservation Zones and WDNR HCP lands in Washington, with *Northwest Forest Plan* 40-mile and 55-mile inland zones indicated (double line on eastern portion of map).
Source: Conservation Zones displayed in this map are the same as those used in the analysis for the Northwest Forest Plan 20-year monitoring report (Raphael et al 2016, p. 41).

The best indication we have of reproduction and productivity in murrelets in Washington is derived from at-sea counts of hatch-year juveniles. The ratio of hatch-year juveniles to adults provides an index of reproduction, however it does not provide breeding rates or nest success rates. Marine surveys for murrelets the San Juan Islands from 1995 to 2012 documented a -3.9 percent annual decline in murrelets over this period, which mirrors the estimated rate of decline for the Washington population (Lorenz and Raphael 2018, p. 210). Despite the decline in the total number of murrelets, the annual productivity ratio over this period (number of juvenile murrelets) averaged 7 percent ($\pm$ 2%) (Lorenz and Raphael 2018, p. 206). This indicates that while the overall murrelet population has declined, reproduction has been relatively stable, and low.

In summary, the productivity of murrelets in Washington is not sufficient to sustain a stable population at this time. The factors most likely responsible for this are low rates of breeding and low nesting success rates. A low propensity for breeding may indicate that some adults murrelets in the population may have been displaced from the breeding population due to loss of nesting habitat (Lorenz et al. 2017, p. 317). Poor marine foraging conditions also affect breeding success. Murrelets in Washington have the largest recorded marine home ranges documented for the species, with some individuals flying over 100 km (62 miles) one way from nest sites to preferred marine foraging areas (Lorenz et al. 2017, p. 317). The authors of this study conclude: *"…our results suggest that efforts to improve the health of marine food webs in the Salish Sea and Pacific Coast would benefit murrelets in this region. Given the relatively long over-land commutes by breeding murrelets in our study, we encourage measures to protect and enhance terrestrial nesting habitat closer to sea. This will require protecting nesting habitat on state and private lands, because federal lands in Washington are already protected under the Northwest Forest Plan. Without improvements to both marine and terrestrial habitat, the low reproductive output of this population may continue and contribute to further declines of marbled murrelets in this region"* (Lorenz et al. 2017, p. 319).

9.3 Current Condition of the Species in the Action Area

The Action Area for this analysis includes WDNR-managed lands within the range of the murrelet in Washington (1.38 million acres), and other lands located within a distance of one mile from WDNR-managed lands (2.45 million acres). Most of the land area located adjacent to WDNR-managed lands (within one mile) is in private or other ownerships (86 percent), while the remainder (14 percent) is comprised of federal lands. Due to the complex nature of the ownership patterns within the action area, we use the best available information regarding murrelet habitat conditions and trends on State, federal, and other ownerships in Washington to describe the environmental baseline, with an emphasis on current conditions on WDNR-managed lands.

9.3.1 Occurrence of Murrelets on WDNR-Managed Lands

Murrelet surveys to identify occupied sites and inform habitat relationship studies on WDNR-managed lands were conducted between 1996 and 2008. Surveys were located in areas identified as "reclassified habitat" or as "suitable and potential habitat" (FEIS 2019, pp. D-9 –

D-11). Surveys were conducted according to inland survey protocols developed and updated by the Pacific Seabird Group (e.g., Evans Mack et al. 2003) or other methods approved by USFWS (FEIS 2019, p. D-5). As a result of the HCP survey effort, 397 occupied sites, totaling approximately 43,000 acres, were identified on WDNR-managed lands. These occupied sites range in size from under 5 acres to 3,100 acres and are located between 0.1 and 53 miles from marine waters (FEIS 2019, p. D-5).

The occupied site boundaries identified within the Straits, OESF, South Coast and Columbia HCP planning units were reviewed and adjusted by a "Science Team" assembled in 2004 by WDNR to develop recommendations for long-term murrelet conservation (Raphael et al. 2008). The Science Team recommended increasing the total acres associated with occupied sites on WDNR-managed lands to approximately 59,300 acres; this was an increase of approximately 16,000 acres over what was originally delineated as occupied under the 1997 HCP (FEIS 2019, p. D-2). Occupied sites in the North and South Puget HCP planning units were delineated by WDNR staff in the field based on the location of platform-bearing trees or through the inspection of color orthophotos (FEIS 2019, p. D-3).

For the proposed HCP amendment, the second iteration of occupied sites (59,330 acres) mapped by the Science Team was adopted by WDNR for planning and conservation purposes. This effort resulted in a total of 388 mapped polygons of occupied sites ranging in size from less than 1 acre to greater than 6,000 acres, with an average patch size of 153 acres. The small occupied site polygons ($\leq$1 acre) represent areas along the boundaries of WDNR-managed lands where an occupied site is located primarily on an adjacent ownership, but habitat contiguous with the occupied site extends into WDNR-managed lands.

Because of the difficulty in finding a specific tree within a forest stand that a murrelet might be using as a nest tree, most occupied sites are determined through observation of murrelets flying below, through, or into or out of the forest canopy, and/or murrelets circling above a forest stand within one tree height of the top of the canopy. This type of observation is documented as an occupied behavior detection (Paton 1995, pp. 115-116). A majority of the occupied sites mapped on WDNR-managed lands were identified through occupied detections. Few occupied sites have been documented by finding an actual nest location. Out of the 5,202 occupied detections recorded in Washington, only 51 are associated with confirmed nests; and of those, 13 are located on WDNR-managed lands. Classifying occupied sites based on detections of occupancy behaviors is a prudent approach to determining where murrelets are likely to be nesting. Although scientific uncertainty exists regarding the interpretation of murrelet occupancy behaviors, there is consistent evidence that occupied behaviors occur in the vicinity of known murrelet nest sites (Paton 1995, pp. 115-116, Plissner et al. 2015, p. 19).

Surveys for murrelets in the OESF, Straits, and southwest Washington were based on the delineation of "reclassified" habitat under the Interim Strategy. In the case of the North Puget HCP planning unit, the reclassified habitat model did not perform well due to the low number of occupied sites found in the habitat relationship study, and alternative methods were used to identify habitat for surveys (FEIS 2019, p. D-6). Not all areas of potential nesting habitat were surveyed for murrelets, and other areas were surveyed without detecting murrelet occupancy behaviors. Surveys were completed in the South Coast, Columbia, and Straits HCP planning units (Table 8). Surveys were not entirely completed in the OESF planning unit (75 percent), or North Puget planning units, and audio-visual surveys were not attempted in the South Puget planning unit. A limited survey effort using radar was completed in the South Puget area, resulting in the delineation of 576 acres of occupied sites (FEIS 2019, p. D-6).

Table 8. Summary of murrelet surveys on WDNR-managed lands (acres) completed for habitat relationships studies (1996-2008).

HCP Planning Unit	Estimated habitat area (reclassified habitat model)	Estimated reclassified habitat area surveyed for murrelets	HCP - identified occupied sites	Unsurveyed reclassified habitat acres	Years surveys were completed
OESF	54,308	40,687	25,874	13,621	1996 - 2002
Straits	15,397	15,397	3,940	0	2000 - 2003
Columbia	6,635	6,635	2,980	0	1998 - 2001
South Coast	20,288	20,288	5,742	0	1998-2001
North Puget	5,247	17,500	3,853	~	2001-2008
South Puget	1,164	~	576	~	~

Notes. HCP occupied sites included here do not include the additional 16,000 acres that were added during the development of the Science Team Report (Raphael et al. 2008). Sources: HCP amendment, Appendix A, Table A-1, FEIS 2019, pp- D-5 – D-6.

The surveys for murrelets that were completed in the late 1990's and early 2000's correspond to the period when the at-sea monitoring of murrelet populations was initiated under the Northwest Forest Plan. The estimated murrelet population in Washington has declined from approximately 11,000 murrelets in 2001 to about 6,000 murrelets in 2017 (McIver et al. 2019), indicating a cumulative population decline of about 40 percent in Washington over a period of 16 years. Based on the observed declines in Washington, it is likely that some areas identified as occupied in the late 1990's may no longer be occupied by murrelets. However, the protection of occupied sites remains a high priority for murrelet conservation due to the species demonstrated fidelity to nesting sites, particularly in areas where habitat is fragmented by past timber harvest (Burger et al. 2009, p. 217).

9.3.2 Murrelet Habitat on WDNR- Managed Lands

Under the Interim Strategy, WDNR completed habitat relationship studies for the South Coast, Columbia, OESF, and Straits HCP planning units. The habitat models derived from these studies are referred to as "reclassified habitat" (FEIS 2019, Appendix D). The estimated habitat identified with the reclassified model is summarized in (Table 8, above). An attempt was made to develop a reclassified habitat model for the North Puget landscape, but this effort was abandoned due to a low number of occupied sites detected during surveys. Alternative methods for identifying potentially suitable habitat were applied in both the North Puget and South Puget HCP planning units (FEIS 2019, p. D-6). Due to the limitations of the reclassified habitat model, WDNR developed the P-stage habitat classification model for conservation planning purposes on Washington state trust lands.

9.3.3 P-stage Habitat Classification

P-stage is a habitat classification system that assigns a probability of occupancy to habitat based on the habitat complexity – older more complex stands have higher probability of occupancy relative to younger, less complex stands. The P-stage habitat classification was originally developed for the 2008 Science Team report (Raphael et al. 2008, pp. 4.1 - 4.19). P-stage is based on WDNR forest inventory data such as forest type, stand origin, and stand age and represents a generalized relationship of different forest stand development stages and the probability of use by murrelets. Forest stands[10] are classified as non-habitat (P-stage 0) or as one of five stages of increasing habitat quality (0.25, 0.36, 0.47, 0.62, and 0.89). WDNR updated the P-stage classification to include all WDNR-lands within 55-miles of marine waters, and a 6th category (P-stage 1) was added for the classification of mapped, occupied sites (FEIS 2019, pp. E-6 to E-7). The addition of the P-stage 1 category for occupied sites recognizes the special status of these locations for murrelet conservation, and also recognizes that as occupied sites they have a high probability of continued use by the species. In this analysis, "habitat" is any area that has a P-stage classification greater than 0.

P-stage classification values increase as forest stands age and presumably develop more structurally-complex forest conditions (e.g., multiple canopy layers, increasing abundance of trees with platforms, etc.), and stands that are more structurally complex (e.g., old-growth) are more likely to be used by murrelets for nesting relative to younger or more simple-structured stands. For example, P-stage 0.25 is so classified because stands with that general suite of characteristics were found to be occupied about one-fourth as frequently as the highest quality habitat (FEIS, p. E-13). P-stage classes 0.25 and 0.36 represent lower-quality habitat with more simple stand structure, and includes naturally-regenerated western hemlock-dominated stands that are 70 to 109 years of age, or Douglas-fir dominated stands that are 120 to 219 years old (FEIS 2019, p. E-7). P-stage classes 0.47, 0.62, and 0.89 represent higher-quality habitat and includes naturally-regenerated western hemlock-dominated stands that are 110 years of age or older, or Douglas-fir dominated stands that are 220 years old or older (FEIS 2019, p. E-7).

The P-stage habitat classification revised for the 2019 FEIS identified approximately 207,000 acres of existing murrelet habitat, which represents about 15 percent of the 1.38 million acres of WDNR-managed lands within the range of the murrelet in Washington (Table 9). This is a greater area of habitat than was estimated for WDNR lands using the Maxent habitat model developed for Northwest Forest Plan monitoring (187,000 acres). The difference between the two models is not unexpected, as P-stage classification applies to individual stands delineated in WDNR's forest inventory database which average about 49 acres in size, with most stands between 5 and 100 acres in size (FEIS 2019, p. E-11). The Maxent habitat model is based on

[10] A forest stand is a contiguous group of trees sufficiently uniform to be a distinguishable unit.

satellite imagery that predicts and maps murrelet habitat across three states at the scale of 30-meter square pixels (0.22 acres) and was not developed to estimate habitat at the scale of individual forest stands (Raphael et al. 2016, p. 85). Detailed information on P-stage is provided in the FEIS (2019, Appendix E), and an explanation of updates made to P-stage for the FEIS are provide in the FEIS (2019, Appendix O).

9.3.3.1 Distribution of P-stage Habitat

Murrelet habitat is broadly distributed in scattered patches across WDNR lands and represents about 15 percent of the total WDNR land-base within the range of the murrelet. For this analysis, we summarized existing habitat by HCP planning unit (Table 9) and by murrelet strategic landscapes as presented in the FEIS (Table 10). Both summaries are useful in understanding the distribution of murrelet habitat located on WDNR lands. The HCP planning units are based on major watershed areas in Washington, and are comparable to murrelet conservation zones. HCP planning units in Zone 1 include the Straits, North Puget, South Puget, and Yakima. HCP planning units in Zone 1 include the OESF, South Coast, and Columbia planning units. While the OESF slightly overlaps both Zone 1 and Zone 2, the majority of the unit is in Zone 2.

In the HCP planning units, the OESF contains the greatest ratio of suitable habitat to land area (25 percent) and contains the highest density of occupied sites. The North Puget HCP planning unit contains the largest area of WDNR lands, and the greatest amount of high-quality habitat outside of mapped occupied sites. The South Coast, Columbia, Straits, and South Puget all have low ratios of habitat to land area (15 percent or less) (Table 9).

9.3.4 Uncertainties Associated with P-stage Classification

There is an unquantified level of uncertainty associated with the accuracy of P-stage habitat classification (FEIS 2019, p. E-13). P-stage classes do not correspond directly to other metrics typically used to quantify murrelet habitat and probability of occupancy (e.g., density of large trees, density of platforms, etc.). In other words, habitat classified as P-stage 0.25 does not contain a specific number of expected platforms per acre, but rather represents a stand that is greater than 70 or 120-years old, is naturally regenerated, and as such, may have some scattered remnants or residual trees from a previous stand. Most of the existing habitat on WDNR lands in southwest Washington, including habitat in occupied sites, is comprised of P-stage 0.25 or 0.36 habitat.

Table 9. Distribution of existing murrelet habitat (raw acres) on WDNR-managed lands, by P-stage class and HCP planning units.

P-stage class	HCP Planning Unit							Grand Total
	Columbia	North Puget	OESF	South Coast	South Puget	Straits	Yakima	
0	84,256	367,978	204,776	242,258	162,000	112,769	2,082	1,176,121
0.25	8,638	37,548	9,820	8,614	9,658	6,449	273	80,998
0.36	2,903	6,544	9,179	1,419	2,020	1,428	67	23,560
0.47	184	3,529	5,351	433	1,433	161	0	11,091
0.62	135	4,199	3,563	246	1,025	572	0	9,739
0.89	0	21,221	801	121	21	17	166	22,347
1	2,694	3,853	39,595	6,952	576	5,661	0	59,330
WDNR Totals	98,810	444,871	273,084	260,044	176,733	127,056	2,588	1,383,187
Total habitat	**14,554**	**76,893**	**68,309**	**17,786**	**14,733**	**14,287**	**505**	**207,066**
Percent of total habitat	7 %	37 %	33 %	9 %	7 %	7 %	0.2%	100%
Percent WDNR land in habitat	15 %	17 %	25 %	7 %	8 %	11 %	-	15%

Source: WDNR large data overlay pivot table summaries dated 20190628.

The strategic landscape area with the highest percentage of existing habitat and occupied sites is the OESF/Straits west of the Elwha River, which has 25 percent of the existing habitat and 71 percent of the existing occupied sites on WDNR lands. In contrast, the Marginal Landscape, which contains a significant portion of the WDNR land base (16 percent), contains less than 2 percent of the existing habitat on WDNR lands. About half of the existing habitat on WDNR lands consists of lower quality habitat (P-stage 0.25, 0.36), and about 29 percent is classified as P-stage 1 (occupied sites) (Table 10).

Table 10. Distribution of existing murrelet habitat on WDNR-managed lands, by P-stage class and landscape area.

Landscape Area	P-stage class (raw acres)							Total habitat	Total land
	0	0.25	0.36	0.47	0.62	0.89	1		
Southwest Washington	140,656	12,993	3,874	400	158	2	8,905	26,332	166,988
OESF and Straits west Elwha River	230,297	12,564	10,039	5,418	3,791	818	42,171	74,801	305,099
North Puget	304,617	26,258	4,818	2,598	3,564	19,088	3,834	60,161	364,778
Other high-value landscapes	280,103	25,898	4,621	2,452	1,999	2,439	4,420	41,830	321,933
Marginal landscape	220,447	3,285	208	222	227	0	0	mar	224,390
Totals	**1,176,121**	**80,998**	**23,560**	**11,091**	**9,739**	**22,347**	**59,331**	**207,066**	**1,383,187**
Percent of total habitat area	~	39%	11%	5%	5%	11%	29%	100%	~

Source: FEIS, Table 3.6.1.

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 is more complex and unpredictable. As noted in the FEIS (2019, Appendix E), some areas classified as P-stage habitat appear to lack abundant trees with platforms and/or individual trees with abundant platforms, which is also true for some areas classified as occupied stands (FEIS 2019, p. E-9). The fact that some areas within occupied sites are not classified as P-stage habitat is not entirely unexpected. While there is overlap between the reclassified habitat model used to identify habitat for murrelet surveys, not all areas mapped as reclassified habitat are mapped as P-stage habitat. This is particularly true in the Straits HCP planning unit, where Douglas-fir dominated stands are more prevalent. As noted above, a 100-year old stand dominated by Douglas-fir with scattered remnant old-growth trees is not classified as P-stage habitat until the stand reached an average age of 120-years (FEIS 2019, p. E-7). Other occupied sites have been degraded by windthrow, particularly in the South Coast area. These damaged areas were not remapped for the Long-Term Strategy, because all sites damaged by windthrow still retain some areas of intact forest.

A comparison of the accuracy of P-stage classification with the Maxent model used for the Northwest Forest Plan is presented in the FEIS (2019, Appendix E). Both models found that the 59,000 acres of occupied sites on WDNR lands are comprised primarily of high-quality habitat under both Maxent (43 percent) and P-stage (54 percent) classifications. However, both models identify considerable amounts of occupied sites as non-habitat, Maxent (25 percent) and P-stage (15 percent) (FEIS 2019, p. E-9) (Table 11).

Table 11. Summary of current P-stage habitat associated with occupied sites (raw acres) by HCP planning unit.

P-stage class	HCP Planning Unit						Totals	Percent
	Columbia	N.Puget	OESF	S.Coast	S.Puget	Straits		
0	351	1,084	2,299	1,369	307	3,694	9,105	15%
0.25	463	796	2,632	3,712	98	1,399	9,100	15%
0.36	1,104	546	5,789	1,007	37	445	8,929	15%
0.47	418	278	6,870	346	25	113	8,050	14%
0.62	182	274	15,736	406	107	10	16,715	28%
0.89	176	874	6,269	112	0	0	7,432	13%
Totals	2,694	3,853	39,595	6,952	576	5,661	59,330	100%

Source: WDNR large data overlay pivot table summaries 20190628.

Although no conclusive comparisons of model performance can be made, habitat classification using P-stage is considered by the USFWS to be the best available stand-level murrelet habitat model for WDNR-managed lands because it is based on WDNR's forest inventory data, is consistent with our understanding of murrelet habitat relationships, and applies a simple ruleset for predicting how murrelet habitat may change over time (FEIS 2019, p. E-10). There is no evidence to suggest that P-stage classification is consistently biased to predict areas of non-habitat as habitat, or consistently classifying areas of habitat as non-habitat. In other words, there is some level of error in P-stage classification, but it is not likely to be biased one way or the other. The Maxent model developed for Northwest Forest Plan 20-year monitoring report remains the best available information for assessing murrelet habitat on federal and other non-federal lands, but the application of the Maxent model is limited to the assessment large landscape areas only, it is not accurate at the scale of individual stands (Raphael et al. 2016, p. 85).

The use of P-stage classification to represent the relative probability of murrelet occupancy is a conservative approach to conservation planning on WDNR-managed lands. P-stage is a conservative approach because the analysis of the relationship between murrelet occupancy and stand development stages was based on surveys that were completed during the late 1990's and early 2000's when the estimated population of murrelets in Washington was significantly greater than it is today; and, habitat areas that were surveyed and were not identified as occupied sites are treated as potentially occupied using P-stage classification.

P-stage classification is being used to establish the baseline of existing conditions for determining habitat quantity and quality on WDNR-managed lands, and over the life of the 1997 HCP. 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. P-stage classification does not account for these factors when evaluating habitat. However, the *Analytical Framework* used for assessing impacts and mitigation adjusts P-stage values to reflect edge effects, geographic location, and other important factors affecting habitat quality (FEIS 2019, Appendix H). The use of adjusted acres will be discussed further in the *Effects of the Proposed Action*.

9.3.5 Nesting Habitat as an Index of Murrelet Distribution and Habitat Capacity

The number of murrelets associated with habitat on WDNR-managed lands is unknown. To estimate the portion of the population of the murrelet population in Washington that is associated with the WDNR-managed lands we used a coarse-scale estimate of average murrelet density. This estimate is based on the total amount of available nesting habitat in Washington following the methods of Raphael and others (2018, p. 317).

To estimate the ratio of habitat area to the murrelet population, we used the 5-year average of the reported state-wide murrelet population estimates for the years 2013 through 2017 derived from marine surveys (6,239 murrelets) and applied this value to the total habitat area (1.34 million acres) in Washington, which yields an average of 215 acres of potential nesting habitat per murrelet (Table 12). This value represents both breeding and non-breeding murrelets in the population, so the average density of habitat acres per nesting pair is likely to be higher than this value. Washington has the lowest average density of murrelets to habitat area within the range of the species (Raphael et al. 2018, p. 317).

Table 12. Murrelet population size, estimate of habitat, and ratio of population to habitat area in Washington.

Year	Estimated murrelet population in Washington	Estimated nesting habitat in Washington (acres)	Habitat area per murrelet (acres)
2013	5,646	1,343,100	215
2014	4,977		
2015	7,494		
2016	7,095		
2017	5,984		
2013-2017 average	6,239		

Sources: Population estimates: McIver et al. 2019. Habitat: Raphael et al. (2018, pp. 315).

Peery and Jones (2019) developed a population viability analysis (PVA) model to explore the relationship between murrelets and nesting habitat in Washington. In that analysis, the authors used the same method described above to define the initial populations attributed to WDNR habitat and other ownerships (Peery and Jones, 2019, p. 13). However, in that analysis, the 5-year average of the population estimate for the period from 2011 to 2015 was used (~7,232 murrelets, or 3,616 female murrelets) (Peery and Jones, 2019, p. 13), which yields an average density of 186 acres of habitat per murrelet in Washington, compared to the current average of 215 acres per murrelet (Table 12, above). Based on an analysis of habitat capacity by major land ownership, 15 percent of the murrelet population in Washington was attributed to WDNR-managed lands (Peery and Jones 2019, p.13). Peery and Jones assigned a starting population of 542 female murrelets (15 percent) to WDNR lands, and 3,074 female murrelets to other ownerships (85 percent) in the PVA.

In order to accurately model the observed rate of annual decline in murrelet population trends in Washington for the period from 2001 to 2015 Peery and Jones (2019, p. 14) assumed that only about 40 percent of the total murrelet population in Washington is comprised of breeding adults, while the remainder of the population are juveniles and non-breeding adults (Peery and Jones 2019, pp. 25-26). This yielded an estimate of 217 nesting females on WDNR-managed lands. While this appears to be a low estimate for the ratio of breeding adults, it is higher than breeding rates observed in murrelet telemetry studies in Washington (5-20 percent) (Lorenz et al. 2017, p. 312), and is comparable to breeding rates observed in Alaska (48 percent) (Barbaree et al 2014, p. 177).

While the more recent population data indicate a slightly lower current population in Washington than was used in the PVA, for consistency with the analyses presented in the 2019 FEIS, we are using the same average starting population data (542 females, 1,084 murrelets associated with WDNR habitat) used by Peery and Jones (2019) for our analysis of effects to murrelets in this Opinion. Using the current P-stage estimate of 207,000 raw acres, we get an average density of 191 acres of habitat per murrelet on WDNR lands (breeders and non-breeders). These estimates can be further refined by calculating average density using P-stage adjusted acres.

Density estimates for murrelets are useful in two ways: 1) habitat capacity analysis – the density index can be used as a measure to describe how the changes in habitat quantity will equate to increased or decreased capacity to support murrelets based on an assumed density (Raphael et. al. 2008, p. 4-3); and, 2) estimating effects to individuals – using a density index allows for an estimate of the number of individuals potentially impacted by forest management activities based on the area of habitat affected. These concepts will be discussed in detail in the *Effects of the Action* section.

9.4 Factors Responsible for the Condition of the Species in the Action Area

Habitat models developed for the *Northwest Forest Plan* 20-year monitoring report indicate a 13.3 percent decline in habitat in Washington for the period from 1993 – 2012. The decline in habitat varies greatly by land ownership. Habitat on federal lands has remained fairly stable over the monitoring period, with an estimated 1 percent decline, while habitat on state-managed lands declined by approximately 14 percent (Table 13). By far the greatest loss of habitat in Washington is attributed to private forest lands, with an estimated loss of 159,300 acres (39 percent) of the potential nesting habitat (Table 13). These trends demonstrate the conservation value provided by the 1997 HCP and murrelet habitat management under the Interim Strategy. Without the 1997 HCP, WDNR would be required to manage murrelet habitat in accordance with the Washington Forest Practices rules for murrelets. The Forest Practices rules protect habitat associated with known occupied sites, but generally do not protect habitat that is not associated with occupied sites or other areas deferred from harvest (e.g., riparian buffers, unstable slopes, etc.), likely resulting in a substantial decline in murrelet habitat on private lands in Washington since 1993.

Table 13. Estimated changes in acres of suitable murrelet nesting habitat from 1993 to 2012 by land ownership in Washington based on *Northwest Forest Plan* habitat monitoring.

Land Ownership	1993	2012	Change (acres)	Change (percent)
Federal	899,700	887,100	-12,600	-1%
State	243,700	209,700	-34,000	-14%
Other ownerships	405,600	246,300	-159,300	-39%
Totals	1,549,000	1,343,100	-205,900	-13%

Source: Raphael et al. 2018, p. 315. State lands in this table include WDNR-HCP lands, as well as lands managed by Washington Department of State Parks, and the Washington Department of Fish and Wildlife.

9.4.1 Past Forest Management on WDNR-managed Lands

Management for murrelets under the 1997 HCP has occurred under the Interim Strategy that focused on identifying murrelet habitat and generally avoiding timber harvest in areas deemed likely to be occupied by murrelets. In the absence of an approved HCP amendment for a long-term conservation strategy, WDNR would continue to implement the Interim Strategy, which represents the "environmental baseline" against which the proposed Long-Term Strategy is compared. Continued implementation of the Interim Strategy is described in the FEIS as Alternative A – the no action alternative (FEIS 2019, p. 2-37 to 2-40).

Under the Interim Strategy, WDNR has established murrelet habitat protection measures in the North and South Puget HCP planning units and restricted harvests in the southwest Washington, OESF, and Straits HCP planning units. In sum, WDNR established protections of habitat across approximately 190,000 acres, which dramatically reduced the harvest-related loss of habitat on WDNR-managed lands to only the lowest-quality habitat (FEIS 2019, p. 5-5).

The Interim Strategy authorized the removal of low-quality ("marginal") murrelet habitat that would be expected to contain a maximum of 5 percent of potential occupied sites (WDNR 1997, p. IV.40, Step 3) and allowed for some harvest of habitat that was surveyed but determined to be unoccupied (WDNR 1997, p. IV.40, Step 4).

In the 1997 Opinion, the USFWS anticipated habitat removal of between 18,245 and 74,286 acres of suitable murrelet habitat. This range of habitat, based on the habitat relationship study conducted by WDNR, was expected to be marginal habitat that contained a maximum of 5 percent of the occupied sites on WDNR-managed lands within each planning unit. This did not include any known occupied sites (WDNR HCP, p. IV. 40). The USFWS also estimated that disturbance effects (disruption of nesting behaviors due to exposure from noise, activity, and adjacent habitat removal) to murrelets from covered activities could average about 23,500 acres per year, representing approximately 16 percent of occupied murrelet habitat annually (USFWS 1997, p. 90).

To date, approximately 29,000 acres of marginal habitat and 3,300 acres of surveyed unoccupied habitat have been harvested, for a cumulative total of 32,300 acres of potential murrelet habitat harvested (FEIS 2019, p. 5.5). This equates to an average of about 1,600 acres of murrelet habitat harvested per year over the 20-year period from 1997 to 2017. The amount of habitat released for harvest under the Interim Strategy is within the range of effects to murrelets anticipated in the 1997 Opinion (USFWS 1997, p. 94). We do not have estimates of annual disturbance effects to murrelets that have occurred under the Interim Strategy but have no reason to believe that disturbance effects have been greater than anticipated under the 1997 Opinion.

Additionally, natural disturbance events, including the "Great Coastal Gale of 2007," resulted in a loss of murrelet habitat, and salvage activities have occurred on approximately 1,200 acres of windthrow-damaged murrelet habitat on WDNR-managed lands. While most murrelet habitat has been retained on WDNR-managed lands since 1997, timber management in interspersed areas of non-habitat has fragmented remaining habitat patches and contributed to edge effects.

9.4.1.1 Measures of Habitat Fragmentation and Forest Edges

The relationship between human activities and predators, and their potential impact on murrelet nesting success, has been identified as a significant threat to murrelets (USFWS 2019b, p. 45). Research conducted in Washington and British Columbia has demonstrated that the risk of murrelet nest failure due to predation is highest within 50 m (164 ft) of a forest edge, especially in areas close to human settlements and recreation areas, and along "hard" (recent clearcut) forest edges (Malt and Lank 2007, p. 160; Malt and Lank 2009, p. 1274; Raphael et al. 2002, p. 221). Corvids (jays, crows, and ravens) are known predators of murrelet eggs and nestlings, and are more abundant in patchy, fragmented landscapes and in landscapes with higher levels of human use (Luginbuhl et al. 2001, Raphael et al. 2002, Neatherlin and Marzluff 2004, Malt and Lank 2009).

A forest edge is an abrupt transition between two habitat types or forest stands 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 forest stands, and these man-made edges increase the risk of disturbance to habitat and increase the predation risk to murrelet nest sites.

In the analysis of current habitat conditions on WDNR-managed lands we defined areas of "interior forest" as areas that are not influenced by forest edges. Interior forest habitat is defined as patches (of any size) that are at least 328 ft (100 m) from any type of edge. Interior forest patches have reduced risk of predation relative to forests in edge-influenced areas and are better protected from the effects of windthrow and other disturbances that have been found to affect murrelet habitat or nests. Edge categories are defined as below (FEIS 2019, p. 3-34):

- The *inner edge* of the interior forest patch is located 167 to 328 ft (51 to 100 m) from the edge of an actively managed forest.
- The *outer edge* of the interior forest patch is located 0 to 164 feet (0 to 50) from the edge of an actively managed forest.

- A *stringer* is a narrow area (less than 656 ft [200 m] wide), predominantly a riparian management zone, where adjacent uplands have not been designated as long-term forest cover.

The adverse impacts of edges are expected to decline with increasing distance from edge and as edge-creating stands mature (FEIS 2019, Appendix H). Currently, about 40 percent of the habitat on WDNR lands is classified as interior forest, and about 18 percent is in small, fragmented patched classified as *stringers* (Table 14). How edge conditions influence habitat quality is described in detail in the *Effects of the Action* and the FEIS (2019, Appendix H).

Table 14. Configuration of current P-stage habitat on WDNR-managed lands (raw acres).

Interior Forest	Inner Edge	Outer Edge	Stringer	Total
82,861	40,531	46,702	36,973	207,067
40 %	20 %	23 %	18 %	100 %

Source: FEIS 2019, p. 3-34.

9.4.1.2 Habitat Patch Size

Interior forest patches provide higher quality habitat than forest near an edge. In general, larger patches of habitat contain more interior forest and less edge, although this is not always true depending on patch configuration. The 1997 HCP identifies five acres as the minimum patch size for murrelet habitat management under the Interim Strategy (WDNR 1997). An analysis of habitat patch size indicates there are 170,000 acres of inland habitat in patches greater than or equal to five acres (FEIS 2019, p. 3-37). By area, most habitat patches are between 100 and 500 acres in size (Figure 5).

9.4.2 Forest Management on Federal Lands

Federal lands within the range of the murrelet in Washington include National Parks and National Forests, as well as smaller areas associated with National Wildlife Refuges and Department of Defense military reservations. As with WDNR-managed lands, much of the historic murrelet habitat that existed on federal lands outside of National Parks was harvested prior to the listing of the murrelet as a threatened species in 1992 (USFWS 1997).

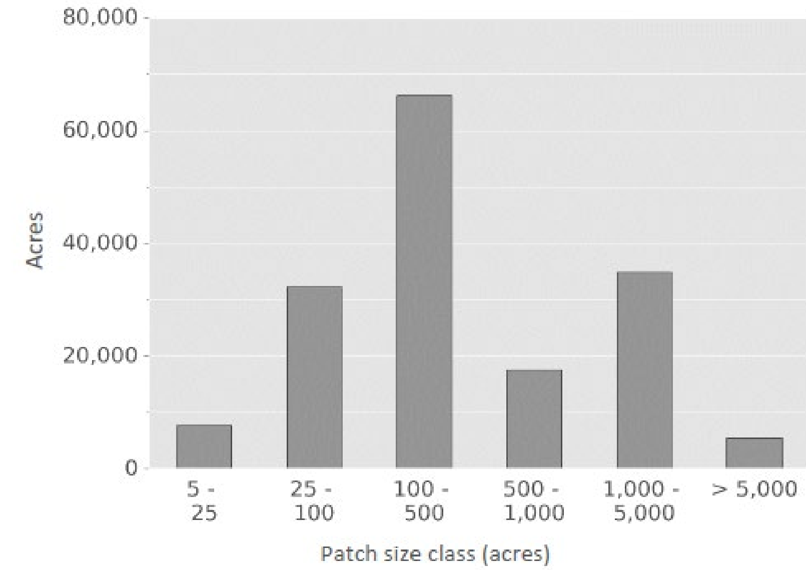

Figure 5. Current size distribution of habitat patches.
Source: FEIS 2019, p. 3-38.

The Northwest Forest Plan (USDA and USDI 1994) established a large network of late-successional reserves on National Forest lands for the specific purpose of maintaining and recruiting late-successional and old-growth forests. These areas, along with National Parks and congressionally-designated wilderness areas, are all considered federal reserves. In Washington, nearly 90 percent of federal lands within the range of the murrelet are in federal reserves. Federal reserves are expected to provide the primary role for the conservation and recovery of the murrelet in most areas (USFWS 1997). Murrelet habitat in conservation reserves on federal lands is expected to increase over the next 50 years as young forests transition to more mature forests and the quality of current habitat increases through a reduction of past habitat fragmentation and edge effects (Raphael et al. 2016, p. 114).

Under the Northwest Forest Plan, the focus of forest management in National Forests has shifted from regeneration timber harvest to a program of restoration thinning, with each National Forest (Olympic, Mt. Baker-Snoqualmie, and Gifford Pinchot) implementing between 1,000 and 2,000 acres of restoration thinning projects annually. Since 2003, the USFWS has consulted on the removal of approximately 105 acres of suitable murrelet habitat on federal lands in Washington. Exposure to noise and visual disturbance, and increased predation risk associated with campgrounds and recreation facilities on federal lands likely affect nesting success of murrelets on federal lands. On the Olympic National Forest, the USFWS estimated that up to 7,000 acres of murrelet habitat is likely to be exposed to noise and visual disturbance annually (about 3 percent of the total habitat area on Olympic National Forest) (USFWS 2013).

9.4.3 Forest Management on Private Lands

Private industrial forestlands are intensively managed and typically have trees less than 60 years old. Very few late-successional forests are present on such lands. Private industrial forestlands are focused on timber production, with many areas being harvested on relatively short rotations (40 to 50 years) (Davies 2011).

Current estimates indicate over 260,000 acres of murrelet habitat occur on private lands, which represents about 20 percent of the total estimated murrelet habitat remaining in Washington. Most habitat remaining on private lands is highly fragmented and occurs in small, scattered patches. Currently, only about 4 percent of the habitat-capable area on private lands contains murrelet habitat (Falxa and Raphael 2016).

Private timber harvest in Washington must comply with the Washington Forest Practices Act (RCW 76.09) as well as the Washington Forest Practices Rules (Title 222 WAC), although the requirements could vary if the landowner has a federally approved HCP. Washington forest practices rules require murrelet surveys in habitat as defined in WAC-222-16-010 and provide protection for known occupied and presumed-to-be occupied murrelet habitat until it is shown not to support murrelets.

The USFWS has developed several HCPs and Safe Harbor Agreements (SHAs) that cover forest management on certain private lands in the Action Area. These include the Green Diamond HCP, Port Blakely SHA, West Fork Timber Company HCP, the City of Seattle HCP, and others. In general, the lands encompassed by these HCPs/SHAs contain limited areas of murrelet habitat, and conservation of murrelet habitat under these HCPs is limited primarily to riparian area buffers and small areas associated with known occupied sites.

Monitoring for the *Northwest Forest Plan* indicates that potential murrelet habitat on non-federal lands in Washington has declined by as much as 39 percent over the past 20 years, primarily due to timber harvest, and other natural disturbances (Table 6, above). It is important to note that estimates of potential murrelet habitat identified through remote sensing models are not directly comparable to field-based habitat delineations required under the Washington Forest Practices Rules. However, habitat models derived from remote-sensing data indicate that most of the potential murrelet habitat on private lands is now largely confined to areas associated with known occupied murrelet sites, riparian corridors, potentially unstable slopes, and other areas deferred from harvest through existing HCPs or other deferrals under the Washington forest practices rules.

The USFWS completed a formal consultation on the Washington State Forest Practices Rules HCP for aquatic species in 2006 and anticipated that essentially all potential murrelet habitat located on private lands that is not associated with occupied sites or other protected areas will eventually be lost due to timber harvest (USFWS 2006, p. 477). Although the USFWS determined that ongoing forest practices on private lands “may affect, and is likely to adversely affect” murrelets, we concluded that these effects are not likely to jeopardize the continued existence of murrelets (USFWS 2006, p. 482). This conclusion was based on the protection of the occupied murrelet sites provided by the Forest Practices Rules, which is consistent with the murrelet recovery plan which calls for the protection of occupied habitat on private lands (USFWS 1997, p. 133).

9.4.4 Other Factors Affecting Murrelets in the Action Area

Ongoing actions that affect the murrelet in the action area include the U.S. Department of the Navy training and testing operations and impacts associated with Growler jets from the Whidbey Island Naval Air Station. The USFWS reviewed these actions and determined that the Navy's Northwest Training and Testing program "may affect, and is likely to adversely affect" the murrelet by exposing murrelets to aircraft noise and underwater sound impacts in marine foraging areas in Puget Sound, and by exposing murrelets to aircraft noise over habitat on the Olympic Peninsula (USFWS 2016). The USFWS determined that the expansion of Growler operations including local field carrier landing practice flights from Whidbey Naval Air Station "may affect, and is likely to adversely affect" the murrelet by exposing murrelet to aircraft noise in marine foraging areas (USFWS 2018). These activities contribute to the complex suite of environmental and human-caused stressors to murrelets in Washington. While these Navy activities are likely to impact individual murrelets, the impact of these ongoing activities on murrelet population trends is difficult to quantify due to the broad area of habitat exposed to these stressors and the patchy and variable distribution of murrelets in Puget Sound and adjacent upland forests capable of providing murrelet nesting habitat.

In May 2019, the USFWS completed an FEIS on an HCP application for the Skookumchuck Wind Energy Project located in Thurston and Lewis Counties, and issued a record of decision authorizing USFWS to issue an incidental take permit for project operations. This HCP covers the operation of up to 38 wind turbine generators over a period of 30 years. The wind turbine generators pose a collision risk for murrelets flying through the project area, and the FEIS estimates that the project could directly kill an average of 2.5 murrelets per year. Mitigation measures are anticipated to offset the impacts of the take associated with this project. These measures include the acquisition of conservation lands for murrelet habitat in southwest Washington (adjacent to proposed WDNR-managed conservation areas) and removal of derelict fishing gear in Puget Sound (USFWS 2019d).

Other sources of human-caused mortality to murrelets include oil spills and gillnet fisheries. Several studies have documented murrelets becoming entangled in gill-nets in Washington and British Columbia (USFWS 2019b). While efforts to reduce fisheries bycatch remain in place, the USFWS estimates that about five murrelets per year may be killed in Washington fisheries (USFWS 2019b). While there have been no recent major oil spills with documented mortalities of murrelets in Washington, the risk of oil spills remains and may be increasing as result of new and expanded oil transportation facilities being developed in Washington and British Columbia (USFWS 2019b). Impacts can result from direct mortality through oiling, and through changes in prey base, marine habitat, and vessel disturbance.

9.5 Factors Responsible for the Condition of Critical Habitat

The critical habitat designation in Washington identified approximately 426,800 acres of state lands (26 percent) managed under the 1997 state lands HCP. Because these lands are managed under an approved HCP issued under section 10(a) of the Act, these lands are excluded from critical habitat by description in the final rule (81 FR 51365 [August 4, 2016]). Therefore, this analysis is focused on the condition of designated critical habitat on federal lands adjacent to WDNR-managed lands.

The action area for designated critical habitat is based on the potential effects to the physical and biological features of the critical habitat. For this analysis, we used a distance of 328 ft to represent the area where management activities on WDNR-managed lands could result in edge effects (e.g., windthrow, microclimate changes) in designated critical habitat. Critical habitat in Washington is designated in 33 CHUs, and includes over 1.2 million acres of federal lands, and 2,509 acres of private lands. Based on the Maxent habitat model, only about 26 percent (311,000 acres) of designated critical habitat is currently in habitat, while the remaining acres are comprised of areas that have either been previously harvested, or areas that are not habitat capable (e.g., alpine, wetlands, etc.). Based on GIS-analysis, we estimated there is approximately 5,234 acres of designated critical habitat located within a distance of 328 ft. of WDNR-managed lands. These acres are widely dispersed along the margins of 26 murrelet CHUs, and represent less than 1 percent of total designated critical habitat acres in Washington (Table 15).

9.6 Conservation Role of the Action Area

Lands identified as essential for the conservation and recovery of the murrelet in the 1997 *Recovery Plan* include all nesting habitat located within the range of the murrelet on federal lands; all nesting habitat on state lands within 40 miles of marine waters; and all nesting habitat associated with occupied murrelet sites on private lands (USFWS 1997, pp. 132-133).

Since the *Recovery Plan* was published in 1997, we have learned much about the status and distribution of murrelets and their habitat. Extensive surveys conducted by WDNR under the Interim Strategy demonstrated that certain areas (e.g., Capitol Forest) are not likely to be currently occupied by murrelets, and due to the limited habitat area and fragmented nature of existing habitat, these areas have been classified as a “marginal landscape” with a very low probability of occupancy by murrelets, despite being located less than 40 miles from marine waters (FEIS 2019, pp. H-18 to H-20).

Table 15. Summary of murrelet critical habitat located adjacent to WDNR-managed lands.

Conservation Zone	CHU Name	Ownership	Total acres in CHU	Potential murrelet nesting habitat (acres)	Percent of CHU with potential murrelet habitat	CHU acres located within 328 ft. of WDNR lands	Percent of CHU adjacent to WDNR land
1	WA-01-b	Federal	8,172	5,566	68%	134	2%
1	WA-03-b	Federal	65,027	17,330	27%	0	0%
1	WA-06-a	Federal	71,539	23,499	33%	405	1%
1	WA-06-b	Federal	44,236	15,445	35%	481	1%
1	WA-07-b	Private	1,075	475	44%	29	3%
1	WA-07-c	Federal	88,759	20,234	23%	265	0%
1	WA-08-a	Federal	85,254	21,853	26%	359	0%
1	WA-09-a	Federal	1,826	787	43%	39	2%
1	WA-09-b	Federal	108,076	21,119	20%	1,063	1%
1	WA-09-c	Federal	4,959	1,068	22%	193	4%
1	WA-10-a	Federal	76,593	11,204	15%	42	0%
1	WA-10-b	Federal	41,956	7,177	17%	63	0%
1	WA-10-c	Federal	25,712	3,284	13%	160	1%
1	WA-11-a	Federal	72,196	6,884	10%	84	0%
1	WA-11-b	Federal	11,139	539	5%	0	0%
1	WA-11-d	Federal	51,360	8,407	16%	1	0%
2	WA-02-a	Federal	15,955	11,429	72%	266	2%
2	WA-02-b	Federal	1,982	1,017	51%	155	8%
2	WA-02-c	Federal	46,342	23,515	51%	123	0%
2	WA-02-d	Federal	412	238	58%	36	9%
2	WA-03-a	Federal	97,847	43,665	45%	206	0%
2	WA-05-b	Private	401	195	49%	0	0%
2	WA-05-c	Private	297	62	21%	0	0%
2	WA-05-d	Private	327	109	33%	32	10%
2	WA-05-f	Private	191	16	8%	0	0%
2	WA-05-g	Private	218	50	23%	0	0%
2	WA-11-c	Federal	37,589	5,671	15%	127	0%
1 & 2	WA-01-a	Federal	60,477	25,391	42%	460	1%
1 & 2	WA-07-a	Federal	78,207	15,220	19%	293	0%
1 & 2	WA-07-d	Federal	24,112	6,653	28%	60	0%
1 & 2	WA-08-b	Federal	20,410	3,934	19%	94	0%
1 & 2	WA-09-d	Federal	13,051	2,727	21%	0	0%
1 & 2	WA-09-e	Federal	48,827	6,191	13%	62	0%
		Totals	**1,204,524**	**310,954**	**26%**	**5,232**	**0.4%**

Notes: Murrelet habitat estimates are approximate values that represent conditions in 2012, as depicted by Raphael et al. (2016) map data, moderate (class 3) and highest (class 4) suitability. Due to limitations of the habitat model used, the habitat amounts listed above are estimates only, and are not considered to be absolute values.

The strategic locations identified in this analysis (Figure 2, above) include those areas that contain the majority of current murrelet habitat and occupied sites that are located on WDNR-managed lands and identify the locations where these lands are in closest proximity to important marine foraging areas for murrelets. WDNR-managed lands in southwest Washington have a significant role for the conservation of murrelets due to the lack of federal lands in that landscape. In developing the proposed Long-Term Strategy, both WDNR and USFWS agreed to the following objective for WDNR-managed lands:

- *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 expects to make a significant contribution to maintaining and protecting marbled murrelet populations* (FEIS 2019, p. 1-2).

The *Recovery Plan* acknowledges the important role of HCPs for the conservation of murrelets: *"…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."* (USFWS 1997, p. 120).

9.7 Climate Change

Consistent with USFWS policy, our analyses under the ESA include consideration of ongoing and projected changes in climate. The term "climate" refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (IPCC 2014a, pp. 119-120). The term "climate change" thus refers to a change in the mean or variability of one or more measures of climate (e.g., temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both (IPCC 2014a, p. 119). Various types of changes in climate can have direct or indirect effects on species and critical habitats. These effects may be positive, neutral, or negative, and they may change over time. The nature of the effect depends on the species' life history, the magnitude and speed of climate change, and other relevant considerations, such as the effects of interactions of climate with other variables (e.g., habitat fragmentation) (IPCC 2014b, pp. 64, 67-69, 94, 299). In our analyses, we use our expert judgment to weigh relevant information, including uncertainty, in our consideration of various aspects of climate change and its effects on species and their critical habitats. We focus in particular on how climate change affects the capability of species to successfully complete their life cycles, and the capability of critical habitats to support that outcome.

Within the action area, changes in temperature and precipitation are altering ecological processes within forests, and these changes are expected to continue and to increase in magnitude over the next 50 years. These changes are expected to result in forest stand disturbance and development patterns that differ from those of the past. In turn, changes in forest stands will affect the structure, suitability, and availability of nesting habitat. In addition, changes in the terrestrial environment may have a direct effect on murrelet reproduction, for example due to reduced energy expenditure on thermoregulation, but little is known about whether or how such direct effects may occur. Changes in the marine environment, outside of the action area, are also expected to affect the survival and reproduction of murrelets within the action area; see Appendix A (Status of the Species) for a discussion of these effects.

Projected changes to the climate within the action area include air and sea surface temperature increases, changes in precipitation seasonality, and increases in the frequency and intensity of extreme rainfall events (Mauger et al. 2015, pp. 2-1 – 2-18). Air temperature warming is already underway, and is expected to continue, with the mid-21st century projected to be approximately four to six degrees Fahrenheit (F) (2.2 to 3.3 degrees Celsius [C]) warmer than the late 20th century (Mauger et al. 2015, p. 2-5). Summer precipitation is expected to decrease by 22 percent (averaged across models, relative to the late 20th century) by the mid-21st century, while winter precipitation is expected to increase (Mauger et al. 2015, p. 2-7). In particular, heavy rainfall events are projected to occur approximately three times as frequently and to be about 19 percent more intense, on average, in the late 21st century than they were during the late 20th century (Warner et al. 2015, pp. 123-124).

Forested habitats in western Washington are affected by climate change mainly via changes in disturbances, including wildfire, insects, tree diseases, and drought mortality. These types of disturbances can all cause the loss of murrelet nesting habitat, though it is hoped that this loss will be offset by ingrowth as existing mid-successional forest matures. However, the maturation of mid-successional forest may also be affected by climate change; see below. Following stand-replacing disturbances, climate conditions may not allow recruitment of the tree species that are currently present, leading to ecotype change; however, the effect of this kind of ecotype change may not directly affect murrelet habitat availability until many decades in the future.

9.7.1 Wildfire

Western Washington's fire regime has historically been typified by large, infrequent, stand-replacing fires (Halofsky et al. 2018a, pp. 3-4). For example, approximately half of the Olympic Peninsula burned around 1308; a large fire covered much of the northern and eastern Olympic Peninsula around 1701; and there were many other years with widespread fire in the intervening 400 years (Henderson et al. 1989, pp. 13-19). However, fires of this nature have not occurred during the 20th-century period usually used for statistical analyses of fire behavior or projections of future fire (Littell et al. 2010, p. 150). For example, between 1993 and 2012, monitoring based on a database of large (1,000 acres or greater) fire perimeters detected only 300 acres of stands 80 years old and older and only 200 acres of Maxent-modeled high-quality murrelet nesting habitat on non-federal lands in Western Washington (Davis et al. 2015, p. 31; Raphael et al. 2016, p. 81). A model based on fire data collected in 1971 through 2015 classifies only 1 percent of state and local forest lands in Oregon and Washington (including those east of the Cascade Crest) as being currently "highly suitable" for large fires, with 17 percent "moderately suitable" (Davis et al. 2017, pp. 179-182). The fire regime in Western Washington has historically been sensitive to climate conditions (Henderson et al. 1989, pp. 13-19; Littell et al. 2010, p. 140; Weisberg and Swanson 2003, pp. 23-25).

The 3,300-acre Maple Fire in 2018 burned approximately 300 acres within the action area, including a 31-acre occupied site. The burned portion of the action area also included and surrounding forested stands that, while not currently suitable for murrelet nesting, were expected to mature into suitable habitat within the next 50 years. Within the Maple Fire, some areas burned at high severity, with greater than half of the basal area lost from the stand, according to fire severity data collected immediately after the fire (USFS 2018, and see also Estep 2018, in litt.). We assume that the loss of half the basal area in a stand is equivalent to habitat loss, especially considering the additional, delayed mortality that will continue for several years following the fire (Whittier and Gray 2016, p. 203). Thus, we estimate that the habitat lost from the Maple Fire includes 12 acres (40 percent) of the occupied site, as well as18 acres that would otherwise have developed into habitat over the next 50 years. We lack any other specific information about past fire effects to murrelet habitat on WDNR lands. There have likely been other fires within the action area, but if so, they were smaller than the 1,000-acre minimum size for inclusion in the national Monitoring Trends in Burn Severity data set (Eidenshink et al. 2007, p. 10).

The area burned in Western Washington is expected to increase in the coming decades, but there is great uncertainty about the magnitude of the increase, and it is likely to affect some areas more than others. On state and local lands in Washington and Oregon, the percentage of forested area highly suitable for large fires is projected to increase from the current 1 percent up to 12 percent by the late 21st century, though only around half of this increase is projected to occur by the 2060s (Davis et al. 2017, pp. 179-182). At the same time, the percentage of state lands with low suitability for large fire is expected to decrease from the current 82 percent to 67 percent, and this change will progress more quickly, with much of the change occurring by the 2060s. The increase in large fire suitability is expected to affect the Cascades to a greater extent than the Coast Ranges (Davis et al. 2017, pp. 181). In Washington's Western Cascades, the annual burned area is projected to increase 3-fold or more by the 2040s and more than 8-fold by the 2080s, but there is a lot of uncertainty around those figures (Littell et al. 2010, p. 143).

One study has classified all of the murrelet range in Washington as having low vulnerability to fire for the 2020-2050 period, but it appears that the classification is relative to the entire Western US, rather than a measure of absolute vulnerability (Buotte et al. 2018, pp. 5, 8). A different study found that forests west of the Cascade Crest are more vulnerable to fire than other western forests, because they will be sensitive to hotter, drier summers, but will not benefit from increased winter precipitation since soils are already saturated during winter months (Rogers et al. 2011, p. 6). All of these studies are based on the recent period in which fire frequency has been lower than it was prior to European settlement, and since the future projections do not account for the historical fire regime, the projections are more likely to be underestimates than overestimates, especially given that extreme fire weather that could trigger these fires is increasing in frequency (Halofsky et al. 2018a, p. 6; Littell et al. 2010, p. 149).

Two recent studies have modeled future fires based on projected climate and vegetation characteristics, rather than simply using statistical projections based on past rates of wildfire. These studies showed, respectively, a 1.5- to 5-fold increase between the historical period and the 21st century, and a 2- to 4-fold increase between the late 20th century and mid-century (Halofsky et al. 2018b, p. 10; Sheehan et al. 2019, p. 14). In both studies, the lower increases were associated with a model assumption that firefighting would continue to be effective. In one of these studies, the baseline annual percentage of area burned was based on information about pre-European settlement fire rotation in western Washington, and at 0.2 to 0.3 percent of the forest land base burned per year, is an much greater annual area burned than we have observed in the recent past; the late 21st-century annual area burned was expected to reach 0.3 to 1.5 percent of the forest land base per year, with extreme fire years burning 5 to 30 percent of the forest land base (Halofsky et al. 2018b, p. 10). The results of the other study, which also included Western Oregon, estimated an even larger annual percentage of area burned, starting at 0.47 to 0.56 percent per year in the late 20th century and increasing to 1.14 to 1.99 percent by the mid-21st century (Sheehan et al. 2019, p. 14).

9.7.2 Forest Insects, Disease, and Drought Mortality

Insects and disease were the leading natural cause of murrelet habitat loss in Washington between 1993 and 2012 (Raphael et al. 2016, p. 81). Across the non-federal lands of the Olympic Peninsula, Western Lowlands, and Western Cascades, 10,060 acres of forests 80 years old and older, and 4,891 acres of Maxent-modeled high-quality murrelet habitat were lost to insects and disease. The USFS and WDNR have worked together since 1981 to collect and distribute aerial survey data regarding the presence of insects, disease, and other damage agents in Washington's forests (WDNR and USFS 2018). This dataset indicates the identity of various insect and disease problems that have been recorded in the current murrelet habitat: Douglas-fir beetle (*Dendroctonus pseudotsugae*), "dying hemlock," fir engraver (*Scolytus ventralis*), spruce aphid (*Elatobium abietinum*), Swiss needle cast (*Phaeocryptopus gaeumannii*), and western (*Lambdina fiscellaria lugubrosa*) and phantom (*Nepytia phantasmaria*) hemlock loopers.

It is likely that various root diseases have also attacked murrelet habitat, but these are generally classified as bear damage during the aerial surveys (Clark et al. 2018, p. 31). Root diseases that may be present include annosus (*Heterobasidium annosum*), armillaria (*Armillaria ostoyae*), and black stain (*Leptographium wageneri*) root diseases, as well as laminated (*Phellinus weirii*), tomentosus (*Inonotus tomentosus*), and yellow (*Parenniporia subacida*) root rots (Goheen and Willhite 2006, pp. 72-87). Some of these pests, such as Swiss needle cast, are most typically found in younger stands, and are more likely to affect the development of murrelet habitat over the long term; whereas others, such as Douglas-fir beetle, are more likely to attack older trees (Goheen and Willhite 2006, pp. 30, 224).

Drought has not historically been a major factor in western Washington forests, because these forests are not typically water limited (Littell et al. 2010, p. 139). Nonetheless, all of western Washington has been affected by multi-year drought at some point during the 1918-2014 period, varying geographically from areas with occasional mild two-year droughts, to areas with at least one extreme two-year drought, to areas with moderate-severity three-year droughts (Crockett and Westerling 2018, p. 345). In the Pacific Northwest generally, drought is associated with Douglas-fir canopy declines that can be observed via satellite imagery (Bell et al. 2018, pp. 7-10). In Western Washington, Oregon, and Southwestern British Columbia, tree mortality more than doubled (from around 0.5 percent per year to more than 1 percent per year) over the 30-year period between 1975 and 2005, likely due to increasing water stress (van Mantgem et al. 2009, pp. 522-523). Tree mortality may be caused by warm dry conditions in and of themselves (via xylem failure) or when hot, dry conditions compound the effects of insects, disease, and fire.

Some of the insects and pathogens already present in murrelet habitat, such as Douglas-fir beetles, are likely to become more prevalent and cause greater mortality in the future. Douglas-fir trees stressed by heat and drought emit ethanol, which attracts Douglas-fir beetles, and have lowered chemical defenses, which is likely to increase the endemic levels of Douglas-fir infestation and could result in higher probability of epidemic infestation (Agne et al. 2018, p. 326-327). There is more uncertainty with respect to future levels of infection by Swiss needle cast, a disease that that has increased in severity over the past decade (Agne et al. 2018, p. 326). Warm, wet spring weather is thought to provide ideal conditions for Swiss needle cast infection, whereas warm, dry spring weather may inhibit the pathogen. Future spring weather will be warmer, but it is not clear whether it will be wetter, drier, or both (i.e., more variable), or perhaps current precipitation patterns will continue. Swiss needle cast effects to trees appear to be more severe during drought conditions, however. Therefore, the worst-case scenario for Swiss needle cast would be warm, wet springs followed by hot, dry summers. Future climate conditions are also hypothesized to promote other diseases, such as Armillaria root disease, that could affect murrelet habitat (Agne et al. 2018, p. 326).

All climate models project increased summer warming for Western Washington, and most project decreased spring snowpack and summer precipitation, resulting in increasing demand on smaller amounts of soil water in the forest during the growing season. Western Washington forests are expected to experience increasing water deficits over the 21st century (McKenzie and Littell 2017, pp. 33-34). These deficits will not be uniform across the action area, with parts of North Puget, along with eastern Southwest Washington and the northern and especially eastern parts of the Olympic Peninsula, projected to experience much greater hydrological drought, starting sooner than in other places, while there are even projected reductions in water deficit for some other portions of the North Puget area (McKenzie and Littell 2017, p. 31). The projected future warm, dry conditions, sometimes called “hotter drought” or “climate change-type drought” in the scientific literature, are expected to lead to continued increases in tree mortality.

Though projections of future drought mortality in Western Washington are not available, the effects of the recent multi-year drought in California may provide some context about what to expect. Drought conditions in California during 2012 through 2015 led to an order of magnitude increase in tree mortality in Sierra Nevada forests (Young et al. 2017, p. 83). Although wetter regions, such as western Washington, are unlikely to have near-future impacts as severe as those already seen in California, extreme climate conditions that will occur during the next 50 years are likely to further increase drought stress and tree mortality, especially since trees in moist forests are unlikely to be well-adapted to drought stress (Allen et al. 2010, p. 669; Allen et al. 2015, pp. 19-21; Anderegg et al. 2013, p. 705; Crockett and Westerling 2018, p. 342; Prestemon and Kruger 2016, p. 262; Vose et al. 2016, p. 10).

9.7.3 Blowdown

Blowdown is another forest disturbance that has historically caused extensive stand-replacing disturbances in western Washington. The effect of climate change on blowdown frequency, extent, and severity is unknown, and there are reasons to believe that blowdowns may become either more or less frequent or extensive. Hurricane-force winds hit the Washington coast approximately every 20 years during the 20th century (Henderson et al. 1989, p. 20). Blowdown events are often associated with extra-tropical cyclones, which are often associated with atmospheric rivers. Blowdown is influenced by wind speeds and by soil saturation. Destructive windstorms have occurred in the Pacific Northwest in 1780-1788, 1880, 1895, 1921, 1923, 1955, 1961, 1962, 1979, 1981, 1993, 1995, and 2006 (Henderson et al. 1989, p. 20; Mass and Dotson 2010, pp. 2500-2504). During the last century, the events in 1921, 1962, and 2006 were particularly extreme. Although there are some estimates of timber losses from these events, there are no readily available estimates of total murrelet habitat loss from particular events. However, in 2008, a letter from WDNR to the Service reported that following a large windstorm on December 3, 2007, approximately 800 acres of murrelet habitat was blown down within the action area. This included 595 acres within known occupied sites and 205 acres of other murrelet habitat (WDNR 2008, in litt.). Note that this wind damage was not recorded in studies that relied on remotely sensed data (e.g., Davis et al. 2015, pp. 30-31; Raphael et al. 2016, pp. 80-81) because much of the wind-damaged timber was subsequently salvaged and was categorized as being disturbed by harvest rather than wind. In addition to habitat loss from these extreme blowdown events, a smaller amount of habitat is lost each year in "endemic" blowdown events.

Because we did not locate any studies attempting to project murrelet habitat or forest blowdown into the future, we looked to studies regarding the conditions associated with blowdown: wind, rain, and landscape configuration. There are indications that average wind speeds over the Pacific Northwest have declined since 1950, and average wind speeds are projected in most climate models to decline further by the 2080s (Luce et al. 2013, pp. 1361-1362). However, it is not clear how average wind speeds might be related to blowdown, since blowdown events usually happen during extreme wind events. Extreme extra-tropical cyclones are expected to become less frequent in the Northern Hemisphere in general, and perhaps in Washington in particular, but these predictions involve many uncertainties. Different models show local increases in storm frequency in different places (Catto et al. 2011, pp. 5344-5345). Also, how "extreme" events are categorized differs between studies, and the results vary depending on what definition of "extreme" is used (Catto et al. 2001, p. 5348; Ulbrich et al. 2009, p. 127). One recent model projects no change in the extreme ground-level winds most likely to damage nesting habitat, and an increase in the frequency of extreme high-altitude winds (Chang 2018, pp. 6531, 6539). Atmospheric rivers are expected to become wetter and probably more frequent. The frequency of atmospheric river days is expected to increase by 150 to 600 percent over the 21st century (Gao et al. 2015, p. 7185; Warner and Mass 2017, p. 2135), though some models project up to an 18 percent decrease in frequency (Payne and Magnusdottir 2015, p. 11,184). The most extreme precipitation events are expected to be 19 percent wetter (Warner et al. 2015, p. 123). If increased rain causes greater soil saturation, it is easily conceivable that blowdown would become likely at lower wind speeds than would be needed to cause blowdown in less saturated conditions, but we did not find studies addressing this relationship. Since blowdown is more likely at forest edges, increasing or decreasing fragmentation may lead to more or less blowdown for the same wind speed and amount of soil saturation. Thus, the amount of murrelet habitat within the action area likely to be lost to blowdown over the next 30 years is highly uncertain.

9.7.4 Synergistic Effects

Synergistic effects between drought, disease, fire, and/or blowdown are likely to occur to some extent and could become widespread. If large increases in mortality do occur, interactions between these agents are likely to be involved (Halofsky et al. 2018a, pp. 4-5). The large recent increase in tree mortality in the Sierra Nevada has been caused in large part due to these kinds of synergistic interactions. As noted above, western Washington is unlikely to be as severely affected and severe effects are likely to happen later in time here than in other places (where such effects are already occurring). In fact, one study rates nearly all of Washington's forests as having low vulnerability, relative to other western forests, to drought or fire effects by 2049 (Buotte et al. 2018, p. 8). However, many other studies do indicate that there is a risk of one or more of these factors acting to cause the loss of some amount of murrelet habitat over the next 30 years.

9.7.5 Changes in Stand Development

The forest disturbances discussed above will not only affect the amount of existing murrelet habitat, but will also affect the maturation of stands from non-habitat to suitable habitat conditions. For example, the Maple Fire, described above, burned over 100 acres of forest that would otherwise have been expected to mature into suitable habitat over the next 50 years. Approximately 18 acres were burned at high enough severity to kill at least half of the trees in the stand. When stand-replacing (or nearly stand-replacing) disturbances occur in a forested stand that had been expected to develop into suitable habitat, the time until the stand becomes suitable for murrelet nesting is likely to be extended, because the nesting structures and visual cover that were in the process of developing will be largely or entirely destroyed.

Stand development may also be delayed or altered even without a dramatic disturbance event. For example, warm, dry summer weather limits tree growth in many parts of the action area (Chen et al. 2010, pp. 3379-3380; Nakawatase and Peterson 2006, pp. 86-89). As longer, drier summers become more common in the future, reductions in growth rates will increase the time it takes for trees to develop platforms large enough to be suitable for use as nest sites. Young trees of many species, including Douglas-fir, western hemlock, and western red cedar, are particularly sensitive to hot, dry conditions, which will impede re-establishment of these species following disturbances (Dobrowski et al. 2015, p. 925 and Appendix S4). While reduced recruitment of particular species is unlikely to affect the amount of suitable murrelet habitat available over the next 50 years, it will affect the structure and composition of the habitat, as the understory species assemblage is likely to be different from what would have been present historically. Over the long term, shifts in species composition could lead to reductions in the availability of murrelet habitat; if so, these shifts would occur later than the end of the 50-year permit term, but perhaps not much later. Therefore, any effects that extend beyond the permit term (e.g., from the conversion of naturally-regenerated stands to plantations) should be considered in conjunction with the potential for species composition shifts in unmanaged stands.

Increases in tree growth are also a potential consequence of climate change. At some higher elevation areas of western Washington, tree growth is currently limited by growing season length (Nakawatase and Peterson 2006, pp. 84-89). In these high-elevation areas, longer future growing seasons are likely to increase tree growth rates, thereby decreasing the time for a tree to grow a large platform. A model of future tree growth rates across North America projects some areas of increased tree growth in western Washington, especially when the model assumptions included benefits from carbon fertilization (Charney et al. 2016, p. 1125). Carbon fertilization is an effect in which increased CO_2 concentration in the atmosphere sometimes allows plants to use water more efficiently, potentially decreasing a plant's demand for water or increasing growth rates for a fixed amount of water (Allen et al. 2015, pp. 13-15; Charney et al. 2016, p. 1122; Chmura et al. 2011, pp. 1126-1127). In coniferous forests, including Douglas-fir forests in the Pacific Northwest, beneficial carbon fertilization effects are only apparent at a minority of the sites where the subject has been researched, but can be important at a local scale (Allen et al. 2015, p. 15; Camarero et al. 2014, pp. 743-747; Duan et al. 2015, pp. 762-763, Gedalof and Berg 2010, pp. 2-5). However, even where trees are able to grow large platforms faster, the size of a platform alone does not guarantee suitability as a nest site; other elements, such as a moss layer and visual cover around the platform are also important.

9.7.6 Changes in Habitat Features within Stands

Changes in climate are likely to affect habitat features not only at the stand scale, but also at the scale of the individual structures murrelets use for nesting. For example, the mosses that help to make platform structures suitable for use as nest sites are likely to be vulnerable to damage resulting from the longer, drier summers projected for the future (Aubrey et al. 2013, p. 743). Forest disturbances that are not severe enough to be stand-replacing, for example, low-severity fires, will nonetheless affect stand structure and murrelet habitat values. Although the death of a moderate proportion of trees within a stand would not affect the successional stage of the stand, it would likely decrease the total density of existing or developing platform structures within the stand, and would also likely decrease the amount of visual cover surrounding remaining platform structures. In addition, there is at least one recent example of a generally low-severity fire near the action area burning moss off of branches, while leaving many portions of the stand untouched (Ahearn 2015, entire; NPS 2015). This type of fire behavior would likely result in the loss of suitable platforms; even if the branch structure remained intact, it would take many years for the moss covering to develop again.

Climate change could result in some positive effects within stands as well. For example, in western hemlock-dominated stands, "witches' broom" structures suitable for nest platforms often develop on western hemlock trees infected with hemlock dwarf mistletoe (*Arceuthobium tsugense*). Hemlock dwarf mistletoe infection rates increase from north to south between southeastern Alaska and Oregon, and climate change is projected to lead to large increases in hemlock dwarf mistletoe range and infection rates in Alaska over the next five decades (Barrett et al. 2012, pp. 650-653). We do not have projections of future hemlock dwarf mistletoe infection rates in Washington, but it is seems likely that the same effects expected to increase its prevalence in Alaska, such as lengthening growing seasons, will also increase its prevalence within the action area. This in turn could lead to increased density of suitable nest platforms for murrelets within the action area. On the other hand, if climate conditions are unsuitable for moss growth (see above), an increase in witches' brooms that lack moss coverings may not equate to an increase in suitable nest platforms.

9.7.7 Summary of Climate Change

Climate changes affecting the action area, particularly warming air temperatures, drier summers, and changes in winter storms, will lead to a variety of effects to murrelet nesting habitat. We expect the most dramatic effect to be an increase in habitat loss due to increased forest disturbances from fire, insects, tree diseases, drought, and perhaps blowdown, as well as synergistic interactions between these disturbances. Increases in forest disturbances will also affect the developmental trajectory of stands that are currently expected to mature into suitable habitat, potentially delaying habitat ingrowth. Moderate disturbance events that do not result in stand re-initiation are likely to affect the quality of the habitat, for example through reduced availability of suitable nest platforms. Climatic changes are also expected to affect habitat quality in the absence of obvious disturbance events, for example via changes in moss cover or dwarf mistletoe infection rates. Some climate effects to habitat may be beneficial; for example, in some parts of the action area, tree growth rates may increase with longer growing seasons and CO_2 fertilization effects. Overall, however, we expect that climate change will have a net negative effect on the quantity and quality of suitable murrelet nesting habitat within the action area.

9.8 Summary of the Environmental Baseline

WDNR-managed lands comprise approximately 10 percent of the land area within the range of the murrelet in Washington and contain approximately 14 to 15 percent of the available nesting habitat in Washington. WDNR-managed lands provide significant areas of existing habitat and occupied sites in strategic locations, and WDNR-managed lands have a significant role for the conservation of murrelets in the southwest Washington, the OESF/Straits, and North Puget strategic locations. The conservation policies under the 1997 HCP have protected the majority of existing murrelet habitat on WDNR lands. Murrelet habitat has declined on WDNR-managed lands over the past two decades under the Interim Strategy, but these declines are consistent with the effects anticipated under the 1997 HCP and are substantially less than the rate of habitat decline on private forest lands in Washington.

Approximately 32,300 acres of murrelet habitat was harvested on WDNR-managed lands under the Interim Strategy, indicating an average rate of habitat loss of about 1,600 acres per year over the 20 year-period from 1997 to 2017. Monitoring for the *Northwest Forest Plan* program indicated a habitat loss of 14 percent on state lands from 1993 to 2012 (Table 13, above), an average rate of habitat loss of about 0.7 percent per year, compared to an average rate of 2 percent habitat loss per year on private lands. Annual disturbance effects to murrelets have not been summarized for the Interim Strategy but were estimated at up to 23,500 acres per year, representing exposure to about 16 percent of habitat per year.

9.8.1 Murrelet Reproduction, Numbers and Distribution in the Action Area

The murrelet population in Washington is estimated at about 6,000 murrelets and is currently declining at a rate of about -3.9 percent per year, with a higher rate of decline indicated for Zone 1 (-4.9 percent per year). Annual survival rates for murrelets are estimated at 83 to 92 percent, meaning that in any given year, approximately 8 to 17 percent of adult murrelets die. Estimated average productivity in Washington is about 7 percent per year, which is not sufficient to achieve a stable population. Habitat loss, fragmentation, and poor marine foraging conditions are the major factors driving the continued population decline.

Based on the area of habitat, we attribute 15 percent of the murrelet population in Washington to habitat on WDNR lands, and this population is expected to be declining at the same rate as the larger Washington population. Currently about 40 percent of habitat on WDNR-managed lands is classified as interior forest patches, while the remaining habitat is in edge or stringer configurations, indicating a high percentage of the existing habitat is exposed to edge effects, which contribute to poor reproduction in murrelets.

The distribution of habitat in Washington is currently disjunct, with a major gap in distribution of habitat and occupied sites occurring on the southwest Washington coast from roughly the Grays Harbor south to the Columbia River. WDNR has significant land ownership in this region (260,000 acres in the South Coast HCP Unit), but only about 7 percent of this land base currently contains habitat (Table 9, above). However, WDNR-managed lands contain the majority of known occupied sites and habitat remaining in this region of the state. The OESF contains the highest concentration of habitat and occupied sites on WDNR-lands and represents a significant portion of the existing habitat in Zone 2, while WDNR-managed lands in the North Puget strategic location contain significant areas of habitat that are closer to marine waters than federal lands. At the scale of WDNR-managed lands, approximately 15 percent of the land base currently contains habitat. About 78 percent of the current habitat occurs in LTFC provided by existing conservation policies under the HCP.

Natural disturbances have resulted in murrelet habitat loss over the past two decades, but we expect the rate of forest disturbances from fire, insects, tree diseases, drought, and perhaps blowdown, are likely to increase under changing climate conditions. Increases in forest disturbances will also affect the developmental trajectory of stands that are currently expected to mature into suitable habitat, potentially delaying habitat ingrowth. These stressors are additive to stressors in the marine environment, which include significant human impacts from urbanization and development, military operations, net fisheries, and degradation of marine habitat driven by changing climatic conditions, which have resulted in reduced prey availability and quality, affecting both murrelet survival and reproduction in Washington. The impacts of past actions that have resulted in habitat loss, habitat degradation, disturbance impacts, and direct injury to murrelets are reflected in the declining population trend in Washington, where populations have apparently declined by as much as 40 percent over the past 16 years.

10 EFFECTS OF THE ACTION

The effects of the action refers to all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action. A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action (84 FR 45016 [Aug. 27, 2019]).

The following effects analysis is divided into two major parts. In the Part 1, we describe the *Analytical Framework* used to calculate impacts and mitigation for the Long-Term Strategy, and we provide estimates of habitat released for harvest, estimates of habitat degraded by edge effects, expected habitat gains.

In Part II of the Effects Analysis, we describe the anticipated effects to individual murrelets, habitat distribution, and murrelet populations from the proposed Long-Term Strategy.

11 EFFECTS ANALYSIS – Part I: Estimates Of Habitat Change

The analysis of the effects of the proposed Long-Term Strategy is based on an evaluation of the effects to murrelet nesting habitat. A habitat-based approach is a common practice of the USFWS in biological opinions and in the development of HCPs. As described in the *Environmental Baseline*, we use P-stage classification to account for habitat quality and the relative probability of murrelet occupancy. A habitat-based approach to evaluating the effects of the proposed action on murrelets is appropriate due to the difficulty in locating actual murrelet nest sites, the variation in the number of murrelets that actually breed each year, and the patchy distribution of murrelets in nesting habitat. The murrelet was federally-listed as a threatened species in Washington, Oregon, and California primarily due to the loss and fragmentation of nesting habitat, and numerous studies have demonstrated that murrelet numbers are strongly correlated with the amount of available nesting habitat at the scale of local watersheds (Burger 2001, Raphael et al. 2002, Burger et al. 2004). For these reasons, quantifying effects to murrelet nesting habitat is a scientifically credible approach to evaluating the effects of the proposed action on murrelets.

11.1 Raw Acres, Adjusted Acres, and Application of the Analytical Framework

The *Analytical Framework* is a methodology that was agreed upon by WDNR and USFWS to provide an objective, repeatable analysis of habitat impacts and mitigation for murrelets (FEIS 2019, Appendix B). The *Analytical Framework* accounts for habitat quality (P-stage), location, configuration, and future habitat development within areas of long-term forest cover (LTFC) provided by the HCP.

For the analysis of impacts and mitigation, P-stage values are used to provide resource equivalency values for murrelet habitat on WDNR-managed lands. This is necessary, because the impact of harvesting 1,000 acres of low-quality habitat is not equal to the impact of harvesting 1,000 acres of high-quality habitat. Likewise, adjusted acres are used to calculate the area of habitat required to mitigate the impacts of habitat released for harvest. If acres of high-quality habitat released for harvest are to be mitigated by conserving acres of low-quality habitat, the area of habitat conserved for mitigation must have an equivalent value. Adjusted acres provide an index for habitat equivalency. Raw acres are the area of forest with an assigned P-stage classification. Adjusted acres are calculated by multiplying the P-stage value by the number of acres. For example, 1,000 acres of P-stage 0.36 is equivalent to 360 P-stage adjusted acres (1,000 x 0.36 = 360) (Table 16).

Table 16. Example of P-stage raw acres and P-stage adjusted acres.

P-stage category	Raw acres	P-stage adjusted acres
0	1,000	0
0.25	1,000	250
0.36	1,000	360
0.47	1,000	470
0.62	1,000	620
0.89	1,000	890
1	1,000	1,000
Totals	7,000	3,590

Adjusted acres are further discounted to account for habitat configuration, edge effects, and geographic location. The *Analytical Framework* applies a classification of *interior forest, inner edge, outer edge,* and *stringers* to classify areas of mapped long-term forest cover (LTFC) (Figure 6). Detailed explanations for each of these categories, and the methods used to define discounts applied to habitat in LTFC are provided in FEIS Appendices B and H. A brief summary of these categories is provided here:

- *Interior forest*: The interior forest is comprised of forested areas within LTFC that are at least 328 ft (100 m) from any type of edge. These interior forest areas are protected from effects associated with forest edges created by timber harvesting.
- *Inner edge*: The inner edge is a forested area within LTFC that is 167 to 328 ft (51 to 100 m) from the edge of the actively managed forest lands and is adjacent to the interior forest patch.
- *Outer edge*: The outer edge of the interior forest patch within LTFC that is located between 0 and 164 ft (0 to 50 m) from the edge of the actively managed forest. Because this area is immediately adjacent to the actively managed forest, edge effects are more pronounced in the outer edge.
- *Stringers*: Stringers are narrow areas of LTFC (less than 656 ft [200 m wide) that are predominately comprised of riparian management zones. These areas can provide limited nesting opportunities for murrelet when they are surrounded by security forest or nesting habitat. Security forest is defined as closed-canopy second-growth forest over 80-ft tall that is located adjacent to nesting habitat. Security forest is not nesting habitat, but it provides security to adjacent nesting habitat from windthrow, predation, and other

disturbances (FEIS 2019, p. 2-8). Stringers comprise a major component of the LTFC on WDNR-managed lands. However, because they lack interior forest, if they are used for nesting, those nests are unlikely to be successful. Therefore, habitat within stringers is not assigned mitigation value for purposes of calculating impacts and mitigation (FEIS 2019, Appendix H).

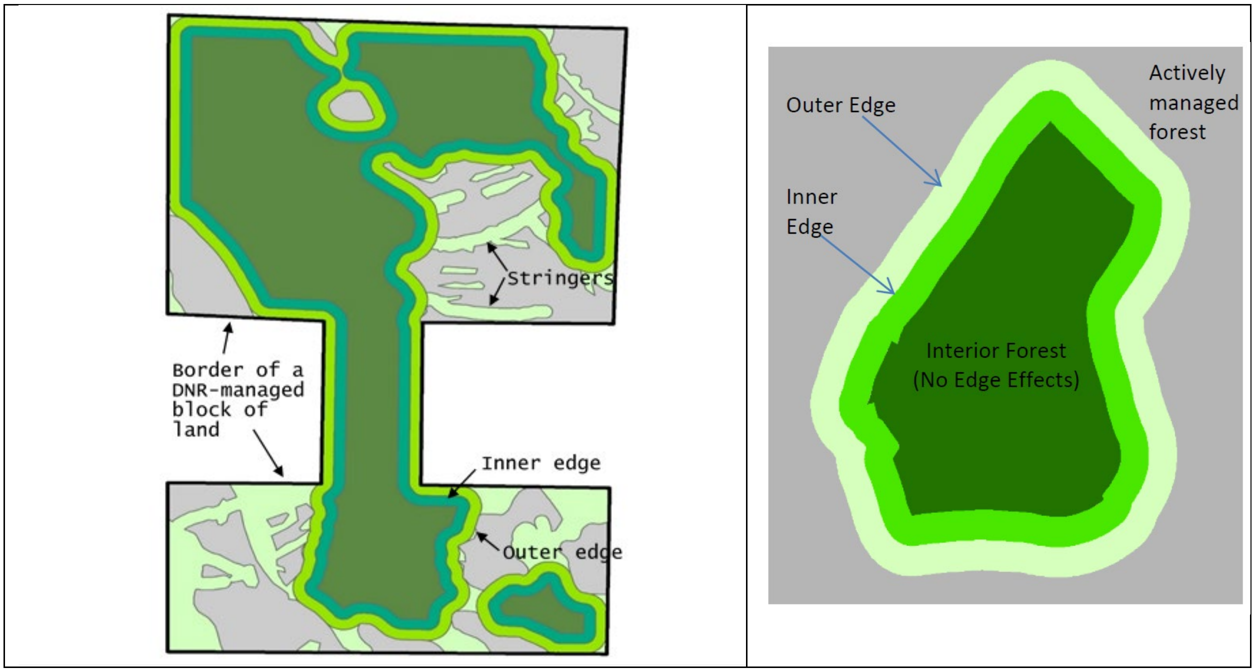

Figure 6. Illustration of edge and interior forest zones in long-term forest cover mapping.
Sources: FEIS 2019, Chapter 2, p. 2-72; FEIS Appendix G, p. G-5.

11.1.1 Edge Conditions and Application of Edge Discounts

Timber harvesting can create a high contrast edge along the boundary between the harvested area and the adjacent forested stand. Timber harvest edges can influence adjacent murrelet habitat in two ways: through increased risk of nest predation from corvids and habitat degradation resulting from windthrow and microclimate changes. Forest edge effects diminish over time, as harvested areas regenerate and develop into mature forest stands. To account for different edge conditions, we applied three categories, hard, soft, and none (FEIS 2019, pp. H-3 to H-9):

- *Hard edges* are created when the managed forest adjacent to LTFC is 0-20 years old, with young trees that are 0 to 40-ft. tall. Habitat in LTFC located adjacent to hard edges has the highest level of habitat degradation from windthrow, microclimate effects, and predation risk.

- *Soft edges* are areas where the managed forest adjacent to LTFC is 20-40 years old, with trees that are 40 to 80 ft. In these areas, the managed forest has generally achieved a dense, closed-canopy condition. These areas still have degraded habitat condition (e.g., reduced platforms) but do not have increased predation risk.
- *No edge*: When adjacent managed forest lands are greater than 80 ft in height, they are assumed to have no discernable edge effects.

Edge conditions are not static over time; they change as forests regenerate or are harvested in areas outside of designated LTFC. The relative percentage of forest in each edge condition (hard, soft, or no edge) on a decadal basis is expected to be similar throughout the life of the HCP because WDNR will continue a regular pattern of sustainable harvest in areas designated as general management lands, while areas of LTFC will largely be left unmanaged to develop naturally.

The percentage of LTFC in each edge condition, and the discount factors applied to account for edge effects is summarized in Table 17 (*outer edges*) and Table 18 (*inner edges*).

Example of Edge Discounts:

(P-stage 0.36) x (1,000 raw acres) = 360 P-stage adjusted acres
Outer Edge discount factor = 0.27 (Table 17)
(360 P-stage adjusted acres) x *Outer Edge* discount (73 percent) = 263 adjusted acres.
Final adjusted acres = 73 percent of P-stage adjusted acres in *Outer Edges*

(P-stage 0.36) x (1,000 raw acres) = 360 P-stage adjusted acres
Inner edge discount factor = 0.13 (Table 18)
(360 adjusted acres) x *Inner Edge* discount (87 percent) = 313 adjusted acres.
Final adjusted acres = 73 percent of P-stage adjusted acres in *Inner Edges*

A portion of the existing P-stage habitat released for harvest under the proposed HCP amendment is also comprised of small, remnant patches of habitat ("slivers") that are degraded by edge effects. A similar process of discounting P-stage habitat in these habitat slivers outside of LTFC was applied to the final adjusted "take" acres (FEIS 2019, p. O-4).

11.1.2 Marginal Landscape Discount

The marginal landscape is located primarily in the Puget Trough lowlands where there are no known occupied sites, and existing murrelet habitat is highly fragmented. WDNR lands in the marginal landscape include over 224,000 acres, but less than 4,000 acres of P-stage habitat (< 2 percent). Extensive surveys for murrelets were completed by WDNR in this area under the Interim Strategy, and no murrelet occupied sites were ever documented. Because habitat in the marginal landscape is limited and there are no occupied sites located on WDNR lands or adjacent ownerships, the marginal landscape area is considered to have a low probability of occupancy by murrelets currently, or in the future. To account for this, an additional discount of 75 percent is applied to all P-stage adjusted acres in the marginal landscape (adjusted acres x 0.25) (FEIS 2019, pp. H-18 – H-19).

Example:

(P-stage 0.36) x (1,000 raw acres) = 360 P-stage adjusted acres
(360 P-stage adjusted acres) x marginal landscape discount (0.25) = 90 adjusted acres.
Final adjusted acres = 25 percent of P-stage adjusted acres

Table 17. Edge condition, and discounts applied to P-stage adjusted acres in *Outer Edges.*

Forest Inventory Data-Derived Edge Condition[a]			**Discount Multiplier**		**Outer Edge Factor**
Hard	18.2%	x	.83 [b]	=	.15
Soft	29.3%	x	.40 [c]	=	.12
No-Edge	52.5%	x	0 [d]	=	0
			Sum	=	**.27**

[a] Percentages are the same as those applied to the proposed HCP amendment (FEIS 2019 Alternative H).

[b] van Rooyen, et al. (2011) found that platform tree density at hard edges is 25% of the density found in interior forests. McShane et al. (2004) summarized from different sources that nests at hard edges are 69% as successful as nests in interior forests. When combined (.25 x .69 = .17), an 83% discount results for this edge condition.

[c] Microclimate conditions in soft, outer edges result in only 60% of the platform density relative to interior forests (van Rooyen et al. 2012). Therefore, a 40% discount is applied.

[d] No edge discounts are assumed.

Source: FEIS 2019, Appendix H.

Table 18. Edge condition, and discounts applied to P-stage adjusted acres in *Inner Edges.*

Forest Inventory Data-Derived Edge Conditions			**Discount Multiplier**		**Inner Edge Factor**
Hard	18.2%	x	.415[a]	=	.08
Soft	29.3%	x	.20[b]	=	.06
No-Edge	52.5%	x	0 [c]	=	0
			Sum	=	**.135**

[a] 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).

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

[c] No edge discounts are assumed.

Source: FEIS 2019, Appendix H.

11.1.3 Road Edge Discount

Forest roads create edges that can alter the way corvid species such as crows, ravens, and jays use forest habitat, resulting in increased predation risk in murrelet habitat located adjacent to forest roads. To account for this effect, WDNR estimated the amount of habitat in LTFC that is located within 50 m (164 ft) of WDNR roads = 4.85 percent. This percentage is assumed to remain the same throughout the life of the HCP. A 15.5 percent discount is applied to P-stage adjusted acres to account for road edge effects (road-side acres x 0.845) (FEIS 2019, pp. H-23 – H-24). This discount is applied in LTFC and to habitat outside of LTFC released for harvest.

Example:

(P-stage 0.36) x (1,000 raw acres) = 360 P-stage adjusted acres
360 adjusted acres x (4.85 %) = 17.5 acres degraded by road edge
(17.5 adjusted acres) x (0.845 % road edge discount) = 14.7 adjusted acres
The reduction in adjusted acres to account for road edge is 17.5 – 14.7 = 2.8 acres
360 p-stage adjusted acres - 2.8 acres = 357 adjusted acres
Final adjusted acres = 99 percent of P-stage adjusted acres.

11.1.4 LTFC Stringers

Stringers are narrow areas of LTFC with no interior forest. These areas have neutral value in the *Analytical Framework* because they will remain forested and can function as marginal nesting habitat when they are surrounded by other habitat or security forest, but are assumed to have no value as nesting habitat when they are surrounded by recently harvested areas or young forest plantations. Therefore, raw acres of P-stage habitat in LTFC stringers have zero value as adjusted acres in the *Analytical Framework* (FEIS 2019, p. 2-71).

11.1.5 Decadal Discounts

A decadal discount is applied in the *Analytical Framework* for the purposes of calculating the mitigation value of habitat that develops in future decades (FEIS 2019, p. H-17). Mitigation is provided by the ingrowth of new habitat within LTFC (e.g., forest that currently is P-stage 0 transitions to P-stage 0.25), or; existing habitat conserved in LTFC increases in quality over time (e.g., P-stage 0.25 transitions to P-stage 0.36, or higher).

The decadal adjustment factor is based on how much habitat develops in a decade, as well as which decade that habitat is realized. For example, the 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 adjusted acres are counted. However, the total habitat that develops between the first and second decades receive only 80 percent 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 percent credit (three out of five decades of growth), and so forth through to the end of the 1997 HCP (Table 19).

Table 19. Example of how habitat that develops in future decades is discounted for mitigation credit.

Decade	Habitat (adjusted acres)	Difference in adjusted acres of between decades	Decade adjustment factor	Acres of mitigation credit
0	1,000			
1	2,000	1,000	1.00	1,000
2	3,000	1,000	0.80	800
3	4,000	1,000	0.60	600
4	5,000	1,000	0.40	400
5	6,000	1,000	0.20	200
	Total increase in adjusted acres:	**5,000**	**Total acres of mitigation credit:**	**3,000**

Note: Numbers presented here are illustration purposes only. Source: FEIS 2019, Appendix H.

11.1.6 Mitigation Acres

Mitigation credit is applied to adjusted acres of habitat that are conserved in LTFC, excluding habitat in LTFC *stringers*. Adjusted acres of habitat conserved in *interior forest*, *inner edg*e, and *outer edge* LTFC provide mitigation, and it is the increase in adjusted acres conserved in LTFC from one decade to the next that contribute to mitigation (Table 19, above). Habitat in occupied sites (P-stage 1) and habitat classified as P-stage 0.89 do not contribute to mitigation because these acres do not increase in quality from one decade to the next under the *Analytical Framework*. The protection of occupied sites and P-stage 0.89 habitat is considered a significant minimization measure. Increases in adjusted acres of habitat protected in occupied site buffers do contribute to mitigation.

11.1.7 Summary of Raw Acres and Adjusted Acres

Applying the adjustments to raw P-stage emphasizes the value of habitat conserved in interior forest patches, reduces the value of habitat in edges, and discounts habitat in stringers. The effects analysis is based on both raw acres of P-stage and adjusted acres. Raw P-stage acres provide an index of the total area of habitat on the landscape now, and in the future. Adjusted acres provide an index of habitat quality, and time-adjusted acres apply an appropriate decadal discount to habitat that develops in future decades. High-quality habitat and occupied sites weight the adjusted acres appropriately, reflecting the relative value of each of the landscape areas to support murrelets (Table 20).

Table 20. Summary comparison of P-stage raw acres and adjusted acres by landscape (current conditions).

Landscape Area	P-stage Habitat (raw acres)	Percent of raw acres	P-stage adjusted acres	Edge, road, and landscape adjusted acres	Percent of adjusted acres
Southwest Washington	26,332	13%	13,836	11,662	11%
OESF and Straits west Elwha River	74,801	36%	54,551	50,353	49%
North Puget	60,161	29%	32,552	26,299	26%
Other high-value landscapes	41,830	20%	17,121	13,695	13%
Marginal Landscape	3,943	2%	1,141	182	0.2%
Totals	**207,067**	**100%**	**119,200**	**102,192**	**100%**

Notes: Final adjusted acres depicted here applies road, edge, stringer, and landscape discounts to existing habitat, and is based on the estimated LTFC for the proposed Long-Term Strategy. Includes 11,085 adjusted acres of habitat outside of LTFC that will be released for harvest.

11.2 Raw Acres and Adjusted Acres of Habitat Released for Harvest

Existing murrelet habitat that is not located within occupied sites and occupied site buffers, SHAs, and other areas of LTFC will be released for harvest. Although this habitat will be available for harvest, it is not known if it will be harvested. Some areas of habitat may be conserved under other policies (e.g., protection of old-growth stands). With the exception of covered activities located within occupied sites and buffers, habitat released for harvest will not be seasonally-restricted to avoid harvest during the murrelet nesting season. The amount of habitat that will be released for harvest is estimated at 38,774 raw acres which represents about 19 percent of the existing raw acres of P-stage habitat. Most of the habitat released for harvest (86 percent) is comprised of low-quality P-stage acres (0.25 and 0.36) (Table 21).

With the application of P-stage adjustments, the total acres released for harvest equal 11,085 adjusted acres, which represents about 11 percent of the total baseline of adjusted habitat acres that exist today (Table 22). At the scale of HCP planning units, over half (54 percent) of the total adjusted acres released for harvest are in the North Puget and South Puget HCP planning units (Table 23). The adjusted acres released for harvest is the basis for which mitigation acres are measured against.

Table 21. Summary of P-stage habitat (raw acres) released for harvest by landscape area.

P-stage	Southwest Washington	OESF and Straits west Elwha River	North Puget	Other high-value landscapes	Marginal landscape	Totals
0.25	4,210	4,068	9,409	7,709	1,525	26,921
0.36	1,189	2,471	1,637	1,424	52	6,773
0.47	118	679	478	704	1	1,981
0.62	66	478	819	418	99	1,880
0.89	0	111	904	204	0	1,219
Total acres released for harvest	5,584	7,806	13,248	10,459	1,677	38,774
Total raw acres in landscape (baseline)	26,332	74,801	60,161	41,830	3,943	207,066
Percent of raw acres released for harvest	21%	10%	22%	25%	43%	19%

Source: WDNR Amendment take and mitigation calculator_20190917.

Table 22. Summary of adjusted habitat acres released for harvest by landscape area.

	Southwest Washington	OESF and Straits west Elwha River	North Puget	Other high-value landscapes	Marginal landscape	Totals
Total adjusted acres in landscape (baseline):	11,662	50,353	26,299	13,695	182	102,191
Adjusted acres released for harvest	1,488	2,405	4,079	3,008	105	11,085
Percent of adjusted acres released for harvest	13%	5%	16%	22%	58%	11%

Source: WDNR Amendment take and mitigation calculator_20190917.

Table 23. Summary of raw acres and adjusted acres released for harvest in HCP planning units.

HCP planning unit:	Columbia	South Coast	OESF	Straits	North Puget	South Puget	Yakima	Totals
Raw habitat acres released for harvest	4,088	3,782	6,662	4,009	14,769	5,314	150	38,774
P-stage-weighted acres released for harvest	1,161	1,110	2,326	1,104	4,886	1,640	122	12,349
Adjusted acres released for harvest	1,040	841	2,128	1,030	4,457	1,469	120	11,085
Percent of adjusted acres released for harvest	9%	8%	19%	9%	40%	13%	1%	100%

Source: WDNR Amendment_take_sum_pvt_09232019

11.2.1 Rate of Harvest and Metering

Habitat located outside of LTFC will be harvested over the 48 years that remain in the initial 70-year term of the HCP. In order to evaluate a reasonable worst-case scenario, this analysis assumes that all habitat released will be harvested in the first two decades following implementation of the Long-Term Strategy. Under the proposed HCP amendment, WDNR will delay harvest of (meter) 5,000 adjusted acres (approximately 15,000 raw acres) of murrelet habitat. The objective of metering is to achieve "not net loss" of adjusted acres of habitat at the scale of all WDNR-managed lands within the range of the murrelet. With metering, approximately 6,085 acres will be harvested during the first decade of implementation, or about 608 adjusted acres per year. Approximately 5,000 adjusted acres will be harvested in the second decade of implementation. These metered acres will become available for harvest at the beginning of the second decade, and we assume the rate of harvest will be about 500 adjusted acres per year. This equates to an average harvest rate of about one percent per year of adjusted habitat acres over 20 years. This harvest rate does not account for habitat gains that may occur in LTFC over the same period.

11.2.2 New Roads and Yarding Corridors in Occupied Sites and Buffers

The proposed HCP amendment estimates 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). The location of these acres is unknown at this time.

Yarding corridors are assumed to be 20 ft wide, and trees within the yarding corridor will be harvested. A yarding corridor 1,000 ft long x 20 ft wide = 20,000 ft^2 or 0.45 acres. These result in narrow strips of openings that reduce canopy cover, remove platform trees, and reduce habitat capacity at the scale of the affected patch.

Roads are assumed to have a 60-ft prism width: 1,000 ft of road x 60 ft wide = 60,000 ft^2 or 1.37 acres. Roads remove platform trees and result in a canopy gap through the forest, with minor, but permanent edge effects while they are maintained as open roads.

We assume that adjusted acres removed for roads and yarding corridors will be distributed across the remaining term of the HCP at rate of about 23 adjusted acres per decade.

11.2.3 Summary of Adjusted Acres Released for Harvest

Total adjusted acres released for harvest is 11,085 acres located outside of LTFC, and 114 acres within occupied sites and buffers for a total of 11,199 acres of adjusted acres of habitat removed.

11.3 Estimated Habitat Gains in Long-Term Forest Cover

Total acres of raw habitat on WDNR-lands is projected to increase to over 272,000 acres by the end of the HCP. Much of the existing low-quality habitat acres is projected to transition to higher P-stage classes, resulting in a projected increase in total high-quality habitat acres over the term of the HCP (Table 24). Currently, about 50 percent of raw habitat acres are classified as high-quality habitat. At the end of the HCP, about 65 percent of raw habitat acres are projected to be high-quality habitat.

Table 24. Summary of estimated habitat (raw acres) by the final decade of the HCP.

	Southwest Washington	**OESF/Straits west of Elwha River**	**North Puget**	**Other Landscapes**	**Marginal Landscape**	**Totals**
Baseline (raw acres)	26,332	74,801	60,161	41,830	3,943	207,067
Final decade **low-quality** habitat	11,069	4,196	21,621	37,249	21,258	95,394 (35 %)
Final decade **high-quality** habitat	25,214	70,743	50,443	28,518	2,528	177,446 (65 %)
Final decade **total habitat** (raw acres)	**36,283**	**74,939**	**72,064**	**65,767**	**23,786**	**272,840**
Net gain in raw acres	+9,951	+138	+11,903	+23,937	+19,843	+65,773

Note: Low-quality habitat = P-stage (0.25, 0.36), high-quality habitat = P-stage (0.47, 0.62, 0.89, 1)

The adoption of the proposed Long-Term Strategy will result in the designation of SHAs and occupied site buffers, which results in a shift in both land area and existing habitat located within LTFC. For example, existing habitat that is classified as *interior forest* is estimated at 82,861 raw acres. This classification is based on the configuration of habitat as it exists today, regardless of whether it is located within areas of LTFC. The analysis of habitat losses and gains under the proposed Long-Term Strategy is based on the estimated configuration of LTFC created by the Long-Term Strategy. By overlaying the map of LTFC for the proposed amendment, the amount of habitat classified as *interior forest* automatically shifts from the current baseline of 82,861 acres to 99,137 raw acres (Table 25), which is not a representation of existing habitat conditions, but rather a reflection of how areas of mapped LTFC overlay the existing habitat.

Table 25. Comparison of habitat configuration of current P-stage habitat under the proposed Long-Term Strategy and baseline conditions.

Existing habitat configuration (raw acres)					
Current condition	**Interior Forest**	**Inner Edge**	**Outer Edge**	**Stringer**	**Totals**
Acres	82,861	40,531	46,702	36,973	207,066
Percent	40 %	20 %	23 %	18 %	100 %

Habitat configuration based on the estimated LTFC for the proposed Long-Term Strategy (raw acres)						
Current condition	**Interior Forest**	**Inner Edge**	**Outer Edge**	**Stringers**	**Not LTFC**	**Totals**
Acres	99,167	18,403	18,579	32,193	38,755	207,066
Percent	48%	9%	9%	16%	19%	100%

Sources: FEIS 2019, p. 3-34, WDNR ldo_summary_mm_area_mm_amend_20190628

Under the proposed Long-Term Strategy, areas mapped as *interior forest* within an SHA or an occupied site buffer can contain a mix of conditions, in some cases there may by recently-harvested stands inter-mixed with occupied sites or other habitat, but the estimate of raw habitat acres within the mapped LTFC zones is accurate. In other words, the 99,137 raw acres of habitat located within mapped *interior forest* under the proposed Long-Term Strategy is habitat that exists today, but some of this habitat may be degraded by edge effects from past harvest. Existing hard edges will soften and disappear as forests within SHAs, occupied site buffers, and other areas of LTFC mature. By the final decade of the HCP, we expect that the configuration of habitat on the landscape will reflect the areas of LTFC established by the Long-Term Strategy.

11.3.1 Estimated Mitigation

In the following analyses, we use the overlay of estimated LTFC for the proposed Long-Term Strategy as the basis for calculating habitat gains and mitigation under the *Analytical Framework*. As described above, the *Analytical Framework* assumes that the amount of percentage of habitat that is degraded by roads and edges remains approximately the same, so as habitat increases over time, the amount of habitat degraded by roads or edge conditions also increases, because the discounts applied to adjusted acres reflect a percentage of the habitat area within LTFC.

Total raw habitat acres are projected to increase in LTFC by over 104,000 acres over the next 5 decades (Table 26). The projected increases result from forested areas that are currently classified as P-stage 0 transitioning to P-stage 0.25 habitat or higher. The raw acres of habitat released for harvest (38,774 acres) outside of LTFC will be replaced by an estimated gain of 41,372 raw acres of new habitat that develops in *interior forest*, *inner edge*, and *outer edge*. Most habitat gains will occur in areas classified as LTFC *stringers* (63,155 acres), which are not counted as mitigation acres, but habitat in conserved in LTFC stringers contribute to the total area of habitat conserved on the landscape.

Table 26. Projected increases in habitat (raw acres) conserved in long-term forest cover.

Decade 0	**Interior Forest**	**Inner Edge**	**Outer Edge**	**Stringer**	**Totals**
North Puget	22,547	6,041	6,294	12,043	46,924
OESF/Straits	49,086	6,068	5,561	6,281	66,996
Other	15,433	4,430	4,744	6,766	31,373
SWWA	11,606	1,620	1,692	5,833	20,751
Marginal	465	245	288	1,270	2,268
Current totals (raw acres)	**99,137**	**18,403**	**18,579**	**32,193**	**168,311**
Decade 5	**Interior Forest**	**Inner Edge**	**Outer Edge**	**Stringer**	**Totals**
North Puget	26,879	8,854	9,649	26,683	72,064
OESF/Straits	50,995	7,070	6,733	10,141	74,939
Other	23,953	8,724	9,836	23,253	65,767
SWWA	13,508	2,526	2,918	17,330	36,283
Marginal	1,621	1,816	2,409	17,940	23,786
Final decade Totals	**116,956**	**28,990**	**31,545**	**95,348**	**272,839**
Habitat gains (raw acres)	**+17,820**	**+10,587**	**+12,966**	**+63,155**	**+104,527**

Note: Values provided here are based on the estimated configuration of LTFC for the proposed Long-Term Strategy. Source: WDNR ldo_summary_mm_area_mm_amend_20190628

Existing habitat that is conserved by the proposed Long-Term Strategy is also projected to increase in habitat quality over the term of the HCP. The combination of existing habitat transitioning to higher P-stage classes within LTFC, as well as the recruitment of new habitat acres within LTFC contribute to a total projected increase of 20,389 adjusted habitat acres conserved in *interior forest*, *inner edge*, and *outer edge* zones of LTFC (Table 27).

Table 27. Projected increases in habitat (adjusted acres) conserved in long-term forest cover.

Decade 0	Interior Forest	Inner Edge	Outer Edge	Totals
North Puget	16,169	3,262	2,790	22,220
OESF/Straits west of Elwha River	42,569	3,051	2,328	47,948
Other high value areas	7,453	1,705	1,530	10,688
Southwest Washington	8,739	782	653	10,174
Marginal landscape	43	17	16	76
Current Totals (adjusted acres)	**74,973**	**8,816**	**7,317**	**91,106**
Decade 5	**Interior Forest**	**Inner Edge**	**Outer Edge**	**Totals**
North Puget	18,893	4,539	4,043	27,474
OESF/Straits	45,515	4,117	3,241	52,874
Other	11,373	3,331	3,110	17,815
SWWA	10,530	1,277	1,163	12,970
Marginal	127	111	123	362
Final decade totals	**86,439**	**13,376**	**11,680**	**111,495**
Habitat gains (adjusted acres)	**+11,466**	**+4,560**	**+4,363**	**+20,389**

Note: Adjusted acres presented here include road, edge, and landscape discounts, but do not include decadal discounts. Based on the estimated configuration of LTFC for the proposed Long-Term Strategy. Source: WDNR Amend_take_mit_calculator_2019_09_17.

As described above, the *Analytical Framework* used to calculate mitigation acres applies a decadal discount to the net increase in adjusted acres that accrue from one decade to the next. By applying the decadal discount to the adjusted acres added in LTFC (20,389 adjusted acres), the adjusted acres are further discounted to a final estimate of 11,095 mitigation acres for the proposed Long-Term Strategy (Table 28).

Table 28. Summary of decadal increases in adjusted habitat acres and final mitigation acres by strategic landscapes.

Decade	North Puget	OESF/Straits west of Elwha River	Other high-value areas	Southwest Washington	Marginal landscape	WDNR totals	Net increase adjusted acres	Decadal discount applied	Final mitigation adjusted acres
0	22,220	47,948	10,688	10,174	76	91,106	-	-	-
1	23,423	49,337	11,821	10,862	86	95,530	+4,423	100%	4,423
2	24,154	50,215	12,878	11,290	112	98,649	+3,119	80%	2,495
3	25,093	51,186	14,050	11,766	154	102,250	+3,601	60%	2,161
4	26,414	52,048	16,065	12,374	234	107,134	+4,884	40%	1,954
5	27,474	52,874	17,815	12,970	362	111,495	+4,361	20%	872
Total gains in adjusted acres:							**+20,388**	**-**	**+11,905**

Note: Decade 0 represents the current baseline in LTFC, and does not include adjusted acres of habitat released for harvest. Source: WDNR Amend_take_mit_calculator_2019_09_17

The proposed Long-Term Strategy is projected to increase both the total raw acres of habitat conserved in LTFC across all landscapes, as well as the total adjusted acres of habitat. However, in the North Puget strategic location, the total estimated increase in habitat acres conserved in LTFC (5,245 adjusted acres) is further discounted to 3,091 time-adjusted acres, resulting in a mitigation deficit at the scale of the North Puget strategic location (Table 29). All other landscape areas are projected to have net gains in mitigation acres. When the total adjusted acres released for harvest and future road/yarding impacts (11,119 acres) are compared with the final mitigation acres (11,905 acres), there is a net positive of balance of +706 time-adjusted mitigation acres for the anticipated habitat-related impacts (harvest, roads, edges) over the remaining term of the HCP (Table 29).

11.3.2 Summary of Habitat Gains and Mitigation

The preceding analysis demonstrates the complexity of the *Analytical Framework* used to evaluate habitat gains and losses in the Long-Term Strategy. In summary, there is approximately 207,067 acres of raw habitat on WDNR lands currently. Of these, 38,774 raw acres will be released for harvest, while the remaining 168,293 raw acres of habitat will be conserved in LTFC under the proposed Long-Term Strategy. There is also a projected increase of 104,527 raw acres of "new" habitat that develops in LTFC over the term of the HCP. The total raw habitat acres are projected to increase to 272,839 acres by the final decade, increasing the total habitat area on WDNR lands from about 15 percent to 20 percent, with a significant increase in the amount of habitat conserved in *interior forest* (82,861 raw acres currently, with a projected increase to 116,956 raw acres, an increase of 141 percent).

Table 29. Summary of adjusted acres released for harvest and final estimated mitigation acres by landscape area.

Landscape	Habitat released for harvest (adjusted acres)	Mitigation (time-adjusted acres)	Difference (*epsilon*)
North Puget	4,079	3,091	-987
OESF and Straits west of Elwha River	2,405	3,184	+779
Other high value areas	3,008	3,838	+831
Southwest Washington	1,488	1,678	+191
Marginal landscape	105	114	+7
Subtotals	**11,085**	**11,905**	**+820**
Habitat acres released for roads/yarding corridors in occupied sites/buffers	114	-	-
Totals	**11,199**	**11,905**	**+706**

Source: WDNR Amend_take_mit_calculator_2019_09_17

There are currently 102,192 adjusted acres of habitat on WDNR lands, including 11,085 acres that will be released for harvest, and 91,106 acres that will be conserved in *interior forest*, *inner edges*, and *outer edges*. Adjusted acres are projected to increase to 111,495 adjusted acres, a net gain of 20,389 adjusted acres. Comparing adjusted acres released (11,085 acres) with habitat gains (20,389 acres), there is a net positive balance of 9,304 adjusted acres (a ratio of 1.8 adjusted acres added for 1 adjusted acre of habitat removed). When the decadal discounts are applied to the adjusted acres, the estimated mitigation for the proposed Long-Term Strategy is 11,905 time-adjusted acres, a net positive balance of 820 time-adjusted acres. Subtracting the additional 114 adjusted acres released for roads and yarding corridors in occupied sites and buffers, we get a final balance of 11,199 acres of habitat released measured against 11,905 time-adjusted mitigation acres, for a net positive balance of 706 time-adjusted mitigation acres.

11.4 Estimated Habitat Loss from Natural Disturbance and Climate Change

The Long-Term Strategy is intended to mitigate against the spectrum of uncertainties surrounding murrelet habitat conservation on WDNR-managed HCP lands (WDNR 2019, p. 22). These uncertainties include the potential effects of natural disturbances. Habitat loss from natural disturbance is not considered a form of Incidental Take and is not an impact that results from otherwise covered activities under the HCP. However, habitat loss due to natural disturbance can erode the amount of habitat conserved in LTFC to provide mitigation for covered activities on WDNR-managed lands. WDNR developed an estimate of future habitat loss due to natural disturbance, with the objective of providing additional mitigation acres in recognition that some habitat conserved in LTFC is likely to be lost or degraded by natural disturbance events.

Wildfires, windthrow, landslides, floods, insects and diseases are all forms of natural disturbances that can result in the loss or degradation of forest habitat, including murrelet nesting habitat. Raphael and others (2016, p. 81) reported 11,116 acres of "higher quality habitat" was lost to natural disturbances across all ownerships in Washington, including federal reserves over a 20-year period (1993 to 2012). This represents a cumulative 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 disturbances (wildfire, windthrow, insects, and disease).

The *Analytical Framework* accounts for some habitat loss associated with windthrow in *inner edge* and *outer edge* LTFC. In developing the proposed Long-Term Strategy, WDNR recognized that habitat losses from natural disturbance are likely to continue in the future, and that climate change is likely to increase the rate of natural disturbance over the next 50 years. Based on the information in Section 3.2 of the FEIS, WDNR estimated that the rate of habitat loss from natural disturbance will likely double by the end of the 50-year analysis period due to the influence of climate change. The amount of mitigation currently estimated under the proposed HCP Amendment for all five decades is 11,905 adjusted acres. Assuming the natural disturbance rate reported by Raphael et al. (2016, p. 81) doubles over the term of the HCP, the total mitigation is reduced to 11,510 acres, a reduction of 395 time-adjusted mitigation acres (Table 30).

Table 30. Calculation of time and natural disturbance adjusted mitigation acres, including an adjustment for increased rates of future disturbance due to climate change.

Decade	Estimated habitat gains (adjusted acres)	Decadal discount	Time-adjusted mitigation acres	Estimated natural disturbance rate	Natural disturbance multiplier to account for increased disturbance in future	Adjusted disturbance loss rate	Combined decadal and disturbance loss adjustment	Decade and natural disturbance adjusted mitigation acres
1	4,423	1.00	4,423	0.36%	1.2	0.43%	0.9957	4,404
2	3,119	0.80	2,495	0.72%	1.4	1.00%	0.7900	2,464
3	3,601	0.60	2,161	1.08%	1.6	1.72%	0.5828	2,099
4	4,884	0.40	1,954	1.44%	1.8	2.58%	0.3742	1,828
5	4,361	0.20	872	1.79%	2.0	3.59%	0.1641	716
Totals	**20,388**	**-**	**11,905**	**-**	**-**	**-**	**-**	**11,510**

Source: WDNR 2019, Appendix C, Attachment C-5, Table 2.

As describe above, the estimated mitigation (11,905 time-adjusted acres), compared to total adjusted acres released for harvest, roads, and yarding corridors (11,199 adjusted acres) yields a net positive balance of +706 time-adjusted mitigation acres. Using WDNR's assumptions regarding future natural disturbance rates, the mitigation acres are reduced to 11,510 time-adjusted acres, which still yields a net positive balance of +311 time-adjusted acres.

How climate change will influence natural disturbance rates in the future is unknown, but the past rates of disturbance may not be good predictors of future changes. We (USFWS) examined the scientific literature for information regarding historical and projected future rates of natural disturbance in murrelet habitat. We separately examined blowdown, wildfire, and a combination of insect, disease, and drought mortality. For each type of disturbance, we constructed low-disturbance and high-disturbance scenarios consistent with the scientific literature (USFWS 2019d).

We corrected for habitat value (p-stage, edges and stringers, marginal landscapes) and timing to approximate the mitigation calculation in the *Analytical Framework*. For each scenario, we added together the habitat losses from the three disturbance types. In the low disturbance scenario, we estimated that 5,648 raw acres, equivalent to 1,011 P-stage and time-adjusted mitigation acres could be lost to natural disturbance. In the high disturbance scenario, we estimated that 22,896 raw acres, equivalent to 3,434 P-stage and time-adjusted mitigation acres could be lost (USFWS 2019d, p. 15) (Table 31). If future natural disturbance rates occur as estimated in our low-disturbance scenario or worse, the mitigation acres provided by the proposed Long-Term Strategy will not compensate for additional habitat losses from natural disturbance.

Table 31. Combined estimates of future habitat losses from wildfire, blowdown, insects, and diseases (time-adjusted mitigation acres) under low disturbance and high disturbance scenarios.

Low disturbance scenario					**High disturbance scenario**			
Decade	**Estimated mitigation**	**Estimated loss from natural disturbance**	**Disturbance -adjusted mitigation**		**Decade**	**Estimated mitigation**	**Estimated loss from natural disturbance**	**Disturbance -adjusted mitigation**
1	4,423	302	4,121		1	4,423	784	3,639
2	2,495	251	2,244		2	2,495	792	1,703
3	2,161	284	1,877		3	2,161	889	1,272
4	1,954	121	1,833		4	1,954	622	1,332
5	872	53	819		5	872	347	525
Totals	**11,905**	**-1,011**	**10,894**		**Totals**	**11,905**	**-3,434**	**8,471**

Sources: USFWS 2019d, p. 15; WDNR 2019, Appendix C, Attachment C-5, Table 2.

In the *Northwest Forest Plan* 20-year monitoring report, insects and disease accounted for the majority (58 percent) of murrelet habitat losses attributed to natural disturbance (Raphael et al. 2016, p. 81). This finding is unusual in the context of western Washington, where insect and disease damage is generally characterized as patchy in nature, resulting in small canopy gaps or pockets of dead and dying trees, rather than entire stand-replacing events which are commonly observed in the eastern Cascades and other parts of the interior Pacific Northwest. This result may be influenced by two factors: 1) rates of habitat loss attributed to blowdown are underestimated in the assessment because areas that blowdown are often salvaged and the loss is attributed to timber harvest (Davis et al. 2015, p. 98); and, 2), the disturbance maps were produced at a minimum scale of 2.5 acres, so relatively small patches of reduced forest canopy cover can be classified as habitat loss (Davis et al. 2015, p. 98). Small-scale patches of disturbance can degrade habitat without resulting in stand-replacing disturbance. For example, if a mapped 100-acre stand of P-stage habitat has small scattered patches of tree mortality associated with root-disease, this patch is still likely to function as habitat, even though there has been some loss of functional habitat within the stand.

In our natural disturbance scenario assessments, insects, disease, and drought are the primary stressors driving natural disturbance, accounting for 72 percent and 82 percent of the estimated future habitat losses under the low disturbance and high disturbance scenarios, respectively (USFWS 2019d, p. 15). If we exclude insect, disease, and drought from our estimates of future disturbance, the estimated rate of future habitat loss is much reduced. In the low disturbance scenario, we estimated that 1,247 raw acres, equivalent to 218 P-stage and time-adjusted mitigation acres could be lost to wildfire and blowdown. In the high disturbance scenario, we estimated that 3,816 raw acres, equivalent to 603 P-stage and time-adjusted mitigation acres could be lost (Table 32) (USFWS 2019d, p. 15).

Table 32. Combined estimates of future habitat losses from wildfire and blowdown only (time-adjusted mitigation acres).

Low disturbance scenario					**High disturbance scenario**			
Decade	**Estimated mitigation**	**Estimated loss from natural disturbance**	**Disturbance -adjusted mitigation**		**Decade**	**Estimated mitigation**	**Estimated loss from natural disturbance**	**Disturbance -adjusted mitigation**
1	4,423	38	4,385		1	4,423	212	4,211
2	2,495	33	2,462		2	2,495	82	2,413
3	2,161	120	2,041		3	2,161	179	1,982
4	1,954	18	1,936		4	1,954	68	1,886
5	872	9	863		5	872	61	811
Totals	**11,905**	**-218**	**11,687**		**Totals**	**11,905**	**-603**	**11,303**

Sources: USFWS 2019d, p. 15; WDNR 2019, Appendix C, Attachment C-5, Table 2.

The proposed Long-Term Strategy includes additional mitigation acres above the level of an exact 1:1 ratio of take and mitigation as measured through the *Analytical Framework*. This extra mitigation to account for uncertainty has been referred to as *epsilon*. WDNR recognized the need to include additional mitigation acres to account for some uncertainty associated with the rate of future habitat loss due to natural disturbance (WDNR 2019, pp. 22-23). Based on WDNR's analysis, the estimated mitigation that will be provided by the Long-Term Strategy (11,905 acres) exceeds the estimated habitat impacts (11,199 acres) by +706 time-adjusted mitigation acres. This level of additional mitigation accounts for the estimated habitat losses due to natural disturbance (-395 time-adjusted acres).

In our independent analysis, we found evidence in the scientific literature to suggest that the rates of future habitat loss, particularly due to insects, diseases, and drought, could occur at much higher rates than those estimated by WDNR. However, there is a high level of uncertainty about how tree mortality from these stressors will manifest on the landscape in western Washington. If we exclude these stressors (insects, disease, drought), from our estimates of natural disturbance, the future disturbance rates are comparable to those estimated by WDNR. The additional mitigation provided by the proposed Long-Term Strategy accounts for uncertainty associated with future natural disturbances. Whether this level of additional mitigation is enough to account for the influence of climate change is uncertain, since the actual effects of future natural disturbance will be unknown until after they have already occurred. The combined elements of the proposed Long-Term Strategy ensure that murrelet conservation on HCP-covered lands has inherent resiliency to natural disturbance by including conservation in different geographic regions of the western Washington, that are representative of the range of ecological conditions that support murrelet nesting habitat. These conservation elements include establishment of SHAs in strategic locations, protection of all occupied sites, including additional mitigation acres to address uncertainty, and metering the harvest of 5,000 adjusted acres to the second decade to maintain habitat capacity in the near term.

11.5 Accounting for Habitat Fragmentation and Edge Effects

Forest management under the proposed Long-Term Strategy will result in fragmentation and edge effects in areas released for harvest and will also result in the reduction of past habitat fragmentation effects in the SHAs and occupied sites. Habitat degraded by edge effects is accounted for in the *Analytical Framework* in the calculation of adjusted acres presented in preceding sections. The science used to inform our assessment of fragmentation and edge effects, and discount habitat degraded by edge effects is detailed in the FEIS 2019, Appendix H.

11.5.1 Criteria Used to Evaluate Fragmentation and Edge Effects

Key measures used to evaluate habitat fragmentation and edge effects include the amount of habitat in *interior forest*, *inner edge*, *outer edge*, habitat within proximity to occupied sites, and habitat patch size.

11.5.1.1 Interior Forest Patches

Habitat patches in *interior forest* are projected to increase from approximately 82,861 raw acres (current condition) to an estimated 116,956 raw acres in the final decade of the HCP (Table 33). Increasing habitat in *interior forest* patches is expected to improve overall murrelet nesting success on WDNR lands by reducing habitat area degraded by edge effects. Due to the configuration of LTFC, habitat patches classified as *interior forest* are generally not degraded by edge effects except where roads pass through *interior forest.*

Table 33. Summary of murrelet habitat in *interior forest* patches, and habitat degraded by roads.

Decade:	1	2	3	4	5
Raw habitat in *interior forest* LTFC:	104,212	105,879	108,018	113,079	116,956
P-stage adjusted acres in *interior forest* LTFC:	78,295	80,212	82,214	84,903	87,312
Adjusted acres in *interior forest* LTFC (applies discounts for road edge):	77,512	79,410	81,392	84,054	86,439
Adjusted acres in interior forest degraded by road edge (1 %):	**-783**	**-802**	**-822**	**-849**	**-873**

Source: WDNR Amend_take_mit_calculator_2019_09_17

The adjusted acres in *interior forest* degraded by road edge do not count towards mitigation and are accounted for in the *Analytical Framework*. The *Analytical Framework* applies a minor discount (about 1 percent) to account for habitat degraded by road edges in *interior forest*. The preceding analysis quantifies the habitat acres of *interior forest* that are degraded by roads resulting in habitat that is removed (discounted) from the total habitat acres that otherwise would provide mitigation under the proposed Long-Term Strategy.

11.5.1.2 Edge Effects

Edge effects are accounted for in the *Analytical Framework*. The calculation of adjusted acres and time-adjusted mitigation acres discounts the mitigation value of habitat degraded by edge conditions, and completely discounts habitat in LTFC *stringers*. In this analysis, we use the estimate of the average amount of habitat located in *inner edge* and *outer edge* LTFC that is in hard, soft, and no-edge condition to calculate the amount of habitat degraded by edge effects. These areas (*inner edge* and *outer edge*) are representative of the estimated average edge conditions in occupied site buffers, SHAs, and other areas of LTFC that are large enough to create a patch of *interior forest* habitat (Table 34).

Table 34. Summary of edge condition of habitat in *inner edge* and *outer edge* (combined) LTFC by decade (raw acres).

Decade:	1	2	3	4	5
Hard edge: (18.2%)	7,745	8,001	8,543	9,952	11,018
Soft edge: (29.3 %)	12,468	12,880	13,753	16,021	17,737
No edge: (52.5 %)	22,341	23,079	24,642	28,707	31,782
Decade totals	**42,553**	**43,959**	**46,938**	**54,681**	**60,537**

Source: WDNR Amend_take_mit_calculator_2019_09_17

The combined edge discounts that are applied to *inner edge* and *outer edge* LTFC in the *Analytical Framework* result in an average of about 21 percent of the habitat in *inner edge* and *outer edge* LTFC degraded per decade (Table 35). The ratio of 21 percent habitat degraded is based on the combined edge condition and edge discounts (including road edges) applied to habitat located in *inner edge* and *outer edge* LTFC (FEIS 2019, Appendix H, pp. H-3 to H-9).

Table 35. Summary of habitat degraded by edge effects in *inner edge* and *outer edge* LTFC.

Decade:	1	2	3	4	5
Raw habitat in *inner edge* and *outer edge* LTFC (raw acres):	42,553	43,959	46,938	54,681	60,537
P-stage adjusted acres in *inner edge* and *outer edge* LTFC	22,724	24,270	26,323	29,145	31,654
Adjusted acres in *inner edge* and *outer edge* LTFC based on discounts for edge condition and roads	18,018	19,239	20,858	23,081	25,057
Adjusted acres degraded by edge effects (21 %)	**-4,706**	**-5,031**	**-5,465**	**-6,064**	**-6,597**

Source: WDNR Amend_take_mit_calculator_2019_09_17

The adjusted acres degraded by edge effects do not count towards mitigation and are accounted for in the *Analytical Framework*. The preceding analysis quantifies the habitat acres that are degraded by edge effects resulting in habitat that is removed (discounted) from the total habitat acres that otherwise would provide mitigation under the proposed Long-Term Strategy.

11.5.1.3 Edge Effects to Habitat on Adjacent Federal Lands

Timber harvest on WDNR-managed lands can result in edge effects to murrelet habitat on adjacent ownerships, primarily federal lands. To estimate the area of federal lands located adjacent to WDNR-managed lands, we used GIS to apply a 328-ft wide buffer around the perimeter of WDNR lands. This yielded an estimate of 21,353 acres of federal land located within 328 ft. of WDNR-managed lands (primarily National Forests and National Parks). We then refined this analysis to estimate the area of federal lands adjacent to WDNR-managed lands that will be available for harvest (non-LTFC) (14,479 acres). Using the Maxent model to identify potential murrelet habitat on federal lands, we estimate there are approximately 4,500 raw acres of existing murrelet habitat that have the potential to be degraded by edge effects. If we assume all of these areas will be affected over the next two decades, we get an average of about 225 raw acres degraded by edge effects per year on adjacent federal lands.

We are not seeking additional mitigation for indirect impacts to habitat on federal lands, because WDNR has assumed that all boundaries of their ownership are edges, and the edge discounts that are applied to habitat conserved in LTFC are applied along all boundaries of LTFC, regardless of whether the adjacent ownership is federal or private. This results in additional acres discounted for edge effects where SHAs or other areas of LTFC that will not be managed is adjacent to federal lands (e.g. Olympic National Park). Given the discounts that are applied to LTFC *inner* and *outer* edges (about a 21 percent reduction in mitigation value) we consider the habitat discounts applied in the *Analytical Framework* to be conservative. Based on this, we consider the habitat effects of WDNR management to adjacent federal lands to be within the scope of the habitat discounts applied to *inner edge* and *outer edge* LTFC in the *Analytical Framework*.

11.5.1.4 Edge Effects to Habitat on Adjacent Non-federal Lands

Habitat on non-federal lands is not protected from timber harvest except where there are identified occupied sites or other conservation easements in place. All currently documented non-federal occupied sites that border WDNR lands are included in the occupied site buffers included in the proposed HCP amendment, so we do not anticipate edge effects to habitat on adjacent non-federal lands. Edge effects from private forest management adjacent to WDNR-managed lands are accounted for as well, because all outer boundaries of WDNR-managed lands are mapped as *outer edge* and *inner edge* in the *Analytical Framework*.

11.5.1.5 Proximity to Occupied Sites

We used two measures to evaluate habitat conserved in proximity to occupied sites: 0.5-miles and 3.1-miles. Meyers and others (2002) found that murrelets are less likely to occupy habitat if it is isolated (greater than 3.1 miles [five km]) from other occupied sites. Habitat within 0.5-miles of occupied sites is also an important indicator, because these areas are considered to have a higher likelihood of occupancy relative to habitat located further from occupied sites.

Under the Interim Strategy, habitat located with 0.5 miles of occupied sites is conserved, whereas under the proposed Long-Term Strategy, only habitat that occurs within occupied site buffers, SHAs and other areas of LTFC is conserved, which will result in a release of some habitat acres that have been conserved under the Long-Term Strategy, and protection of other existing habitat that is not conserved by Interim Strategy. Habitat is projected to increase over time at both scales (0.5-miles and 3.1 miles) (Table 36).

Table 36. Summary of habitat located in LTFC within 0.5-mile and 3.1-miles of occupied sites under the proposed Long-Term Strategy.

	Habitat within 0.5-mile of occupied sites (raw acres)	**Habitat within 3.1-miles of occupied sites (raw acres)**
Decade 0	82,000	130,000
Decade 5	94,000	176,000
Projected increase in habitat: (raw acres)	115%	135%

Source: FEIS 2019, p. 4-54

11.5.1.6 Habitat Patch Size

Habitat patch size is projected to increase. The designation of occupied site buffers and SHAs under the proposed Long-Term Strategy will result in a substantial increase in the habitat patches greater than 1,000 acres in size, as well as an increase in the number of habitat patches five acres or larger will increase, as will the total area of habitat in these patches (Table 37). More habitat patches and more area in large habitat patches will benefit murrelets by providing more potential nesting sites in interior forest and reducing edge effects compared to current conditions (Figure 7).

Table 37. Summary of expected increases in habitat patch size compared to current conditions.

	Number of patches 5 acres or larger in size	Sum of habitat in patches 5 acres or larger in size (raw acres)	Number of patches 1,000 acres or larger in size	Sum of habitat in patches 1,000 acres or larger in size (raw acres)
Current condition:	1,500	170,000	20	46,000
Decade 5:	1,803	177,000	29	70,000

Source: FEIS 2019, p. 3-37; p. 4-55.

11.6 Habitat Capacity to Support Murrelet Nesting

Applying an average density index of murrelet habitat capacity, we estimated there are currently 217 nesting pairs associated with habitat on WDNR lands, or 471 adjusted acres per nesting pair. If we apply this average density to the final decade habitat (111,495 adjusted acres), the proposed Long-Term Strategy will provide capacity to support 237 nesting pairs, an increase of 109 percent over current habitat capacity (Table 38). This habitat capacity is based on the *Analytical Framework*, which excludes habitat in stringers, and applies a P-stage value of 1 to all occupied sites, so there is no increase in habitat capacity within the occupied sites in this analysis. As described later in the *Population Viability Analysis* section, increases in habitat quality within occupied sites may lead to greater increases in habitat capacity than what is depicted here.

As demonstrated in the estimate of adjusted acres presented in Table 38, metering harvest of adjusted acres over two decades maintains habitat capacity on the landscape over the first three decades of the HCP. Based on the simple index of average density, the habitat acres released for harvest (11,805 adjusted acres) will displace approximately 23 nesting pairs, while the habitat acres added (20,839 adjusted acres) will provide habitat capacity to support 44 nesting pairs, a net positive gain in habitat capacity to support 21 additional nesting pairs above the habitat acres released for harvest.

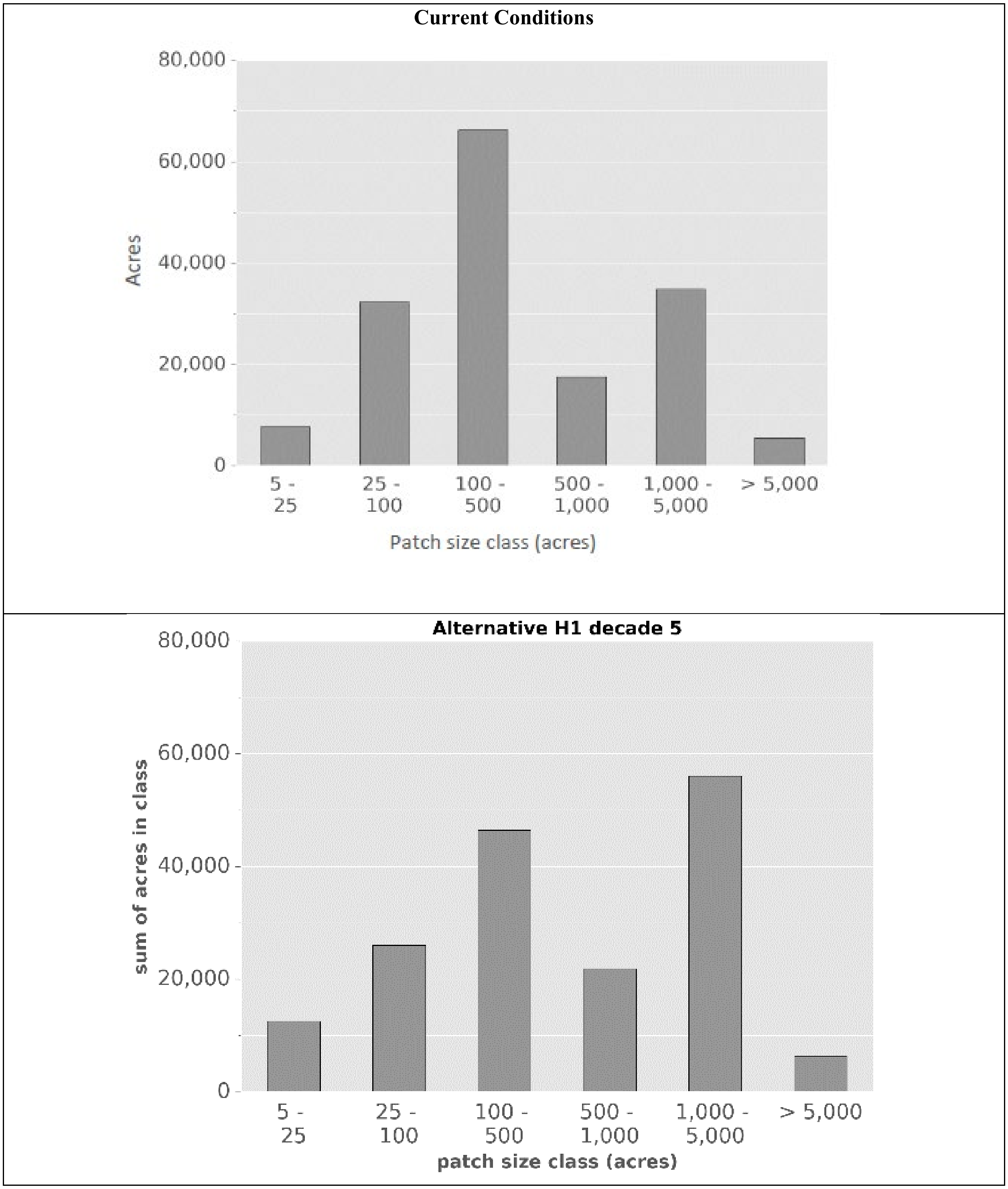

Figure 7. Habitat patch size – current conditions and expected future conditions.
Source: FEIS 2019, p. 3-38; p. 4-56.

Table 38. Summary of estimated habitat capacity (adjusted acres) on WDNR-managed lands.

	Current Condition	Decade 1	Decade 2	Decade 3	Decade 4	Decade 5	Percent Increase
Habitat (adjusted acres)	102,192	101,615	103,649	102,250	107,134	111,495	109%
Habitat capacity (nesting pairs)	217	216	220	217	227	237	109%

Note: Adjusted acres in this table do not apply the decadal discounts used in the *Analytical Framework*.

If we use raw habitat acres to calculate average density, the estimated total murrelets associated with the HCP-covered lands is 1,084 murrelets (15 percent of the total Washington population), for an average density of 191 raw acres per murrelet (207,066 raw acres / 1,084 murrelets = 191 acres per murrelet). If we apply this average density to the estimated future habitat acres (272,839 raw acres / 191 acres per murrelet), the projected future habitat capacity will support 1,428 murrelets, or an increase of 132 percent over current habitat capacity as measured by raw habitat acres.

The total number of murrelets associated with habitat on WDNR lands is unknown. The density index used here is intended to provide a basis for the comparison of habitat gains and losses, and to provide context for interpreting the relative impacts of habitat changes (both positive and negative) to murrelets from the proposed Long-Term Strategy. The effects of habitat changes to murrelets will be discussed in more detail below in the *Population Viability Analysis* section.

11.7 Estimates of Commercial Thinning in Occupied Site Buffers and SHAs

WDNR may implement selective commercial thinning in occupied site buffers and within selected SHAs. Thinning and related silviculture will be allowed only in forests that are not classified as P-stage habitat (non-habitat) and must follow a specific management objective to enhance or maintain security forest with a windfirm canopy within the occupied site buffers. Stands available for thinning include young forest that is not classified as security forest (e.g., with trees that are less than 80 ft tall), and security forest stands (closed-canopy second-growth forest with trees greater than 80 ft tall) (FEIS 2019, p. 2-8). Security forest protects adjacent stands of nesting habitat from windthrow and edge effects, and supports lower densities of nest predators, particularly in landscapes near residences or campgrounds (Marzluff et al. 2000, p. 1137). Security forest can be a component of the forest in an occupied site buffer and/or a component of the forest types within an SHA. Security forest in SHAs is expected to increase the success of reproduction in suitable habitat within SHAs. Thinning typically requires temporary roads, gaps for landings, or creates openings that are attractive to predators, which can reduce the function of security forest in thinned areas.

11.7.1 Commercial Thinning in Occupied Site Buffers

The occupied sites comprise 59,330 acres. Each occupied site has a 328-ft wide buffer designated around the occupied site. The total area in the occupied site buffers is 32,777 acres (WDNR 2019, Table A-3). Forest buffers are intended to protect occupied sites from habitat loss and degradation associated with edge effects; buffers increase the area of interior forest habitat within occupied sites, and the buffers minimize exposure to temporary noise/visual disturbance from timber harvest activities that may otherwise occur during the murrelet nesting season. We expect some windthrow damage will occur within occupied site buffers. The buffer is designated to absorb the impacts of windthrow that would otherwise occur in occupied sites, and to provide security forest function adjacent to the occupied habitat. Not all areas within occupied site buffers currently provide security forest.

WDNR has identified approximately 27,300 acres of young forest stands within the buffers around occupied site. Some of these stands could be classified as security forest, while other stands are less than 80-ft tall and are not considered security forest. We do not have specific estimates of the current condition in the occupied site buffers. Not all of the area within the occupied site buffers is available for thinning. Thinning will only be allowed in in the outer 164-ft of the buffer in non-murrelet habitat, and must follow a specific management objective to enhance or maintain security forest with a windfirm canopy by thinning from below, maintaining a minimum relative density (RD) of 35, with no gap creation, and must follow daily limited operating periods if carried out during the nesting season (WDNR 2019, Table A-4). Gaps are defined as canopy openings 0.25 acres or larger (WDNR 2006, p. 24).

By limiting thinning to the outer 164 ft of occupied site buffers, the potential area available for thinning is reduced by roughly half. In total, of the 27,300 acres of non-habitat within occupied site buffers, approximately 12,300 acres (45 percent) will be available for thinning over the term of the HCP (Table 39).

Table 39. Summary of young forest (non-murrelet habitat) acres within occupied site buffers available for potential thinning treatments.

Location	Acres of young forest within occupied site buffers	Acres available for potential thinning treatments
Non-habitat in occupied site buffers located outside of SHAs:	22,559	11,280
Non-habitat in occupied site buffers located within SHAs in spotted owl management units:	2,124	1,062
Non-habitat in occupied site buffers within SHAs that are outside of spotted owl management units:	2,616	0
Totals:	27,299	12,342

Note. The acres available for potential thinning represent an estimate for the purpose of this analysis. Source: WDNR *Estimates for occupied site buffer thinning in and outside of NSO management areas 20190221*.

11.7.2 Commercial Thinning in Special Habitat Areas

The 1997 HCP identifies spotted owl management units with landscape objectives to achieve a targeted percentage of spotted owl nesting, roosting, foraging, or dispersal habitat. Consistent with the objectives identified in the HCP, WDNR commonly uses variable density commercial thinning treatments (restoration thinning) in young forest stands to enhance the development of spotted owl habitat. Where SHAs have been designated within spotted owl management areas, WDNR will maintain the option to implement restoration thinning treatments consistent with the achieving spotted owl habitat objectives. The same minimization measures for management within occupied site buffers apply within the SHAs. Thinning is limited to non-habitat areas only, and limited to the outer 164-ft of occupied site buffers within the SHAs. Of the 20 SHAs proposed for the Long-Term Strategy, there are 7 SHAs within spotted owl management areas, and a total of 6,947 acres of non-habitat that will be available for thinning over the term of the HCP (Table 40).

Table 40. Summary of non-murrelet habitat acres within Special Habitat Areas (SHAs) available for potential thinning treatments.

Landscape	**SHA Name**	**Total acres in SHA**	**Acres of non-habitat available for potential thinning treatments**	**Percent of SHA with potential thinning treatments**
OESF	Clallam East	1,898	687	36%
OESF	Clallam West	412	120	29%
OESF	Queets	7,549	3,145	42%
OESF	Reade Hill	3,238	660	20%
North Puget	Lake Shannon East	1,130	302	27%
North Puget	Middle Fork	2,486	1,267	51%
North Puget	Pilchuck River	1,861	766	41%
	Totals	**18,574**	**6,947**	**37%**

Source: WDNR 2019, Table A-6.

The remaining 13 SHAs located outside of spotted owl management area (28,351 acres) will have no proposed thinning treatments. This includes all SHAs in southwest Washington, the Straits, and portions of the North Puget landscapes. The USFWS recognized the potential benefits of restoration thinning treatments to accelerate the future development of murrelet habitat in the *Marbled Murrelet Recovery Plan*, with the recommendation that unthinned buffers should be left around any occupied stands (USFWS 1997, pp. 143-144). Thinning in occupied site buffers and SHAs will effect murrelets by reducing the function of security forest adjacent to stands of suitable habitat, and by causing audio/visual disturbance to murrelets (discussed below) where treatments are implemented during the nesting season.

11.7.3 Assessment of the Effects of Thinning

Thinning treatments that reduce overstory canopy cover increase sunlight to the forest floor and stimulate the growth of understory shrubs that are attractive to corvids. We do not expect that thinning treatments will increase predation risk to the same extent that a clearcut edge will, but we recognize that there is a potential for a short-term increase in predation risk along old-forest edges where adjacent thinning treatments reduce canopy cover to less than 60 percent. Where stands are thinned, there is potential for a shift in habitat use by resident corvids in the thinned stands and along roads constructed to implement thinning treatments. Canopy cover in thinned stands is expected to increase at a rate of about 1 to 2 percent per year (Chan et al. 2006, p. 2696), so any increased predation risk associated with proposed thinning should diminish over a period of approximately 10 to 15 years after thinning.

We use a distance of 328 ft (50 m) to account for habitat degradation and increased predation risk along the boundaries of thinning units. 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 recent clearcuts and along roads (Masselink 2001, p. ii, Malt and Lank 2009, pp. 1283-1284). While Steller's jays will use a variety of forest seral stages, in landscapes that have recent clearcuts, they spend most of their foraging time within 55 yards on either side of abrupt forest edges (Masselink 2001, p. ii, Vigallon and Marzluff 2005, p. 36.).

At local landscape scale, patches of security forest bordering nesting habitat reduces predation risk. Marzluff et al. (2000, p. 1137) suggest that old-growth stands used by murrelets for nesting might be best buffered by surrounding the stands with maturing, simple-structured forests in which there are relatively few predators, particularly in areas near human settlements. This is the basis for conserving a mix of existing habitat and security forest within the SHAs. There has been no direct research that documents the effects of adjacent thinning treatments on murrelet nest success or habitat selection (Raphael et al. 2018, p.,333). We infer that thinning that reduces overstory canopy cover and increases understory development will result in increased predation risk along the edge of thinning unit boundaries based on our understanding of corvid foraging behavior and habitat use in the Pacific Northwest.

11.7.3.1 Conclusions Regarding Thinning Effects

Thinning in occupied site buffers will be limited to the outer edge (164-ft) of the buffers, so we do not anticipate significant habitat degradation or increased predation risk to habitat within the occupied sites from adjacent thinning, because the *inner edge* of the buffer (164 ft) will remain unthinned and protect habitat within the occupied sites from minor habitat degradation associated with thinning. The same rules apply to occupied site buffers within the SHAs in owl management areas. Thinning within the *outer edge* of the occupied site buffers, if done during the nesting season, will result in audio/visual disturbance effects to murrelets (discussed below).

No buffers will be applied for thinning adjacent to other P-stage habitat (outside of occupied site buffers) in the SHAs in owl management areas, so minor habitat degradation and increased predation risk, as well as audio/visual disturbance will occur along the edges of thinning units within SHA. We assume that the effect of the thinning to adjacent habitat is similar to the soft edge discount applied to *inner edges* (6 percent reduction in adjusted acres) described in the *Analytical Framework* (Tables 18, above). Based on the total area of 6,947 acres of non-habitat potentially available for thinning in SHAs (Table 40, above), we expect the amount of habitat degraded by adjacent thinning treatments within SHAs will be a fraction of these acres (e.g., about 6 percent).

We have presented the above information in this section of the Opinion to describe the anticipated effects of thinning in occupied site buffers and SHAs in owl management areas. The assessment of impacts (take) for the Long-Term Strategy is based on estimates of habitat removed, habitat degraded by edge effects, and habitat exposed to audio/visual disturbance at the scale of all WDNR-lands on a decadal basis, which include the effects of thinning in the occupied site buffers and SHAs in owl management areas. In other words, the effects of thinning to murrelets (e.g., reduced nesting success caused by audio/visual disturbance or predation) are not accounted for separately from the combined effects of all covered activities described in the *Effects to Murrelets* section.

12 EFFECTS ANALYSIS – Part II: Effect To Murrelets

Implementation of the Long-Term Strategy will result in negative effects to murrelets from covered activities, such as timber harvesting and road construction in specific areas of habitat released for harvest. The Long-Term Strategy will also result in beneficial effects by protecting specific areas of habitat and increasing total habitat area and capacity on WDNR-managed lands in areas conserved as LTFC.

Timber harvesting and road construction can result in both direct and indirect effects to murrelets. These effects can include the direct loss and fragmentation of nesting habitat, increased risk of nest predation near clearcut edges, habitat degradation associated with clearcut edges, disruption of nesting behaviors associated with audio and visual disturbance, and the potential for direct injury or mortality of murrelet eggs or chicks (USFWS 1997, p. 100-101).

12.1.1 Background Information – Effects of Habitat Removal to Murrelets

Habitat removal during the murrelet nesting season is likely to result in direct mortality of murrelet eggs or nestlings and has the potential to result in direct mortality of breeding adults. Nelson (1997, p. 20) notes that at least 5 adult murrelets have been found dead or stunned after trees were felled in British Columbia and Alaska. While it is possible that adults could be killed during tree felling, we are not reasonably certain that such an outcome is likely to occur. We assume that most adult murrelets on a nest branch (either incubating or delivering prey) will flush and be able to escape direct injury during tree felling. However, eggs and/or nestlings, if present, are reasonably certain to be killed as a result of tree felling during the nesting season.

Loss of nesting habitat reduces nest site availability and, as a result, displaces adult murrelets that have nesting fidelity to the logged area (Raphael et al. 2002, p. 232). Murrelets have demonstrated fidelity to nesting stands, and in some instances, fidelity to individual nest trees (Burger et al. 2009, p. 217; McShane et al. 2004, p. 2-14). Murrelets returning to recently logged areas may not breed for several years or until they have found suitable nesting habitat elsewhere (Raphael et al. 2002, p. 232). The effects of displacement due to habitat loss include nest site abandonment, delayed breeding, failure to initiate breeding in subsequent years, and failed breeding due to increased predation risk at a marginal nesting location (Divoky and Horton 1995, p. 83; Raphael et al. 2002, p. 232). Each of these outcomes reduces the nesting success for individual breeding pairs, and ultimately results in the reduced recruitment of juvenile birds into the local population (Raphael et al. 2002, pp. 231-233).

Research in Oregon (Meyer et al. 2002, p. 110) and in British Columbia (Zharikov et al. 2006, p. 117) indicates that murrelets do not immediately abandon fragmented or degraded habitats. Murrelets are likely to maintain fidelity to their nesting sites as long as the local area retains some suitable nesting structures and the birds are able to successfully nest at the site (Divoky and Horton 1995, pp. 83-84). Murrelet nesting has been documented in remnant habitat patches ranging from 10 ha (24 acres) (Zharikov et al. 2006, p. 113) down to < 2 ha (< 5 acres) in size (Nelson and Wilson 2002, p. 104). However, murrelet populations eventually decline in fragmented habitats, most likely as a consequence of increased predation at nest sites along clearcut edges (McShane et al. 2004, p. 4-108; Meyer et al. 2002, p. 110; Raphael et al. 2002, p. 232).

We do not expect a reduction in adult survival due to displacement from habitat loss, but we do expect that affected murrelets may continue to visit areas from which they were displaced due to their high site fidelity. Raphael et al. (2002, p. 232) speculated that where displaced murrelets crowd into adjacent habitat patches, that nesting density in remaining habitat eventually declines to pre-harvest levels over the longer-term, resulting in local population decline.

Based on the above information, we assume that direct habitat removal results in nest failure (mortality of eggs/or chicks) and effectively removes displaced adults from the breeding population for at least one year. Adults displaced by habitat removal are expected to survive the immediate effects of displacement (i.e., they abandon their nesting effort and become nonbreeding adults for at least one year). Adults displaced by the loss of nesting habitat may rejoin the breeding population in subsequent years, but this outcome is uncertain. No research has ever documented the response of individual murrelets displaced by habitat removal. There is evidence that breeding dispersal in murrelets does occur. Hall and others (2009, p. 5080) documented that 6 percent of the murrelet population in central California is comprised of migrants that had dispersed to central California from northern populations. The composition of the central California murrelet population appears to be a mixture of three categories of individuals: residents, migrants that have recruited into the resident breeding population, and temporary migrants from the northern populations. At least some migrant murrelets attempt to breed in central California, because telemetry data for a single radio-tagged migrant indicated that the bird attempted to nest in central California, but was unsuccessful (Hall et al. 2009, p. 5083). The researchers in this study speculated that the annual increase in the proportion of migrants in central California may have been due to ongoing loss of nesting habitat in the northern areas that caused murrelets to disperse and prospect for new breeding sites (Hall et al. 2009, p. 5083).

Monitoring of murrelet populations in British Columbia also indicate large-scale inter-annual shifts in murrelet distribution, suggesting that in years when food resources are poor in one region, murrelets will migrate to other regions along the British Columbia coast (Bertram et al. 2015, p. 15-16). The authors of this study noted that in 2005, 68 percent fewer murrelets were detected entering watersheds on West Vancouver Island compared to 2004. During these same years, murrelets detected entering watersheds in the Haida Gwaii region were 14 percent higher in 2005 compared to 2004, with an average increase of 65 percent more murrelets detected entering watersheds on the west coast of Haida Gwaii compared to 2004 (Bertram et al. 2015, p. 16). The authors do not link this dispersal to habitat loss, rather they linked the dispersal to ocean conditions, concluding that the large increases in murrelets entering watersheds during the breeding season on Haida Gwaii were consistent with a northward movement of birds from Vancouver Island in 2005 when ocean conditions in southern British Columbia were poor (Bertram et al. 2015, p. 16).

In the PVA analysis, Peery and Jones (2019, p. 11) assume that breeding murrelets displaced by habitat loss became nonbreeders for at least one year, but they could become breeders in later years if increases in nesting habitat capacity in LTFC replaced nesting habitat removed. Based on the evidence of variable site fidelity in murrelets (Burger et al. 2009, p. 217), we agree with Peery and Jones (2019, p. 11) assessment – adult murrelets that lose nest sites from habitat removal become nonbreeders for at least one year, and then may re-enter the breeding population in subsequent years by locating an alternate nest site near the location they previously nested, or by dispersing and locating a nest site in another area.

12.1.2 Background Information - Fragmentation and Edge Effects

Clearcut timber harvesting creates a high contrast edge along the boundary between the harvested areas and adjacent forested stands. Exposed clearcut edges alter light, moisture, and temperature gradients in adjacent old-forest stands for distances of up to 240 m (787 ft) (Chen et al. 1993, p. 291, 1995, p. 74). We use a distance of 100 m (328 ft) to account for the most significant physical and biological effects to murrelet habitat along clearcut 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 et al. 1992, pp. 390-391, van Rooyen et al. 2011, p. 549, Malt and Lank 2009, p. 1274).

12.1.2.1 Edge Effects – Increased Predation Risk Adjacent to Managed Forest Edges

McShane and others (2004, p. 4-89) compiled a review of known murrelet nesting success relative to edge habitats. This review found murrelet nests located within 50 m (164 ft) of a recent clearcut edge have lower success rates relative to nests located within interior forests. Overall murrelet nest success was 38 percent within 50 m of the forest edge and 55 percent at distances greater than 50 m from an edge. Most of the nests failed because of predation, and failure due to predation was higher within 50 m of an edge than within interior forests. No murrelet nests located >150 m from an edge failed because of predation (McShane et al. 2004, p. 4-89).

Simulated murrelet nests located within 50 m (164 ft) of high contrast edges created by recent clearcuts 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). These increased predation attempts are associated primarily with Steller's jays 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 recent clearcuts (Malt and Lank 2009, pp. 1283-1284). While Steller's jays will use a variety of forest seral stages, in landscapes that have recent clearcuts, they spend most of their foraging time within 50 m on either side of abrupt forest edges (Masselink 2001, p. ii, Vigallon and Marzluff 2005, p. 36.).

Predation risk associated with clearcut 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). This study compared the fates of known murrelet nests with simulated nests and found that although real nests ''failed'' more often than simulated nests were disturbed, patterns of nest fates between real and simulated nests did not differ (Malt and Lank 2009, p. 1283).

Although increased predation risk associated with habitat fragmentation and edge effects is a threat to murrelets, we do not conclude that all edge habitats have no value to murrelets. Not all murrelet nests located along managed forest edges fail due to predation. Rather, nests in these locations are approximately 30 percent more likely to fail due to predation risk relative to nests located in interior forest habitats.

12.1.2.2 Increased Risk of Predation adjacent to Campgrounds and Roads

The risk of predation on murrelet nests by avian predators (especially corvids) appears to be highest in close proximity to forest edges (including roads), campgrounds, and settlements (Raphael et al. 2002, Marzluff and Neatherlin 2006). Research at campgrounds on the Olympic Peninsula demonstrated that American crows *(Corvus brachyrynchos)* and common ravens (*Corvus corax*) nesting within 1 km of human settlements or campgrounds increased in abundance, produced more young, and lived longer than birds nesting > 5 km from campgrounds (Marzluff and Neatherlin 2006, p. 301). Crows and ravens that foraged in campgrounds occupied smaller home ranges and tolerated a higher level of overlap with neighboring conspecifics, leading to an increased density of nesting corvids in the surrounding landscape (Marzluff and Neatherlin 2006, p. 301). This relationship was strongest with crows. Raven populations showed only slight increases in density due to proximity to campgrounds, and Steller's jays did not increase in abundance (Marzluff and Neatherlin 2006, p. 311). Steller's jays are highly territorial and apparently do not tolerate encroachment by conspecifics (Marzluff and Neatherlin 2006, p. 311).

Studies with simulated murrelet nests have documented that nest predation rates are highest within 50 m of forest edges (Raphael et al. 2002, p. 221). Nests located within 50 m of the forest edge tended to be preyed upon faster and to a greater extent than nests located further into a stand's interior. This edge effect was consistent near human activity where the edge of the forested stand abutted a campground or small settlement (Raphael et al. 2002, p. 230). Corvids accounted for 32.5 percent of nest predation events, and jays were responsible for most of the observed corvid depredation (Marzluff and Neatherlin, 2006, p. 310). Permanent roads through forest act as edges as well. Although forest habitat is not greatly reduced by construction of roads, they can bisect murrelet nesting habitat and draw Stellers jays into the forest interior resulting in increased predation risk in habitat within 50 m on either side of the road (Masselink 2001, pp.ii, 110-111). Similar relationships have been noted for ravens, where paved roads are preferentially used for foraging by ravens over other areas within their home ranges (Scarpignato and George 2013, p.147).

Based on the evidence regarding murrelet nest success along managed edges, we consider the creation of hard edges by timber harvesting adjacent to murrelet nesting habitat to be a significant habitat modification that results in a reduction in murrelet reproduction and nest success in the affected habitat. For analysis purposes, we assume murrelets nesting in *interior forest* have an average nest success rate of 0.55, while murrelets nesting in *outer edges* adjacent to a hard edge have a nest success rate of 0.38, and we use an intermediate value of 0.465 for nest sites within *inner edges* adjacent to a hard edge condition (Peery and Jones, 2019, p. 19). For road edges, we assume nesting success within 50 m of permanent roads is the same as that applied for *inner edges* (0.465).

12.1.2.3 Edge Effects – Habitat Loss and Degradation from Windthrow and Microclimate Changes

The creation of edges, such as those associated with clearcut boundaries, has been shown to increase wind damage, as trees once protected by neighboring trees are now exposed to greater wind forces (Roberts et al. 2007, p. 285). Windthrow usually occurs in the first few years after harvesting, particularly where more susceptible trees are exposed to stronger winds as a result of harvesting. Windthrow damage can extend into adjacent stands for hundreds of feet (Sinton et al. 2000, p. 2547), although most damage is usually concentrated within the first 30 to 60 feet of the cutting boundary edge (Strathers et al. 1994, p. 9).

In addition to windthrow effects, edge environments can experience higher temperatures and solar radiation, lower humidity and stronger winds relative to interior forest (Chen et al. 1995, p. 74), and these effects can result in the loss and degradation of murrelet nesting habitat in edge-influenced stands. A study in British Columbia found that murrelet habitat located within 50 m of a hard edge had fewer trees with suitable murrelet nest platforms relative to adjacent interiors, and hard-edged patches had the reduced epiphyte (moss) cover overall, which reduced the number of available platforms in the affected habitat (van Rooyen et al. 2011, p. 549). This study documented that the availability of suitable nesting platforms is significantly decreased at edges, through the loss of trees with platforms, and the loss of moss as a result of wind damage, and from microclimate effects that reduce the growth, survival, and colonization of mosses. These negative effects persist for 20 to 30 years, and diminish as adjacent forests regenerate (van Rooyen et al. 2011, p. 558).

Based on the above information, we assume that habitat degradation resulting from edge effects degrades habitat quality, and reduces habitat capacity to support nesting murrelets through the loss of individual platform trees and a reduction in the density of available platforms. The reduction in habitat capacity along managed forest edges is accounted for in the habitat discounts applied through the *Analytical Framework.*

12.1.2.4 Fragmentation Effects

Landscape studies of murrelet occupancy indicate that murrelet habitat patches that are surrounded by large areas of closed-canopy second-growth forest (security forest) have a higher probability of occupancy, and a lower risk of nesting predation than landscapes with greater amounts of clearcuts and young forest (Raphael et al. 1995, p. 188, Meyer et al. 2002, pp. 111-

112). This is the basis for the USFWS' identification of "*forested areas within 0.5 mile of individual trees with nesting platforms, and with a canopy height of at least one-half the site potential tree height*" as a primary constituent element of murrelet critical habitat (61 FR 26264 [May 24, 1996]). Stands of mature forest with uniform stand structure (i.e., security forest) also support lower densities of potential nest predators (Marzluff et al. 2000, p. 1137, Raphael et al. 2002, p. 230).

In this analysis we have used the estimated habitat area in interior forest patches, and habitat patch size as measures of fragmentation, with the assumption that nesting success is higher in interior forest patches (0.55), relative to habitat degraded by edge effects.

12.2 Effects of Habitat Removal and Degradation to Murrelets on WDNR-Managed Lands

The proposed Long-Term Strategy will release 38,774 raw acres of habitat, and meter this habitat removal over 20 years. The average rate of habitat loss will be about 2,100 raw acres per year during the first decade, and about 1,700 raw acres per year during the second decade. This rate of habitat loss will exceed the average baseline rate of about 1,600 acres of habitat removed per year under the Interim Strategy. This is not unexpected, since WDNR has deferred much of the potential harvest that otherwise would have occurred while developing the proposed Long-Term Strategy. Individual adult murrelets that are nesting in habitat that is removed during the nesting season will be displaced by the habitat removal, disrupting their nesting cycle, and killing eggs or chicks at the nest sites affected. We assume that adults displaced by nesting habitat are removed from the breeding population for at least one year.

There are approximately 102,192 adjusted acres of murrelet nesting habitat located on the WDNR lands (Table 20, above). Most of the adjusted acres (89 percent) will be retained in areas of LTFC. The remaining 11 percent (11,085 acres) is assumed to be harvested over the next 20 years. Habitat loss will be metered – with 6,085 adjusted acres released in the first decade, and 5,000 adjusted acres in the second decade. The average rate of habitat loss of adjusted acres represents 0.6 percent of the total available nesting habitat on WDNR lands per year during the first decade, and 0.5 percent per year during the second decade (Table 41).

Habitat removed for roads and yarding corridors in occupied site and buffers (114 adjusted acres) will result in localized effects at a site-specific scale – about 23 adjusted acres removed per decade on average (2.3 adjusted acres per year). The effects of habitat removal for roads and yarding are the same (disrupted nesting, displacement nesting birds), but because these effects are localized, the risk of directly impacting nesting murrelets is much lower considering the average density of nesting murrelets on WDNR lands. These effects are by no means discountable. Because the impact occurs within the occupied sites or occupied site buffers, they are likely to affect murrelets at the occupied site either through direct removal of a nest site, disruption of nesting behavior directly adjacent to the habitat removal, and/or increased predation risk along road edges. However, because the effects are localized, they present a lower risk of directly destroying an active nest compared to the removal of 600 adjusted-acres of habitat in a year. For example, a new road that removes one acre of habitat on the outer edge of 100-acre occupied site will certainly remove and degrade habitat at the site of impact, but it will not render the larger occupied site unusable by murrelets for nesting.

Table 41. Summary of the effects of murrelet habitat released for harvest and habitat gains on WDNR-managed lands.

Effects Category	HCP Decade					Totals	Effects to Murrelets
	1	**2**	**3**	**4**	**5**		
Habitat released for harvest (adjusted acres):	6,085	5,000	0	0	0	11,085	Disruption of nesting behaviors, displacement of adults from nest sites, mortality of eggs or nestlings.
Habitat released for yarding corridors and roads in occupied sites, buffers, or SHAs (114 adjusted acres):	23	23	23	23	22	114	Disruption of nesting behaviors, displacement of adults from active nest sites, mortality of eggs or nestlings.
Habitat removed (adjusted acres):	**6,108**	**5,023**	**23**	**23**	**22**	**11,199**	
Total available habitat on WDNR lands at the end of each decade (adjusted acres)	101,615	103,649	102,250	107,134	111,495	-	
Percentage of habitat removed per decade (adjusted acres)	6%	5%	0.02%	0.02%	0.02%	-	Less than one percent of nesting habitat removed per year.
Average annual rate of habitat loss (adjusted acres):	611	502	2	2	2	-	Approximately 1 potential nest site lost per year during first 10 years, and 0.5 potential nest sites lost per year during the 2nd decade.
Habitat gains (excluding stringers) (adjusted acres):	4,423	3,119	3,601	4,884	4,361	20,388	Increased capacity to support murrelet nest sites.
Habitat added per decade (adjusted acres):	4%	3%	4%	5%	4%	-	Habitat ingrowth may allow murrelets displaced by nesting habitat loss to locate alternative nest sites.

Note: Estimates presented in the above table are approximate values based on projected future conditions for analysis purposes.

As described in the *Environmental Baseline*, we estimate 15 percent of murrelets in the Washington are associated with habitat on WDNR-managed lands. Using the same assumptions used in the PVA developed by Peery and Jones (2019, p. 47), we estimate there are approximately 217 nesting pairs of murrelets associated with habitat on WDNR lands at current nesting densities, and 1,229 nesting pairs in the Washington population. Applying this average to the adjusted acres on WDNR lands (102,192 adjusted acres / 217 pairs), we get an average density of 471 adjusted acres/per breeding pair on WDNR lands. If all 11,085 adjusted acres of habitat released for harvest were removed in a single year, we estimate about 23 murrelet nest sites would be directly affected, representing a direct loss of eggs/chicks, and displacement of breeding adults for 11 percent of the total breeding population on WDNR lands, and about 1.8 percent of the total breeding population in Washington (1,229 nesting pairs). However, that is not the level of impact anticipated due to the timing of habitat removal. Because habitat loss will occur over a period of 20 years, concurrent with approximate equivalent habitat gains in LTFC, the number of individual murrelets that will be affected by habitat removal on annual basis represents a small fraction of the total population breeding in Washington each year. While the total number of nest sites affected (23) may seem like a low estimate, it reflects the fact that the majority of the nesting habitat that will be removed is low-quality habitat with a low probability of occupancy (P-stage 0.25 and 0.36), and the fact that nesting murrelets in Washington occur at very low densities relative to the total available habitat in the state (over 1.3 million acres).

As described above, we assume habitat removal will occur over a period of 20 years. If the average density of nesting murrelets remained static, about 1.2 nesting pairs per year will be displaced by habitat removal, representing an average rate of decline of 0.5 to 0.6 percent of the total nesting population on WDNR lands per year. However, because the murrelet population in Washington is currently declining at an average rate of 3.9 percent per year, the average density of nesting murrelets is also declining at a similar rate. Each year that passes results in lower densities of murrelets nesting on the landscape. With an average decline of 3.9 percent per year, within 10 years the average density will be 30 percent lower than it is today, and within 20 years it will be 50 percent lower than current density. Assuming a continued rate of decline of 3.9 percent per year, we expect about 10 nesting pairs will be displaced during the first 10 years of harvest, and about 5 nesting pairs will be displaced during the second decade of harvest. Delaying the release of 5,000 adjusted acres (metering) not only benefits murrelets by maintaining habitat capacity across WDNR-managed lands, there is a secondary benefit in that habitat that is metered is likely to support a lower density of murrelets, resulting in fewer nesting pairs directly affected by habitat removal.

We are reasonably certain that habitat removal on WDNR-managed lands will result in the destruction of individual murrelets nests, and the direct displacement of breeding adults from nesting sites for one or more years. Discerning the effects of lost reproduction from habitat removal and displacement of adults from the breeding population in the context of a declining population is more complex than just calculating a simple density index. We do not know how many murrelets will be directly affected by the covered activities in any given year, but we have specific estimates of the total amount of habitat that will be released for harvest, and habitat gains. Using these estimates, we can infer how changes in habitat will affect the murrelet population in Washington under different assumptions of population response to changes in habitat. The population-level effects of habitat loss and habitat gains including the effect that lost reproduction from one generation has on future generations, is analyzed in the *Population Viability Analysis*.

Likewise, habitat degraded by edge effects caused by roads and managed forest edges will reduce habitat capacity and increase predation risk to murrelets nesting in affected habitat. Harvest patterns are expected to result in 18.2 percent of nesting habitat in LTFC edges to be exposed to hard edge conditions on a decadal basis. As habitat increases over time, we assumed the relative percentage of habitat exposed to hard edge conditions remains the same (18.2 %). Based on this percentage, the adjusted acres in *inner edge* and *outer edge* exposed to hard edge conditions ranges from about 4,700 acres in Decade 1, to 5,700 acres in Decade 5. Including road edges and soft edge, approximately 6 to 7 percent of the adjusted acres in LTFC (excluding *stringers*) is degraded by edge effects each decade (Table 42).

Table 42. Summary of murrelet habitat degraded by edge effects on WDNR-managed lands.

	HCP Decade					
Effects Category	**1**	**2**	**3**	**4**	**5**	**Effects to Murrelets**
Habitat degraded by **hard edge** conditions in *inner edge* and *outer edge* LTFC (adjusted acres):	4,136	4,417	4,791	5,304	5,761	Increased nest predation, reduced habitat capacity.
Habitat degraded by **soft edge** conditions in *inner edge* and *outer edge* LTFC (adjusted acres):	570	614	674	760	836	Reduction in adjusted acres of habitat capacity. Soft edges do not have increased nest predation.
Habitat degraded by **road edges** in *interior forest* patches (adjusted acres):	783	802	822	849	873	Increased nest predation.
Total habitat degraded by edge effects in LTFC (excluding *stringers*) (adjusted acres):	**5,489**	**5,833**	**6,287**	**6,913**	**7,470**	Increased nest predation, reduced habitat capacity.
Total habitat in LTFC (adjusted acres)	95,530	98,530	102,250	107,134	111,495	
Percent of habitat (adjusted acres) in LTFC degraded by edge effects per decade	6%	6%	6%	6%	7%	About 6 percent of nesting habitat will have increased predation per decade due to edge effects.
Habitat degraded (raw acres) based on average P-stage	11,364	11,393	11,818	12,994	13,937	

Note: Estimates presented in the above table are approximate values based on projected future conditions for analysis purposes.

We are reasonably certain that individual murrelets that use nesting sites within 328 ft of hard edges created by forest management are likely to have increased nest predation, resulting in a lower nesting success for about 5 to 6 percent of the nesting population on WDNR lands per decade. At current nesting densities, this equates to about 12 nests per year with increased nest predation. Increased nest predation does not mean all nests along edges fail. For analysis purposes, Peery and Jones (2019, p. 19), assume murrelets nesting in *interior forest* have an average nest success rate of 0.55, while murrelets nesting in *outer edges* adjacent to a hard edge have a nest success rate of 0.38, and used an intermediate value of 0.465 for nest sites within *inner edges* adjacent to a hard edge condition (Peery and Jones, 2019, p. 19). This means 10 nests in *interior forest* habitat will produce on average 5.5 fledglings (0.55 nest success), while 10 nests in hard *outer edge* habitat would produce 3.8 fledglings (0.38 nest success), a reduction of 31 percent productivity. Weighting the combined edge effects in the categories presented above in Table 42, together results in an average nest success of about 0.44 in the edge -degraded habitats, indicating an average reduction in nesting success of about 20 percent (0.44 is 80 percent of 0.55) compared to the assumed nesting success in *interior forest* patches. So, if on average, there are 12 nests located in edge-degraded habitats each year, these nests will have an average nest success of about 44 percent, compared to 55 percent nest success in *interior* forest patches.

The purpose of this analysis is not to describe exactly how many nests are likely to fail on an annual basis due to edge effects. The objective of the analysis is to describe the amount of habitat that is likely to be degraded on decadal basis due to ongoing forest management on WDNR-managed lands and describe how this habitat degradation effects individual murrelets. As described in previous sections of the effects analysis, the Long-Term Strategy is expected to result in an increase of habitat in interior forest patches, and a reduction of existing edge effects in the occupied site buffers and SHAs as previously managed forests in these areas develop and transition to soft edge conditions, which will improve nesting success in the occupied sites and the SHAs. Raw acres in interior forest patches are projected to increase from about 40 percent to 43 percent by the end of the HCP, while about 80 percent habitat in LTFC (excluding *stringers*), is in *interior forest* patches. The occupied sites (59,330 acres) currently comprise over 60 percent of the adjusted acres in LTFC.

We are reasonably certain that individual murrelets that use nesting sites within habitat degraded by edge effects are likely to have increased nest predation, resulting in a lower nesting success. Discerning the effects of reduced nesting productivity of a relatively small proportion of the breeding population in the context of a declining population is complex, and difficult to discern from background rates of decline. We do not know exactly how many murrelets will be directly affected by the covered activities in any given year, but we have specific estimates of the total amount of habitat that will be released for harvest, and habitat gains, and using these habitat estimates, we can infer how changes in habitat will affect the murrelet population in Washington under different assumptions of population response to changes in habitat. The population-level effects of the expected habitat changes (both losses and gains) will be discussed in more-detail below under *Population Viability Analysis*.

12.2.1.1 Conclusions Regarding Habitat Removal and Degradation

We expect 0.5 to 0.6 percent of nesting murrelets per year on WDNR-managed lands will be displaced by direct habitat removal, resulting in nest failure, and displacing the adults from the breeding population for one or more years for the first 20 years of implementation of the proposed Long-Term Strategy. At current nesting density, this is approximately 1 nest site removed per year for the first 10 years.

We expect 5 to 6 percent of nesting murrelets per year on WDNR-managed lands will have increased nest predation in habitat degraded by edge effects. At current nesting density, about 12 nest sites per year are in edge-degraded habitat. Nest success in edges is expected to be reduced by about 20 percent annually compared to *interior* forest patches. The relative percentage of nesting habitat degraded by edge effects is expected to remain relatively constant and increase to about 7 percent by the end of the HCP term. Nesting success in occupied sites and SHAs is expected to improve as existing hard edges transition to soft or no-edge conditions.

Over 90 percent of nesting murrelets on WDNR-managed lands are expected to nest in *interior forest* patches with no reduction in nesting success.

12.3 Estimates of Disturbance

In this analysis, we use the term “disturbance” to mean audio/visual stressors resulting from human activities within or adjacent to murrelet nesting habitat. We use the term “disruption” to specify where we expect exposure to audio/visual disturbance will disrupt normal nesting behaviors such as incubation or chick provisioning. The use of chainsaws, yarding equipment, log trucks, and other motorized equipment in close proximity to murrelet habitat can disrupt normal murrelet nesting behaviors if the activities coincide with the murrelet nesting season. In Washington, the USFWS defines the murrelet nesting season as April 1 to September 23. The murrelet nesting cycle from egg-laying to fledging, typically lasts from 60 to 70 days (Nelson 1997, pp. 17-19). However, murrelet nesting is asynchronous, meaning not all murrelets initiate nesting at the same time, resulting in a prolonged season when murrelets may be nesting (176 days).

The USFWS has previously completed analyses for noise and visual disturbance to murrelets (USFWS 2015 entire). In these analyses, we concluded that normal murrelet nesting behaviors are likely to be disrupted by loud noises that occur in close proximity to an active nest or when the activity occurs within the line-of-sight of a nesting murrelet. For chainsaws, heavy equipment, and most ground-based activities we use a distance threshold of 0.25-mile to represent the area where disturbance “may affect” murrelets, and we use a threshold distance of 328 ft (100 m) (from an active nest, or unsurveyed nesting habitat) where ground-based activities are likely to disrupt murrelet nesting behaviors (USFWS 2015, p. 14). Exceptions include blasting, (0.25 mile-radius disruption distance), and large aircraft (for example, military jets) where the threshold distance is defined by where the aircraft sound at the receiver meets or exceeds 92 dBA SEL (A-weighted decibels as a Sound Exposure Level) (USFWS 2015, p. 14).

Murrelet responses to audio/visual stressors can include delay or avoidance of nest establishment, flushing of an adult from a nest or branch within nesting habitat, aborted or delayed feeding of juveniles, or increased vigilance/alert behaviors of adults and chicks at nest sites with implications for reduced individual fitness and reduced nesting success (USFWS 2015, pp. 13-14). Disturbances that cause a murrelet to flush can advertise the nest's location, thereby creating a likelihood of predation of the eggs or nestlings. When an adult is flushed, it can alert a predator to its location and the location of its egg or chick, thereby facilitating predation. These behavioral disruptions create a likelihood of injury by increasing the risk of predation, reducing the fitness of nestlings as a result of missed feedings, and/or increased energetic costs to incubating adults.

The intensity, frequency, duration, and magnitude of a disturbance event are all important factors the USFWS considers in the evaluation of disturbance effects. In general, we consider low intensity, short-duration actions (e.g., less than 1 day at a site) to be of much lower risk for disrupting murrelet nesting when compared to prolonged actions that require several days or weeks at a site to complete (e.g., major construction projects, variable retention timber harvesting, commercial thinning).

When evaluating the potential for audio/visual disturbance of nesting murrelets, the HCP covered-activities were divided into three major categories:1) aircraft, 2) ground-based activities, and 3) impulsive noise-generating activities such as blasting and pile-driving. These major categories were further evaluated for duration, and severity of murrelet response. WDNR evaluated the covered activities for intensity and duration and estimated the habitat area (P-stage adjusted acres) likely to be exposed to disturbance on annually (FEIS 2019, Appendix H) (Table 43).

12.3.1 Group 1 – Short Duration and/or Low-Intensity Activities

The most common and widespread types of disturbance, Group 1 activities (short duration, low intensity), are estimated to occur over 9,200 adjusted acres annually. These activities include brief duration and generally low intensity activities such as forest inventory, tree planting, pre-commercial thinning, minor road maintenance and repairs, special forest products, and other ground-based activities that have a duration of one day or less at any given location, and do not involve habitat modification. Because these activities are of short duration, they are considered to pose a low risk to murrelets. This conclusion is based on disturbance trials and other observations of murrelet behavioral responses.

Table 43. Estimates of habitat (adjusted acres) exposed to audio/visual 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 within LTFC)
Group 1 (Includes green collecting, pre-commercial thinning, non-motorized trail use, minor road repair and maintenance)	Ground-based noise and visual disturbance	≤328 feet (100 m)	< 1 day	No significant response based on duration; minimal to no impacts	9,200
Group 2 (Includes firewood collection, road reconstruction, major road and trail maintenance, communications facilities)	Ground-based noise and visual disturbance	≤328 feet (100 m)	< 7 days	Aborted feedings, adults flushing; disruption of normal behaviors	310
Group 3 (Campground use and maintenance, includes felling danger trees)	Ground-based noise and visual disturbance Predator attraction	≤328 feet (100 m)	> 1 month	Increased predation risk, aborted feedings, adults flushing; potential injury and/or mortality if live trees with platforms are felled	142
Group 4 (Includes audio/visual disturbance from adjacent timber harvest, thinning, motorized trail use, new road and bridge construction)	Ground-based noise and visual disturbance	≤328 feet (100 m)	>7 days, < 1 month	Aborted feedings, adults flushing; disruption of normal behaviors	1,630
Group 5 (Sand and gravel extraction, blasting)	Ground-based noise and visual disturbance	≤ 1,312 feet (400 m)	>7 days, < 1 month	Hearing damage from blast noise (within 100 m), aborted feedings, adults flushing; injury; disruption of normal behaviors	52
Group 6 (Aerial herbicide application)	Aircraft noise	≤328 feet (100 m)	< 7 days	Aborted feedings, adults flushing; disruption of normal behaviors	50

Source: FEIS 2019, p. 4-79. Estimates presented in this table are based on averages reported for the covered forest management activities on WDNR-managed lands in annual reports.

During incubation, adult murrelets exchange incubation duties every 24 hours at dawn. The normal behavior of the adults is to remain motionless at the nest and avoid detection from predators. Adult murrelets are not likely to flush during incubation unless they are confronted at the nest directly by a predator such as a raven (Singer et al. 1991, p. 333), or direct approach by human researchers (Long and Ralph, p. 16). The observed responses of adult murrelets exposed to brief disturbance trials have been increased vigilance and alert behaviors, without flushing from the nest (Hebert and Golightly, 2006, pp. 35-36). The normal behavior of incubating adults is to rest and remain motionless during the day. Prolonged disturbance disrupts this normal behavior by causing the adults to remain vigilant and alert during a time when they are normally resting. Because adults exchange incubation duties each day, we assume that each adult can tolerate exposure to audio/visual stressors for a 1-day cycle without consequence to individual fitness or increased predation risk to the egg.

Observations of murrelet nestlings exposed to disturbance trials indicate nestlings appear to be mostly unaffected by visual or noise disturbance (Hebert and Golightly 2006, p. 36). The greatest risk to murrelet chicks from exposure to audio/visual stressors is the potential for missed feedings, which occur primarily during dawn and dusk periods. Murrelets have evolved several mechanisms to avoid predation; they have cryptic coloration, are silent around the nest, minimize movement at the nest, and limit incubation exchanges and chick feeding to occur primarily during twilight hours (Nelson 1997, p. 14). Murrelets appear to be most sensitive to audio/visual stressors when they are approaching a nest site or delivering fish to a nestling. There are several documented instances where ground-based activities caused adult murrelets to abort or delay feedings of nestlings (Hamer and Nelson 1998, pp. 8-17). Missed feedings can reduce the fitness of nestlings. During chick rearing, adults feed the young 1 to 8 times per day (mean = 3.2 ±1.3 SD) (Nelson and Hamer 1995, p. 61). If we assume an average of 4 feedings per day, a single aborted feeding constitutes a loss of 25 percent of that day's food and water intake for the nestling. While any reduction in feeding is potentially detrimental to nestling development, murrelets and other fish-eating alcids are physiologically adapted to inconsistent provisioning by prioritizing wing and bill growth during development (Janssen et al. 2011, p. 859, Oyan and Anker-Nilssen 1996, p. 830).

Because most feedings occur at both dawn and dusk, activities with a brief duration during daylight hours poses a low risk of disrupting chick provisioning. Because murrelet nestlings exhibit wide variations in development (27 to 40 days) (DeSanto and Nelson 1995, p. 45) we assume that murrelet chicks can experience a single missed feeding without a significant delay in development or survival.

12.3.1.1 Conclusion Regarding Group 1 Activities

Based on the above information, we conclude that the effects of brief exposures (one day or less) to short duration, ground-based activities that do not result in the removal of platform-bearing trees, or trees providing canopy cover to potential nesting platforms are insignificant and immeasurable. Likewise, we consider exposure to distant audio/visual stressors to be insignificant. For example, a road construction project located further than the defined disruption distance (328 ft), but within the disturbance threshold distance (0.25 mile) from an active murrelet nest will expose the nesting murrelets to distance equipment noise. Low-level equipment sounds that are detectable to murrelets may result in minor behavioral responses, such as scanning or head-turning behaviors, or increased vigilance for short periods (Hebert and Golightly 2006, pp. 35-36). Such minor behavioral responses are considered to have insignificant effects to nesting murrelets.

12.3.2 Group 2 – Ground-based Activities with a Duration of 1 to 6 Days

Group 2 activities include road reconstruction, bridge or culvert replacements, maintenance of recreation facilities and trails, and other covered activities with a duration of less than seven days. These activities occur at various locations. Habitat exposure from these activities is estimated to average 310 adjusted acres per year. These activities can include a component of vegetation management (e.g. clearing forest from an overgrown road during road reconstruction). Because the duration of these activities is more than one day, but less than one week, these activities pose increasing risk that murrelet chicks will experience missed feedings or increase the risk of nest abandonment during incubation. We expect most habitat exposed to these activities will be located along existing roads, trails, or adjacent to habitat conserved in *inner edge* and *outer edge* LTFC.

Based on our review of the murrelet disturbance literature, we expect that murrelets nesting in close proximity to these activities will be exposed to audio/visual stressors that will result in a significant disruption of nesting behaviors, with implications for reduced individual fitness, reduced hatching success, and increased risk of nest predation for any murrelets nesting in close proximity to these activities.

For analysis purposes, we assume that nesting habitat exposed to Group 2 audio/visual disturbance has the same nest success rate as habitat degraded by road edges (0.465). The implications of this reduced nesting success will be discussed below in the *Summary of Disturbance Effects*.

12.3.3 Group 3 – Campgrounds and Developed Recreation Sites

These sites represent fixed locations where the same habitat is exposed to audio/visual stressors each year, and the duration of exposure is generally more than one month and may overlap the entire nesting season. WDNR estimated there are 142 adjusted acres adjacent to campgrounds and developed recreation sites (e.g., day-use picnic areas).

Habitat that is repeatedly exposed to audio/visual disturbance such as in campgrounds, is not rendered unusable by murrelets. Nesting habitats located adjacent to campgrounds are subject to high levels of human disturbance during the summer months, and attract corvids (crows, ravens, and jays) which can increase the risk of nest predation for murrelets (Marzluff and Neatherlin 2006, p. 308). Although relatively few murrelet nest sites have been found near open roads or campgrounds, murrelets do occasionally nest successfully in such areas (Hamer and Nelson 1998, p. 21, Bloxton and Raphael 2009, pp. 11-12).

Based on our review of the murrelet disturbance literature, we expect that murrelets nesting in close proximity to campgrounds and recreation facilities will be exposed to prolonged audio/visual stressors that will result in a significant disruption of nesting behaviors, with implications for reduced individual fitness, reduced hatching success, and increased risk of nest predation for any murrelets nesting in close proximity to these activities.

For analysis purposes, we assume that nesting habitat exposed to Group 3 audio/visual disturbance has the same nest success rate as habitat degraded by hard edge conditions in outer edges (0.38). The implications of this reduced nesting success will be discussed below in the *Summary of Disturbance Effects*.

12.3.4 Group 4 – Ground-based Activities with a Duration of 7 to 30 Days

Group 4 activities include variable retention timber harvest, commercial thinning, new road construction, major bridge replacement projects, and other intensive projects, including habitat removal or harvesting of security forest adjacent to habitat in LTFC. These activities include disturbance from yarding corridors and new roads constructed through occupied sites and buffers. Habitat exposure from these activities is estimated to average 1,630 adjusted acres per year.

12.3.4.1 Severe Disturbance from Variable Retention Timber Harvest

We further refined the estimates for these activities to account for severe disturbance effects associated with variable retention harvest creating hard edges adjacent to habitat. This can occur where P-stage released for harvest is removed, resulting in partial removal of a patch, or where security forest is harvested adjacent to habitat conserved in LTFC. Based on WDNR's projection of average edge conditions in LTFC, 18.2 percent of habitat in *inner edge* and *outer edge* is expected to be in a hard edge condition per decade. Based on this average, we estimated that the area of habitat exposed to severe disturbance effects will average about 900 raw acres a year, or about 400 adjusted acres per year located in *inner edge* and *outer edge* LTFC.

Timber harvest and road construction activities may occur throughout the nesting season, including timber felling for road construction. Due to dry season limitations associated with road construction, much harvest will occur from June through September, which directly overlaps the murrelet nesting season. By mid-June, breeding murrelets have established nests sites and are either incubating eggs or tending to nestlings with multiple daily feedings. Each timber harvest unit will have weeks of intensive activity, including temporary road construction, followed by felling and yarding of trees using various methods. Murrelets nesting along the edge of an active harvest unit will be exposed to intensive audio/visual stressors over a period of many days to several weeks while harvest activities are underway. The audio/visual disturbance effects to murrelets are further intensified by the direct loss of adjacent forest cover (whether suitable habitat or younger forest adjacent to habitat) and creation of a hard-edge adjacent to nesting habitat retained in LTFC or adjacent federal lands.

Considering the duration and severity of disturbance effects associated with variable retention timber harvesting (loss of forest cover which alters habitat conditions and prolonged exposure to noise and visual stressors), any murrelets nesting in habitat directly adjacent (within 328 ft) to an active timber harvest unit are likely to be exposed to both disturbance and significant habitat modification that impairs essential nesting behaviors, resulting in a high likelihood of nest abandonment or nest failure.

For this analysis, we assume that the combined stressors associated with variable retention timber harvest will result in direct nesting failure to murrelets due to the abandonment of the nest by the adults. Disturbance is not expected to displace effected adults from the breeding population. Where nest sites are conserved in LTFC, we expect adults will return to these locations to nest in subsequent years, as has been observed in a number of studies that have located murrelet nests adjacent to recently harvested edges (McShane et al. p. 4-87).

12.3.4.2 Other Group 4 Activities

Other activities in this group include commercial thinning, road construction, bridge replacements, etc. Other Group 4 activities (other than variable retention harvest) will expose about 1,200 adjusted acres of habitat per/year. Based on our review of the murrelet disturbance literature, we expect that murrelets nesting in close proximity to these activities will be exposed to prolonged audio/visual stressors that will result in a significant disruption of nesting behaviors, with implications for reduced individual fitness, reduced hatching success, and increased risk of nest predation for any murrelets nesting in close proximity to these activities. If disturbance at a nest site is prolonged, each successive day of disturbance represents an increasing risk that multiple missed feedings will trigger a significant delay in nestling growth and development processes, cause permanent stunting, or result in the mortality of a nestling due to malnourishment, abandonment by the adults, accidental death, or predation.

In summary, for the Group 4 activities, we assume habitat exposed to severe disturbance effects from the creation of hard edges (about 400 adjusted acres/year) will have a nesting success rate of 0. For other Group 4 activities we assume habitat exposed to prolonged disturbance has the same nest success rate as habitat degraded by hard edge conditions in outer edges (0.38). The implications of this reduced nesting success will be discussed below in the *Summary of Disturbance Effects*.

12.3.5 Group 5 – Rock, Sand, and Gravel Quarries

These sites represent fixed locations where the same habitat is exposed to audio/visual stressors each year, and the duration of exposure is generally more than one month and may overlap the entire nesting season. Because rock quarries can include blasting, the disruption distance for these activities is 0.25 mile. WDNR estimated there are 52 adjusted acres of habitat within a 0.25-mile radius of existing quarries and borrow-pits.

The noise associated with blasting is highly variable and depends on the size of the charge, the material being blasted, and whether noise minimization techniques are employed. As noted above in Table 43 (above), blasting within a distance of 328 ft of a murrelet nest site could result in physical injury to murrelets due to hearing damage, or disturbance to murrelets during the nesting season at a distance of 0.25 miles from the blast site (USFWS 2015, pp. 11-12). The habitat located within a 0.25-mile radius of existing quarries or gravel mines is estimated at 52 adjusted acres, indicating a low risk of physical injury from blasting due to limited habitat area exposed, but the potential for disruption of normal nesting behaviors from ongoing quarry activities is expected, given the remaining term of the HCP.

Because quarries and borrow-pits create large openings in the forest, they create hard-edge conditions that can persist for decades. For analysis purposes, we assume that nesting habitat exposed to Group 5 audio/visual disturbance has the same nest success rate as habitat degraded by hard edge conditions in *outer edges* (0.38). The implications of this reduced nesting success will be discussed below in the *Summary of Disturbance Effects*.

12.3.6 Group 6 – Aircraft Operations

Group 6 activities includes aircraft operations associated with WDNR-management activities. This includes aerial application of herbicide or fertilizers or aircraft used for natural resource inventory flights, or fire suppression activities. It may also include the use of helicopters to service communications facilities, or transmission lines with right-of-way through WDNR-managed lands, or helicopters used to support aquatic restoration projects by cooperating agencies. The category does not include military training operations carried out by the Department of Defense, as those activities are evaluated through separate ESA section 7 consultations. WDNR estimated there will be, on average, 50 adjusted acres per year exposed to aircraft operations. Exposure to aircraft noise is usually a brief, high intensity event as aircraft pass over a specific location, or it may involve several days of activity at a specific project location, so the duration of aircraft operations was defined as less than 7 days.

There are no experimental studies that have evaluated murrelet responses to aircraft overflights. However, there are a handful of incidental observations that have been described. Long and Ralph (1998, p. 19) noted that murrelets did not have an observable response to either airplanes or helicopters flying overhead, except perhaps when they passed at low altitude. One chick did not respond to an airplane passing twice within 0.25 mile at a height of about 1,000 ft, but another chick lay flat on the branch “when an aircraft passed at low altitudes” (“low altitudes” was not defined) (Long and Ralph 1998, p. 19). During a study of radio-tagged murrelets in British Columbia, helicopters were used to locate the incubating adults by circling and hovering over nest sites. The hovering and circling came within distances of 100 to 300 m of the nest and lasted approximately three minutes. None of the radio-tagged adults that were incubating nests flushed in response to the helicopters (n = 125) (R. Bradley, Univ. BC, 2002, pers. comm. in (USFWS 2003, p. 278)).

Based on our review of the murrelet disturbance literature, we expect that the response of murrelets to most aircraft overflights will be brief alerting behaviors with no significant effects to the individuals. This is the expected response for most aircraft overflights that pass by quickly in transit from one location to another. Projects that involve prolonged exposures such as hovering, helicopter sling-operations, or repeated low-altitude flights at project-specific locations increase the potential to result in a significant disruption of nesting behaviors.

For analysis purposes, we assume that nesting habitat repeatedly exposed to aircraft audio/visual stressors has the same nest success rate as habitat degraded by road edges (0.465). The implications of this reduced nesting success will be discussed below in the *Summary of Disturbance Effects*.

12.3.7 Application of Daily Limited Operating Periods

The application of daily limited operating periods is an important minimization measure for reducing disturbance effects to individual murrelets. A daily limited operating period means that implementation of covered activities is limited to the period beginning two hours after official sunrise, to two hours before official sunset each day during the murrelet nesting season (April 1 to September 23). All incubation exchanges between nesting adults occur at dawn, and typically over 90 percent of chick provisioning events occur during dawn and dusk hours (Lorenz et al. 2019, p. 161, Barbaree 2011, 128). Under the proposed Long-Term Strategy, WDNR will apply a daily limited operating period to covered activities that occur within the occupied sites and occupied site buffers during the nesting season (WNDR 2019, Table A-4). These restrictions do not apply to other habitat conserved in LTFC.

The adjusted acres conserved in LTFC include over 59,000 acres of occupied sites, and about 2,200 adjusted acres of habitat in the buffers, indicating over 60 percent of habitat conserved in LTFC (excluding *stringers*) will have the daily limited operating periods applied. Application of daily limited operating periods greatly reduces the potential to disrupt murrelets during feeding and incubation exchanges, but it does not ensure that all murrelets will be protected from disturbance under all circumstances. Unrestricted activities that occur during the mid-day hours will result in the disruption of adult nesting behaviors (increased vigilance, and increased risk of nest abandonment), or result in occasional disrupted feedings of nestlings during mid-day hours. While most feedings occur during dawn and dusk, murrelets do occasionally provision chicks during the day (USFWS 2012, p. 5, Lorenz et al. 2019, p. 161). Longer duration projects (7 days or more) have a higher risk of disrupting mid-day feedings. In summary, the application of daily limited operating periods is an important minimization measure, which ensures that most chick provisioning will occur uninterrupted by audio/visual stressors. However, projects with a duration of more than 1 or 2 days that employ daily limited operating periods still create a likelihood of injury due to a significant disruption of normal nesting behaviors (USFWS 2012, p. 5). However, we consider the risk that such projects will result in nest failure due to malnourishment from multiple missed feedings to be discountable, because the limited operating period ensures that all incubation exchanges and most chick provisioning events will occur uninterrupted.

12.3.8 Summary of Habitat Exposed to Disturbance Effects on WDNR -Managed Lands

Based on our review of the covered activities, we determined the effects of Group 1 activities are insignificant. The remaining groups are estimated to expose a cumulative total of 2,184 adjusted acres of habitat annually to audio/visual stressors that are of sufficient duration and intensity that we anticipate disruption of nesting behaviors, with implications for reduced nesting success. The estimated 2,184 adjusted acres of habitat exposed to disturbance effects represents an average exposure rate of about 2.3 percent of the adjusted acres conserved in LTFC. Because habitat in LTFC is projected to increase over the term of the HCP, we assume the relative proportion of habitat expose remain the same (2.3 percent annually), but the total acres exposed to disturbance is likely to increase each decade (Table 44).

Table 44. Summary of the average annual estimates of murrelet habitat to exposed to significant audio/visual disturbance on WDNR-managed lands.

	HCP Decade					
Activity Group	**1**	**2**	**3**	**4**	**5**	**Effects to Murrelets**
Group 3 (campgrounds) and **Group 5 (**quarries) - The same habitat is exposed each year (adjusted acres).	194	200	208	218	226	Disruption of nesting behaviors, increased nest failure. Assume average nest success is 0.38 (same as hard edge effect along *outer edges*).
Group 2 (various activities) and **Group 6** (aircraft)- duration of activity is less than 7 days (adjusted acres):	360	371	385	404	420	Disruption of nesting behaviors, increased nest failure. Assume average nest success is 0.465 (same as hard edge condition in *inner edges*).
Group 4 - Severe disturbance by adjacent variable retention timber harvest. Various locations where duration of activity is greater than 7 days (adjusted acres):	414	442	479	530	576	Disruption of nesting behaviors, nest abandonment by adults, mortality of eggs or nestlings. Represents 0.4 to 0.5 percent of nesting habitat in LTFC per year
Group 4 - Various activities and locations – prolonged duration of disturbance is greater than 7 days (adjusted acres):	1,216	1,239	1,266	1,298	1,326	Disruption of nesting behaviors, increased nest failure. Assume average nest success is 0.38 (same as hard edge effect along *outer edges*).
Total average annual habitat exposed to audio/visual disturbance (adjusted acres)	**2,184**	**2,253**	**2,338**	**2,449**	**2,549**	-
Total habitat in LTFC (adjusted acres)	95,530	98,530	102,250	107,134	111,495	-
Average annual percentage of habitat in LTFC exposed to disturbance effects	2.3%	2.3%	2.3%	2.3%	2.3%	About 2.3 percent of nests per year exposed to audio/visual disturbance with increased nest failure due to disturbance.
Average habitat (raw acres) exposed to disturbance (based on average P-stage)	4,522	4,400	4,395	4,603	4,756	-

Note: Estimates presented in the above table are approximate values based on projected future conditions for analysis purposes and are not intended to represent exact values.

If we assume an average P-stage value of 0.5 in LTFC, the 2,814 adjusted acres is equivalent to about 4,400 raw acres of habitat exposed to disturbance effects annually, and about 21,840 adjusted acres each decade. The average estimates listed above in Table 44 are not intended to represent an exact accounting of habitat exposed to disturbance but are intended to provide a general estimate of these impacts. The rate of timber harvest, road construction, and other covered activities will vary somewhat from year to year.

Habitat conserved in LTFC that is exposed to ephemeral disturbance effects will remain on the landscape and continue to provide potential nesting opportunities for murrelets. Most habitat areas exposed to intensive audio/visual disturbance events (e.g., timber harvesting adjacent to nesting habitat in LTFC) will only be exposed to that type of disturbance once during the term of the HCP due to the time it takes for managed forests to regenerate between harvest cycles. Most of the habitat in LTFC that will be exposed to audio/visual stressors will occur (*inner edge*, *outer edge*, and *stringers*) has some degradation from edge effects also resulting in reduced nesting success.

Exposure to disturbance effects, particularly for prolonged actions that do not adhere to daily limited operating periods, increase the risk of murrelet nesting failure due to disrupted incubation or chick rearing. Murrelets suffer high rates of nest failure due to various causes, including nest predation, nest abandonment, malnourishment, and accidental death (chicks falling from a nest) (Nelson 1997, p. 20, Lorenz et al. 2019, p. 162). Exposure to audio/visual stressors increases the risk of nest failure from one of these causes, but not all nest sites exposed to disturbance are expected to fail.

We are reasonably certain that individual murrelets that use nesting habitat along roads, near campgrounds, developed recreation sites, quarries, and adjacent to managed forest edges will have reduced nesting success from exposure to disturbance effects. Based on current nesting density (471 adjusted acres per nest), we assume about 5 nest sites per year will be disrupted by disturbance, including one nest site that is expected to fail as a result of exposure to severe disturbance from adjacent timber harvest. Weighting the combined nest success rates in the categories presented above in Table 44, together results in an average nest success of about 0.32 in habitat exposed to disturbance, indicating a reduction in nesting success of about 41 percent (0.32 is 58 percent of 0.55) compared to the assumed nesting success in *interior forest* patches.

12.3.8.1 Conclusions Regarding Disturbance Effects on WDNR-Managed Lands

We expect a cumulative total of 2.3 percent of nesting murrelets per year on WDNR-managed lands will be exposed to significant audio/visual disturbances. At current nesting density, about 5 nest sites per year are in habitat affected by disturbance.

We expect 0.4 to 0.5 percent of nesting murrelets per year on WDNR-managed lands will have nest failure due to the combined stressors of audio/visual disturbance and habitat modification where variable retention timber harvest removes forest cover adjacent to habitat conserved in LTFC.

We expect 2.3 percent of nesting adults on WDNR-managed lands will have reduced nest success as result of disturbance effects. Nest success in habitat exposed to disturbance is expected to be reduced by about 40 percent annually, compared to nests in *interior* forest. The relative proportion of nesting habitat exposed to disturbance effects is expected to remain relatively constant at 2.3 percent of adjusted acres per year.

12.3.9 Disturbance Effects to Habitat on Adjacent Federal Lands

As described above under the discussion of *Habitat Fragmentation and Edge Effects*, we estimate there are approximately 4,500 raw acres of existing murrelet habitat located on adjacent federal lands (within 328-ft of WDNR-managed areas) that have the potential to be degraded by edge effects and exposed to audio/visual disturbances. If we assume all of these areas will be affected over the next two decades, we get an average of about 225 raw acres habitat exposed to disturbance effects per year on adjacent federal lands. The effects of this exposure to disturbance are the same as those described above for WDNR lands.

12.3.10 Summary of the Effects of WDNR Forest Management on Murrelet Nesting Success

We applied the assumed nest success rates for the covered activities as described above to get perspective on what the combined effects of habitat removal, habitat degradation from edge effects, and disturbance effects have on annual murrelet nest success on WDNR-managed lands.

Starting with the assumption that there are 217 nesting pairs of murrelets associated with habitat on WDNR-managed lands, we estimated that there are 471 adjusted acres per nesting pair. Using the combined annual estimates of habitat affected by forest management (8,248 adjusted acres) divided by the average density (471 adjusted acres), we get an estimated 18 murrelet nest sites affected by forest management (8 percent), and 199 nest sites (92 percent) with no expected management effects.

The assumed nest success rate for *interior* forest patches is 0.55. Applying this value to 217 nests yields an estimate of 119 successful nests (55 percent of 217).

Applying the assumed reduced nesting success rates for habitat removal, degradation, and disturbance to the 18 nests affected by management, we found that the management effects result in the loss of 3 nests annually – one from habitat removal, one from edge effects, and one from disturbance effects. This results in a 3 percent reduction in nest success on WDNR lands compared to if all nests were in *interior* forest patches (116 successful nests compared to 119 successful nests) (Table 45).

Table 45. Comparison of the estimated annual effect of habitat removal, edge effects, and disturbance to murrelet nesting success on WDNR-managed lands.

Effect Category	Habitat affected (adjusted acres)	Assumed management effects on nesting success			Comparison of nesting success if habitat was not managed		Difference in nest success due to management effects
		Number of nest sites effected	Assumed nest success rate	Number of successful nests	Assumed normal nest success rate	Number of successful nests	
Habitat released for harvest	611	**1.3**	0	0.0	0.55	0.7	**0.7**
Edge Effects							
Hard *outer edge*	2,068	4.4	0.38	1.7	0.55	2.4	-0.7
Hard *inner edge*	2,068	4.4	0.465	2.0	0.55	2.4	-0.4
Road edge in *interior forest*	783	1.7	0.465	0.8	0.55	0.9	-0.1
Soft edges	570	1.2	0.55	0.7	0.55	0.7	-0.0
Total - edge effects	**5,489**	**11.7**		**5.1**		**6.4**	**-1.3**
Disturbance effects							
Campgrounds and quarries	194	0.4	0.38	0.2	0.55	0.2	-0.1
Limited duration (< 7 days)	360	0.8	0.465	0.4	0.55	0.4	-0.1
Severe disturbance from timber harvest (> 7 days)	414	0.9	0	0.0	0.55	0.5	-0.5
Prolonged disturbance (> 7 days)	1,216	2.6	0.38	1.0	0.55	1.4	-0.4
Total - disturbance effects	**2,184**	**4.6**	**-**	**1.5**	**-**	**2.6**	**-1.1**
Combined totals	**8,284**	**18**	**-**	**7**	**-**	**10**	**-3**
Nests in interior forest patches (no management effects)		**199**	0.55	**109**	-	-	-
Total nests on WDNR:		**217**	-	**116**	0.55	**119**	**-3**

Note: Estimates presented in the above table are approximate values for analysis purposes and are not intended to represent exact values. Nest density in the above table is assumed to be 471 adjusted acres /per nest.

The purpose of this analysis is to demonstrate what how forest management potentially effects nesting success rates on WDNR lands. Currently, forest management on WDNR-managed is ongoing, exposing murrelets to existing disturbance and edge effects. Because murrelets are declining in Washington nesting density is expected to decline as well, but the relative proportion of habitat exposed to management effects is expected to remain the same.

12.3.10.1 Conclusion Regarding Nesting Success

Habitat removal, habitat degradation, and disturbance effects from forest management all result in reduced nesting success on WDNR-managed lands. Because overall murrelet nest success is low, and the amount of habitat removed, degraded, or disturbed represents only about 8 percent of the total adjusted acres, the difference in nesting success with management vs. without management is small (3 percent). This level of lost reproduction is not detectable compared to ongoing rates of harvest, edge effects, and disturbance currently ongoing under the Interim Strategy. Implementation of the proposed Long-Term Strategy will continue to result in reduced nesting success in habitat located adjacent to roads and managed areas. However, the protection of occupied sites, buffers, and SHAs is projected to increase the area of available nesting habitat in interior forest patches, which will improve murrelet nesting success on WDNR-managed lands compared to the habitat configuration that exists today.

12.4 Effects to the Distribution of Murrelet Habitat

At the scale of the WDNR-HCP lands within the range of the murrelet, the proposed Long-Term Strategy is projected to result in an increase in both raw acres and adjusted acres, indicating the distribution of murrelet habitat is maintained and/or improved at the scale of the landscape analysis areas (Table 46).

Table 46. Summary of the distribution of current habitat and projected future habitat by landscape area.

Landscape Analysis Area	Total WDNR lands (acres)	Current habitat (raw acres)	Percent of land with habitat (current)	Estimated future habitat (decade 5) (raw acres)	Percent of WDNR land with habitat (decade 5)
Southwest Washington	166,988	26,332	16%	36,283	22%
OESF and Straits west of Elwha River	305,099	74,801	25%	74,939	25%
North Puget	364,778	60,161	16%	72,064	20%
Other high-value landscapes	321,933	41,830	13%	65,767	20%
Marginal Landscape	224,390	3,943	2%	23,786	11%
Total	**1,383,188**	**207,067**	**15%**	**272,839**	**20%**

Source: WDNR large data overlay pivot table summaries dated 20190628.

12.4.1 Distribution of Habitat in Conservation Zones

As noted in the *Environmental Baseline* section, the HCP planning units are based on major watershed areas in Washington, and therefore are more directly comparable to murrelet conservation zones than the strategic landscapes. HCP planning units in Zone 1 include the Straits, North Puget, South Puget, and Yakima. In Zone 1, the distribution of habitat (raw acres) as measured by the percentage of WDNR-managed lands is projected to increase in all HCP planning units, with substantial increases in the total habitat area in the Straits (183 percent increase) and South Puget planning units (205 percent increase over baseline) (Table 47).

Table 47. Summary of the distribution of current and estimated future habitat (raw acres) on WDNR-managed lands in Conservation Zone 1.

HCP Planning Unit:		Straits	North Puget	South Puget	Yakima	Zone 1 Totals
Current conditions	Total WDNR land in HCP Planning Unit (acres)	127,056	444,871	176,733	2,588	751,248
	Total habitat (raw acres)	14,287	76,893	14,733	505	106,418
	Percent WDNR land in habitat	**11%**	**17%**	**8%**	**20%**	**14%**
Decade 5 Estimated future conditions	**Decade 5** Total habitat (raw acres)	26,143	94,823	30,253	1,007	152,226
	Percent of WDNR-lands in habitat	**21%**	**21%**	**17%**	**39%**	**20%**
Net change in habitat from baseline:		183%	123%	205%	199%	143%

Note: Totals represent WDNR-managed land area and habitat within the range of the murrelet. Source: WDNR large data overlay pivot table summaries dated 20190628.

HCP planning units in Zone 2 include the OESF, South Coast, and Columbia planning units While the OESF slightly overlaps both Zone 1 and Zone 2, the majority of the HCP unit is in Zone 2. In Zone 2, the distribution of habitat (raw acres) as measured by the percentage of WDNR-managed lands is projected to increase in all HCP planning units except the OESF, which has a slight reduction (3 percent) in raw habitat acres. Substantial increases in total habitat is projected in the South Coast HCP unit (215 percent increase), increasing total habitat on WDNR lands in the South Coast unit from 7 percent to 15 percent (Table 48).

Table 48. Summary of the distribution of current and estimated future habitat (raw acres) on WDNR-managed lands in Conservation Zone 2.

HCP Planning Unit:		OESF	South Coast	Columbia	Zone 2 Totals
Current conditions	Total WDNR land in HCP Planning Unit (acres)	273,084	260,044	98,810	631,938
	Total habitat (raw acres)	68,309	17,786	14,554	100,649
	Percent WDNR land in habitat	**25%**	**7%**	**15%**	**16%**
Decade 5 Estimated future conditions	**Decade 5** Total habitat (raw acres)	66,199	38,284	16,129	120,612
	Percent of WDNR-lands in habitat	**24%**	**15%**	**16%**	**19%**
Net change in habitat from baseline:		97 %	215 %	111 %	120 %

Note: Totals represent WDNR-managed land area and habitat within the range of the murrelet. Source: WDNR large data overlay pivot table summaries dated 20190628.

12.4.2 Watershed Analysis of Habitat Distribution

To supplement the landscape distribution analysis, WDNR also completed a watershed scale analysis to document areas where habitat on WDNR-managed lands is projected to increase or decrease over time. Watersheds that contained a minimum of 50-adjusted acres of existing habitat were selected for this analysis (FEIS 2019, p. 3-36). Watersheds are a useful indicator for evaluating habitat distribution because murrelets are believed to have a high level of site fidelity to nesting habitat within watersheds, and the number of murrelets detected entering watersheds is positively associated with total habitat area (Burger 2002, p. 35, Raphael et al. 2002, p. 337).

The analysis identified 60 watersheds that currently contain a minimum of 50 adjusted habitat acres. The watersheds used for the analysis are mapped by the U.S. Geological Survey as hydrologic units at a scale of approximately 50,000 to over 200,000 acres, with average size of about 100,000 acres (hydrologic unit code 10) (HUC). WDNR lands within the watersheds range from less than 1 percent (225 acres – Wallucut/Columbia River frontal) to 80 percent ownership (78,500 acres in the Clearwater River watershed in the OESF). The full tabular results of the watershed analysis is provided in the administrative record for this Opinion (USFWS 2019e).

Consistent with the landscape analysis, the distribution of both raw habitat and adjusted acres is either maintained or projected to increase in total area over the term of the HCP. Of the 60 watersheds analyzed, there are 6 watershed areas where both raw habitat acres and adjusted habitat acres are projected to decrease over the term of the HCP (Table 49).

Table 49. Summary of watersheds where habitat on WDNR is projected to decrease in both raw acres and adjusted acres.

HCP Unit	HUC	Watershed name	Watershed acres	WDNR-managed land within watershed (acres)	Percent of watershed area in WDNR lands	Current WDNR habitat (raw acres)	Percent of WDNR with habitat	Estimated WDNR future habitat (raw acres)	Percent of WDNR land with future habitat
North Puget	1711000803	Stillaguamish River-Frontal Port Susan	104,417	19,029	18%	4,171	22%	3,155	17%
North Puget	1711000508	Cascade River	75,158	7,887	10%	3,952	50%	3,472	44%
North Puget	1711000401	Upper North Fork Nooksack River	123,475	2,515	2%	976	39%	840	33%
OESF	1710010106	Sol Duc River-Quillayute River	149,085	21,232	14%	5,156	24%	4,169	20%
South Coast	1710010206	Moclips River-Frontal Pacific Ocean	91,204	4,764	5%	838	18%	541	11%
Straits	1711002003	Dungeness River	126,922	5,113	4%	1,149	22%	855	17%

Source: WDNR HUC analysis 20190930.

None of the watersheds that are projected to have decreases in habitat over the term of the HCP will result in an elimination of habitat from WDNR lands within the watershed. Occupied sites, occupied site buffers, and other LTFC maintain much of the existing habitat on WDNR lands in these watersheds (Table 48, above). The Sol Duc, Dungeness, Cascade, and Upper North Fork Nooksack are watersheds where federal lands comprise more than 50 percent of the total watershed area and provide significant existing conservation of murrelet habitat. Both the Moclips and Stillaguamish-Port Susan watersheds represent areas where most of the land ownership is private, and habitat remaining in these areas is highly fragmented, with limited capability of growing additional habitat over the term of the HCP.

Specific areas that were identified as being important to murrelet distribution at a local landscape scale are conserved by the proposed Long-Term Strategy. For example, in the northwest OESF, the Clallam area was identified as representing an important conservation opportunity that would result in a reduction in the distribution of habitat if not conserved. The designation of the Clallam SHAs (East and West) will result in conservation of over 4,200 acres of existing habitat and security forest in an area that is near marine waters known to support high-densities of murrelets during the summer nesting season (Raphael et al. 2015, p. 21). Other SHAs complement existing murrelet conservation on provided on federal lands by conserving large blocks of existing habitat and occupied sites adjacent to federal lands (e.g., Queets and Reade Hill SHAs in the OESF, and the Middle Fork and Lake Shannon SHAs in North Puget.

Because of the lack of federal lands in southwest Washington, the proposed Long-Term Strategy emphasizes conservation in this strategic landscape area. The watershed in southwest Washington with greatest area of existing habitat that will be released for harvest is the Elochoman River – Frontal Columbia River (HUC 1708000307), which includes the combined area of the Skamakowa and Elochoman Rivers (Figure 8). Habitat in this watershed was extensively surveyed in the 1990s under the Interim Strategy, resulting in the delineation of the occupied sites. All habitat released for harvest in this watershed was surveyed and found to be unoccupied, which is true for all essentially all other areas of existing habitat released for harvest in southwest Washington (Raphael et al. 2008, pp 3-21 to 3-31). The Elochoman watershed analysis area includes the Skamakawa South and Elochoman SHAs, which combined provide conservation in over 6,400 acres of existing habitat and security forest (WDNR 2019, Table A-6). The conservation provided by the SHAs, occupied site buffers, and other LTFC are projected to maintain raw habitat in the Elochoman watershed at about 31 percent raw acres, while adjusted acres are projected to increase overtime due to increase in interior forest habitat patches in conserved in SHAs.

The watershed analysis indicates that the amount of habitat (raw acres) on WDNR lands in southwest Washington will either increase or stay the same in each of the watershed analysis areas over the term of the HCP (Table 50).

Management under the Interim Strategy has maintained most of the existing habitat on WDNR lands, resulting in the documentation and protection of occupied sites, and has protected existing reclassified habitat within a 0.5-mile radius of occupied sites. The proposed Long-Term Strategy will result in the release of some habitat that would otherwise be protected under the Interim Strategy but will also establish SHAs in key areas for maintaining and improving the distribution murrelet habitat by creating large contiguous blocks of long-term forest cover.

The proposed SHAs and other areas of LTFC will provide conservation in areas that would otherwise be subject to continued habitat fragmentation and edge effects under the Interim Strategy. This is particularly true in the North Puget landscape, where there are few documented occupied sites (3,834 acres) representing only 6 percent of the existing habitat. Conservation of habitat under the Interim Strategy, particularly in the North and South Puget HCP planning units is random and based on the field delineation of small patches of habitat. These habitat patches are not harvested, but harvest may occur all around them, resulting in increasing habitat fragmentation and edge effects over time. WDNR also has the option to implement surveys for murrelets under the Interim Strategy, and release habitat for harvest that is not occupied. Implementing a survey and manage approach under a continued Interim Strategy would ultimately result in substantial reduction in the distribution of habitat on WDNR lands, because as the murrelet population in Washington continues to decline, the probability of detecting new occupied sites continues to decrease as well.

Table 50. Summary of changes in the distribution of habitat (raw acres) on WDNR-lands by watershed area in southwest Washington.

HCP Unit	HUC	Watershed name	Acres of WDNR-managed land	Decade 0 habitat (raw acres)	Decade 0 percent of WDNR land in habitat	Decade 5 habitat (raw acres)	Decade 5 percent of WDNR land in habitat	Increase or decrease in distribution of habitat
Columbia	1708000307	Elochoman River-Frontal Columbia River	23,349	7,347	31%	7,197	31%	Same
Columbia	1708000306	Germany Creek-Frontal Columbia River	21,431	2,997	14%	3,413	16%	Increase
Columbia	1708000603	Grays Bay	12,183	2,690	22%	3,458	28%	Increase
Columbia	1708000604	Wallacut River-Frontal Columbia River	225	213	94%	213	94%	Same
South Coast	1710010305	Black River-Chehalis River	99,107	2,435	2%	12,789	13%	Increase
South Coast	1710010601	North River	4,998	739	15%	819	16%	Increase
South Coast	1710010603	Willapa River	43,245	3,116	7%	6,022	14%	Increase
South Coast	1710010301	South Fork Chehalis River-Chehalis River	32,638	1,042	3%	4,392	13%	Increase
South Coast	1710010604	Nemaha River-Frontal Willapa Bay	13,819	3,754	27%	4,386	32%	Increase
South Coast	1710010605	Naselle River-Frontal Willapa Bay	12,668	3,196	25%	4,584	36%	Increase

Source: WDNR HUC analysis 20190930.

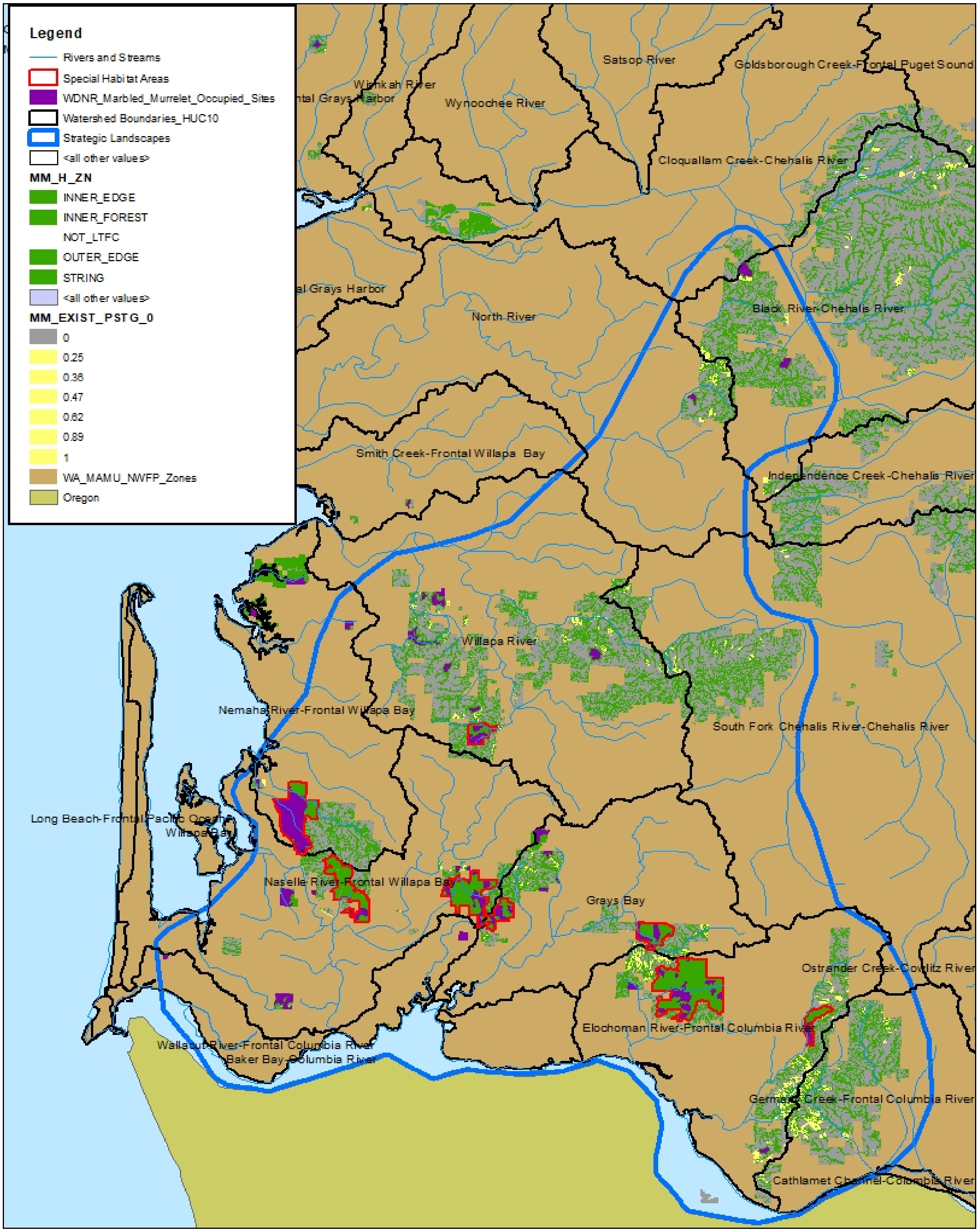

Figure 8. Watershed analysis areas in southwest Washington. Green and purple (occupied sites) areas represent long-term forest cover. Yellow areas indicate habitat that will be released for harvest.

The distribution of murrelet habitat in Washington is currently disjunct, with a major gap in distribution of habitat and occupied sites occurring on the southwest Washington coast from roughly the Grays Harbor south to the Columbia River. WDNR has significant land ownership in this region (260,000 acres in the South Coast HCP Unit), but only about 7 percent of this land base currently contains habitat. The proposed Long-Term Strategy is projected to increase the amount raw habitat in the South Coast HCP unit from 7 percent to about 15 percent representing a significant increase in the distribution of murrelet habitat in this location (Table 50, above). The Science Team (Alternative F) (FEIS 2019, Chapter 2) recommended much greater conservation of lands in the South Coast HCP unit compared to the proposed Long-Term Strategy. However, this would require additional conservation commitments that would far exceed the habitat impacts anticipated under the proposed Long-Term Strategy. Rather than focus on increasing the amount of habitat in areas that currently have very little existing murrelet habitat, the proposed Long-Term Strategy focuses conservation efforts in those areas where WDNR lands still contain significant amounts of existing habitat. The network of SHAs and occupied sites conserved in the southwest Washington strategic locations represent the highest priority locations for maintaining and improving distribution of habitat in this landscape.

12.4.2.1 Conclusion Regarding Effects to Habitat Distribution

All of the measures that we have to evaluate the distribution of habitat on WDNR lands indicate that the proposed Long-Term Strategy will maintain or improve the distribution of habitat on WDNR land at the scale of the HCP planning units and the strategic locations, within significant increases in the distribution of habitat estimated in the Straits, South Puget, and South Coast HCP planning units. The watershed analysis indicated six watersheds where the distribution of habitat on WDNR-managed lands is expected to decrease. In each case, none of the watersheds that are projected to have decreases in habitat over the term of the HCP will result in an elimination of habitat from WDNR lands within the watershed.

The designation of SHAs in the strategic locations represent key locations where conservation on WDNR-managed lands is essential for maintaining and improving distribution of habitat in the action area and in Washington. As described in the previous sections, the area of habitat in both raw acres and adjusted acres is projected to increase at the scale of all WDNR lands within the HCP area, replacing habitat released for harvest, and increasing the total amount of murrelet habitat (raw acres) on WDNR lands from approximately 15 percent to 20 percent by the end of the HCP.

12.5 Population Viability Analysis

Murrelet populations in Washington are declining. Continued loss of habitat and lag effects from past habitat loss and fragmentation are major factors contributing to the decline. However, factors other than nesting habitat also contribute to poor reproduction and survival in murrelets. With a declining population, it can be difficult to discern the effect of a particular action from the background rate of decline. To help understand how murrelet populations might respond to changes in nesting habitat under different conservation alternatives, WDNR engaged Peery and

Jones (2019), to develop a PVA using projected estimates of future habitat. The information presented here is a summary of the detailed information provided in Peery and Jones final report, which is included in the FEIS (2019, Appendix C).

The PVA model is not intended to provide an absolute estimate of population response. Instead, it is intended as a tool to determine how murrelet populations might respond to different conservation alternatives compared to each other. On WDNR-managed lands, the P-stage model was used to project future habitat growth. This information was not available on non-WDNR-managed lands, so Maxent[11] data were used to estimate current murrelet habitat for all other lands. Maxent does not project habitat into the future, so habitat quantity and quality were assumed to be static on non-WDNR-managed lands. This is a recognized limitation of the PVA, but it also provides a perspective on how, if all else is equal, habitat changes on WDNR-lands may influence population trends in Washington.

As is common in PVAs, several simplifying assumptions regarding murrelet demography, dispersal, and breeding biology were required. For example, the values used for average nesting success in the PVA are higher than what is typically reported for murrelets. Nesting success in the PVA used a value of 0.55 for interior forest, and 0.38 for forest degraded by hard edge conditions (Peery and Jones 2019, p. 19). These values were derived from observations of murrelet nesting success in edges vs. interior forest patches (McShane et al. 2004, p. 4-89), and they were used to reflect habitat degradation associated with edges. Applying these values to the adjusted acres (which excludes habitat in *stringers*), results in a baseline nesting success rate of 0.5343 on WDNR lands (Peery and Jones 2019, p. 48), compared to an average nest success rate of about 0.33 reported for murrelets across their entire range (Raphael et al. 2018, p. 322). Nest success is quite variable (ranging from 0 to 69 percent), but is typically low, usually less than 50 percent (Raphael et al. 2018, p. 322).

Model predictions of risk and population size are best viewed in a relative sense. The uncertainties underlying the population viability model do not support absolute predictions of ending population size (for example, the exact number of murrelets at a given point in time). Due to uncertainty in factors influencing future murrelet population trends, Peery and Jones developed two different modeling scenarios:

- A “risk analysis” scenario was developed based on the assumption that both habitat loss and other environmental stressors such as marine conditions are responsible for the murrelet population decline in Washington. This scenario used relatively pessimistic demographic rates that result in a declining murrelet population with less ability to use habitat as it develops. In the risk scenario adult survival was assumed to be 0.87 (i.e., 87 percent of adult murrelets survive from one year to the next) (Peery and Jones 2019, p. 8).

[11] Maxent is a habitat model that was used to estimate marbled murrelet habitat across all land ownerships for the Northwest Forest Plan 20-year monitoring report (Falxa and Raphael 2016).

- An "enhancement analysis" scenario assumes that loss of habitat is the primary cause for population decline and uses more optimistic demographic rates that result in a murrelet population with greater capacity to respond positively to increases in habitat as it develops. In the enhancement scenario adult survival was assumed to be 0.90 (Peery and Jones 2019, p. 2018).

To focus on the relative differences between the alternatives, murrelets in Washington were assumed to belong to two simplified subpopulations (one on WDNR-managed lands, and one on non-WDNR lands), with habitat conditions artificially held constant on non-WDNR lands. Simulations of the Washington population assumed that the two subpopulations were connected by dispersal, while simulations of the population on WDNR-managed lands alone assumed no dispersal. The PVA model simulated murrelet populations over 50 years in response to current and projected future habitat conditions on WDNR-managed lands.

The starting population used in the model represents the average population in Washington for the years from 2011 to 2015 (7,232 murrelets). The PVA is a female-based model, so the number of females was assumed to be 3,616 murrelets (Peery and Jones 2019, p. 13). Based on estimates of habitat capacity, 15 percent of the population was assumed to be associated with habitat on WDNR-managed lands (542 females), and 85 percent are assumed to associated with all other lands (3,074 females). The total number of females includes juveniles, subadults, and adults. All model simulations begin with a starting population that assumed that 40 percent of adults were non-breeding (i.e., the population is above carrying capacity), in order in order to simulate the 5 percent annual rate of decline in the murrelet population estimated in Washington for the period from 2001 to 2015 (Peery and Jones 2019, p. 18). With a starting population above habitat carrying capacity, the modeled populations continue to decline in the initial years of the simulation in all scenarios.

Model outputs include average ending population size and the proportion of model runs that fell below specified fractions of the initial population size as a measure of quasi-extinction probability. The quasi-extinction probability is the probability of the population dropping below a certain fraction (e.g., ½, ¼) of the starting population. The model results are based on an average of 10,000 model simulations with biologically appropriate levels of random variation in survival and reproductive rates to simulate environmental stochasticity.

The PVA projections for the Washington population are greatly influenced by the assumption that murrelet habitat capacity will remain static on non-WDNR-managed lands, and the only change in habitat is that which occurs on WDNR-managed lands. In fact, inland habitat is expected to increase on federal lands over the next 50 years as a result of the *Northwest Forest Plan*, but the rate of future murrelet habitat development on federal lands in Washington has not been quantified (Raphael et al. 2018, p. 316).

Because the PVA results are comparative in nature, we present 4 conservation alternatives in this summary – Alternative A, which represents continued implementation of the Interim Strategy, Alternative H with metering, which represents the proposed Long-Term Strategy, Alternative F, which represents the maximum conservation alternative analyzed and Alternative B, which represents the minimum conservation alternative analyzed These alternatives are described in detail in the FEIS (2019, Chapter 2). Alternative A provides a basis to compare the proposed action against the baseline of continued implementation of the Interim Strategy, while Alternative B, and F represent bookends for conservation alternatives analyzed in the PVA. Also included in the summaries is a "baseline" model scenario which demonstrates how the simulated population responds if habitat conditions on WDNR remained the static over time.

Peery and Jones (2019) did not explicitly report on rates of population change over time. We used the population estimate reported by Peery and Jones (2019, p. 50) for each decade to calculate the average rate of population change under the risk and enhancement scenarios. These estimates were derived by calculating the percent difference between population estimates at each 10-year interval and then dividing this by 10 to get an average annual rate of population change for each decade in the model simulation. The average rate of population change (*lambda*) can then be used to compare between the observed rate of population change in Washington, and the potential future rates estimated from the PVA analysis.

12.5.1 PVA Risk Analysis – Population Estimates and Quasi-Extinction Risk

In the risk analysis, average murrelet survival rates are lower, so the simulated murrelet populations continue to decline over the entire 50 years, but the rate of population decline stabilizes in the 3rd decade at a rate of about -1.4 to -1.5 percent per year (Table 51). At the scale of the WDNR lands, the murrelet population is projected to decline to 23 to 37 percent of the current population size depending on conservation alternative, with the proposed Long-Term Strategy projected to decline to about 33 percent of the current population (Table 52). Compared to continuing the Interim Strategy (which releases 3,073 fewer acres of habitat for harvest), the proposed Long-Term Strategy is projected to have a lower rate of population decline over the 50-year simulation period, resulting in a larger ending population (33 percent vs. 28 percent). At the scale of the Washington population, the change in habitat on WDNR-managed land results in slight differences in ending population sizes, with proposed Long-Term Strategy projected to support a larger population relative to the continuing the Interim Strategy (Table 53).

Table 51. PVA Risk Analysis – Average annual rate of population change on WDNR lands for each 10-year interval.

WDNR lands – Risk analysis	**Year of Simulation**					
Alternative	**0**	**10**	**20**	**30**	**40**	**50**
Alt B - Minimum LTFC:	-5%	-4.9%	-3.0%	-1.4%	-1.4%	-1.4%
Alt A - Interim Strategy:	-5%	-4.3%	-2.2%	-1.3%	-1.4%	-1.5%
Alt H - Proposed Long-Term Strategy	**-5%**	**-3.5%**	**-2.0%**	**-1.5%**	**-1.4%**	**-1.4%**
Alt F – Maximum LTFC	-5%	-3.1%	-1.4%	-1.4%	-1.4%	-1.5%
Baseline (no change in habitat)	-5%	-3.6%	-2.1%	-1.8%	-1.7%	-1.6%

Source: Derived from the PVA results reported by Peery and Jones (2019, p. 50).

Table 52. PVA Risk Analysis - WDNR lands. Projected mean population sizes (number of female murrelets) at each 10-year interval.

WDNR lands – risk analysis	**Year of Simulation**						**Percent of starting population**
Alternative	**0**	**10**	**20**	**30**	**40**	**50**	
Alt B - Minimum LTFC:	542	278	195	169	146	125	23%
Alt A - Interim Strategy:	542	306	241	208	179	153	28%
Alt H - Proposed Long-Term Strategy	**542**	**350**	**279**	**238**	**205**	**177**	**33%**
Alt F – Maximum LTFC	542	372	319	275	236	201	37%
Baseline (no change in habitat)	542	349	276	227	188	158	29%

Source: Peery and Jones (2019, p. 50).

Table 53. PVA Risk Analysis - Washington. Projected mean population sizes (number of female murrelets) at each 10-year interval.

Washington – risk analysis	**Year of Simulation**						**Percent of starting population**
Alternative	**0**	**10**	**20**	**30**	**40**	**50**	
Alt B - Minimum LTFC:	3,616	2,294	1,806	1,500	1,260	1,066	29.5%
Alt A - Interim Strategy:	3,616	2,320	1,837	1,533	1,291	1,089	30.1%
Alt H - Proposed Long-Term Strategy	**3,616**	**2,345**	**1,863**	**1,551**	**1,311**	**1,114**	**30.8%**
Alt F – Maximum LTFC	3,616	2,362	1,892	1,577	1,328	1,125	31.1%
Baseline (no change in habitat)	3,616	2,340	1,863	1,545	1,291	1,089	30.1%

Source: Peery and Jones (2019, p. 50).

In the risk analysis, the population continues to decline over the entire modelling period, so the probability that the simulated murrelet population will decline to ½ the current population size is high (78 percent or higher). At the scale of WDNR-lands, the proposed Long-Term Strategy has lower quasi-extinction risk compared to continuing the Interim Strategy, particularly at the ¼ population threshold, where there is a 10 percent difference in quasi-extinction risk between the Interim Strategy and proposed Long-Term Strategy (Table 54). At the scale of the Washington population, the proposed Long-Term Strategy is projected to have a slightly lower quasi-extinction risk compared to the Interim Strategy (Table 55).

Table 54. PVA Risk Analysis – WDNR lands. Quasi-extinction probabilities – probability that the murrelet population will decline to a specified fraction of the current population size.

WDNR lands – Risk analysis	**Fraction of Initial Population Size**			
Alternative	**1/2**	**1/4**	**1/8**	**1/16**
Alt B - Minimum LTFC:	94%	66%	24%	4%
Alt A - Interim Strategy:	89%	53%	16%	2%
Alt H - Proposed Long-Term Strategy	**85%**	**43%**	**9%**	**0.6%**
Alt F – Maximum LTFC	78%	35%	7%	0.4%
Baseline (no change in habitat)	90%	46%	10%	1%

Source: Peery and Jones (2019, p. 49). A probability of 90 % means that in 9,000 out of 10,000 simulations, the modelled population dropped below the defined threshold.

Table 55. PVA Risk Analysis – Washington. Quasi-extinction probabilities – probability that the murrelet population will decline to a specified fraction of the current population size.

Washington – Risk analysis	**Fraction of Initial Population Size**			
Alternative	**1/2**	**1/4**	**1/8**	**1/16**
Alt B - Minimum LTFC:	82%	34%	5%	0%
Alt A - Interim Strategy:	80%	32%	5%	0%
Alt H - Proposed Long-Term Strategy	**79%**	**32%**	**5%**	**0%**
Alt F – Maximum LTFC	78%	30%	5%	0%
Baseline (no change in habitat)	80%	32%	5%	0%

Source: Peery and Jones (2019, p. 49). A probability of 90 % means that in 9,000 out of 10,000 model simulations, the modelled population dropped below the defined threshold.

12.5.2 PVA Enhancement Analysis – Population Estimates and Quasi-Extinction Risk

In the enhancement analysis, average murrelet survival rates are higher, so the population has the potential to increase with increases in habitat on WDNR-lands. Because the current population is assumed to be above current habitat capacity, the modelled populations continue to decline during the first decade, but the rate of decline gradually slows, and by the 3rd decade, the modelled population on WDNR lands is projected to begin increasing in response to increases in habitat. By the end of the analysis period, the rate of population change is positive at about 1 percent growth per year (Table 56).

At the scale of the WDNR lands, the murrelet population is projected to decline, but then gradually increases to 70 to 120 percent of the current population size depending on conservation alternative. Under the proposed Long-Term Strategy, the population declines to about 73 percent of the current population size by year 20, but then gradually increases to about 90 percent of the current population (Table 57). Compared to continuing the Interim Strategy (which releases 3,073 fewer acres of habitat for harvest), the proposed Long-Term Strategy is projected to have a lower rate of population decline during the first three decades, and then a similar rate of population increase, resulting in a slightly larger ending population (90 percent vs. 88 percent). The enhancement analysis also indicates that under the maximum conservation alternative considered (e.g., Alt F), it is theoretically possible to stabilize, and reverse population decline at the scale of WDNR lands within 20 to 30 years, resulting in a projected ending population that is at or above the current population level.

At the scale of the Washington population, the change in habitat on WDNR land results in slight differences in ending population sizes, with proposed Long-Term Strategy projected to support a larger population relative to the continuing the Interim Strategy (Table 58).

Table 56. PVA Enhancement Analysis – Average annual rate of population change on WDNR lands for each 10-year interval.

WDNR lands – Risk analysis	Year of Simulation					
Alternative	**0**	**10**	**20**	**30**	**40**	**50**
Alt B - Minimum LTFC:	-5%	-3.00%	-1.69%	+0.28%	+0.88%	+1.02%
Alt A - Interim Strategy:	-5%	-2.48%	-0.82%	+0.53%	+0.98%	+1.05%
Alt H - Proposed Long-Term Strategy	**-5%**	**-2.03%**	**-0.79%**	**+0.25%**	**+0.91%**	**+0.97%**
Alt F – Maximum LTFC	-5%	-1.55%	+0.27%	+0.98%	+1.15%	+1.30%
Baseline (no change in habitat)	-5%	-2.05%	-0.90%	-0.46%	-0.23%	-0.22%

Source: Derived from the PVA results reported by Peery and Jones (2019, p. 50).

Table 57. PVA Enhancement Analysis – WDNR lands. Projected mean population sizes (number of female murrelets) on WDNR lands at each 10-year interval.

WDNR lands – Enhancement analysis	Year of Simulation						Percent of starting population
Alternative	**0**	**10**	**20**	**30**	**40**	**50**	
Alt B - Minimum LTFC:	542	379	315	324	352	388	72%
Alt A - Interim Strategy:	542	407	374	394	433	479	88%
Alt H - Proposed Long-Term Strategy	**542**	**432**	**398**	**407**	**444**	**488**	**90%**
Alt F – Maximum LTFC	542	458	470	516	575	650	120%
Baseline (no change in habitat)	542	431	392	374	365	358	66%

Source: Peery and Jones (2019, p. 50).

Table 58. PVA Enhancement Analysis – Washington. Projected mean population sizes (number of female murrelets) on WDNR lands at each 10-year interval.

Washington – Enhancement analysis	Year of Simulation						Percent of starting population
Alternative	**0**	**10**	**20**	**30**	**40**	**50**	
Alt B - Minimum LTFC:	3,616	2,843	2,558	2,472	2,453	2,454	68%
Alt A - Interim Strategy:	3,616	2,868	2,617	2,522	2,514	2,532	70%
Alt H - Proposed Long-Term Strategy	**3,616**	**2,893**	**2,649**	**2,558**	**2,537**	**2,558**	**71%**
Alt F – Maximum LTFC	3,616	2,918	2,715	2,661	2,681	2,734	76%
Baseline (no change in habitat)	3,616	2,890	2,640	2,526	2,467	2,428	67%

Source: Peery and Jones (2019, p. 50).

In the enhancement analysis, the assumed higher annual survival rates result in much lower quasi-extinction risk compared to the risk analysis. The probability that the simulated murrelet population will decline to ½ the current population size is low (about 10 percent). At the scale of WDNR-lands, the proposed Long-Term Strategy has a slightly lower quasi-extinction risk (9 percent) compared to continuing the Interim Strategy (10 percent) at the ½ threshold (Table 59). At the scale of the Washington population, the risk that the population will decline to ½ the current population size was estimated at 5 to 7 percent, indicating low population risk. The proposed Long-Term Strategy is projected to have a slightly lower quasi-extinction risk (6 percent) compared to the Interim Strategy (7 percent) at the ½ threshold (Table 60).

Table 59. PVA Enhancement Analysis –WDNR lands. Quasi-extinction probabilities – the probability that the murrelet population will decline to a specified fraction of the current population size.

WDNR lands – Enhancement analysis	Fraction of Initial Population Size			
Alternative	**1/2**	**1/4**	**1/8**	**1/16**
Alt B - Minimum LTFC:	19%	1.2%	0%	0%
Alt A - Interim Strategy:	10%	0.6%	0%	0%
Alt H - Proposed Long-Term Strategy	**9%**	**0.4%**	**0%**	**0%**
Alt F – Maximum LTFC	5%	0.4%	0%	0%
Baseline (no change in habitat)	16%	0.5%	0.0%	0.0%

A probability of 90 % means that in 9,000 out of 10,000 model simulations, the modelled population dropped below the defined threshold. Source: Peery and Jones (2019, p. 49).

Table 60. PVA Enhancement Analysis –Washington. Quasi-extinction probabilities – the probability that the murrelet population will decline to a specified fraction of the current population size.

Washington Enhancement analysis	Fraction of Initial Population Size			
Alternative	**1/2**	**1/4**	**1/8**	**1/16**
Alt B - Minimum LTFC:	7%	0%	0%	0%
Alt A - Interim Strategy:	7%	0%	0%	0%
Alt H - Proposed Long-Term Strategy	**6%**	**0%**	**0%**	**0.0%**
Alt F – Maximum LTFC	5%	0%	0%	0.0%
Baseline (no change in habitat)	7%	0%	0%	0.0%

A probability of 90 % means that in 9,000 out of 10,000 model simulations, the modelled population dropped below the defined threshold. Source: Peery and Jones (2019, p. 49).

12.5.3 Projected Rates of Population Change

Under the risk analysis, the estimated rate of population change gradually decreases and continues to decline at rate of about -1.7 to -1.5 percent per year, with little discernable difference amongst the conservation alternatives on WDNR lands (Table 61). The rate of population decline under the proposed Long-Term Strategy is slightly less compared to the rate of change estimated for continuing the Interim Strategy.

Table 61. PVA Risk Analysis – Average annual rate of population change in Washington for each 10-year interval.

Washington – Risk analysis	Year of Simulation					
Alternative	**0**	**10**	**20**	**30**	**40**	**50**
Alt B - Minimum LTFC:	-5%	-3.7%	-2.1%	-1.7%	-1.6%	-1.5%
Alt A - Interim Strategy:	-5%	-3.6%	-2.1%	-1.7%	-1.6%	-1.6%
Alt H - Proposed Long-Term Strategy	**-5%**	**-3.5%**	**-2.1%**	**-1.7%**	**-1.6%**	**-1.5%**
Alt F – Maximum LTFC	-5%	-3.5%	-2.0%	-1.7%	-1.6%	-1.5%
Baseline (no change in habitat)	-5%	-3.5%	-2.0%	-1.7%	-1.6%	-1.6%

Source: Derived from the PVA results reported by Peery and Jones (2019, p. 50).

Under the enhancement analysis, the estimated rate of population decline stabilizes in the 3rd or 4th decade and begins to increase by the 5th decade of the model simulations. Under the enhancement analysis, changes in habitat on WDNR lands result in positive population growth rates at the scale of WDNR lands in later decades, which is discernable in the projections at the scale of the Washington population. Using the enhancement analysis for comparison, the proposed Long-Term Strategy results in a lower rate of population decline and increased rates of population growth by the end of the modelled period compared to the Interim Strategy (Table 62).

Table 62. PVA Enhancement Analysis – Average annual rate of population change in Washington for each 10-year interval.

Washington – Enhancement analysis	**Year of Simulation**					
Alternative	**0**	**10**	**20**	**30**	**40**	**50**
Alt B - Minimum LTFC:	-5%	-2.14%	-1.00%	-0.33%	-0.08%	+0.01%
Alt A - Interim Strategy:	-5%	-2.07%	-0.88%	-0.36%	-0.03%	+0.07%
Alt H - Proposed Long-Term Strategy	**-5%**	**-2.00%**	**-0.84%**	**-0.34%**	**-0.08%**	**+0.08%**
Alt F – Maximum LTFC	-5%	-1.93%	-0.70%	-0.20%	+0.07%	+0.20%
Baseline (no change in habitat)	-5%	-2.01%	-0.86%	-0.43%	-0.24%	-0.16%

Source: Derived from the PVA results reported by Peery and Jones (2019, p. 50).

As stated above, the projected population changes in Washington represent theoretical scenarios in which habitat does not change on non-WDNR lands. While this is a recognized limitation of the model, it also provides perspective on the relative contribution of nesting habitat on WDNR lands to the total population performance in Washington. All else being equal, habitat conservation on WDNR lands can influence population change at the scale of the Washington population, however the degree of influence is relatively small for the range of alternatives considered. If habitat on federal lands increases over the term of the HCP (which is likely), the WDNR lands will have a smaller role in contributing to murrelet populations than this analysis shows. If on the other hand, habitat declines on federal lands due natural disturbance, then WDNR lands could have a larger proportional effect on the Washington population than this analysis shows. Both risk and enhancement scenarios demonstrate that metering habitat loss over two decades as opposed to releasing all habitat in the first decade of implementation results in a reduced rate of initial population decline, sustains a larger population over time, and results in lower quasi-extinction risk.

12.5.4 PVA Habitat Analysis

The habitat analysis used in the PVA scenarios modelled by Peery and Jones (2019) relies on the underlying P-stage value of habitat located in occupied sites and allows projected increases in habitat quality within occupied sites to contribute to an increase in adjusted acres of habitat over time. This is a departure from the *Analytical Framework* used to calculate impacts and mitigation, where all forest in occupied sites is assigned a P-stage value of 1, and there is no transition of habitat within occupied sites to higher P-stage values, so any recruitment of "new" habitat within the occupied sites is not credited in the *Analytical Framework*.

As noted in the *Environmental Baseline*, there is an estimated 207,066 acres of P-stage habitat on WDNR lands. This estimate includes 9,105 acres within occupied sites that have an underlying P-stage value of 0, indicating the forest stand inventory information in WDNR's database for these stands do not meet minimum criteria for P-stage (70 years for western hemlock, 120 years for Douglas-fir dominated stands). However, most of these 9,105 acres were originally identified as "reclassified habitat" and surveys at these sites documented murrelet occupancy behaviors, which is why these sites are classified as occupied sites with a P-stage value of 1.

The habitat analysis used in the PVA allows for the recruitment of new habitat within occupied sites, which contributes to an increase in total adjusted acres of habitat overtime. Consistent with the *Analytical Framework*, the PVA excludes all habitat located in *stringers,* and discounts habitat value for edge effects, and calculates an annual average P-stage value for all habitat on WDNR lands. This results in a starting habitat baseline of 162,592 acres in the PVA:

P-stage raw habitat = 207,066 (includes all P-stage 1 stands)
-9,105 (occupied sites with an underlying P-stage value of 0)
197,961 (baseline of underlying P-stage habitat).
-35,369 (habitat in located in *stringers*)
= 162,592 starting raw habitat baseline used in all PVA scenarios.

The murrelet population projections in the PVA are based on a starting baseline of 162,592 raw acres of habitat on WDNR lands, and the projected habitat changes over time. Because different conservation alternatives result in different configurations and quality of habitat conserved on WDNR lands, the average P-stage value of habitat varies by alternative.

Using raw acres of habitat as a basis for comparison, neither continuing the Interim Strategy or the proposed Long-Term Strategy recruit sufficient new habitat in the PVA analysis to fully recover raw habitat acres released for harvest – both alternatives have an ending balance of raw habitat acres that are slightly lower than the starting raw habitat (97 percent for the proposed Long-Term Strategy) (Table 63). However, the number of adjusted acres (not including a time discount), which is the measure of both habitat quality and configuration, increases to 127 percent of the starting habitat value, demonstrating that the Long-Term Strategy replaces the adjusted acres of habitat removed by harvest, and will result in an increase in habitat quality on WDNR lands. Habitat projections for both the Interim Strategy and the proposed Long-Term Strategy result in similar amounts of raw habitat conserved on WDNR lands, but because the proposed Long-Term Strategy conserves more habitat in *interior* forest compared to the Interim Strategy, the adjusted acres of habitat conserved are slightly higher under the proposed Long-Term Strategy, resulting in higher projected murrelet populations in the PVA simulations (Table 63).

In addition to evaluating the conservation alternatives, WDNR also produced a theoretical habitat scenario in which all current habitat and any stand that is capable of transitioning to habitat over the remaining term of the HCP is conserved, which resulted in a doubling of both raw acres and adjusted acres on WDNR lands (Table 63). Peery and Jones (2019) did not include this scenario in their final PVA simulations.

Table 63. PVA enhancement analysis. Comparison of estimated habitat and projected mean population sizes (number of female murrelets) on WDNR lands at each 10-year interval.

WDNR lands – Enhancement analysis	**Year of Simulation**						**Percent of current estimate**
Alt B – Minimum LTFC	**0**	**10**	**20**	**30**	**40**	**50**	
Raw habitat	162,592	113,039	116,278	121,012	132,051	140,890	87%
Average P-stage	0.409	0.502	0.527	0.542	0.538	0.539	~
Adjusted habitat	66,475	56,765	61,248	65,625	71,080	75,895	114%
Projected murrelet population	542	379	315	324	352	388	72%

Alt A – Interim Strategy:	**0**	**10**	**20**	**30**	**40**	**50**	**Percent**
Raw habitat	162,592	127,943	131,976	137,705	149,901	159,647	98%
Average P-stage	0.409	0.483	0.509	0.526	0.526	0.529	~
Adjusted habitat	66,475	61,752	67,185	72,396	78,883	84,377	127%
Projected murrelet population	542	407	374	394	433	479	88%

Alt H - Proposed Long-Term Strategy	**0**	**10**	**20**	**30**	**40**	**50**	**Percent**
Raw habitat	162,592	137,607	130,835	136,206	148,487	157,942	97%
Average P-stage	0.409	0.483	0.512	0.532	0.532	0.536	~
Adjusted habitat	**66,475**	**66,417**	**66,933**	**72,430**	**78,943**	**84,640**	**127%**
Projected murrelet population	542	432	398	407	444	488	90%

Alt F – Maximum LTFC	**0**	**10**	**20**	**30**	**40**	**50**	**Percent**
Raw habitat	162,592	159,539	164,027	171,543	193,078	212,037	130%
Average P-stage	0.409	0.443	0.475	0.501	0.499	0.501	~
Adjusted habitat	66,475	70,625	77,952	85,988	96,265	106,178	160%
Projected murrelet population	542	458	470	516	575	650	120%

Maximum potential habitat on WDNR	**0**	**10**	**20**	**30**	**40**	**50**	**Percent**
Raw habitat	162,592	199,463	206,231	219,493	260,455	308,969	190%
Average P-stage	0.409	0.401	0.440	0.467	0.460	0.446	~
Adjusted habitat	66,475	79,888	90,652	102,591	119,787	137,863	207%

Sources: Peery and Jones 2019, p. 50, and WDNR pva_input_2019_06_06.

12.5.5 PVA Habitat Capacity Analysis

Habitat carrying capacity is a measure of the potential population size that can be supported by a given amount of suitable nesting habitat. Using habitat capacity as a simple index, we used the habitat projections developed for the PVA to compare habitat capacity over time. Both the "risk" and "enhancement" scenarios in the PVA begin with the assumption that of the 542 female murrelets associated with WDNR-managed lands, 217 are breeding adults with nest sites (Peery and Jones 2019, p. 25). Using the PVA habitat analysis, these nest sites are associated with the 66,475 adjusted acres of habitat currently on WDNR-managed lands (306 adjusted acres per pair). Assuming the habitat capacity index is constant (306 adjusted acres per pair), we can calculate a simple index of available nesting sites on WDNR lands over the projected term of the HCP. The resulting numbers can be compared with the starting 217 females expected to be able to nest currently on WDNR-managed lands.

As with previous comparisons of the PVA outputs, the projected differences between continuing the Interim Strategy and the proposed Long-Term Strategy show very slight differences in future habitat capacity – both alternatives increase habitat capacity to about the same amount - 127 percent of current capacity (Table 64). The major differences occur in the first two decades of habitat projections, where metering habitat released for harvest under the proposed Long-Term Strategy over two decades maintains the adjusted acres of habitat relatively constant (habitat ingrowth and habitat removal are balanced). By the final decade, the total amount of adjusted acres under the proposed Long-Term Strategy is slightly higher, with an ending habitat capacity to theoretically support 276 nesting pairs.

Table 64. PVA habitat capacity – an index of potential murrelet nest sites on WDNR lands at each 10-year interval.

WDNR lands – Enhancement analysis	**Year of Simulation**						**Percent of starting population**
Alternative	**0**	**10**	**20**	**30**	**40**	**50**	
Alt B - Minimum LTFC:	217	185	200	214	232	248	114%
Alt A - Interim Strategy:	217	202	219	236	258	275	127%
Alt H - Proposed Long-Term Strategy	**217**	**217**	**218**	**236**	**258**	**276**	**127%**
Alt F – Maximum LTFC	217	231	254	281	314	347	160%
Maximum potential habitat on WDNR	217	261	296	335	391	450	207%

WDNR lands have a much greater capacity to support murrelet conservation than that proposed under the Long-Term Strategy. If all existing habitat and stands capable of transitioning to habitat over the next 50 years were conserved, habitat capacity on WDNR lands will increase by over 200 percent compared to the current conditions. This level of conservation is far outside the scope of potential alternatives considered in detail in the FEIS.

12.5.6 Summary and Interpretation of the Population Viability Analysis

The PVA projections provide insight into how murrelet populations may change over time in response to changes in habitat on WDNR lands within the framework of assumptions that were applied in the model. The assumptions used in the PVA are biologically based and are reasonable in the context of comparing the conservation alternatives considered. Because the model developed by Peery and Jones (2019) incorporates some measures of environmental stochasticity, the projections are much more informative than simple deterministic projections of population decline. Because the PVA uses both risk and enhancement scenarios, it provides comparative measures of both population change and population risk with an element of biological realism. Neither scenario is a true projection of the future population trends in Washington, because habitat on the non-WDNR lands remains static, the PVA does not represent potential population growth that could occur due to increases in habitat on federal lands, or additional loss of habitat on private lands. However, it does provide insight into the relative potential of habitat on WDNR land to influence population trends in Washington if all else remains the same. The model sensitivity analysis completed by Peery and Jones (2019, p. 35) found that acre for acre, murrelet population growth was most sensitive to changes in higher-quality nesting habitat. Considering the PVA results, we draw the following conclusions:

- The rate of harvest (both in amount and quality of habitat) in the first decade drives the duration and depth of the initial population declines.
- Metering harvest of habitat slows the initial population decline and lowers quasi-extinction risk.
- Conservation of larger amounts of higher quality habitat allows for slower decline or quicker recovery, depending on assumptions about survival rates.
- To the extent that the WDNR-only model assumptions are realistic, we expect the largest benefits to come from increases in the amounts of high-quality habitat and *interior* forest, and the largest losses to come from the harvest of the same categories.

The USFWS does not use the PVA results as a direct measure of impact and mitigation provided by the proposed Long-Term Strategy, nor are we using the results to predict the number of murrelets that are likely to be displaced or have their nesting cycle disrupted by HCP-covered activities. We use the PVA results as a basis to compare the proposed Long-Term Strategy to other conservation alternatives considered, including continuation of the Interim Strategy. Whether or not the PVA simulations show a result that the murrelet population "recovers" to the starting population level or higher is not a measure of the mitigation of the proposed Long-Term Strategy, because the baseline rate of population decline used in the PVA exceeds the effect of habitat released for harvest during the first two decades of PVA simulations. WDNR is not solely responsible for the baseline rate of population decline in Washington. In the PVA risk scenarios, populations continue to decline, and none of the alternatives show a recovery to the starting population levels. In the enhancement scenarios, it is theoretically possible for habitat ingrowth on WDNR lands to recover the assumed WDNR-portion of the murrelet population to the starting population level or higher, but the level of habitat conservation (mitigation) required to achieve this potential outcome far exceeds the level of habitat impact WDNR has proposed under the Long-Term Strategy.

All of the comparative measures available from the PVA results demonstrate that metering harvest of habitat over two decades and increasing the amount of habitat conserved in *interior* forest patches (e.g., SHAs and buffering occupied sites), compared to continuing the Interim Strategy (Alternative A), results in improved population projections for murrelet populations under both *risk* and *enhancement* scenarios.

12.6 Summary of Effects to Murrelets in the Action Area

Our assessment of the effects to murrelets includes estimates of nesting habitat affected by removal, edge effects and habitat area exposed to audio/visual disturbance effects. In the preceding sections we described the following habitat effects:

12.6.1.1 Habitat Removal

Removal of up to 38,774 acres of nesting habitat, which equates to 11,085 adjusted habitat acres. Habitat loss will be metered over a minimum of two decades. Habitat removal also includes up to 114 adjusted acres for yarding corridors and new road construction within occupied sites, occupied site buffers, or SHAs. Divided over 5 decades, this equates to about 23 adjusted acres per decade. We expect 0.5 to 0.6 percent of nesting murrelets per year on WDNR-managed lands will be displaced by direct habitat removal, resulting in nest failure, and removing the adults from the breeding population for one or more years for the first 20 years of implementation. Approximately 1 nest site will be lost per year during first 10 years, and 0.5 nest sites will be lost per year during the 2^{nd} decade.

12.6.1.2 Habitat Degradation

Habitat degradation from edge effects is expected to degrade habitat conditions adjacent to roads and *inner edge* and *outer edg*e LTFC. The total acres degraded range from about 5,500 acres up to 7,400 acres per decade. The effect of habitat degradation is reduced habitat capacity and increased predation risk. We expect 5 to 6 percent of nesting murrelets per year on WDNR-managed lands will have increased nest predation in habitat degraded by edge effects (12 nest sites per year at current average nesting density), resulting in about a 20 percent reduction in nest success for the affected nest sites compared to nests in *interior* forest. The relative proportion of nesting habitat exposed to disturbance effects is expected to remain relatively constant at 5 to 6 percent of adjusted acres per year.

12.6.1.3 Disturbance

We expect 2.3 percent of nesting adults on WDNR-managed lands will have reduced nest success as result of disturbance effects (5 nests per year at current average nesting density). Habitat exposed to significant disturbance effects is estimated to range from about 2,200 adjusted acres per year up to about 2,500 adjusted acres per year. Nest success in habitat exposed to disturbance is expected to be reduced by about 40 percent annually, compared to nests in *interior* forest. The relative proportion of nesting habitat exposed to disturbance effects is expected to remain relatively constant at 2.3 percent of adjusted acres per year.

12.6.1.4 Nesting Success

Applying the assumed reduced nesting success rates for habitat removal, degradation, and disturbance to the 18 nests affected by management per year, we found that the management effects result in the loss of 3 nests – one from habitat removal, one from edge effects, and one from disturbance effects. This results in a 3 percent reduction in nest success on WDNR lands per year compared to if all nests were located in *interior* forest patches. This level of lost reproduction is not detectable compared to ongoing rates of harvest, edge effects, and disturbance currently ongoing under the Interim Strategy.

12.6.1.5 Effects to Murrelets on Adjacent Federal Lands

We estimate 225 acres of nesting habitat (raw acres) per year will be degraded by edge effects and exposed to disturbance on adjacent federal lands. At current average nesting densities in raw habitat, this represents less than one nest site disturbed per year on federal lands. The effects of disturbance and habitat degradation due to edge effects to individual murrelets are the same as those described above for WDNR-managed lands (reduced nesting success). This level of reduced nesting success is not detectable compared to ongoing rates of edge effects and disturbance on adjacent federal lands currently ongoing under the Interim Strategy.

12.6.1.6 Discussion of the Effects to Murrelets

Under the proposed Long-Term Strategy, most of the existing murrelet habitat remaining on the WDNR-managed lands will be conserved in LTFC, and these areas are projected to recruit over 100,000 acres of new habitat over the remaining term of the HCP. Protection of all documented occupied sites with 328 ft.-wide forested buffers, and the designation of 20 SHAs in strategic locations are projected to result in a net increase in total habitat area conserved in *interior* forest patches, increased habitat patch size, and will either maintain or increase the current distribution of murrelet habitat on WDNR lands. The percent of WDNR land with habitat is projected to increase from 15 percent (207,000 acres) to about 20 percent (273,000 acres) over the remaining term of the HCP.

Scattered patches of mostly low-quality murrelet habitat located outside of LTFC and other set-asides is likely to be harvested over the next 20 years. Habitat released for harvest (38,774 raw acres), represents about 19 percent of the total habitat that currently exists on WDNR-managed lands. The effects of habitat loss, habitat fragmentation, and disturbance to murrelets are complex, but all such effects ultimately lead to a reduction in murrelet numbers through the displacement of breeding birds, direct mortality of eggs or chicks, and reduced nesting success in affected habitat. Habitat loss without compensatory habitat gains in conserved areas is expected to lead to further population decline. The proposed Long-Term Strategy will meter the effects of habitat loss over two decades, which is intended to maintain habitat capacity to support murrelet nesting (adjusted acres) and recruit new habitat in conserved areas. The effect of metering, along with increasing the amount of habitat conserved in *interior* forest patches is projected to maintain habitat capacity in the short-term (20 years) and increase the total adjusted acres of habitat capacity over the remaining term of the HCP (50 years).

12.6.1.7 Numbers of Murrelets Affected in the Action Area

Unrestricted timber harvest during the nesting season will result in direct mortality to murrelet eggs and/or chicks, and displacement of adult murrelets from nesting habitat. If all habitat was removed at once, we would expect about 23 nesting pairs would be displaced by habitat removal at current nesting densities representing a loss of about 11 percent of the breeding pairs of murrelets assumed to be associated with habitat on WDNR-managed lands. Because habitat removal will be metered over two decades, we estimate about one nesting pair per year will be displaced during the first 10 years, and about half that rate will be displaced by the habitat removal during the second decade. While the rate of habitat loss is measurable, the effects of the projected habitat loss in terms of reduced reproduction or survival of murrelets was not detectable in the PVA from the baseline rate of population decline currently ongoing in Washington.

Based on the simple index of average density, the habitat acres released for harvest (11,805 adjusted acres) will displace approximately 23 nesting pairs, while the habitat acres added (20,839 adjusted acres) will provide habitat capacity to support 44 nesting pairs, a net positive gain in habitat capacity to support 21 additional nesting pairs above the habitat acres released for harvest.

12.6.1.8 Effects to Reproduction of Murrelets in the Action Area

Habitat removal, habitat degradation, and disturbance effects from forest management all result in reduced nesting success on WDNR-managed lands. At current densities, the combined effects result in 3 failed nests per year. Because overall murrelet nest success is low, and the amount of habitat removed, degraded, or disturbed represents only about 8 percent of the total adjusted acres, the difference in nesting success with management vs. without management is small (3 percent). Implementation of the proposed Long-Term strategy will continue to result in reduced nesting success in habitat located adjacent to roads and managed areas. However, the protection of occupied sites, buffers, and SHAs is projected to increase the area of available nesting habitat in *interior* forest patches, which will improve murrelet nesting success on WDNR-managed lands compared to the habitat configuration that exists today.

The PVA provides a robust analysis of the potential effects of both habitat removal and habitat degradation of edge effects in the context of the ongoing population decline in at both the scale of WDNR lands and the Washington population. Under both risk and enhancement scenarios, the habitat effects in the first decades are not discernable from the background rate of population declines, however in both scenarios, reproduction is improved under the Long-Term Strategy in comparison with continuing the Interim Strategy.

12.6.1.9 Effects to Distribution of Murrelets in the Action Area

The distribution of murrelet habitat in Washington is currently disjunct, with a major gap in distribution of habitat and occupied sites occurring on the southwest Washington coast from roughly the Grays Harbor south to the Columbia River. WDNR has significant land ownership in this region (260,000 acres in the South Coast HCP Unit), but only about 7 percent of this land base currently contains habitat. The proposed Long-Term Strategy is projected to increase the amount raw habitat in the South Coast HCP unit from 7 percent to about 15 percent representing a significant increase in the distribution of murrelet habitat in this location. WDNR lands have the capacity to support a much greater increase in the distribution of habitat than what is projected under either continuing the Interim Strategy or the proposed Long-Term Strategy. However, this would require additional conservation commitments that would far exceed the habitat impacts anticipated under the proposed Long-Term Strategy.

All of the measures that we have to evaluate the distribution of habitat on WDNR lands indicate that the proposed Long-Term Strategy will maintain or improve the distribution of habitat on WDNR land at the scale of the Conservation Zones, HCP planning units and the strategic locations, within significant increases in the distribution of habitat estimated in the Straits, South Puget, and South Coast HCP planning units. The watershed analysis indicated six watersheds where the distribution of habitat on WDNR-managed lands is expected to decrease. In each case, none of the watersheds that are projected to have decreases in habitat over the term of the HCP will result in an elimination of habitat from WDNR lands within the watershed.

The designation of SHAs in the strategic locations represent key locations where conservation on WDNR-managed lands is essential for maintaining and improving distribution of habitat in the action area and in Washington. As described in the previous sections, the area of habitat in both raw acres and adjusted acres is projected to increase at the scale of all WDNR lands within the HCP area, replacing habitat released for harvest, and increasing the total amount of murrelet habitat (raw acres) on WDNR lands from approximately 15 percent to 20 percent by the end of the HCP.

13 EFFECTS TO DESIGNATED CRITICAL HABITAT

The critical habitat designation in Washington identified approximately 426,800 acres of state lands (26 percent) managed under the 1997 state lands HCP. Because these lands are managed under an approved HCP issued under section 10(a) of the Act, these lands are excluded from critical habitat by description in the final rule (81 FR 51365 [August 4, 2016]). Therefore, the effects analysis is focused on the effects to designated critical habitat on federal lands adjacent to WDNR-managed lands.

When the USFWS evaluates the effects of a proposed action within critical habitat, we analyze the impacts to individual CHUs in light of their overall contribution to the survival and recovery of murrelets within the individual Conservation Zones, and within the overall range of the murrelet in Washington, Oregon, and California. We do this by analyzing the effects projects may have on the PCEs of the critical habitat that represent specific physical and biological features that are essential to the conservation of the species and may require special management considerations or protection. The PCEs of murrelet critical habitat include (1) individual trees with potential nesting platforms and (2) forested areas within 0.8 kilometer (0.5 mile) of individual trees with potential nesting platforms that have a canopy height of at least one-half the site potential tree height. This includes all such forest, regardless of contiguity (76 FR 61604).

13.1.1 Effects to PCE 1 – Individual Trees with Potential Nesting Platforms

As described in detail under *Fragmentation and Edge Effects*, we anticipate there will be habitat loss and degradation associated with edge effects in designated murrelet critical habitat located adjacent to managed boundaries on HCP-covered lands. For this analysis we used a distance of 100 m (328 ft) to account for the most significant physical and biological effects to murrelet habitat along clearcut 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 et al. 1992, pp. 390-391, van Rooyen et al. 2011, p. 549, Malt and Lank 2009, p. 1274).

Based on our proximity buffers, we estimate there are 5,232 acres of designated critical habitat located within 328 ft. of WDNR-managed boundaries. To estimate potential habitat area affected, we excluded WDNR area conserved in LTFC, and then estimated the habitat area adjacent to WDNR-managed lands. Based on this analysis, we estimated 1,512 acres of potential murrelet nesting habitat is located adjacent to WDNR-managed boundaries (Table 65). The habitat exposed to edge effects is distributed along the perimeter of 17 designated CHUs. Habitat within these areas is likely to be degraded through a reduction in the number of platform trees located along clearcut edges, and a reduction in the total available platforms, and these effects can persist for decades after harvest has occurred (van Rooyen et al. 2001, p. 558).

13.1.2 Effects to PCE 2 – Forested Areas within 0.5-miles of Trees with Platforms

We lack data to specify whether forests along the WDNR-managed boundaries would meet the definition of PCE 2. Based on our proximity buffers, the maximum area of such forest will be about 3,700 acres of forest, dispersed along the boundaries of 26 CHUs in Washington. This estimate is derived by subtracting the estimated nesting habitat along CHU edges from the total estimated lands (5,232 – 1512 = 3,720 acres). Windthrow along managed edges will degrade the function of PCE 2 by reducing overstory canopy cover adjacent to potential platform trees.

Table 65. Summary of designated murrelet critical habitat units in Washington, and potential nesting habitat within CHUs adjacent to WDNR-managed lands.

Conservation Zone	**CHU Name**	**Ownership**	**Total acres in CHU**	**Potential murrelet nesting habitat in CHU (acres)**	**Percent of CHU acres with potential murrelet habitat**	**CHU acres located within 328 ft. of WDNR lands**	**Potential nesting habitat within 328 ft. of WDNR lands**
1	WA-01-b	Federal	8,172	5,566	68%	134	54
1	WA-03-b	Federal	65,027	17,330	27%	0	0
1	WA-06-a	Federal	71,539	23,499	33%	405	201
1	WA-06-b	Federal	44,236	15,445	35%	481	151
1	WA-07-b	Private	1,075	475	44%	29	0
1	WA-07-c	Federal	88,759	20,234	23%	265	17
1	WA-08-a	Federal	85,254	21,853	26%	359	32
1	WA-09-a	Federal	1,826	787	43%	39	0
1	WA-09-b	Federal	108,076	21,119	20%	1,063	109
1	WA-09-c	Federal	4,959	1,068	22%	193	89
1	WA-10-a	Federal	76,593	11,204	15%	42	0
1	WA-10-b	Federal	41,956	7,177	17%	63	0
1	WA-10-c	Federal	25,712	3,284	13%	160	0
1	WA-11-a	Federal	72,196	6,884	10%	84	0
1	WA-11-b	Federal	11,139	539	5%	0	0
1	WA-11-d	Federal	51,360	8,407	16%	1	0
2	WA-02-a	Federal	15,955	11,429	72%	266	145
2	WA-02-b	Federal	1,982	1,017	51%	155	26
2	WA-02-c	Federal	46,342	23,515	51%	123	20
2	WA-02-d	Federal	412	238	58%	36	22
2	WA-03-a	Federal	97,847	43,665	45%	206	90
2	WA-05-b	Private	401	195	49%	0	0
2	WA-05-c	Private	297	62	21%	0	0
2	WA-05-d	Private	327	109	33%	32	0
2	WA-05-f	Private	191	16	8%	0	0
2	WA-05-g	Private	218	50	23%	0	0
2	WA-11-c	Federal	37,589	5,671	15%	127	34
1 & 2	WA-01-a	Federal	60,477	25,391	42%	460	379
1 & 2	WA-07-a	Federal	78,207	15,220	19%	293	98
1 & 2	WA-07-d	Federal	24,112	6,653	28%	60	35
1 & 2	WA-08-b	Federal	20,410	3,934	19%	94	10
1 & 2	WA-09-d	Federal	13,051	2,727	21%	0	0
1 & 2	WA-09-e	Federal	48,827	6,191	13%	62	0
-	-	**Totals:**	**1,204,524**	**310,954**	**26%**	**5,232**	**1,512**
-	-	-	-	-	**Percent:**	**0.43%**	**0.49 %**

Notes: Murrelet habitat estimates are approximate values that represent conditions in 2012, as depicted by Raphael et al. (2016) map data, moderate (class 3) and highest (class 4) suitability. Due to limitations of the habitat model used, the habitat amounts listed above are estimates only, and are not considered to be absolute values.

13.1.3 Summary of Effects to Designated Murrelet Critical Habitat

Critical habitat subunits in Washington encompass over 1.2 million acres in 33 critical habitat units. The degradation of up to 1,500 acres of murrelet habitat located within 328 ft of managed boundaries adjacent to WDNR HCP lands is considered to be an adverse effect to the critical habitat, due to the loss and degradation of individual trees with platforms, and the creation of clearcut edges which reduce the capability of the critical habitat to support successful murrelet reproduction at the scale of the affected stands. However, the affected stands are broadly dispersed along the boundaries of the affected critical habitat subunits and represents a cumulative total of about 0.4 percent of the current nesting habitat within designated critical habitat (Table 65, above). Windthrow and edge effects along WDNR HCP boundaries are not expected to significantly reduce the capability of the critical habitat to provide for a well-distributed and self-sustaining murrelet population at the scale of any critical habitat subunit, Conservation Zone, or range-wide. The conservation role of critical habitat to provide for large blocks of nesting habitat to support successful murrelet reproduction will not be significantly reduced by the effects of forest management on WDNR-managed lands.

14 CUMULATIVE EFFECTS

Cumulative effects include the effects of future state, tribal, local, or private actions that are reasonably certain to occur in the action area considered in this Opinion. Future federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Many actions affecting murrelets within the action area have a federal nexus, and are therefore included in the baseline, rather than as cumulative effects. For example, as discussed in the *Environmental Baseline*, several private timber companies have HCPs, providing a federal nexus for timber harvest activities on their land. Therefore, these actions are included in the baseline rather than as cumulative effects. However, there are still some timber harvest activities on private lands that may negatively affect murrelets. In addition, human population growth and other development in western Washington is likely to lead to other impacts to murrelets and their populations.

14.1.1 Forest Practices

Non-federal lands in the action area are managed primarily for timber production, but almost all forest that was potential murrelet nesting habitat on these lands has been previously harvested. Private timber harvest in the area must comply with the Washington Forest Practices Act (RCW 76.09) as well as the Washington Administrative Code with respect to the Washington Forest Practices Rules (WAC 222).

In the absence of a federally-approved HCP or a State-approved special wildlife management plan, suitable murrelet habitat on non-federal lands is only protected by the Washington Forest Practices Rules where protocol surveys document an occupied murrelet site. Due to specific exemptions within the Washington Forest Practices Rules, a landowner in Washington could be in full compliance with the Forest Practices regulations and have some risk of causing adverse impacts to murrelets if their forest practices activity resulted in the loss of occupied murrelet habitat. These situations include:

1. Timber harvesting or road construction in suitable murrelet habitat that occurs outside murrelet detection areas. Outside murrelet detection areas, only habitat that has a high probability of murrelet occupancy (i.e., ≥ 5-7 nest platforms/acre, depending on the location) is required to be surveyed prior to harvest (WAC 222-16-080(j)(iii) and (iv)). Murrelet habitat with fewer than 5-7 platforms per acre has a lower probability of occupancy. However, lower platform density does not ensure that the habitat is unoccupied by murrelets. Timber harvest that removes suitable murrelet habitat without pre-harvest protocol surveys can potentially result in the loss of occupied habitat and direct injury/mortality of murrelets.

2. Timber harvesting or road construction in suitable murrelet habitat that occurs where a landowner owns less than 500 acres and the land does not contain a known occupied murrelet site (WAC 222-16-080(j)(vi). Landowners with less than 500 acres are not required by the Washington Forest Practices Rules to conduct pre-harvest murrelet surveys. Therefore, if a small landowner has suitable murrelet habitat on their property that is not part of a known occupied site, this habitat could be harvested without a State Environmental Policy Act review or pre-harvest surveys, potentially resulting in the loss of occupied habitat and direct injury/mortality of murrelets.

3. Timber harvesting along federal boundary areas with suitable murrelet habitat. Unless there is an occupied murrelet site documented on the adjacent federal lands to trigger the protections of the Washington Forest Practices Rules for murrelets, a landowner could harvest timber (non-habitat) up to the federal boundary, potentially resulting in a significant disruption of murrelet breeding if the harvest occurs during the nesting season (disturbance). Clearcut harvest could also result in long-term adverse effects to the suitable habitat on adjacent federal lands associated with exposed clearcut boundaries. There are few occupied murrelet sites documented on federal lands, so the Washington Forest Practices Rules that require seasonal restrictions to avoid disturbance, and managed buffers to avoid edge effects to occupied murrelet sites may not be applied to federal boundary areas.

The above situations represent the greatest risk for cumulative effects to murrelets associated with private forest practices in the action area. Other situations that have the potential to result in adverse cumulative effects to murrelets include: (1) harvesting suitable murrelet habitat that occurs in stands less than 7 acres in size; and (2) harvesting occupied murrelet habitat that has been surveyed to protocol, but the surveys failed to detect murrelets (i.e., survey error).

In summary, the Washington Forest Practices rules provide a high level of protection for known occupied murrelet habitat in Washington. However, habitat that is not currently occupied, or does not meet the minimum habitat definitions provided in WAC 222-16-010 is likely to be harvested. The greatest risks for adverse cumulative effects to occur are through harvest of small remnant habitat patches (less than 7 acres in size), and habitat areas that do not meet minimum platform density criteria to trigger a survey.

The USFWS completed a formal consultation on the Washington State Forest Practices Rules HCP for aquatic species in 2006 and anticipated that essentially all potential murrelet habitat located on private timber lands that is not associated with occupied sites or other protected areas (e.g., riparian buffers) will eventually be lost due to timber harvest (USFWS 2006, p. 477). We did not exempt incidental take of murrelets in this consultation. We identified the areas where compliance with Washington Forest Practices rules could result in impacts to murrelets. Because the consultation was focused on aquatic species, the State (WDNR) did not request an Incidental Take Permit for murrelets. Therefore, the situations identified above represent a risk of cumulative effects to murrelets. In our consultation on the Washington Forest Practices Rules for aquatic species, the USFWS determined that ongoing forest practices on private lands "may affect, and is likely to adversely affect" murrelets. However, we concluded that these effects are not likely to jeopardize the continued existence of murrelets (USFWS 2006, p. 482). This conclusion was based on the protection of the occupied murrelet sites on provided by the Forest Practices Rules, which is consistent with the murrelet recovery plan which calls for the protection of occupied habitat on private lands (USFWS 1997, p. 133).

14.1.2 Development

The human population in western Washington is growing quickly, with an estimated increase of 700,000 people between 2008 and 2020 (Washington Department of Ecology 2016). Rapid population growth is expected to continue (WOFM 2017). Expansion of suburban and urban areas toward murrelet habitat is likely to enhance corvid populations, potentially increasing nest predation in the nearby nesting habitat (Marzluff and Neatherlin 2006, pp. 306-310; Neatherlin and Marzluff 2004, pp. 712, 715). The increasing population is also likely to lead to increasing levels of recreation, such as hiking and camping, in forested areas. Where this increase occurs on federally-managed lands, or where recreation is a covered activity under an HCP, its effects will be incorporated into the environmental baseline. However, recreational activities may also increase on non-federal lands that are not covered under an HCP, and this increase in recreational activity is likely to be associated with increases in corvid presence, leading to elevated levels of nest predation in nearby nesting habitat (Marzluff and Neatherlin 2006, pp. 306-310; Neatherlin and Marzluff 2004, p. 712).

Other types of development, including construction, road work, levee repair, and so on, has the potential to create noise and visible activity. When these stressors occur within 100 m (111 yd) of murrelet nesting habitat while that habitat is in use during the breeding season, they could alter important murrelet breeding behaviors. Where there is a federal nexus, projects that create these effects are required to undergo section 7 consultation and are added to the environmental baseline. However, in some cases there may not be a federal nexus (i.e., county road repairs with no federal funding).

14.1.3 Designated Murrelet Critical Habitat

The project action area contains federal, state and private lands. Private lands in the action area are managed primarily for timber production, but almost all forest that was potential murrelet nesting habitat on these lands has been previously harvested. Private timber harvest in the action area must comply with the Washington Forest Practices Act (RCW 76.09) as well as the Washington Administrative Code with respect to the Washington Forest Practices Rules (WAC 222). The USFWS completed formal consultation on the Washington State Forest Practices Rules in 2006 and anticipated that there will be adverse effects to murrelet critical habitat from forest practices activities (e.g., edge effects), but concluded that these effects are not likely to adversely modify murrelet critical habitat (USFWS 2006, p. 483).

14.1.4 Summary of the Cumulative Effects

Murrelet habitat on private timber lands is estimated to have declined by 39 percent in Washington from 1993 to 2012 (Raphael et al. 2018, p. 315). The loss of habitat on private lands emphasizes the need for conservation of remaining habitat on federal and state lands in Washington, as there seems to be little incentive for industrial forest landowners to develop HCPs for murrelets. In our review of the Washington Forest Practices Rules, we concluded that the loss of surveyed, unoccupied habitat on private forest lands posed a low risk of directly impacting murrelets, but the cumulative loss of unoccupied habitat ultimately curtails the opportunity for improving habitat distribution and supporting the long-term recovery of murrelets on private lands. This is apparent in the southwest Washington landscape, where over 60 percent of the land base is privately owned industrial forest land. Habitat that exists on these lands has been reduced to riparian buffers, and a few scattered occupied sites. The proposed conservation on WDNR lands will be essential for ensuring that numbers, reproduction, and distribution of murrelets within the action area is maintained or improved, particularly in the southwest Washington strategic landscape.

15 INTEGRATION AND SYNTHESIS OF EFFECTS

The Integration and Synthesis section is the final step in assessing the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the effects of the action and the cumulative effects to the status of the species and critical habitat, and the environmental baseline, to formulate our biological opinion as to whether the proposed action is likely to: (1) appreciably reduce the likelihood of both survival and recovery of the species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated critical habitat for the conservation of the species.

15.1.1 Range-wide Status Summary

Range-wide, as of 2017, there are approximately 23,000 murrelets in the Northwest Forest Plan area (McIver et al. 2019, p. 8). On average, the range-wide population has increased by 0.34 percent per year between 2001 and 2017 (McIver et al. 2019, p. 9), but this trend does not provide strong evidence of population increase or decline, because the 95 percent confidence interval overlaps zero (95 percent confidence interval: -0.9 to 1.6 percent annual population change). If the range-wide population continues to increase at an average rate of +0.34 percent per year, the population will increase by over 35 percent within 10 years, and by over 80 percent within 20 years.

Murrelet population size and marine distribution during the summer breeding season is strongly correlated with the amount and pattern (large contiguous patches) of suitable nesting habitat in adjacent terrestrial landscapes (Falxa and Raphael 2016, p. 109). Rates of nesting habitat loss have been highest in Washington, primarily due to timber harvest on non-federal lands (Falxa and Raphael 2016, pp. 72-81); and the population in Washington has continued to decline. This suggests that the loss of nesting habitat continues to be an important limiting factor for the recovery of murrelets.

Marine habitat degradation also affects murrelet fitness and survival. Stressors include reductions in the quality and abundance of murrelet forage fish species through overfishing and marine habitat degradation; murrelet by-catch in net fisheries; murrelet entanglement in derelict fishing gear; oil spills; and high levels of underwater sound pressure generated by pile-driving and underwater detonations (USFWS 2009, pp. 27-67). As with nesting habitat loss, marine habitat degradation is most prevalent in the Puget Sound area.

15.1.2 Threats to Murrelet Survival and Recovery

Low reproductive success and low recruitment have contributed to continued population declines in parts of the listed range. Factors contributing to these declines likely include ongoing and past loss of nesting habitat, nest predation, changes in prey availability and quality, post-fledging mortality, and cumulative and synergistic effects of these and other factors. Climate change also threatens murrelet survival and recovery.

15.1.3 Murrelet Conservation Needs

Murrelet recovery will depend on the availability of nesting habitat. Federal lands managed under the Northwest Forest Plan may provide increasing amounts of habitat as forested areas currently too young to provide suitable habitat transition into mature and older forest habitat. Specific areas of non-federal land have also been identified as being particularly important to improve the distribution of suitable nesting habitat, including Washington state lands within 40 miles of the coast, especially in southwestern Washington.

15.1.4 Summary of the Environmental Baseline in the Action Area

WDNR-managed lands comprise approximately 10 percent of the land area within the range of the murrelet in Washington and contain approximately 14 to 15 percent of the available nesting habitat in Washington. WDNR-managed lands provide significant areas of existing habitat and occupied sites in strategic locations, and WDNR-managed lands have a significant role for the conservation of murrelets in the southwest Washington, the OESF/Straits, and North Puget strategic locations. The conservation policies under the 1997 HCP have protected the majority of existing murrelet habitat on WDNR lands. Murrelet habitat has declined on WDNR-managed lands over the past two decades under the Interim Strategy, but these declines are consistent with the effects anticipated under the 1997 HCP and are substantially less than the rate of habitat decline on private forest lands in Washington.

Approximately 32,300 acres of murrelet habitat was harvested on WDNR-managed lands under the Interim Strategy, indicating an average rate of habitat loss of about 1,600 acres per year over the 20 year-period from 1997 to 2017. Monitoring for the *Northwest Forest Plan* program indicated a habitat loss of 14 percent on state lands from 1993 to 2012 (Table 13, above), an average rate of habitat loss of about 0.7 percent per year, compared to an average rate of 2 percent habitat loss per year on private lands. Annual disturbance effects to murrelets have not been summarized for the Interim Strategy but were estimated at up to 23,500 acres per year, representing exposure to about 16 percent of habitat per year.

The murrelet population in Washington is estimated at about 6,000 murrelets and is currently declining at a rate of about -3.9 percent per year, with a higher rate of decline indicated for Zone 1 (-4.9 percent per year). Annual survival rates for murrelets are estimated at 83 to 92 percent, meaning that in any given year, approximately 8 to 17 percent of adult murrelets die. Estimated average productivity in Washington is about 7 percent per year, which is not sufficient to achieve a stable population. Habitat loss, fragmentation, and poor marine foraging conditions are the major factors driving the continued population decline.

Based on the area of habitat, we attribute 15 percent of the murrelet population in Washington to habitat on WDNR lands, and this population is expected to be declining at the same rate as the larger Washington population. Currently about 40 percent of habitat on WDNR-managed lands is classified as *interior* forest patches, while the remaining habitat is in edge or stringer configurations, indicating a high percentage of the existing habitat is exposed to edge effects, which contribute to poor reproduction in murrelets.

The distribution of habitat in Washington is currently disjunct, with a major gap in distribution of habitat and occupied sites occurring on the southwest Washington coast from roughly the Grays Harbor south to the Columbia River. WDNR has significant land ownership in this region (260,000 acres in the South Coast HCP Unit), but only about 7 percent of this land base currently contains habitat. However, WDNR-managed lands contain the majority of known occupied sites and habitat remaining in this region of the state. The OESF contains the highest concentration of habitat and occupied sites on WDNR-lands and represents a significant portion of the existing habitat in Zone 2, while WDNR-managed lands in the North Puget strategic location contain significant areas of habitat that are closer to marine waters than federal lands. At the scale of WDNR-managed lands, approximately 15 percent of the land base currently contains habitat. About 78 percent of the current habitat occurs in LTFC provided by existing conservation policies under the HCP.

15.1.5 Summary of the Conservation Role of the Action Area

Lands identified as essential for the conservation and recovery of the murrelet in the 1997 *Recovery Plan* include all nesting habitat located within the range of the murrelet on federal lands; all nesting habitat on state lands within 40 miles of marine waters; and all nesting habitat associated with occupied murrelet sites on private lands (USFWS 1997, pp. 132-133).

The strategic locations include those areas that contain the majority of current murrelet habitat and occupied sites that are located on WDNR-managed lands and identify the locations where these lands are in closest proximity to important marine foraging areas for murrelets. WDNR-managed lands in southwest Washington have a significant role for the conservation of murrelets due to the lack of federal lands in that landscape. In developing the proposed Long-Term Strategy, both WDNR and USFWS agreed to the following objective for WDNR-managed lands:

- *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 expects to make a significant contribution to maintaining and protecting marbled murrelet populations* (FEIS 2019, p. 1-2).

General criteria for murrelet recovery and delisting are established under the murrelet recovery plan (USFWS 1997, p. 114-115). These general criteria include:

- Documenting stable or increasing trends in population size, density, and productivity in four of the six Conservation Zones for a 10-year period; and
- Implementing management and monitoring strategies in the marine and terrestrial environments to ensure protection of murrelets for at least 50 years.

Thus, increasing murrelet reproductive success and reducing the frequency, magnitude, or duration of any anthropogenic stressor that directly or indirectly affects murrelet fitness or survival in the marine and terrestrial environments are the priority conservation needs of the species. The Service estimates recovery of the murrelet will require at least 50 years (USFWS 1997).

15.1.6 Summary of Climate Change Effects to Murrelets

Climate change in Washington is affecting, and will continue to affect, the marine and forested environments on which murrelets depend. Changes in the terrestrial environment may have a direct effect on murrelet reproduction and affect the structure and availability of nesting habitat. Changes in the marine environment affect murrelet food resources. Changes in either the marine or terrestrial environments may affect the likelihood, success, and timing of murrelet breeding in any given year.

The disturbance regime of forested habitats in western Washington is changing, with increases in tree mortality already occurring. Insect and disease damage and wildfire, as well as mortality from drought stress, are expected to increase over the coming decades. Wind damage may increase or decrease in the future. These disturbances can, and do, remove and degrade murrelet habitat, though their effects in Washington have thus far been dwarfed by the effects of timber harvest. Thus, increases in these disturbances are likely to remove larger amounts of suitable habitat. Synergistic effects between these disturbance factors could lead to widespread loss of habitat. Some climate effects to habitat may be beneficial; for example, in some parts of the action area, tree growth rates may increase with longer growing seasons and CO_2 fertilization effects. Overall, however, we expect that climate change will have a net negative effect on the quantity and quality of suitable murrelet nesting habitat within the action area.

15.1.7 Summary of the Effects of the Action to Individual Murrelets

Habitat removal will result in approximately 1 nest site removed (adults displaced, nests destroyed) per year during first 10 years, and 0.5 nest sites will be removed per year during the 2nd decade.

We expect 5 to 6 percent of nesting murrelets per year on WDNR-managed lands will have increased nest predation in habitat degraded by edge effects (12 nest sites per year at current average nesting density), resulting in about a 20 percent reduction in nest success for the affected nest sites compared to nests in *interior* forest.

We expect 2.3 percent of nesting adults on WDNR-managed lands will have reduced nest success as result of disturbance effects (5 nests per year at current average nesting density). Nest success in habitat exposed to disturbance is expected to be reduced by about 40 percent annually, compared to nests in *interior* forest.

Applying the assumed reduced nesting success rates for habitat removal, degradation, and disturbance to the 18 nests affected by management per year, we found that the management effects result in the loss of 3 nests – one from habitat removal, one from edge effects, and one from disturbance effects. This results in a 3 percent reduction in nest success on WDNR lands per year compared to if all nests were located in *interior* forest patches. This level of lost reproduction is not detectable compared to ongoing rates of harvest, edge effects, and disturbance currently ongoing under the Interim Strategy.

We estimate 225 acres of nesting habitat (raw acres) per year will be degraded by edge effects and exposed to disturbance on adjacent federal lands. At current average nesting densities in raw habitat, this represents less than one nest site disturbed per year on federal lands. The effects of disturbance and habitat degradation due to edge effects to individual murrelets are the same as those described above for WDNR-managed lands (reduced nesting success). This level of reduced nesting success is not detectable compared to ongoing rates of edge effects and disturbance on adjacent federal lands currently ongoing under the Interim Strategy.

Metering harvest of adjusted acres over two decades maintains habitat capacity on the landscape over the first three decades of the HCP. Based on the simple index of average density, the habitat acres released for harvest (11,805 adjusted acres) will displace approximately 23 nesting pairs, while the habitat acres added (20,839 adjusted acres) will provide habitat capacity to support 44 nesting pairs, a net positive gain in habitat capacity to support 21 additional nesting pairs above the habitat acres released for harvest. If we consider estimated habitat increases within occupied sites, the habitat capacity is expected to increase to 127 percent above current capacity (capable of supporting 276 nesting pairs, compared to 217 pairs today). Total habitat on WDNR lands is projected to have a net increase of over 100,000 acres of raw habitat, from a current baseline of 207,067 acres to 272,817 acres by the end of the HCP.

All of the comparative measures available from the PVA results demonstrate that metering harvest of habitat over two decades and increasing the amount of habitat conserved in *interior* forest patches (e.g., SHAs and buffering occupied sites), compared to continuing the Interim Strategy (Alternative A), results in improved population projections for murrelet populations under both *risk* and *enhancement* scenarios.

15.1.8 Effects to Conservation Zone 1

In Zone 1, the distribution of habitat (raw acres) as measured by the percentage of WDNR-managed lands is projected to increase in all HCP planning units, with substantial increases in the total habitat area in the Straits (183 percent increase) and South Puget planning units (205 percent increase over baseline). SHAs in Zone 1 conserve significant areas of habitat in both the Straits and North Puget planning units that are located close to important marine foraging areas for murrelets. The SHAs are expected to complement existing habitat conservation on federal lands in Zone 1. Overall, we anticipate a net increase from 14 percent to 20 percent habitat on WDNR lands within Zone 1.

15.1.9 Effects to Conservation Zone 2

In Zone 2, the distribution of habitat (raw acres) as measured by the percentage of WDNR-managed lands is projected to increase in all HCP planning units except the OESF, which has a slight reduction (3 percent) in raw habitat acres, but adjusted acres are projected to increase in this landscape. The OESF contains the highest concentration of occupied sites and high quality habitat on WDNR-managed lands. The protection of occupied sites, occupied site buffers, and the designation of Queets and Reade Hill SHAs will complement the habitat conservation provided on federal lands in the northern portion of Zone 2.

The distribution of habitat in Zone 2 is currently disjunct, with a major gap in distribution of habitat and occupied sites occurring on the southwest Washington coast from roughly the Grays Harbor south to the Columbia River. Substantial increases in total habitat are projected in the South Coast HCP unit (215 percent increase), increasing total habitat on WDNR lands in the South Coast unit from 7 percent to 15 percent. WDNR-lands are capable of supporting a greater distribution of habitat than that which is proposed under the Long-Term Strategy. However, this would require additional conservation commitments that far exceed the habitat impacts anticipated under the proposed Long-Term Strategy.

Because of the lack of federal lands in southwest Washington, the proposed Long-Term Strategy emphasizes conservation in this strategic landscape area. Long-Term Strategy focuses conservation efforts in those areas where WDNR lands still contain significant habitat. The network of SHAs and occupied sites conserved in the southwest Washington strategic locations represent the highest priority locations for maintaining and improving the distribution of habitat in this landscape. The conservation of habitat in the SHAs, occupied sites, and other conservation areas (NAPs and NRCAs) will result in a significant contribution to the conservation and recovery of murrelet in Zone 2. Overall, we anticipate a net increase from 16 percent to 19 percent habitat on WDNR lands within Zone 2.

15.1.10 Effects to the Washington Murrelet Population

Murrelet populations in Washington are declining. Continued loss of habitat and lag effects from past habitat loss and fragmentation are major factors contributing to the decline. However, factors other than nesting habitat also contribute to poor reproduction and survival in murrelets. With a declining population, it can be difficult to discern the effect of a particular action from the background rate of decline. The PVA developed by Peery and Jones (2019) provides a robust analysis of the population-level effects of the proposed Long-Term Strategy in the context of the ongoing population decline in Washington. The modeling scenarios considered are both plausible – in the risk scenario, survival rates are lower, and reproduction is insufficient to stabilize the population despite projected increases in habitat. In the enhancement scenario, survival rates are higher, and after a period continued decline, the population stabilizes and responds positively to increases in habitat conserved on WDNR-managed lands.

The projected population changes in Washington represent theoretical scenarios in which habitat does not change on non-WDNR lands. While this is a recognized limitation of the model, it also provides perspective on the relative contribution of nesting habitat on WDNR lands to the total population performance in Washington. All else being equal, habitat conservation on WDNR lands can influence population change at the scale of the Washington population, however the degree of influence is relatively small for the range of alternatives. If habitat on federal lands increases over the term of the HCP (which is likely), the WDNR lands will have a smaller role in contributing to murrelet populations than this analysis shows. If on the other hand, habitat declines on federal lands due natural disturbance, then WDNR lands could have a larger proportional effect on the Washington population than the PVA analysis shows. Both risk and enhancement scenarios demonstrate that metering habitat loss over two decades as opposed to releasing all habitat in the first decade of implementation results in a reduced rate of initial population decline, sustains a larger population over time, and results in lower quasi-extinction risk.

The assumptions used in the PVA are biologically based and are reasonable in the context of comparing the conservation alternatives considered. Because the model developed by Peery and Jones (2019) incorporates some measures of environmental stochasticity, the projections are much more informative than simple deterministic projections of population decline. Because the PVA uses both risk and enhancement scenarios, it provides comparative measures of both population change and population risk with an element of biological realism. All of the comparative measures available from the PVA results demonstrate that metering harvest of habitat over two decades and increasing the amount of habitat conserved in *interior* forest patches (e.g., SHAs and buffering occupied sites), compared to continuing the Interim Strategy (Alternative A), results in improved population projections for murrelet populations under both *risk* and *enhancement* scenarios.

When we consider that the effects of habitat removal, habitat degradation, and disturbance are projected to result in the loss of 3 nests – one from habitat removal, one from edge effects, and one from disturbance effects each year, we conclude that this level of lost reproduction is not detectable compared to the rate of harvest, edge effects, and disturbance currently ongoing under the Interim Strategy. Considering that metering is projected to maintain habitat capacity, and the SHAs, occupied site buffers, and other conservation areas will increase the total nesting habitat in *interior* forest patches on WDNR-managed lands to support successful reproduction, we conclude that the proposed Long-Term Strategy is not likely to cause an increase in the rate of population decline that is currently ongoing in Washington.

Decreasing fragmentation and increasing habitat area in large contiguous blocks within SHAs will significantly contribute to the recovery and conservation of murrelets in Washington and will complement existing conservation provided by federal lands under the Northwest Forest Plan. Raphael et al. (2018, p. 338) note: *"Murrelet numbers continue to decline in the northern portion of the Plan area. Assuming no large fires, we believe that the current decline in nesting habitat will reverse on federal lands, leading to a net increase in the amount of nesting habitat, and that murrelet populations should also increase in response. How many decades before this reversal in trend occurs is unknown, but at-sea monitoring suggest that the first step of possible population stabilization may be occurring in the southern Plan area."* Considering the minimal Washington-wide population effects of the habitat removal estimated for the Long-Term Strategy, and the total habitat gains, we conclude that that the proposed Long-Term Strategy is not likely to cause an increase in the rate of population decline that is currently ongoing in Washington.

15.1.11 Summary of Cumulative Effects

Murrelet habitat on private timber lands is estimated to have declined by 39 percent in Washington from 1993 to 2012 (Raphael et al. 2018, p. 315). The loss of habitat on private lands emphasizes the need for conservation of remaining habitat on federal and state lands in Washington, as there seems to be little incentive for industrial forest landowners to develop HCPs for murrelets. In our review of the Washington Forest Practices Rules, we concluded that the loss of surveyed, unoccupied habitat on private forest lands posed a low risk of directly impacting murrelets, but the cumulative loss of unoccupied habitat ultimately curtails the opportunity for improving habitat distribution and supporting the long-term recovery of murrelets on private lands. This is apparent in the southwest Washington landscape, where over 60 percent of the land base is privately owned industrial forest land. Habitat that exists on these lands has been reduced to riparian buffers, and a few scattered occupied sites. The proposed conservation on WDNR lands will be essential for ensuring that numbers, reproduction, and distribution of murrelets within the action area is maintained or improved, particularly in the southwest Washington strategic landscape.

15.1.12 Range-wide Effects of the Action, Baseline, and Cumulative Effects

In summary, the effects of the proposed action, considering the baseline and cumulative effects, are not expected to be appreciable at the range-wide scale. As noted in the range-wide status of the species, populations in southern Oregon and northern California are apparently increasing at a rate of +1.4 to +3.7 percent per year. The positive trends in the southern portion of the species range are influencing the total range-wide trend (+0.34 percent per year). If the range-wide population continues to increase at an average rate of +0.34 percent per year, the population will increase by over 35 percent within 10 years, and by over 80 percent within next 20 years.

The effects of habitat loss in the short-term (20 years) are not detectable from current baseline trends, and the designation of conservation areas will have immediate positive effects on decreasing the effects of past habitat fragmentation and edge effects in strategic locations in Washington. Having found no compelling evidence for an appreciable decline in habitat distribution or population-level effects at the scale of the action area, Conservation Zone 1, or Conservation Zone 2, we conclude that the effects of the proposed Long-Term Strategy to reproduction, numbers, and distribution of murrelets are not appreciable range-wide.

General criteria for murrelet recovery and delisting are established under the murrelet recovery plan (USFWS 1997, p. 114-115). These general criteria include:

- Documenting stable or increasing trends in population size, density, and productivity in four of the six Conservation Zones for a 10-year period; and
- Implementing management and monitoring strategies in the marine and terrestrial environments to ensure protection of murrelets for at least 50 years.

The proposed Long-Term Strategy will contribute positively to both these recovery criteria. Replacing the Interim Strategy with Long-Term Strategy will result in an increase of large contiguous blocks of nesting habitat on WDNR-managed lands in key locations for recovery. Under positive population growth scenarios, the Long-Term Strategy has a greater likelihood of reducing the rate of population decline and contributing to population stabilization and recovery. Because the Long-Term Strategy represents a conservation commitment for 50-years or more, it ensures conservation on a time-scale that is necessary to achieve significant increases in habitat on WDNR-managed lands.

16 CONCLUSION

After reviewing the current status of marbled murrelet, the environmental baseline for the action area, the effects of the proposed HCP amendment and the cumulative effects, it is the USFWS' biological opinion that the HCP amendment, as proposed, is not likely to jeopardize the continued existence of the marbled murrelet or is not likely to destroy or adversely modify designated critical habitat.

17 INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct. *Harm* is defined by the USFWS as an act which actually kills or injures wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering (50 CFR 17.3). *Harass* is defined by the USFWS as an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering (50 CFR 17.3). Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the ESA provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The proposed Washington State Department of Natural Resources Marbled Murrelet Long-Term Conservation Strategy Amendment to the 1997 Final State Trust Lands HCP and its associated documents clearly identify anticipated impacts to affected species likely to result from the proposed taking and the measures that are necessary and appropriate to minimize those impacts. All conservation measures described in the proposed HCP Amendment, together with the terms and conditions described in any associated Implementing Agreement, and any section 10(a)(1)(B) permit or permits issued with respect to the proposed HCP Amendment, are hereby incorporated by reference within this Incidental Take Statement as reasonable and prudent measures and terms and conditions pursuant to 50 CFR §402.14(i). Such terms and conditions are non-discretionary. The amount or extent of incidental take anticipated under the proposed Washington State Department of Natural Resources Marbled Murrelet Long-Term Conservation Strategy Amendment to the 1997 Final State Trust Lands HCP, associated reporting requirements, and provisions for disposition of dead or injured animals, are as described in the HCP Amendment, Implementing Agreement, and the accompanying section10(a)(1)(B) permit(*s*).

18 AMOUNT OR EXTENT OF TAKE

The USFWS anticipates incidental take of marbled murrelet will be difficult to detect for the following reason(s): the species is wide-ranging; has a small body size; finding a dead or impaired specimen is unlikely; the species occurs in habitat that makes detection difficult; murrelets are cryptic, nest locations are rarely located, and available data suggest a patchy and inconsistent distribution in the action area. However, pursuant to 50 CFR 402.14(i)(1)(i), a surrogate can be used to express the anticipated level of take in an Incidental Take Statement, provided three criteria are met: (1) measuring take impacts to a listed species is not practical; (2) a link is established between the effects of the action on the surrogate and take of the listed species; and (3) a clear standard is set for determining when the level of anticipated take based on the surrogate has been exceeded.

The USFWS' regulations state that significant habitat modification or degradation caused by an action that results in death or injury to a listed species by significantly impairing its essential behavior patterns constitutes take in the form of harm. Those regulations further state that an intentional or negligent act or omission that creates the likelihood of injury to a listed species by annoying it to such an extent as to significantly disrupt its normal behavioral patterns constitutes take in the form of harass. Such annoyance can be caused by actions that modify or degrade habitat conditions (e.g., excessive noise or smoke). In cases where this causal link between effects of a federal action to habitat and take of listed species is established, and the biological opinion or incidental take statement explains why it is not practical to express and monitor the level of take in terms of individuals of the listed species, the Service's regulations authorize the use of habitat as a surrogate for expressing and monitoring the anticipated level of take, provided a clear standard is established for determining when the level of anticipated take has been exceeded.

The following narrative presents the USFWS' analysis and findings with respect to the three regulatory criteria for use of a surrogate in this Incidental Take Statement to express the anticipated level of take likely to be caused by the proposed action.

The following level of take of marbled murrelet (nesting adults, eggs, nestlings) can be anticipated by quantifying the amount of nesting habitat removed, quantifying the amount of nesting habitat degraded by edge effects, and by quantifying the amount of nesting habitat exposed to disturbance because:

1. A habitat-based approach to evaluating the effects to murrelets is appropriate due to the difficulty in locating actual murrelet nest sites, the variation in the number of murrelets that breed each year, and the patchy distribution of murrelets in nesting habitat. However, numerous studies have demonstrated that murrelet numbers are strongly correlated with the amount of available nesting habitat, and where habitat is removed, marbled murrelet numbers decline.

2. A habitat surrogate will measure the amount of habitat removed, habitat degraded by edge effects, and habitat exposed to disturbance. In the accompanying Opinion, we have provided a detailed explanation of the P-stage habitat classification system used to quantify the probability of murrelet use of habitat, and how we used estimates of marbled murrelet nesting density at the landscape scale to enumerate the proportion of murrelets likely to be affected by the covered activities.

3. Monitoring the amount and quality of murrelet nesting habitat on the landscape provided by the WDNR State Lands HCP is a consistent and reliable method to track HCP implementation and is consistent with existing monitoring and reporting programs established under the 1997 HCP.

We anticipate that implementation of the Long-Term Strategy will begin in 2020 and continue through the remaining term of the HCP (2067). The following level of take of marbled murrelets (nesting adults, eggs, nestlings) can be anticipated by the loss of acres of suitable murrelet nesting habitat, the degradation of murrelet nesting habitat from edge effects caused by forest management, and disturbance effects associated with forest management activities. These habitat areas are the best available surrogate measure of the anticipated take.

- Beginning in 2020, we anticipate incidental take of murrelets in the form of harm and harass associated with the removal of up to 38,774 raw acres of habitat, which equates to 11,085 adjusted habitat acres. Approximately 5,000 adjusted acres will be deferred from harvest for a minimum of 10 years following implementation of the proposed Long-Term Strategy. The distribution of the habitat to be removed by HCP planning unit is listed below in Table 66.

- We anticipate incidental take of murrelets in the form of harm and harass associated with the removal of 114 adjusted acres of habitat for new roads (104 adjusted acres) or yarding corridors (10 adjusted acres) in occupied sites, occupied site buffers, or Special Habitat Areas.

- We anticipate incidental take of murrelets in the form of harm from habitat degradation associated with edge effects caused by covered forest management activities. The amount of habitat degraded be edge effects is approximately 6 percent of adjusted acres of habitat per decade conserved in long-term forest cover mapped as *outer edge* or *inner edge* around *interior* forest patches of murrelet nesting habitat. The estimated amount of habitat degraded by edge effects per decade is listed below in Table 67.

- We anticipate incidental take of murrelets in the form of harm and harass from disturbance associated with habitat modification and prolonged exposure to audio/visual disturbance caused by covered activities. The amount of exposed to disturbance is approximately 2.3 percent of the adjusted acres of habitat per decade conserved in long-term forest cover mapped as *outer edge* or *inner edge* around *interior* forest patches of murrelet nesting habitat. The estimated amount of habitat disturbed per decades is listed below in Table 68.

- We anticipate incidental take of murrelets in the form of harm and harass from habitat degradation associated with edge effects and disturbance caused by covered activities to 225 acres of murrelet nesting habitat per year located on adjacent federal lands (within a distance of 328-ft of WDNR-managed lands).

Table 66. Summary of the take of marbled murrelets from nesting habitat released for harvest on WDNR-managed lands.

HCP planning unit:	**Columbia**	**South Coast**	**OESF**	**Straits**	**North Puget**	**South Puget**	**Yakima**	**Totals**
Raw habitat acres released for harvest	4,088	3,782	6,662	4,009	14,769	5,314	150	**38,774**
P-stage-weighted acres released for harvest	1,161	1,110	2,326	1,104	4,886	1,640	122	12,349
Adjusted acres released for harvest	1,040	841	2,128	1,030	4,457	1,469	120	**11,085**

Note: The take of habitat is 38,774 raw acres over the remaining term of the HCP. The summary acres presented above provide an index of the habitat take per HCP unit. Take acres are not limited to the level indicated by each individual HCP planning unit. Take is limited by the total take acres of 38,774 raw acres.

Table 67. Summary of the take of murrelets associated with nesting habitat degraded by edge effects on WDNR-managed lands per decade.

Effects Category	HCP Decade					Effects to Murrelets
	1	2	3	4	5	
Total habitat degraded by edge effects in LTFC (excluding *stringers*) (adjusted acres):	**5,489**	**5,833**	**6,287**	**6,913**	**7,470**	Habitat with increased nest failure per decade due to edge effects.
Percent of habitat (adjusted acres) in LTFC degraded by edge effects per decade:	6%	6%	6%	6%	7%	Habitat with increased nest failure per decade due to edge effects.
Habitat degraded (raw acres) based on average P-stage	11,364	11,393	11,818	12,994	13,937	

Note: LTFC = long-term forest cover.

Table 68. Summary of the average annual take of murrelets from disturbance on WDNR-managed lands.

Activity Group	HCP Decade					Effects to Murrelets
	1	2	3	4	5	
Total average annual habitat exposed to audio/visual disturbance (adjusted acres)	**2,184**	**2,253**	**2,338**	**2,449**	**2,549**	Disruption of nesting behaviors, increased nest failure.
Average annual percentage of habitat in LTFC exposed to disturbance effects	2.3%	2.3%	2.3%	2.3%	2.3%	Disruption of nesting behaviors, increased nest failure.
Average habitat (raw acres) exposed to disturbance (based on average P-stage)	4,522	4,400	4,395	4,603	4,756	-

Note: LTFC = long-term forest cover.

19 EFFECT OF THE TAKE

In the accompanying Opinion, the USFWS determined that this level of anticipated take is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

20 REASONABLE AND PRUDENT MEASURES AND TERMS AND CONDITIONS

The conservation measures negotiated in cooperation with the USFWS and included as part of the proposed HCP amendment (i.e., designation of Special Habitat Areas, protection of occupied sites and occupied site buffers, and implementation of daily limited operating periods during the marbled murrelet nesting season for covered activities that occur within occupied sites and occupied site buffers) constitute all of the reasonable measures necessary to minimize the impacts of incidental take. On that basis, no Reasonable and Prudent Measures except for monitoring and reporting requirements are included in this Incidental Take Statement.

Monitoring as specified in Section 6.4 of the proposed HCP Amendment for the marbled murrelet Long-Term Strategy is required (WDNR 2019, p. 20). Reporting as specified in Section 6.5 of the HCP Amendment is required (WDNR 2019, p. 21). WDNR's reporting obligations in the 1997 HCP are not changed by the HCP Amendment. Section 17.2, "Notification and Annual Review of Land Transactions," and Section 20.0, "Reporting and Inspections," of the Implementation Agreement (IA); and Section V, "Plan Implementation," of the 1997 HCP describe WDNR's reporting obligations under the 1997 HCP, including this Amendment.

21 REINITIATION NOTICE

This concludes formal consultation on the action outlined in the request for the Washington State Department of Natural Resources Marbled Murrelet Long-Term Conservation Strategy Amendment to the 1997 Final State Trust Lands HCP. As provided in 50 CFR 402.16, reinitiation of formal consultation is required and shall be requested by the Federal agency or by the Service, where discretionary Federal involvement or control over the action has been retained or is authorized by law and: (a) if the amount or extent of taking specified in the incidental take statement is exceeded; (b) if new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (c) if the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the biological opinion; or (d) if a new species is listed or critical habitat designated that may be affected by the identified action.

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APPENDIX A
STATUS OF THE SPECIES: MARBLED MURRELET

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Appendix A
Status of the Species: Marbled Murrelet

The marbled murrelet (*Brachyramphus marmoratus*) (murrelet) was listed by the U.S. Fish and Wildlife Service (Service) as a threatened species in Washington, Oregon, and California in 1992. The primary reasons for listing included extensive loss and fragmentation of the older-age forests that serve as nesting habitat for murrelets, and human-induced mortality in the marine environment from gillnets and oil spills (57 FR 45328 [Oct. 1, 1992]). Although some threats such as gillnet mortality and loss of nesting habitat on Federal lands have been reduced since the 1992 listing, the primary threats to species persistence continue (75 FR 3424 [Jan. 21, 2010]).

Life History

The murrelet is a small, fast-flying seabird in the Alcidae family that occurs along the Pacific coast of North America. Murrelets forage for small schooling fish or invertebrates in shallow, nearshore, marine waters and primarily nest in coastal older-aged coniferous forests. The murrelet lifespan is unknown, but is expected to be in the range of 10 to 20 years based on information from similar alcid species (De Santo and Nelson 1995, pp. 36-37). Murrelet nesting is asynchronous and spread over a prolonged season. In Washington, the murrelet breeding season extends from April 1 to September 23. Egg laying and incubation occur from April to early August and chick rearing occurs between late May and September, with all chicks fledging by late September (Hamer et al. 2003; USFWS 2012a).

Murrelets lay a single-egg which may be replaced if egg failure occurs early in the nesting cycle, but this is rare (Nelson 1997, p. 17). During incubation, one adult sits on the nest while the other forages at sea. Adults typically incubate for a 24-hour period, then exchange duties with their mate at dawn. Chicks hatch between May and August after 30 days of incubation. Hatchlings appear to be brooded by an adult for several days (Nelson 1997, p. 18). Once the chick attains thermoregulatory independence, both adults leave the chick alone at the nest for the remainder of the rearing period, except during feedings. Both parents feed the chick, which receives one to eight meals per day (Nelson 1997, p. 18). Most meals are delivered early in the morning while about a third of the food deliveries occur at dusk and intermittently throughout the day (Nelson and Hamer 1995, p. 62).

Murrelets and other fish-eating alcids exhibit wide variations in nestling growth rates. The nestling stage of murrelet development can vary from 27 to 40 days before fledging (De Santo and Nelson 1995, p. 45). The variations in alcid chick development are attributed to constraints on feeding ecology, such as unpredictable and patchy food distributions, and great distances between feeding and nesting sites (Øyan and Anker-Nilssen 1996, p. 830). Food limitation during nesting often results in poor growth, delayed fledging, increased mortality of chicks, and nest abandonment by adults (Øyan and Anker-Nilssen 1996, p. 836).

Murrelets are believed to be sexually mature at 2 to 4 years of age (Nelson 1997, p. 19). Adult birds may not nest every year, especially when food resources are limited. For example, in central California, the proportion of murrelets attempting to breed was more than four times higher (50 percent versus 11 percent) in a year when prey availability was apparently good than in a year when more foraging effort was required (Peery et al. 2004, p. 1095). In Oregon, none of the 61 murrelets radio-tagged in 2017 attempted nesting, likely because anomalous ocean conditions reduced prey availability (Horton et al. 2018, p. 77). At other times and places, radio-telemetry and demographic modeling indicate that the proportion of adults breeding in a given year may vary from 5 to 95 percent (Lorenz et al. 2017, p. 312; McShane et al. 2004, p. 3-5). In other words, in some years, very few marbled murrelets attempt nesting, but in other years, almost all breeding-age adults initiate nesting.

Murrelets in the Marine Environment

Marbled murrelets spend most (>90 percent) of their time at sea. They generally forage in pairs on the water, but they also forage solitarily or in small groups. In addition to foraging, their activities in the marine environment include preening, social behaviors, and loafing. Following the breeding season, murrelets undergo the pre-basic molt, in which they exchange their breeding plumage for their winter plumage. They replace their flight feathers during this molt, and for a few weeks they are flightless. Therefore, they spend this entire period at sea. Their preferred marine habitat includes sheltered, nearshore waters, although they occur farther offshore in some locations and during the nonbreeding season (Huff et al. 2006, p. 19).

Breeding Season

The murrelet is widely distributed in nearshore waters along the west coast of North America. It occurs primarily within 5 km of shore (Alaska, within 50 km), and primarily in protected waters, although its distribution varies with coastline topography, river plumes, riptides, and other physical features (Nelson 1997, p. 3). Murrelet marine habitat use is strongly associated with the amount and configuration of nearby terrestrial nesting habitat (Raphael et al. 2015, p. 17). In other words, they tend to be present in marine waters adjacent to areas of suitable breeding habitat. Non-breeding adults and subadults are thought to occur in similar areas as breeding adults. This species does occur farther offshore during the breeding season, but in much reduced numbers (Strachan et al. 1995, p. 247). Their offshore occurrence is probably related to current upwelling and plumes during certain times of the year that tend to concentrate their prey species. Even within the breeding season, individual murrelets may make large movements, and large average marine home ranges (505 km^2 and 708 km^2, respectively) have been reported for northern California and Washington (Hébert and Golightly 2008, p. 99; Lorenz et al. 2017, p. 318).

Non-breeding Season

Marbled murrelet marine habitat use during the non-breeding season is poorly documented, but they are present near breeding sites year-round in most areas (Nelson 1997, p. 3). Murrelets exhibit seasonal redistributions following the pre-basic molt (Peery et al. 2008a, p. 119), and can move up to 750 km from their breeding season locations (Hébert and Golightly 2008, p. 101; Adrean et al. 2018). Generally they are more dispersed and may be found farther offshore than during the breeding season, although the highest concentrations still occur close to shore and in protected waters (Nelson 1997, p. 3). For example, murrelets move from the outer exposed coasts of Vancouver Island and the Straits of Juan de Fuca into the sheltered and productive waters of northern and eastern Puget Sound.

Foraging and Diet

Murrelets dive and swim through the water by using their wings in pursuit of their prey; their foraging and diving behavior is restricted by physiology. They usually feed in shallow, nearshore water less than 30 m (98 ft) deep, which seems to provide them with optimal foraging conditions for their generalized diet of small schooling fish and large, pelagic invertebrates: Pacific sand lance (*Ammodytes hexapterus*), northern anchovy (*Engraulis mordax*), Pacific herring (*Clupea harengus*), surf smelt (*Hypomesus* sp.), euphausiids, mysids, amphipods, and other species (Nelson 1997, p. 7). However, they are assumed to be capable of diving to a depth of 47 m (157 ft) based on their body size and diving depths observed for other Alcid species (Mathews and Burger 1998, p. 71).

Contemporary studies of murrelet diets in the Puget Sound–Georgia Basin region indicate that Pacific sand lance now make up the majority of the murrelet diet (Gutowsky et al. 2009, p. 251). Historically, energy-rich fishes such as herring and northern anchovy comprised the majority of the murrelet diet (Becker and Beissinger 2006, p. 470; Gutowsky et al. 2009, p. 247). This is significant because sand lance have the lowest energetic value of the fishes that murrelets commonly consume. For example, a single northern anchovy has nearly six times the energetic value of a sand lance of the same size (Gutowsky et al. 2009, p. 251), so a murrelet would have to eat six sand lance to get the equivalent energy of a single anchovy. Reductions in the abundance of energy-rich forage fish species is likely a contributing factor in the poor reproduction in murrelets (Becker and Beissinger 2006, p. 470).

The duration of dives appears to depend upon age (adults vs. juveniles), water depth, visibility, and depth and availability of prey. Dive duration has been observed ranging from 8 seconds to 115 seconds, although most dives are between 25 to 45 seconds (Day and Nigro 2000; Jodice and Collopy 1999; Thoresen 1989; Watanuki and Burger 1999). Diving bouts last over a period of 27 to 33 minutes (Nelson 1997, p. 9). They forage in deeper waters when upwelling, tidal rips, and daily activity of prey concentrate prey near the surface (Strachan et al. 1995). Murrelets are highly mobile and some make substantial changes in their foraging sites within the breeding season. For example, Becker and Beissinger (2003, p. 243) found that murrelets in California responded rapidly (within days or weeks) to small-scale variability in upwelling intensity and prey availability by shifting their foraging behavior and habitat selection within a 100-km (62-mile) area. In Washington, changes in water temperature, likely also related to prey availability, influence foraging habitat use, but the influence of upwelling is less clear (Lorenz et al. 2017, pp. 315, 318).

For more information on murrelet use of marine habitats, see literature reviews in McShane et al. 2004, USFWS 2009, and USFWS 2019.

Murrelets in the Terrestrial Environment

Murrelets are dependent upon older-age forests, or forests with an older tree component, for nesting habitat (Hamer and Nelson 1995, p. 69). Specifically, murrelets prefer high and broad platforms for landing and take-off, and surfaces which will support a nest cup (Hamer and Nelson 1995, pp. 78-79). In Washington, murrelet nests have been found in live conifers, specifically, western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*), Douglas-fir (*Pseudotsuga menziesii*), and western red cedar (*Thuja plicata*) (Hamer and Nelson 1995; Hamer and Meekins 1999). Most murrelets appear to nest within 37 miles of the coast, although occupied behaviors have been recorded up to 52 miles inland, and murrelet presence has been detected up to 70 miles inland in Washington (Huff et al. 2006, p. 10). Nests occur primarily in large, older-aged trees. Overall, nests have been found in trees greater than 19 inches in diameter-at-breast and greater than 98 ft tall. Nesting platforms include limbs or other branch deformities that are greater than 4 inches in diameter, and are at greater than 33 ft above the ground. Substrate such as moss or needles on the nest platform is important for protecting the egg and preventing it from falling off (Huff et al. 2006, p. 13).

Murrelets do not form the dense colonies that are typical of most other seabird species. Limited evidence suggests they may form loose colonies in some cases (Ralph et al. 1995). The reliance of murrelets on cryptic coloration to avoid detection suggests they utilize a wide spacing of nests in order to prevent predators from forming a search image (Ralph et al. 1995). Individual murrelets are suspected to have fidelity to nest sites or nesting areas, although this is has only been confirmed with marked birds in a few cases (Huff et al. 2006, p. 11). There are at least 15 records of murrelets using nest sites in the same or adjacent trees in successive years, but it is not clear if they were used by the same birds (McShane et al. 2004, p. 2-14). At the landscape scale, murrelets are probably faithful to specific watersheds for nesting (McShane et al. 2004, p. 2-14). Murrelets have been observed visiting nesting habitat during non-breeding periods in Washington, Oregon, and California which may indicate adults are maintaining fidelity and familiarity with nesting sites and/or stands (Naslund 1993; O'Donnell et al. 1995, p. 125).

Loss of nesting habitat reduces nest site availability and displaces any murrelets that may have had nesting fidelity to the logged area (Raphael et al. 2002, p. 232). Murrelets have demonstrated fidelity to nesting stands and in some areas, fidelity to individual nest trees (Burger et al. 2009, p. 217). Murrelets returning to recently logged areas may not breed for several years or until they have found suitable nesting habitat elsewhere (Raphael et al. 2002, p. 232). The potential effects of displacement due to habitat loss include nest site abandonment, delayed breeding, failure to initiate breeding in subsequent years, and failed breeding due to increased predation risk at a marginal nesting location (Divoky and Horton 1995, p. 83; Raphael et al. 2002, p. 232). Each of these outcomes has the potential to reduce the nesting success for individual breeding pairs, and could ultimately result in the reduced recruitment of juvenile birds into the local population (Raphael et al. 2002, pp. 231-233).

Detailed information regarding the life history and conservation needs of the murrelet are presented in the *Ecology and Conservation of the Marbled Murrelet* (Ralph et al. 1995), the Service's 1997 *Recovery Plan for the Marbled Murrelet* (USFWS 1997), and in subsequent 5-year status reviews (McShane et al. 2004; USFWS 2009; USFWS 2019).

Distribution

Murrelets are distributed along the Pacific coast of North America, with birds breeding from central California through Oregon, Washington, British Columbia, southern Alaska, westward through the Aleutian Island chain, with presumed breeding as far north as Bristol Bay (Nelson 1997, p. 2), and non-breeding distribution extending as far south as the Southern California Bight (Hall et al. 2009, p. 5081). The federally-listed murrelet population in Washington, Oregon, and California is classified by the Service as a distinct population segment (75 FR 3424). The coterminous United States population of murrelets is considered significant as the loss of this distinct population segment would result in a significant gap in the range of the taxon and the loss of unique genetic characteristics that are significant to the taxon (75 FR 3430).

The inland nesting distribution of murrelets is strongly associated with the presence of mature and old-growth conifer forests. Murrelets have been detected farther than100 km inland in Washington (70 miles).The inland distribution in the southern portion of the species range is associated with the extent of the hemlock/tanoak vegetation zone which occurs up to 16-51 km inland (10-32 miles) (Evans Mack et al. 2003, p. 4). Although murrelets are distributed throughout their historical range, the area of occupancy within their historic range appears to be reduced from historic levels. The distribution of the species also exhibits five areas of discontinuity: a segment of the border region between British Columbia, Canada and Washington; southern Puget Sound, WA; Destruction Island, WA to Tillamook Head, OR; Humboldt County, CA to Half Moon Bay, CA; and the entire southern end of the breeding range in the vicinity of Santa Cruz and Monterey Counties, CA (McShane et al. 2004, p. 3-70).

Murrelets use inland habitats primarily for nesting, including egg laying, incubation, and feeding of nestlings. In addition, murrelets have been observed in nesting habitat demonstrating social behaviors, such as circling and vocalizing, in groups of up to ten birds (Nelson and Peck 1995, p. 51). Nest sites tend to be clustered spatially, indicating that although murrelets are not colonial seabirds, they also are not strictly solitary in their nesting behavior (Conroy et al. 2002, p. 131; Naslund et al. 1995, p. 12). In California and southern Oregon, marbled murrelets occupy habitat more frequently when there is other occupied habitat within 5 km (Meyer et al. 2002, p. 103), and we assume that the same is true in Washington. Usually, multiple nests can be found in a contiguous forested area, even in places where they are not strongly clustered (Evans Mack et al. 2003, p. 6).

Murrelets spend most of their lives in the marine environment, primarily in nearshore marine waters within 5 km of the coast (Nelson 1997, p. 3). The distribution of murrelets in marine waters during the summer breeding season is highly variable along the Pacific coast, with areas of high density occurring along the Strait of Juan de Fuca in Washington, the central Oregon coast, and northern California (Raphael et al. 2015, p. 20). Low-density areas or gaps in murrelet distribution occur in central California, and along the southern Washington coast (Raphael et al. 2015, p. 21). Analysis of various marine and terrestrial habitat factors indicate that the amount and configuration of inland nesting habitat is the strongest factor that influences the marine distribution of murrelets during the nesting season (Raphael et al. 2015, p. 17). Local aggregations or “hot spots” of murrelets in nearshore marine waters are strongly associated with landscapes that support large, contiguous areas of mature and old-growth forest. In Puget Sound and along the Strait of Juan de Fuca, these "hot spots" are also strongly associated with a low human footprint in the marine environment, for example, areas natural shorelines and relatively little vessel traffic (Raphael et al. 2016a, p. 106).

During the non-breeding season, marbled murrelet distribution varies slightly from the breeding season distribution. The southern end of the range extends as far south as the Southern California Bight; but some individuals also move northward at the end of the breeding season (Hall et al. 2009, p. 5081; Peery et al. 2008a, p. 121). Although marbled murrelet densities remain highest near shore during the non-breeding season, they apparently use offshore areas more frequently than during the breeding season. The farthest offshore records of murrelet distribution are 60 km off the coast of northern California in October and 46 km off the coast of Oregon in February (Adams et al. 2014) and at least 300 km off the coast in Alaska (Piatt and Naslund 1995, p. 287). Known areas of winter concentration include and southern and eastern end of Strait of Juan de Fuca (primarily Sequim, Discovery, and Chuckanut Bays), San Juan Islands and Puget Sound, Washington (Speich and Wahl 1995, p. 314).

Distribution of Nesting Habitat

The loss of nesting habitat was a major cause of the murrelet's decline over the past century and may still be contributing as nesting habitat continues to be lost to fires, logging, insects, tree diseases, and wind storms (Miller et al. 2012, p. 778; Raphael et al. 2016b, pp. 80-81). Due mostly to historical timber harvest, only a small percentage (~11 percent) of the habitat-capable lands within the listed range of the murrelet currently contain potential nesting habitat (Raphael et al. 2016b, p. 69). Monitoring of murrelet nesting habitat within the Northwest Forest Plan (NWFP, equivalent to Conservation Zones 1 through 5) area indicates nesting habitat declined from an estimated 2.53 million acres in 1993 to an estimated 2.23 million acres in 2012, a decline of about 12.1 percent (Raphael et al. 2016b, p. 72). Fire has been the major cause of nesting habitat loss on Federal lands, while timber harvest is the primary cause of loss on non-Federal lands (Raphael et al. 2016b, p. 79). While most (60 percent) of the potential habitat is located on Federal reserved-land allocations, a substantial amount of nesting habitat occurs on non-federal lands (34 percent) (Table 1).

Table 1. Estimates of higher-quality murrelet nesting habitat by State and major land ownership within the area of the NWFP – derived from 2012 data.

State	Habitat capable lands (1,000s of acres)	Habitat on Federal reserved lands (1,000s of acres)	Habitat on Federal non-reserved lands (1,000s of acres)	Habitat on non-federal lands (1,000s of acres)	Total potential nesting habitat (all lands) (1,000s of acres)	Percent of habitat capable land that is currently in habitat
WA	10,851.1	822.4	64.7	456	1,343.1	12 %
OR	6,610.4	484.5	69.2	221.1	774.8	12 %
CA	3,250.1	24.5	1.5	82.9	108.9	3 %
Totals	20,711.6	1,331.4	135.4	760	2,226.8	11 %
Percent		60 %	6 %	34 %	100 %	-

Source: (Raphael et al. 2016b, pp. 78-81).

Population Status

The 1997 *Recovery Plan for the Marbled Murrelet* (USFWS 1997) identified six Conservation Zones throughout the listed range of the species: Puget Sound (Conservation Zone 1), Western Washington Coast Range (Conservation Zone 2), Oregon Coast Range (Conservation Zone 3), Siskiyou Coast Range (Conservation Zone 4), Mendocino (Conservation Zone 5), and Santa Cruz Mountains (Conservation Zone 6) (Figure 1). Recovery zones are the functional equivalent of recovery units as defined by Service policy (USFWS 1997, p. 115). The subpopulations in each Zone are not discrete. There is some movement of murrelets between Zones as indicated by radio-telemetry studies (e.g., Bloxton and Raphael 2006, p. 162), but the degree to which murrelets migrate between Zones is unknown. Genetic studies also indicate that there is movement of murrelets between Zones, although Zone 6 is more isolated genetically than the other Zones (Friesen et al. 2005, pp. 611-612; Hall et al. 2009, p. 5080; Peery et al. 2008b, pp. 2757-2758; Peery et al. 2010, p. 703; Vásquez-Carrillo et al. 2014, pp. 251-252). For the purposes of consultation, the Service treats each of the Conservation Zones as separate sub-populations of the listed murrelet population.

<u>Population Status and Trends</u>

Population estimates for the murrelet are derived from marine surveys conducted during the nesting season as part of the NWFP effectiveness monitoring program. Surveys from 2001 to 2017 indicated that the murrelet population in Conservation Zones 1 through 5 (NWFP area) increased at a rate of 0.34 percent per year (McIver et al. 2019, p. 3). While the trend estimate across this period is slightly positive, the evidence of a detectable trend is not conclusive because the confidence intervals for the estimated trend overlap zero (95% confidence interval [CI]: -0.9 to 1.6 percent), indicating that at the scale of the NWFP area, the population could be decreasing slightly, stable, or increasing slightly (McIver et al. 2019, p. 3) (Table 2).At the state scale, Washington exhibited a significant declining trend between 2001 and 2017 (3.9% decrease per year, while Oregon and California showed significant positive trends (OR = 2.0% increase per year; CA = 4.5% increase per year (McIver et al. 2019, p. 3) (Table 2).

While the direct causes for population declines in Washington are unknown, potential factors include the loss of nesting habitat, including cumulative and time-lag effects of habitat losses over the past 20 years (an individual murrelets potential lifespan), changes in the marine environment reducing the availability or quality of prey, increased densities of nest predators, and emigration (Miller et al. 2012, p. 778). As with nesting habitat loss, marine habitat degradation is most prevalent in the Puget Sound area where anthropogenic activities (e.g., shipping lanes, boat traffic, shoreline development) are an important factor influencing the marine distribution and abundance of murrelets in Conservation Zone 1 (Falxa and Raphael 2016, p. 110).

The most recent population estimate for the entire NWFP area in 2017 was approximately 23,000 murrelets (95 percent CI: 18,500 to 27,600 birds) (McIver et al. 2019, p. 3). The largest and most stable murrelet subpopulations now occur off the Oregon and northern California coasts, while subpopulations in Washington have experienced the greatest rates of decline. Murrelet zones are now surveyed on an every other-year basis, so the last year that an extrapolated range-wide estimate for all zones combined is 2017 (Table 2).

The murrelet subpopulation in Conservation Zone 6 (central California- Santa Cruz Mountains) is outside of the NWFP area and is monitored separately by California State Parks and the U.S. Geological Survey using similar at-sea survey methods (Felis et al. 2019, p. 1). Surveys in Zone 6 indicate a small population of murrelets with no clear trends. Population estimates from 2001 to 2018 have fluctuated from a high of 699 murrelets in 2003, to a low of 174 murrelets in 2008 (Felis et al. 2019, p. 7). In 2018, surveys indicated an estimated population of 370 murrelets in Zone 6 (95% CI: 250-546) (Felis et al. 2019, p. 7) (Table 2).

Table 2. Summary of murrelet population estimates and trends (2001-2017/2018) at the scale of Conservation Zones and states.

Zone	Year	Estimated number of murrelets	95% CI Lower	95% CI Upper	Average density (at sea) (murrelets /km^2)	Average annual rate of change (%)	95% CI Lower	95% CI Upper
1	2018	3,837	1,911	6,956	1.097	-4.9	-7.3	-2.4
2	2017	1,758	1,041	2,623	1.065	-3.0	-6.8	+0.9
3	2018	8,414	5,866	12,183	5.274	+1.4	-0.4	+3.3
4	2017	8,574	6,358	11,155	7.397	+3.7	+1.4	+6.1
5	2017	868	457	1,768	0.983	+7.3	-4.4	+20.3

Zone	Year	Estimated number of murrelets	95% CI Lower	95% CI Upper	Average density (at sea) (murrelets /km^2)	Average annual rate of change (%)	95% CI Lower	95% CI Upper
Zones 1-5	2017	23,040	18,527	27,552	2.623	+0.34	-0.9	+1.6
Zone 6	2018	370	250	546	na	na	na	na
WA	2017	5,984	3,204	8,764	1.16	-3.9	-5.1	-2.0
OR	2017	10,945	8,018	13,872	5.28	2.0	0.5	3.6
CA Zones 4 & 5	2017	6,111	4,473	7,749	3.90	4.5	2.2	6.9

Sources: (McIver et al. 2019, pp. 8-17, Felis et al. 2019, p. 7).

Factors Influencing Population Trends

Murrelet populations are declining in Washington, but increasing in Oregon and northern California (McIver et al. 2019, p. 3). Murrelet population size and distribution is strongly and positively correlated with the amount and pattern (large contiguous patches) of suitable nesting habitat and population trend is most strongly correlated with trend in nesting habitat, although marine factors also contribute to this trend (Raphael et al. 2016, p. 115). From 1993 to 2012, there was a net loss of about 2 percent of potential nesting habitat from on federal lands, compared to a net loss of about 27 percent on nonfederal lands, for a total cumulative net loss of about 12.1 percent across the NWFP area (Raphael et al. 2016, p. 72). Cumulative habitat losses since 1993 have been greatest in Washington, with most habitat loss in Washington occurring on non-Federal lands due to timber harvest (Raphael et al. 2016, pp. 80-81) (Table 3).

Table 3. Distribution of higher-suitability murrelet nesting habitat by Conservation Zone, and summary of net habitat changes from 1993 to 2012 within the NWFP area.

Conservation Zone	1993	2012	Change (acres)	Change (percent)
Zone 1 - Puget Sound/Strait of Juan de Fuca	829,525	739,407	-90,118	-10.9 %
Zone 2 - Washington Coast	719,414	603,777	-115,638	-16.1 %
Zone 3 - Northern to central Oregon	662,767	610,583	-52,184	-7.9 %
Zone 4 - Southern Oregon - northern California	309,072	256,636	-52,436	-17 %
Zone 5 - north-central California	14,060	16,479	+2,419	+17.2 %

Source: (Raphael et al. 2016b, pp. 80-81).

The decline in murrelet populations from 2001 to 2013 is weakly correlated with the decline in nesting habitat, with the greatest declines in Washington, and the smallest declines in California, indicating that when nesting habitat decreases, murrelet abundance in adjacent marine waters may also decrease. At the scale of Conservation Zones, the strongest correlation between habitat loss and murrelet decline is in Zone 2, where murrelet habitat has declined most steeply and marbled murrelet populations have also continued to decline. However, these relationships are not linear, and there is much unexplained variation (Raphael et al. 2016a, p. 110). While terrestrial habitat amount and configuration (i.e., fragmentation) and the terrestrial human footprint (i.e., cities, roads, development) appear to be strong factors influencing murrelet distribution in Zones 2-5; terrestrial habitat and the marine human footprint (i.e., shipping lanes, boat traffic, shoreline development) appear to be the most important factors that influence the marine distribution and abundance of murrelets in Zone 1 (Raphael et al. 2016a, p. 106).

Like other marine birds, murrelets depend for their survival on their ability to successfully forage in the marine environment. Despite this, it is apparent that the location, amount, and landscape pattern of terrestrial nesting habitat are strongest predictors of the spatial and temporal distributions of murrelets at sea during the nesting season (Raphael et al. 2015, p. 20). Outside of Zone 1, various marine habitat features (e.g., shoreline type, depth, temperature, human footprint, etc.) apparently have only a minor influence on murrelet distribution at sea. Despite this relatively weak spatial relationship, marine factors, and especially any decrease in forage species, likely play an important role in explaining the apparent population declines, but the ability to detect or model these relationships is currently limited (Raphael et al. 2015, p. 20). Over both the long and short term, there is evidence that diet quality is related to marbled murrelet abundance and reproductive success (Becker et al. 2007, p. 276; Norris et al. 2007, p. 881).

Population Models

Prior to the use of survey data to estimate trend, demographic models were more heavily relied upon to generate predictions of trends and extinction probabilities for the murrelet population (Beissinger 1995; Cam et al. 2003; McShane et al. 2004; USFWS 1997). However, murrelet population models remain useful because they provide insights into the demographic parameters and environmental factors that govern population stability and future extinction risk, including stochastic factors that may alter survival, reproductive, and immigration/emigration rates.

In a report developed for the *5-year Status Review of the Marbled Murrelet in Washington, Oregon, and California* (McShane et al. 2004, pp. 3-27 to 3-60), models were used to forecast 40-year murrelet population trends. A series of female-only, multi-aged, discrete-time stochastic Leslie Matrix population models were developed for each conservation zone to forecast decadal population trends over a 40-year period with extinction probabilities beyond 40 years (to 2100). The authors incorporated available demographic parameters (Table 4) for each conservation zone to describe population trends and evaluate extinction probabilities (McShane et al. 2004, p. 3-49).

McShane et al. (2004) used mark-recapture studies conducted in British Columbia by Cam et al. (2003) and Bradley et al. (2004) to estimate annual adult survival and telemetry studies or at-sea survey data to estimate fecundity. Model outputs predicted -3.1 to -4.6 percent mean annual rates of population change (decline) per decade the first 20 years of model simulations in murrelet Conservation Zones 1 through 5 (McShane et al. 2004, p. 3-52). Simulations for all zone populations predicted declines during the 20 to 40-year forecast, with mean annual rates of -2.1 to -6.2 percent per decade (McShane et al. 2004, p. 3-52). While these modeled rates of decline are similar to those observed in Washington (McIver et al. 2019, p. 3), the simulated projections at the scale of Zones 1-5 do not match the apparently stable or increasing populations observed in Oregon and California during the 2001-2018 monitoring period.

Table 4. Rangewide murrelet demographic parameter values based on four studies all using Leslie Matrix models.

Demographic Parameter	Beissinger 1995	Beissinger and Nur 1997*	Beissinger and Peery (2007)	McShane et al. 2004
Juvenile Ratio (Ŕ)	0.10367	0.124 or 0.131	0.089	0.02 - 0.09
Annual Fecundity	0.11848	0.124 or 0.131	0.06-0.12	-
Nest Success	-	-	0.16-0.43	0.38 - 0.54
Maturation	3	3	3	2 - 5
Estimated Adult Survivorship	85 % – 90%	85 % – 88 %	82 % - 90 %	83 % – 92 %

*In U.S. Fish and Wildlife (1997).

Reproduction

Overall fecundity is a product of the proportion of marbled murrelets that attempt nesting and the proportion of nest attempts that succeed. Telemetry studies can be used to estimate both the proportion of murrelets attempting nesting, and the proportion of nest attempts that succeed. When telemetry estimates are not available, at-sea surveys that separately count the number of hatch-year and after-hatch-year birds can be used to estimate productivity. Telemetry estimates are typically preferred over marine counts for estimating breeding success due to fewer biases (McShane et al. 2004, p. 3-2). However, because of the challenges of conducting telemetry studies, estimating murrelet reproductive rates with an index of reproduction, referred to as the juvenile ratio (**Ŕ**),[12] continues to be important, despite some debate over use of this index (see discussion in Beissinger and Peery 2007, p. 296).

Marbled murrelet fecundity is likely limited in part by low rates of nesting attempts in some parts of the range. Radio-telemetry monitoring Washington between 2004 and 2008 indicated only a small portion of 158 tagged adult birds actually attempted to nest (13 to 20 percent) (Lorenz et al. 2017, p. 316; Raphael and Bloxton 2009, p. 165). Studies from California and Oregon also report low rates. Two studies from central and northern California reported that an average of

12 The juvenile ratio (**Ŕ**) for murrelets is derived from the relative abundance of hatch-year (HY; 0-1 yr-old) to after-hatch-year (AHY; 1+ yr-old) birds (Beissinger and Peery 2007, p. 297) and is calculated from marine survey data. All ratios presented here are date-corrected using the methods of Peery et al. (2007, p. 234) to account adults incubating and chicks not yet fledged at the time of the survey.

around 30 percent of radio-tagged murrelets attempted to nest (Hébert and Golightly 2006, p. 130; Peery et al. 2004, p. 1093). In preliminary results from a study in Oregon, 137 individuals were tagged over two years, but only 12 individuals, all tagged during the second year, made inland movements indicative of nesting attempts (Adrean et al. 2018, p. 2; Adrean et al. 2019, p. 2; Horton et al. 2018, p. 77). Averaged across years, this indicates that eight percent of tagged birds attempted to breed, the lowest rate yet reported for the species; however, the study is not yet complete and is therefore not comparable to the others cited above. These low rates of nesting are not intrinsic to the species; other studies outside of the listed range reported that between 46 and 80 percent of marbled murrelets attempted to breed each year (Barbaree et al. 2014, p. 177; Bradley et al. 2004, p. 323), and most population modeling studies suggest a range of 80 to 95 percent of adults breed each year (McShane et al. 2004, p. 3-5). The process of radio-tagging or the additional weight and drag of the radio tag itself may reduce the probability that a tagged individual will attempt to breed, but studies reporting higher rates of attempted nesting used similar radio tags, so radio-telemetry methods do not account for differences between the studies conducted in the listed range and those conducted elsewhere (Peery et al. 2004, p. 1094).

Although difficult to obtain, nest success rates[13] are available from telemetry studies conducted in California (Hébert and Golightly 2006; Peery et al. 2004, p. 1094), Washington (Lorenz et al. 2017, p. 312; Lorenz et al. 2019, p. 160),and, preliminarily, in Oregon (Adrean et al. 2019, p. 2). In northwestern Washington, Lorenz and others (2017, p. 312; 2019, pp. 159-160) documented a nest success rate of 0.20 (3 chicks fledging from 15 nest starts). In central California, murrelet nest success is 0.16 (Peery et al. 2004, p. 1098) and in northern California it ranges from 0.069 to 0.243 (Hébert and Golightly 2006, p. 129). In Oregon, preliminary results from a telemetry study indicate that 3 of 7 active nests successfully fledged young, a rate of 0.43, but this success rate may not be comparable to the others reported above; for example, it is not clear whether it includes all nesting attempts (Adrean et al. 2019, p. 2).

At least one telemetry study reported overall fecundity rates, combining both the rates of nesting attempts with the rates of fledging success. In central California, the fecundity rate was estimated to be 0.027, or 2.7 female chicks produced per year for every 100 females of breeding age (Peery et al. 2004, p. 1094). In other studies, the overall fecundity rate is not known, because it is not clear how many of the radio-tagged birds were of breeding age. However, in northern California, of 102 radio-tagged birds, at least two and at most six successfully produced fledglings (Hébert and Golightly 2006, pp. 130-131), and in Washington and southern Vancouver Island, of 157 radio-tagged birds, four produced fledglings (Lorenz et al. 2017, p. 312). If we assume (as in Peery et al. 2004, p. 1094) that 93 percent of captured birds in each sample were of breeding age, and that half of all captured birds and half of all fledged chicks were female, fecundity rates from these samples would be 0.027 in Washington, and between 0.021 and 0.063 in northern California.

Unadjusted and adjusted values for estimates of murrelet juvenile ratios also suggest low reproductive rates. In northern California and Oregon, annual estimates for **Ŕ** range from 0 to 0.140, depending on the area surveyed (Strong 2014, p. 20; Strong 2015, p. 6; Strong 2016, p. 7;

13 Nest success here is defined by the annual number of known hatchlings departing from the nest (fledging) divided by the number of nest starts.

Strong 2017, p. 6; Strong 2018, p. 7; Strong 2019, p. 6; Strong and Falxa 2012, p. 4). In Conservation Zone 4, the annual average between 2000 and 2011 was 0.046 (Strong and Falxa 2012, p. 11). In central California, estimates of **Ŕ** range from 0.01 to 0.11, with an annual average of 0.049, over 19 years of survey between 1996 and 2017 (Felis et al. 2018, p. 9). An independent calculation of **Ŕ** among murrelets captured in central California between 1999 and 2003 resulted in estimates ranging from 0 to 0.111, with an average of 0.037 (Peery et al. 2007, p. 235). Estimates for **Ŕ** in the San Juan Islands in Washington tend to be higher, ranging from 0.02 to 0.12, with an average of 0.067, over 18 years of survey between 1995 and 2012 (Lorenz and Raphael 2018, pp. 206, 211). Notably, **Ŕ** in the San Juan Islands did not show any temporal trend over the 18-year period, even while the abundance of adult and subadult murrelets declined (Lorenz and Raphael 2018, pp. 210-211).

Although these estimates of **Ŕ** are higher than one would expect based on fecundity rates derived from radio-telemetry studies, they are below the level thought to be necessary to maintain or increase the murrelet population. Demographic modeling, historical records, and comparisons with similar species all suggest that murrelet population stability requires juvenile ratios between 0.176 and 0.3 (Beissinger and Peery 2007, p. 302; USFWS 1997, p. B-13). Even the lower end of this range is higher than any current estimate for **Ŕ** for any of the Conservation Zones. This indicates that the murrelet reproductive rate is likely insufficient to maintain stable population numbers throughout all or portions of the species' listed range. These sustained low reproductive rates appear to be at odds with the potentially stable population size measured for Zones 1 through 5, and are especially confusing in light of apparent population increases in Oregon and California.

<u>Integration and Summary: Murrelet Abundance, Distribution, Trend, and Reproduction</u>

A statistically significant decline was detected in Conservation Zones 1 and 2 for the 2001-2017 period (Table 2). The overall population trend from the combined 2001-2017 population estimates (Conservation Zones 1 - 5) indicates a potentially stable population with a 0.34 percent increase per year (McIver et al. 2019, p. 3). Because the confidence intervals for this estimate overlap 0, there is not clear evidence of either or a positive or negative trend. At the state-scale, significant declines have occurred in Washington, while subpopulations in Oregon and California show a statistically meaningful increase (McIver et al. 2019, p. 3).

The current ranges of estimates for fecundity and for **Ŕ**, the juvenile to adult ratio, are below the level assumed to be necessary to maintain or increase the murrelet population. Whether derived from radio-telemetry, marine surveys or from population modeling (**Ŕ** = 0.02 to 0.13, Table 4), the available information is in general agreement that the current ratio of hatch-year birds to after-hatch year birds is insufficient to maintain stable numbers of murrelets throughout the listed range. The current estimates for **Ŕ** also appear to be well below what may have occurred prior to the murrelet population decline (Beissinger and Peery 2007, p. 298).

The reported stability of the population at the larger scale (Zones 1 through 5) and growth of subpopulations in Oregon and California appear to be at odds with the sustained low reproductive rates reported throughout the listed range. A number of factors could contribute to this discrepancy. For example, population increases could be caused by an influx of murrelets moving from the Canadian population into Oregon and California, or into Washington and displacing Washington birds to Oregon and California. The possibility of a population shift from Washington to Canada has previously been dismissed, based on nest-site fidelity and the fact that both Washington and British Columbia populations are declining simultaneously (Falxa et al. 2016, p. 30), but these arguments do not rule out the possibility that non-breeding murrelets originating in Canada may be spending time foraging in Oregon or California waters.

Another possibility is the proportion of birds present on the water during surveys, rather than inland at nest sites, may be increasing. If so, this would artificially inflate population estimates. If so, this could be driven by low nesting rates, as were observed in Oregon in 2017 (Adrean et al. 2018, p. 2; Horton et al. 2017, p. 77); or by shifts toward earlier breeding, for which there is anecdotal evidence (for example, Havron 2012, p. 4; Pearson 2018, in litt.; Strong 2019, p. 6); or a combination of both factors. In either case, individuals that would in earlier years have been incubating an egg or flying inland to feed young, and therefore unavailable to be counted, would now be present at sea and would be observed during surveys. For the same number of birds in the population, the population estimate would increase as adults spend more of the survey period at sea.

Finally, the shift that occurred in 2015 to sampling only half of the Conservation Zones in each survey year (McIver et al. 2019, p. 5) is increasing the uncertainty in how to interpret the survey results, especially in light of large-scale movements that can occur during the breeding season, sometimes involving numerous individuals (Horton et al. 2018, p. 77; Peery et al. 2008a, p. 116). Murrelets that move into or out of the zone being sampled during the breeding season could artificially inflate or deflate the population estimates.

Some of these factors would also affect measures of fecundity and juvenile ratios. For example, if murrelets are breeding earlier on average, then the date adjustments applied to juvenile ratios may be incorrect, possibly resulting in inflated estimates of **Ŕ**. If current estimates of **Ŕ** are biased high, this would mean that the true estimates of **Ŕ** are even lower, exacerbating, rather than explaining, the discrepancy between the apparently sustained low reproductive rates and the apparently stable or increasing subpopulations south of Washington.

Considering the best available data on abundance, distribution, population trend, and the low reproductive success of the species, the Service concludes the murrelet population within the Washington portion of its listed range currently has little or no capability to self-regulate, as indicated by the significant, annual decline in abundance the species is currently undergoing in Conservation Zones 1 and 2. Populations in Oregon and California are apparently more stable, but reproductive rates remain low in those areas, and threats associated with habitat loss and habitat fragmentation continue to occur. The Service expects the species to continue to exhibit further reductions in distribution and abundance into the foreseeable future, due largely to the expectation that the variety of environmental stressors present in the marine and terrestrial environments (discussed in the *Threats to Murrelet Survival and Recovery* section) will continue into the foreseeable future.

Threats to Murrelet Survival and Recovery

When the murrelet was listed under the Endangered Species Act in 1992, several anthropogenic threats were identified as having caused the dramatic decline in the species:

- habitat destruction and modification in the terrestrial environment from timber harvest and human development caused a severe reduction in the amount of nesting habitat
- unnaturally high levels of predation resulting from forest "edge effects" ;
- the existing regulatory mechanisms, such as land management plans (in 1992), were considered inadequate to ensure protection of the remaining nesting habitat and reestablishment of future nesting habitat; and
- manmade factors such as mortality from oil spills and entanglement in fishing nets used in gill-net fisheries.

The regulatory mechanisms implemented since 1992 that affect land management in Washington, Oregon, and California (for example, the NWFP) and new gill-netting regulations in northern California and Washington have reduced the threats to murrelets (USFWS 2004, pp. 11-12). However, additional threats were identified, and more information was compiled regarding existing threats, in the Service's 5-year reviews for the murrelet compiled in 2009 and 2019 (USFWS 2009, pp. 27-67; USFWS 2019, pp. 19-65). These stressors are related to environmental factors affecting murrelets in the marine and terrestrial environments. These stressors include:

- Habitat destruction, modification, or curtailment of the marine environmental conditions necessary to support murrelets due to:
  - elevated levels of toxic contaminants, including polychlorinated biphenyls, polybrominated diphenyl ether, polycyclic aromatic hydrocarbons, and organochlorine pesticides, in murrelet prey species;
  - the presence of microplastics in murrelet prey species;
  - changes in prey abundance and availability;
  - changes in prey quality;
  - harmful algal blooms that produce biotoxins leading to domoic acid and paralytic shellfish poisoning that have caused murrelet mortality;
  - harmful algal blooms that produce a proteinaceous foam that has fouled the feathers of other alcid species, and affected areas of murrelet marine habitat;
  - hypoxic or anoxic events in murrelet marine habitat; and
  - climate change in the Pacific Northwest.

- Manmade factors that affect the continued existence of the species include:
  - derelict fishing gear leading to mortality from entanglement;

- disturbance in the marine environment (from exposures to lethal and sub-lethal levels of high underwater sound pressures caused by pile-driving, underwater detonations, and potential disturbance from high vessel traffic); and
- wind energy generation, currently limited to onshore projects, leading to mortality from collisions.

Since the time of listing, some murrelet subpopulations have continued to decline due to lack of successful reproduction and recruitment, and while other subpopulations appear to be stable or increasing, productivity in these populations remains lower than the levels likely to support sustained population stability. The murrelet Recovery Implementation Team identified five major mechanisms that appear to be contributing to poor demographic performance (USFWS 2012b, pp. 10-11):

- Ongoing and historic loss of nesting habitat.
- Predation on murrelet eggs and chicks in their nests.
- Changes in marine conditions, affecting the abundance, distribution, and quality of murrelet prey species.
- Post-fledging mortality (predation, gill-nets, oil-spills).
- Cumulative and interactive effects of factors on individuals and populations.

Climate Change

In the Pacific Northwest, climate change affects both the marine and forested environments on which marbled murrelets depend. Changes in the terrestrial environment may have a direct effect on marbled murrelet reproduction, and also affect the structure and availability of nesting habitat. Changes in the marine environment affect marbled murrelet food resources. Changes in either location may affect the likelihood, success, and timing of marbled murrelet breeding in any given year.

Changes in the Physical Environment

Projected changes to the climate within the range of the marbled murrelet include air and sea surface temperature increases, changes in precipitation seasonality, and increases in the frequency and intensity of extreme rainfall events (Mauger et al. 2015, pp. 2-1 – 2-18; Mote and Salathé 2010, p. 29; Salathé et al. 2010, pp. 72-73). Air temperature warming is already underway, and is expected to continue, with the mid-21st century projected to be approximately four to six degrees Fahrenheit (°F) (2.2 to 3.3 degrees Celsius [°C]) warmer than the late 20th century (Mauger et al. 2015, p. 2-5; USGCRP 2017, pp. 196-197). Similarly, sea surface temperatures are already rising and the warming is expected to continue, with increases between 2.2 °F (1.2 °C) and 5.4 °F (3 °C) projected for Puget Sound, the Strait of Georgia, and the Pacific Coast between the late 20th century and mid-or late-21st century (Mote and Salathé 2010, p. 16; Riche et al. 2014, p. 41; USGCRP 2017, p. 368). Summer precipitation is expected to decrease, while winter precipitation is expected to increase (Mauger et al. 2015, p. 2-7; USGCRP 2017,

p. 217). In particular, heavy rainfall events are projected to occur between two and three times as frequently and to be between 19 and 40 percent more intense, on average, in the late 21st century than they were during the late 20th century (Warner et al. 2015, pp. 123-124).

The warming trend and trends in rainfall may be masked by naturally-occurring climate cycles, such as the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) (Reeder et al. 2013, p. 76). These oscillations have similar effects in the Pacific Northwest, with relatively warm coastal water and warm, dry winter conditions during a "positive" warm phase, followed by cooler coastal water and cooler, wetter winter conditions during the cool "negative" phase (Moore et al. 2008, p. 1747). They differ in that one phase of the ENSO cycle typically lasts between 6 and 18 months (one to three years for a full cycle), whereas, during the 20th century, each phase of the PDO cycle lasted approximately 20 to 30 years (approximately 40 to 60 years for a full cycle) (Mantua and Hare 2002, p. 36). Some studies break the PDO into two components, one with a full cycle length between 16 and 20 years and the other with a 50 to 70 year period, with the longer component referred to as the Pacific Multidecadal Oscillation (PMO) (Steinman et al. 2015, p. 988). Another recent study has identified a 60-year cycle separate from the longer-term component of the PDO, also referring to this as the PMO (Chen et al. 2016, p. 319). An additional pattern, the North Pacific Gyre Oscillation, is associated with changes in the alongshore winds that drive upwelling, and appears to complete approximately one cycle per decade (Di Lorenzo et al. 2008, pp. 2-3).

The overall warming projections described above for the listed range of the murrelet will be superimposed over the natural climate oscillations. The climate models used to project future trends account for naturally occurring cycles (IPCC 2014, p. 56). Therefore, the projected trend combined with the existing cycles mean that temperatures during a cool phase will be less cool than they would be without climate change, and warm phases will be warmer. During the winter of 2014-2015, the climate shifted from a negative cool phase of the PDO to a positive warm phase (Peterson et al. 2016, p. 46). Additionally, one study predicts that the PMO will enter a positive warm phase around the year 2025 (Chen et al. 2016, p. 322). The phases of these long-term climate cycles in addition to the projected warming trend imply that we should expect sea surface temperatures during the period over the next couple of decades to be especially warm. However, climate change may also alter the patterns of these oscillations, for example, by shortening the cycle length of the PDO (Zhang and Delworth 2016, pp. 6007-6008). Many studies of climate effects to marine species and ecosystems use indices of these climate oscillations, rather than individual climate variables such as sea surface temperature, as their measures of the climatic state (e.g. Becker and Beissenger 2006, p. 473). Therefore, if climate factors that covary with a given oscillation become decoupled, the relationships inferred from these studies may no longer be valid in the future.

Changes in the Forest Environment

Forested habitats in the Pacific Northwest are affected by climate change mainly via changes in disturbances, including wildfire, insects, tree diseases, and drought mortality. These types of disturbances can all cause the loss of marbled murrelet nesting habitat, though it is hoped that this loss will be offset by ingrowth as existing mid-successional forest matures. Following stand-replacing disturbances, climate conditions may not allow recruitment of the tree species that are currently present, leading to ecotype change; however, the effect of this kind of ecotype change may not directly affect marbled murrelet habitat availability until many decades in the future.

Historical fire regimes have varied throughout the range of the marbled murrelet. In many of the moist forests of western Washington and Oregon, the fire regime has historically been typified by large, stand-replacing fires occurring at intervals of 200 years or more (Halofsky et al. 2018a, pp. 3-4; Haugo et al. 2019, pp. 2-3; Long et al. 1998, p. 784). Parts of the murrelet range in southern Oregon and California have historically had low- and mixed-severity fires occurring every 35 years or less (Haugo et al. 2019, pp. 2-3; Perry et al. 2011, p. 707). Still other areas throughout the range historically had mixed severity fires occurring between 35 and 200 years apart (Haugo et al. 2019, pp. 2-3; Perry et al. 2011, p. 707). Within each type of historical fire regime, fire has occurred less frequently during the recent decades usually used for statistical analyses of fire behavior or projections of future fire than it did historically (Huago et al. 2019, pp. 8-9; Littell et al. 2010, p. 150).

Between 1993 and 2012, monitoring based on a database of large (1,000 acres or greater) fire perimeters detected losses associated with wildfires of 22,063 acres of Maxent-modeled high-quality marbled murrelet nesting habitat on federal and non-federal lands in the NWFP area (Raphael et al. 2016b, pp. 80-81). Fire was the leading natural cause of habitat loss within the NWFP area, but this ranking was driven by the 20,235-acre loss to fire on federal lands in the Klamath Mountains, and fire was far less important elsewhere in the range. Within subregions overlapping the listed range of the murrelet, the proportion of area currently "highly suitable" for large fires varies from less than 1 percent in the Coast Range of Oregon and Washington to 18 percent in the Klamath Mountains (Davis et al. 2017, p. 179). The fire regime in the listed range of the murrelet has historically been sensitive to climate conditions, though less so during recent decades (Henderson et al. 1989, pp. 13-19; Littell et al. 2010, p. 140; Littell and Gwozdz 2011, pp. 130-131; Weisberg and Swanson 2003, pp. 23-25).

The area burned in the range of the murrelet is expected to increase in the coming decades, but there is great uncertainty about the magnitude of the increase, and it is likely to affect some areas more than others (Davis et al. 2017, pp. 179-182; Rogers et al. 2011, p. 6; Sheehan et al. 2015, p. 25). On forested lands in the Cascades, Coast Ranges, and Klamath Mountains of Washington and Oregon, the percentage of forested area highly suitable for large fires is projected to increase from the current (less than 1 percent to 18 percent, varying by ecoregion) up to between 2 and 51 percent by the late 21st century, with much of this increase projected to occur after 2050 (Davis et al. 2017, pp. 179-181). At the same time, the percentage of forested lands with low suitability for large fire is expected to decrease from the current range of 21 to 97 percent to a lower range of 4 to 85 percent, depending on ecoregion. The increase in large fire suitability is expected to have the greatest effect on the Klamath ecoregion and the smallest effect on the Coast Ranges, with Cascades ecoregions falling in between (Davis et al. 2017, pp. 181). One study has classified most of the marbled murrelet range as having low vulnerability to fire for the 2020-2050 period, relative to all western forests, but parts of the range in southern Oregon and northern California are classified as having medium or high vulnerability (Buotte et al. 2018, pp. 5, 8). A different study found that forests west of the Cascade Crest are likely to be more vulnerable other western forests, because they will be sensitive to hotter, drier summers, but will not benefit from increased winter precipitation since soils are already saturated during winter months (Rogers et al. 2011, p. 6). Throughout the range, the annual number of days with high wildfire potential is expected to nearly double by mid-century (Martinuzzi et al. 2019, pp. 3, 6). Fire severity is also projected to increase over the 21st century (Rogers et al. 2011, p. 6).

Two recent studies have modeled future fires based on projected climate and vegetation characteristics, rather than simply using statistical projections based on past rates of wildfire. One study projected a 1.5- to 5-fold increase in forest fire in western Washington between the historical period and the 21st century (Halofsky et al. 2018b, p. 10). The baseline annual percentage of area burned was based on information about pre-European settlement fire rotation in western Washington, 0.2 to 0.3 percent of the forest land base burned per year, which is a much greater annual area burned than we have observed in the recent past. The late 21st-century annual area burned was projected to reach 0.3 to 1.5 percent of the forest land base per year, with extreme fire years burning 5 to 30 percent of the forest land base (Halofsky et al. 2018b, p. 10). The other study projected a 2- to 4-fold increase in western Washington and Oregon between the late 20th century and mid-century (Sheehan et al. 2019, p. 14). This study started with even larger baseline annual percentage of area burned, starting at 0.47 to 0.56 percent per year in the late 20th century and increasing to 1.14 to 1.99 percent per year by the mid-21st century (Sheehan et al. 2019, p. 14). In both studies, smaller increases in annual area burned were associated with a model assumption that firefighting would continue to be effective.

Insects and disease were the leading natural cause of marbled murrelet habitat loss within most ecoregions within the NWFP area between 1993 and 2012 (Raphael et al. 2016b, p. 81). Across the NWFP area, 8,765 acres of Maxent-modeled high-quality marbled murrelet habitat were lost to insects and disease, with the majority of these on federal lands in Washington. The USFS and WDNR have worked together since 1981 to collect and distribute aerial survey data regarding the presence of insects, disease, and other damage agents in Washington's forests (WDNR and USFS 2018). This dataset dataset indicates the identity of various insect and disease problems that have been recorded in the current marbled murrelet habitat: Douglas-fir beetle (*Dendroctonus pseudotsugae*), "dying hemlock," fir engraver (*Scolytus ventralis*), spruce aphid (*Elatobium abietinum*), Swiss needle cast (*Phaeocryptopus gaeumannii*), and western (*Lambdina fiscellaria lugubrosa*) and phantom (*Nepytia phantasmaria*) hemlock loopers. It is likely that various root diseases have also attacked marbled murrelet habitat, but these are generally classified as bear damage during the aerial surveys (Clark et al. 2018, p. 31). Root diseases that may be present include annosus (*Heterobasidium annosum*), armillaria (*Armillaria ostoyae*), and black stain (*Leptographium wageneri*) root diseases, as well as laminated (*Phellinus weirii*), tomentosus (*Inonotus tomentosus*), and yellow (*Parenniporia subacida*) root rots (Goheen and Willhite 2006, pp. 72-87).

Some of these pests, such as Swiss needle cast, are most typically found in younger stands, and are more likely to affect the development of marbled murrelet habitat over the long term; whereas others, such as Douglas-fir beetle, are more likely to attack older trees (Goheen and Willhite 2006, pp. 30, 224). Swiss needle cast typically does not result in tree mortality (Maguire et al. 2011, pp. 2069-2070), but can affect mixed-species forest stands by allowing increased western hemlock growth in stands where severe Swiss needle cast affects Douglas-fir growth (Zhao et al. 2014, entire). Higher average temperatures, in particular warmer winters, and increased spring precipitation in the Oregon Coast Range have contributed to an increase in the severity and distribution of Swiss needle cast in Douglas-fir (Stone et al. 2008, pp. 171-174; Sturrock et al. 2011, p. 138; Zhao et al. 2011, p. 1,876; Lee et al. 2013, pp. 683-685; Ritóková et al. 2016, p. 2). The distribution of Swiss needle cast increased from about 131,087 ac (53,050 ha) in 1996 to about 589,840 ac (238,705 ha) of affected trees in 2015 within 31 mi (50 km) of the coast in the Oregon Coast Range (Hansen et al. 2000, p. 775; Ritóková et al. 2016, p. 5).

Drought has not historically been a major factor in most of the listed range of the murrelet, because these forests are not typically water limited, especially in Washington and northern Oregon (Littell et al. 2010, p. 139; McKenzie et al. 2001, p. 531; Nemani et al. 2003, p. 1560). Nonetheless, every part of the listed range has been affected by multi-year drought at some point during the 1918-2014 period, varying geographically from areas with occasional mild two- to five-year droughts, to areas with moderate-severity two- or three-year droughts, to a few small areas, all in Washington, that have had at least one extreme three-year drought (Crockett and Westerling 2018, p. 345). Over the last few decades, the number of rainy summer days has decreased and the rain-free period has lengthened in much of the murrelet's listed range, especially in Oregon and Washington (Holden et al. 2018, p. 4). In the Pacific Northwest generally, drought is associated with Douglas-fir canopy declines that can be observed via satellite imagery (Bell et al. 2018a, pp. 7-10). In Western Washington, Oregon, and Southwestern British Columbia, tree mortality more than doubled (from around 0.5 percent per year to more than 1 percent per year) over the 30-year period between 1975 and 2005, likely due to increasing water stress (van Mantgem et al. 2009, pp. 522-523). Tree mortality may be caused by warm dry conditions in and of themselves (via xylem failure) or when hot, dry conditions compound the effects of insects, disease, and fire.

Some of the insects and pathogens already present in murrelet habitat, such as Douglas-fir beetles, are likely to become more prevalent and cause greater mortality in the future. Douglas-fir trees stressed by heat and drought emit ethanol, which attracts Douglas-fir beetles, and have lowered chemical defenses, which is likely to increase the endemic levels of Douglas-fir infestation and could result in higher probability of epidemic infestation (Agne et al. 2018, p. 326-327; Bentz et al. 2010, p. 605). Similarly, higher temperatures as the 21st century progresses will also increase the potential of spruce beetle (*Dendroctonus rufipennis*) outbreaks, which require mature spruce forests such as those found within the range of the murrelet (Bentz et al. 2010, p. 607). There is more uncertainty with respect to future levels of infection by Swiss needle cast, a disease that that has increased in severity over the past decade (Agne et al. 2018, p. 326). Warm, wet spring weather is thought to provide ideal conditions for Swiss needle cast infection, whereas warm, dry spring weather may inhibit the pathogen. Future spring weather will be warmer, but it is not clear whether it will be wetter, drier, or both (i.e., more variable), or perhaps current precipitation patterns will continue. Swiss needle cast effects to trees appear to be more severe during drought conditions, however. Therefore, the worst-case scenario for Swiss needle cast would be warm, wet springs followed by hot, dry summers. Swiss needle cast is also expected to spread inland and north to sites where fungal growth is currently limited by cold winter temperatures (Stone et al. 2008, p. 174; Zhao et al. 2011, p. 1,884; Lee et al. 2013, p. 688). Future climate conditions are also hypothesized to promote other diseases, such as Armillaria root disease, that could affect murrelet habitat (Agne et al. 2018, p. 326).

All climate models project increased summer warming for the Pacific Northwest, and most project decreased spring snowpack and summer precipitation, resulting in increasing demand on smaller amounts of soil water in the forest during the growing season. Forests within the murrelet range are expected to experience increasing water deficits over the 21st century (McKenzie and Littell 2017, pp. 33-34). These deficits will not be uniform, with the California and southern Oregon Coast Ranges, Klamath region, eastern Olympic Peninsula, and parts of the Cascades and northern Oregon Coast Range projected to experience much greater hydrological drought, starting sooner than in other places, while there are even projected reductions in water deficit for some other portions of the Washington Cascades and Olympic Mountains (McKenzie and Littell 2017, p. 31). Spring droughts, specifically, are projected to decrease in frequency in Washington and most of Oregon, but to increase in frequency in most of California, with some uncertainty as to the future likelihood of spring drought near the Oregon-California border (Martinuzzi et al. 2019, p. 6). The projected future warm, dry conditions, sometimes called "hotter drought" or "climate change-type drought" in the scientific literature, are expected to lead to continued increases in tree mortality. Though projections of future drought-related tree mortality in throughout the listed range of the murrelet are not available, the effects of the recent multi-year drought in the Sierra Nevada may provide some context about what to expect. Drought conditions in California during 2012 through 2015 led to an order of magnitude increase in tree mortality in Sierra Nevada forests (Young et al. 2017, p. 83). More mesic regions, including most areas of marbled murrelet habitat, are unlikely to have near-future impacts as severe as those already seen in the Sierra Nevada. For example, redwood forests in northwestern and central California, which include areas of murrelet nesting habitat, are more resistant to drought effects than other California forests (Brodrick et al. 2019, pp. 2757-2758). However, extreme climate conditions are eventually likely to further increase drought stress and tree mortality, especially since trees in moist forests are unlikely to be well-adapted to drought stress (Allen et al. 2010, p. 669; Allen et al. 2015, pp. 19-21; Anderegg et al. 2013, p. 705; Crockett and Westerling 2018, p. 342; Prestemon and Kruger 2016, p. 262; Vose et al. 2016, p. 10).

Blowdown is another forest disturbance that has historically caused extensive stand-replacing disturbances in the Pacific Northwest. The effect of climate change on blowdown frequency, extent, and severity is unknown, and there are reasons to believe that blowdowns may become either more or less frequent or extensive. Blowdown events are often associated with extra-tropical cyclones, which are often associated with atmospheric rivers. Blowdown is influenced by wind speeds and by soil saturation. Hurricane-force winds hit the Washington coast approximately every 20 years during the 20th century (Henderson et al. 1989, p. 20). Destructive windstorms have occurred in the Pacific Northwest in 1780-1788, 1880, 1895, 1921, 1923, 1955, 1961, 1962, 1979, 1981, 1993, 1995, and 2006 (Henderson et al. 1989, p. 20; Mass and Dotson 2010, pp. 2500-2504). During the 20th century, the events in 1921, 1962, and 2006 were particularly extreme. Although there are some estimates of timber losses from these events, there are no readily available estimates of total marbled murrelet habitat loss from particular events. In addition to habitat loss from these extreme blowdown events, a smaller amount of habitat is lost each year in "endemic" blowdown events. Wind damage may be difficult to detect via methods that rely on remotely sensed data (e.g., Raphael et al. 2016b, pp. 80-81) because much of the wind-damaged timber may be salvaged, and therefore appears to have been disturbed by harvest rather than wind. Nonetheless, between 1993 and 2012, 3,654 acres of

Maxent-modeled higher suitability nesting habitat loss was detected via remote sensing and attributed to blowdown or other natural, non-fire, non-insect disturbances (Raphael et al. 2016b, pp. 80-81). Nearly all of the habitat loss in this category affected federal lands in Washington.

Because we did not locate any studies attempting to project murrelet habitat loss to blowdown into the future, we looked to studies regarding the conditions associated with blowdown: wind, rain, and landscape configuration. There are indications that average wind speeds over the Pacific Northwest have declined since 1950, and average wind speeds are projected in most climate models to decline further by the 2080s (Luce et al. 2013, pp. 1361-1362). However, it is not clear how average wind speeds might be related to blowdown, since blowdown events usually happen during extreme wind events. Extreme extra-tropical cyclones are expected to become less frequent in the Northern Hemisphere in general, and perhaps along the Pacific Northwest coastline in particular, but these predictions involve many uncertainties. Different models show local increases in storm frequency in different places (Catto et al. 2011, pp. 5344-5345). Also, how "extreme" events are categorized differs between studies, and the results vary depending on what definition of "extreme" is used (Catto et al. 2001, p. 5348; Ulbrich et al. 2009, p. 127). One recent model projects no change in the extreme ground-level winds most likely to damage nesting habitat, and an increase in the frequency of extreme high-altitude winds (Chang 2018, pp. 6531, 6539). Atmospheric rivers are expected to become wetter and probably more frequent. The frequency of atmospheric river days is expected to increase by 50 to around 500 percent over the 21st century, depending on latitude and season (Gao et al. 2015, p. 7182; Warner and Mass 2017, p. 2135), though some models project up to an 18 percent decrease in frequency for either the northern or the southern end of the listed range (Payne and Magnusdottir 2015, p. 11,184). The most extreme precipitation events are expected to be between 19 and 40 percent wetter, with the largest increases along the northern California coast (Warner et al. 2015, p. 123). If increased rain causes greater soil saturation, it is easily conceivable that blowdown would become likely at lower wind speeds than would be needed to cause blowdown in less saturated conditions, but we did not find studies addressing this relationship. Since blowdown is more likely at forest edges, increased fragmentation may lead to more blowdown for the same wind speed and amount of soil saturation. The proportion of Maxent-modeled higher suitability nesting habitat located along forest edges increased between 1993 and 2012, and now makes up the majority of habitat in the NWFP area (Raphael et al. 2016b, p. 77). Some forested areas within the range may become less fragmented over the next 30 years, as conservation plans such as the NWFP continue to allow for forest growth; other areas may become more fragmented due to harvest, development, or the forest disturbances discussed above. Thus, the amount of marbled murrelet habitat likely to be lost to blowdown over the next 30 years is highly uncertain.

Synergistic effects between drought, disease, fire, and/or blowdown are likely to occur to some extent, and could become widespread. If large increases in mortality do occur, interactions between these agents are likely to be involved (Halofsky et al. 2018a, pp. 4-5). The large recent increase in tree mortality in the Sierra Nevada has been caused in large part due to these kinds of synergistic interactions. As noted above, range of the murrelet is unlikely to be as severely affected and severe effects are likely to happen later in time here than drier forests (where such effects are already occurring). In fact, one study rates much of the range as having low vulnerability, relative to other western forests, to drought or fire effects by 2049 (Buotte et al.

2018, p. 8). However, that study and many other studies do indicate that there is a risk of one or more of these factors acting to cause the loss of some amount of murrelet habitat over the next 30 years.

In addition to habitat loss resulting from forest disturbances at the scale of a stand or patch, habitat features may be altered as a result of climate change. For example, epiphyte cover on tree branches may change as a result of the warmer, drier summers projected for the future (Aubrey et al. 2013, p. 743). Climate-related changes in epiphyte cover will be additive or synergistic to changes in epiphyte cover resulting from the creation of forest edges through timber harvest (Van Rooyen et al. 2011, pp. 555-556). Epiphyte cover is assumed to have decreased throughout the listed range as the proportion of suitable habitat in edge condition has increased (USFWS 2019, p. 34), and as epiphyte cover decreases further, nest sites will become less available even in otherwise apparently suitable habitat.

In summary, forest disturbances, including wildfire, insect damage, disease, drought mortality, and windthrow, are likely to continue to remove murrelet nesting habitat, and many of these disturbances are likely to remove increasing amounts of habitat in the future. The effects of each type of disturbance are likely to be variable in different parts of the range, with wildfire affecting the Klamath Mountains far more than other parts of the range, and insect and disease damage largely focused in Washington. The magnitude of future increases is highly uncertain, and it is unclear whether windthrow will increase, decrease, or remain constant. Habitat not lost to disturbance may nonetheless be affected by climate change, as particular habitat features may be lost. The effects of habitat loss and the loss of habitat features will reduce the availability of nesting habitat, which will reduce the potential for marbled murrelet reproduction.

Changes in the Marine Environment

Changes in the climate, including temperature changes, precipitation changes, and the release of carbon dioxide into the atmosphere, affect the physical properties of the marine environment, including water circulation, oxygen content, acidity, and nutrient availability. These changes, in turn, affect organisms throughout the marine food web. For top predators like the marbled murrelet, Prey abundance, quality, and availability are all likely to be affected by climate change. Climate change is also likely to change the murrelet's level of exposure to toxic chemicals and potentially to disease agents. All of these changes are likely to alter the reproduction and survival of individual murrelets.

Marine waters within the range of the murrelet have warmed, as noted above. This warming involves not only a gradual increase in average temperatures, but also extreme marine heatwaves, which have dramatic effects on marine ecosystems. Preceding the development of El Niño conditions in 2015, a rise in sea surface temperatures in the Gulf of Alaska occurred in late 2013, likely due to a shift in wind patterns, lack of winter storms, and an increase in sea-level pressure (Bond et al. 2015, p. 3414; Leising et al. 2015, pp. 36, 38, 61). This warm water anomaly expanded southward in 2014, with further warming along the California Current in 2015, and then merged with another anomaly that developed off Baja California, becoming the highest sea surface temperature anomaly observed since 1982 when measurements began (NMFS 2016, p. 5). These anomalies became known as "the Blob" (Bond et al. 2015, p. 3414) and helped to compress the zone of cold upwelled waters to the nearshore (NMFS 2016, p. 7). During the late summer of 2019, a new marine heatwave began developing, and is currently on a trajectory to be as extreme as the 2014-2015 "Blob" (NMFS 2019).

The marine portion of the listed range of the murrelet is located along the California Current and estuary systems (including the Salish Sea) adjacent to it. The California Current is strongly influenced by upwelling, in which water rises from the deep ocean to the surface. Upwelling along the west coast leads to an influx of cold waters rich in nutrients such as nitrates, phosphates, and silicates, but that are also acidic (due to high dissolved carbon dioxide content) and low in dissolved oxygen (Johannessen et al. 2014, p. 220; Krembs 2012, p. 109; Riche et al. 2014, pp. 45-46, 48; Sutton et al. 2013, p. 7191). Changes in upwelling are likely to occur, and to influence the ecosystem components most important to murrelets. If changes in upwelling occur along the outer coast of Washington, these changes will also affect the interchange of waters through the Strait of Juan de Fuca (Babson et al. 2006, p. 30; Newton et al. 2003, p. 718). It has been hypothesized that as climate change accentuates greater warming of air over land areas than of air over the ocean, alongshore winds will intensify, which will lead to an increase in upwelling (Bakun 1990, entire). Historical records show that these winds have intensified over the past several decades (Bylhower et al. 2013, p. 2572; García-Reyes and Largier 2010, p. 6; Sydeman et al. 2014, p. 78-79; Taboada et al. 2019, p. 95; Wang et al. 2015, pp. 390-391). Projections for future changes in upwelling offer some support for this hypothesis, but are more equivocal (Foreman et al. 2011, p. 10; Moore et al. 2015, p. 5; Mote and Mantua 2002, p. 53-3; Rykaczewski et al. 2015, pp. 6426-6427; Wang et al. 2010, pp. 263, 265). Some studies indicate a trend toward a later, shorter (but in some cases, more intense) upwelling season, though at the southern end of the range the season may be lengthening (Bograd et al. 2009, pp. 2-3; Bylhower et al. 2013, p. 2572; Diffenbaugh et al. 2004, p. 30; Foreman et al. 2011, p. 8; García-Reyes and Largier 2010, p. 6). Trends and projections for the future of upwelling in the California Current may be so variable because upwelling is inherently difficult to model, or because upwelling in this region is heavily influenced by climate cycles such as the NPGO, PDO, and ENSO (Macias et al. 2012, pp. 4-5; Taboada et al. 2019, p. 95; Wang et al. 2015, p. 391).

Regardless of potential changes in the timing or intensity of upwelling, the dissolved oxygen content of the waters in the listed range is expected to decrease. The solubility of oxygen in water decreases with increasing temperature, so as the climate becomes warmer, the dissolved oxygen content of the marine environment is expected to decrease (IPCC 2014, p. 62; Mauger et al. 2015, pp. 7-3, 7-8). The oxygen content in the North Pacific Ocean has declined significantly since measurements began in 1987 (Whitney et al. 2007, p. 184), and this decline is projected to continue (Whitney et al. 2013, p. 2204). Hypoxic and anoxic events, in which the lack of dissolved oxygen creates a dead zone, have occurred in Puget Sound and along the outer coasts of Washington and Oregon (PSEMP Marine Waters Workgroup 2017, p. 22; PSEMP Marine Waters Workgroup 2016, p. 15; Oregon State University 2017, entire). These dead zones have expanded into shallower depths and areas closer to shore, and impacts are expected to increase rapidly (Chan et al. 2016, p. 4; Somero et al. 2016, p. 15). If upwelling does increase in intensity, the effect would likely be to further reduce the oxygen content of nearshore waters, but these changes are not likely to be consistent throughout the region or throughout the year. Changes in oxygen content, or in the timing of low-oxygen periods, may have important biological consequences (see below). Oxygen content also responds to biological activity. In addition to climate change-induced effects, some locations will likely experience reductions in oxygen content stemming from biological responses to eutrophication in areas that receive (and do not quickly flush) nutrient inputs from human activities (Cope and Roberts 2013, pp. 20-23; Mackas and Harrison 1997, p. 14; Roberts et al. 2014, pp. 103-104, 108; Sutton et al. 2013, p. 7191).

Similarly, acidification of waters in the listed range is expected to increase, regardless of any changes in upwelling. Acidification results when carbon dioxide in the air dissolves in surface water, and is the direct consequence of increasing carbon dioxide emissions (IPCC 2014, pp. 41, 49). Marine waters are projected to continue becoming more acidic, and ocean acidification is now expected to be irreversible at human-relevant timescales (IPCC 2014, pp. 8-9, 49; IPCC 2019, pp. 1-4, 1-7, 1-14). Both the surface and upwelled waters of North Pacific Ocean have become more acidic due to carbon dioxide emissions (Feely et al. 2008, pp. 1491-1492, Murray et al. 2015, pp. 962-963), and this trend is expected to continue (Byrne et al. 2010, p. L02601; Feely et al. 2009, pp. 40-46). These waters also contribute to acidification Conservation Zone 1 as they flow in through the Strait of Juan de Fuca (Feely et al. 2010, p. 446, Murray et al. 2015, p. 961). Any increase in upwelling intensity or changes in seasonality would respectively increase acidification or change the timing of pH changes in the murrelet range. It is unknown whether regional carbon dioxide emissions cause additional localized acidification within particular parts of the range (Newton et al. 2012, p. 36), but it is likely that other products of fossil fuel combustion, such as sulfuric acid, do contribute (Doney et al. 2007, pp. 14582-14583). Linked to reductions in dissolved oxygen (Riche et al. 2014, p. 49), acidification has important biological consequences (see below), and also responds to biological activity. For example, local areas of eutrophication are likely to experience additional acidification beyond that caused directly or indirectly by carbon dioxide emissions (Newton et al. 2012, pp. 32-33).

Sea level rise is also expected to affect the listed range of the murrelet. Sea level rise is a consequence of the melting of glaciers and ice sheets combined with the expansion of water as it warms (IPCC 2014, p. 42). At regional and local scales, numerous factors affect sea level rise, including ocean currents, wind patterns, and plate tectonics (Mauger et al. 2015, p. 4-1; Dalrymple 2012, p. 81; Petersen et al. 2015, p. 21). Sea level is rising at most coastal locations in the action area (Mauger et al. 2015, p. 4-2; Dalrymple 2012, pp. 79-81; Shaw et al. 1998, p. 37). These increases in sea level are likely to continue and may accelerate in the near future (Bromirski et al. 2011, pp. 9-10; Dalrymple 2012, pp. 71, 102; Mauger et al. 2015, pp. 4-3 – 4-5; Mote et al. 2008, p. 10; Petersen et al. 2015, pp. 21, 29, and Appendix D). However, in some places, such as Neah Bay,Washington, plate tectonics are causing upward land movement that is currently outpacing sea level rise (Dalrymple 2012, p. 80; Montillet et al. 2018, p. 1204; Mote et al. 2008, pp. 7-8; Petersen et al. 2015, pp 24-26). In other places, sea-level rise is expected to have consequences for near-shore ecosystems (see below).

Physical Changes Specific to Conservation Zone 1

Conservation Zone 1 will be affected by changes in upwelling, dissolved oxygen content, and acidification discussed above, but these effects are expected to vary, both between Conservation Zone 1 and the other Zones, and within Zone 1, based on the exchange of waters through the Strait of Juan de Fuca and water circulation patterns within Zone 1. These water circulation patterns, in and of themselves, are expected to be affected by climate change. The complexity of the physical environment within Zone 1 can make some climate change effects difficult to predict.

Changes in temperature and the seasonality of precipitation over land affect the freshwater inflows to Conservation Zone 1. Spring and summer freshwater inflows are expected to be warmer and reduced in volume, whereas winter freshwater inflows are expected to increase (Lee and Hamlet 2011, p. 110; Mauger et al. 2015, p. 3-8; Moore et al. 2015, p. 6; Mote et al. 2003, p. 56). Many watersheds draining to the Salish Sea have historically been fed by a mix of rain and snowmelt, but are expected to be increasingly dominated by rainfall, which will cause the timing of peak flows to shift from spring to winter (Elsner et al. 2010, pp. 248-249; Hamlet et al. 2001, pp. 9-11; Hamlet et al. 2013, pp. 401-404; Mauger et al. 2015, pp. 3-4 – 3-5). With winter warming and increases in heavy rainfall events, flooding has increased, and this increase is expected to continue (Hamlet and Lettenmaier 2007, pp. 25-16; Lee and Hamlet 2011, p. 113; Mauger et al. 2015, pp. 3-6 – 3-7). Increased winter freshwater inflows, in combination with melting glaciers, are expected to bring increased sediments to the mouths of rivers; however, it is uncertain whether these sediments are more likely to enter the marine waters or to be deposited in estuaries (Czuba et al. 2011, p. 2; Lee and Hamlet 2011, pp. 129-134; Mauger et al. 2015, pp. 5-7 – 5-10).

These changes in seasonal freshwater inflows are expected to alter water circulation and stratification within Conservation Zone 1, and to affect the rate and timing of exchange of waters through the Strait of Juan de Fuca between the Puget Sound and the North Pacific Ocean (Babson et al. 2006, pp. 29-30; MacCready and Banas 2016, p. 13; Mauger et al. 2015, p. 6-2, Riche et al. 2014, pp. 37-39, 44-45, 49-50). This exchange occurs in two layers, with fresh water at the surface flowing toward the ocean, and denser, saltier ocean waters flowing from the ocean at greater depths (Babson et al. 2006, p. 30). With the projected changes in timing of freshwater inflows, the rate of exchange is expected to increase during winter and decrease during summer (Mauger et al. 2015, pp. 6-2 – 6-3). The effect of changes in freshwater inflow on stratification is likely to vary by location within the action area, with greater potential for effect in, for example, southern Puget Sound than in well-mixed channels like Admiralty Inlet and Dana Passage (Newton et al. 2003, p. 721).

When hypoxic (low dissolved oxygen) events occur in the waters of Zone 2, these waters also flow into the inland waters of Conservation Zone 1, driving down the oxygen content there as well, although there is considerable variation over time, space, and depth, due to patterns of circulation and mixing within the Salish Sea (Bassin et al. 2011, Section 3.2; Johannessen et al. 2014, pp. 214-220). For example, Hood Canal is particularly susceptible to hypoxic conditions, partly because circulation of water through Hood Canal is slow (Babson et al. 2006, p. 30), whereas the vigorous tidal currents in Haro Strait allow for the mixing of oxygen-rich surface water throughout the water column (Johannessen et al. 2014, p. 216). Increased stratification, as is expected during winter with the larger freshwater inflows, can lead to hypoxic conditions in deeper waters (Mauger et al. 2015, p. 6-3; Whitney et al. 2007, p. 189). On the other hand, weaker stratification, as expected in the summer, may decrease the probability of low oxygen due to greater mixing, or increase the probability of low oxygen due to slower circulation (Newton et al. 2003, p. 725).

Primary Productivity

Changes in temperature, carbon dioxide, and nutrient levels are likely to affect primary productivity by phytoplankton, macroalgae, kelp, eelgrass, and other marine photosynthesizers (IPCC 2019, p. 5-72; Mauger et al. 2015, p. 11-5). In general, warmer temperatures, higher carbon dioxide concentrations, and higher nutrient levels lead to greater productivity (Gao and Campbell 2014, pp. 451, 454; Nagelkerken and Connell 2015, p. 13273; Newton and Van Voorhis 2002, p. 10; Roberts et al. 2014, pp. 11, 22, 108; Thom 1996, pp. 386-387), but these effects vary by species and other environmental conditions, such as sunlight levels or the ratios of different nutrients (Gao and Campbell 2014, pp. 451, 454; Krembs 2012, p. 109; Kroeker et al. 2013, p. 1889; Low-Decarie et al. 2011, p. 2530). In particular, phytoplankton species that form calcium carbonate shells, such as coccolithophores, show weaker shell formation and alter their physiology in response to acidification, and are expected to decline in abundance with continued acidification (Feely et al. 2004, pp. 365-366; IPCC 2019, p. 5-62; Kendall 2015, pp. 26-46). Due to changes in the seasonality of nutrient flows associated with upwelling and freshwater inputs, there may also be alterations in the timing, location, and species composition of bursts of primary productivity, for example, earlier phytoplankton blooms (Allen and Wolfe 2013, pp. 6, 8-9; MacCready and Banas 2016, p. 17; Mauger et al. 2015, p. 6-3). Changes in primary productivity may not occur in every season; for example, during winter, sunlight is the major limiting factor through most of Conservation Zone 1 (Newton and Van Voorhis 2002, pp. 9, 12), and it is not clear whether winter sunlight is likely to change with climate change. Models project reductions in overall annual marine net primary productivity in the world's oceans during the 21st century, trends will vary across the listed murrelet range, with decreases at the southern end of the range and increases at the northern end (IPCC 2019, pp. 5-31, 5-38). Changes in primary productivity are also likely to vary at smaller scales, even within a Conservation Zone; for example, primary productivity in Possession Sound is more sensitive to nutrient inputs than other areas within Puget Sound (Newton and Van Voorhis 2002, pp. 10-11). In sum, in addition to localized increases and decreases in productivity, we expect changes in the timing, location, and species dominance of primary producers.

Eelgrass (*Zostera marina*) is a particularly important primary producer in some parts of the range. In some areas, such as Padilla Bay in Zone 1, sea level rise is expected to lead to larger areas of suitable depth for eelgrass meadows. In such areas, eelgrass cover, biomass, and net primary production are projected to increase during the next 20 years (Kairis 2008, pp. 92-102), but these effects will depend on the current and future topography of the tidal flats in a given area. In addition, increasing dissolved carbon dioxide concentrations are associated with increased eelgrass photosynthetic rates and resistance to disease (Groner et al. 2018, p. 1807; Short and Neckles 1999, pp. 184-186; Thom 1996, pp. 385-386). However, increasing temperatures are not likely to be beneficial for eelgrass, and in combination with increased nutrients, could favor algal competitors (Short and Neckles 1999, pp. 172, 174; Thom et al. 2014, p. 4). Changes in upwelling are likely to influence eelgrass productivity and competitive interactions in small estuaries along the California Current (Hayduk et al. 2019, pp. 1128-1131). Between 1999 and 2013, eelgrass growth rates in Sequim Bay and Willapa Bay increased, but at a site in central Puget Sound, shoot density over a similar time period was too variable to detect trends (Thom et al. 2014, pp. 5-6). Taken together, these studies indicate that climate change may benefit eelgrass over the coming decades, but these benefits may be limited to specific areas, and negative effects may dominate in other areas (Thom et al. 2014, pp. 7-9).

Kelp forests also make important contributions to primary productivity in some parts of the range. Like eelgrass, bull kelp (*Nereocystis luetkeana*) responds to higher carbon dioxide concentrations with greater productivity (Thom 1996, pp. 385-386). On the other hand, kelp forests are sensitive to high temperatures (IPCC 2019, p. 5-72), and warming waters (among other factors) have reduced the range of giant kelp (*Macrocystis pyrifera* [Agardh]) (Edwards and Estes 2006, pp. 79, 85; Ling 2008, p. 892). In central and northern California, kelp forests have declined, but not along Oregon, Washington, and Vancouver Island (Krumhansl et al. 2016, p. 13787; Wernberg et al. 2019, p. 69). Along Washington's outer coast and the Strait of Juan de Fuca, bull kelp and giant kelp canopy area did not change substantially over the 20^{th} century, though a few kelp beds have been lost (Pfister et al. 2018, pp. 1527-1528). In southern Puget Sound, bull kelp declines were observed between 2013 and 2017-2018, likely resulting from increasing temperature along with decreasing nutrient concentrations, suspended sediment, and the presence of parasites and herbivores (Berry et al. 2019, p. 43). In northern California, a severe decline in bull kelp occurred in conjunction with the marine heatwave of 2014 and 2015, though a number of other ecological factors were involved (Catton et al. 2019, entire). In central California, trends in giant kelp biomass are related to climate cycles such as the NPGO, making the effect of climate change difficult to detect (Bell et al. 2018b, p. 11). It is unclear what the future effects of climate change will be on kelp in the listed range of the murrelet.

In contrast, increases in harmful algal blooms (also known as red tides or toxic algae) have been documented over the past several decades, and these changes are at least partly due to climate change (IPCC 2019, pp. 5-85 – 5-86; Trainer et al. 2003, pp. 216, 222). Future conditions are projected to favor higher growth rates and longer bloom seasons for these species. In the case of one species, *Alexandrium catanella,* increases in the length of bloom season are projected primarily due to increases in sea surface temperature (Moore et al. 2015, pp. 7-9). As with other climate change effects discussed above, increases in the length of the toxic algae bloom season is likely to vary across the listed range. Even within Zone 1, in the eastern end of the Strait of Juan de Fuca and the inlets of southern Puget Sound, the *A. catanella* bloom season is projected to increase by 30 days per year by 2069, in contrast with Whidbey basin, where little or no change in season length is projected (Moore et al. 2015, p. 8). In another genus toxic algae, *Pseudo-nitzschia*, toxin concentrations increase with increasing acidification of the water, especially in conditions in which silicic acid (used to construct the algal cell walls) or phosphate is limiting (Brunson et al. 2018, p. 1; Tatters et al. 2012, pp. 2-3). These and many other harmful alga species also exhibit higher growth rates with higher carbon dioxide concentrations (Brandenburg et al. 2019, p. 4; Tatters et al. 2012, pp. 3-4). During and following the marine heatwave in 2015, an especially large and long-lasting outbreak of *Pseudo-nitzschia* species stretched from southern California to the Aleutian Islands and persisted from May to October, rather than the typical span of a few weeks (Du et al. 2016, pp. 2-3; National Ocean Service 2016; NOAA Climate 2015, p. 1). This harmful algal bloom produced extremely high concentrations of toxic domoic acid, including the highest ever recorded in Monterey Bay, California (NOAA Climate 2015, p. 2; Ryan et al. 2017, p. 5575). With future climate change, toxic algae blooms are likely to be more frequent than in the past, and the larger, more toxic event of 2015 may become more typical (McCabe et al. 2016, p. 10374).

Higher Trophic Levels

There are several pathways by which climate change may affect species at higher trophic levels (i.e, consumers, including marbled murrelets and their prey). Changing physical conditions, such as increasing temperatures, hypoxia, or acidification will have direct effects on some species. Other consumers will be affected via changes in the abundance, distribution, or other characteristics of their competitors or prey species. Changes in the timing of seasonal events may lead to mismatches in the timing of consumers' life history requirements with their habitat conditions (including prey availability as well as physical conditions) (Mackas et al. 2007, p. 249). The combination of these effects is likely to cause changes in community dynamics (e.g. competitive interactions, predator-prey relationships, etc.), but the magnitude of these effects cannot be predicted with confidence (Busch et al. 2013, pp. 827- 831).

A wide variety of marine species are directly affected by ocean acidification. Like their phytoplankton counterparts, foraminiferans and other planktonic consumers that form calcium carbonate shells are less able to form and maintain their shells in acidified waters (Feely et al. 2004, pp. 356-366). Similarly, chemical changes associated with acidification interfere with shell development or maintenance in pteropods (sea snails) and marine bivalves (Busch et al. 2014, pp. 5, 8; Waldbusser et al. 2015, pp. 273-278). These effects on bivalves can be exacerbated by hypoxic conditions (Gobler et al. 2014, p. 5), or ameliorated by very high or low temperatures (Kroeker et al. 2014, pp. 4-5), so it is not clear what the effect is likely to be in a future that includes acidification, hypoxia, and elevated temperatures. Acidification affects crustaceans, for example, slowing growth and development in Pacific krill (*Euphausia pacifica*) and Dungeness crabs (*Cancer magister*) (Cooper et al. 2016, p. 4; Miller et al. 2016, pp. 118-119). Fish, including murrelet prey rockfish species (*Sebastes* spp.) and Pacific herring (*Clupea pallasii*), are also negatively affected by acidification. Depending on species, life stage, and other factors such as warming and hypoxia, these effects include embryo mortality, delayed hatching, reduced growth rates, reduced metabolic rates, altered sensory perception, and changes in behavior, among other effects (Baumann 2019, entire; Hamilton et al. 2014, entire; Nagelkerken and Munday 2016, entire; Ou et al. 2015, pp. 951, 954; Villalobos 2018, p. 18).

Climate effects are expected to alter interactions within the marine food web. When prey items decrease in abundance, their consumers are also expected to decrease, and this can also create opportunities for other species to increase. In California's Farallon Islands, the recently increasing variance of climate drivers is leading to increased variability in abundance of prey species such as euphausiids and juvenile rockfish, associated with corresponding variability in the demography of predators such as seabirds and salmon (Sydeman et al. 2013, pp. 1662, 1667-1672). In future scenarios with strong acidification effects to benthic prey in the California Current, euphausiids and several fish species are expected to decline, while other species are expected to increase (Kaplan et al. 2010, pp. 1973-1976). An investigation of the planktonic food web off of Oregon shows that sea surface temperature has contrasting effects on different types of zooplankton, and competitive interactions are much more prevalent during warm phases of ENSO or PDO than during cool phases (Francis et al. 2012, pp. 2502, 2505-2506). A food web model of Puget Sound shows that moderate or strong acidification effects to calcifying species are expected to result in reductions in fisheries yield for several species, including salmon and Pacific herring, and increased yield for others (Busch et al. 2013, pp. 827-829).

Additionally, the same model shows that these ocean acidification effects are expected to cause reductions in forage fish biomass, which are in turn expected to lead to reductions in diving bird biomass (Busch et al. 2013, p. 829). While Busch and coauthors (2013, p. 831) express confidence that this model is accurate in terms of the nature of ocean acidification effects to the Puget Sound food web of the future, they are careful to note that there is a great deal of uncertainty when it comes to the magnitude of the changes. The model also illustrates that some of the effects to the food web will dampen or make up for other effects to the food web, so that changes in abundance of a given prey species will not always correspond directly to changes in the abundance of their consumers (Busch et al. 2013, pp. 827, 830).

Changes in seasonality at lower trophic levels may lead to changes in population dynamics or in interactions between species at higher trophic levels. In central and northern California, reproductive timing and success of common murres (*Uria aalge*) and Cassin's auklets (*Ptychoramphus aleuticus*) are related to not only the strength but also the seasonal timing of upwelling, as are growth rates of *Sebastes* species (Black et al. 2011, p. 2540; Holt and Mantua 2009, pp. 296-297; Schroeder et al. 2009, p. 271). At the northern end of the California Current, Triangle Island in British Columbia, Cassin's auklet breeding success is reduced during years when the peak in copepod prey availability comes earlier than the birds' hatch date, and this mismatch is associated with warm sea surface temperatures (Bertram et al. 2009, pp. 206-207; Hipfner 2008, pp. 298-302). However, piscivorous seabirds (tufted puffins [*Fratercula cirrhata*], rhinoceros auklets [*Cerorhinca monocerata*], and common murres) breeding at the same Triangle Island site have, at least to some extent, been able to adjust their breeding dates according to ocean conditions (Bertram et al. 2001, pp. 292-293; Gjerdrum et al. 2003, p. 9379), as have Cassin's auklets breeding in the Farallon Islands of California (Abraham and Sydeman 2004, p. 240). Because of the changes in tufted puffin, rhinoceros auklet, and common murre hatch dates at Triangle Island, the breeding periods of these species have converged to substantially overlap with one another and with that of Cassin's auklet (Bertram et al. 2001, pp. 293-294), but studies have not addressed whether this overlap has consequences for competitive interactions among the four species. Note that all four of these bird species are in the family Alcidae, which also contains marbled murrelets. All these species also breed and forage within the listed range of the murrelet.

Several studies have suggested that climate change is one of several factors allowing jellyfish to increase their ecological dominance, at the expense of forage fish (Parsons and Lalli 2002, pp. 117-118; Purcell et al. 2007, pp. 154, 163, 167-168; Richardson et al. 2009, pp. 314-216). Many (though not all) species of jellyfish increase in abundance and reproductive rate in response to ocean warming, and jellyfish are also more tolerant of hypoxic conditions than fish are (Purcell 2005, p. 472; Purcell et al. 2007, pp. 160, 163; see Suchman et al. 2012, pp. 119-120 for a Northeastern Pacific counterexample). Jellyfish may also be more tolerant of acidification than fish are (Atrill et al. 2007, p. 483; Lesniowski et al. 2015, p. 1380). In the California Current, jellyfish populations appear to be increasing, but nearshore areas are likely to be susceptible to being dominated by jellyfish, rather than forage fish (Schnedler-Meyer et al. 2016, p. 4). Jellyfish abundance in southern and central Puget Sound has increased since the 1970s (Greene et al. 2015, p. 164). Over the same time period, herring abundance has decreased in south and central Puget Sound, and surf smelt (*Hypomesus pretiosus*) abundance has also decreased in south Puget Sound, although other Puget Sound forage fish populations have been stable or increasing (Greene et al. 2015, pp. 160-162). Forage fish abundance and jellyfish abundance were negatively correlated within Puget Sound and Rosario Strait (Greene et al. 2015, p. 164). In the northern California Current, large jellyfish and forage fish have similar diet composition and likely compete for prey, in addition to the two groups' contrasting responses to climate and other anthropogenic factors (Brodeur et al. 2008, p. 654; Brodeur et al. 2014, pp. 177-179).

Many species of forage fish are expected to fare poorly in the changing climate, regardless of any competitive effects of jellyfish. North of the listed range, in the Gulf of Alaska, Anderson and Piatt (1999, pp. 119-120) documented the crash of capelin (*Mallotus villosus*), Pacific herring, and species of Irish lord (*Hemilepidotus* spp.), prickleback (Stichaeidae family), greenlings and mackerel (*Hexagrammos* and *Pleurogrammus* spp.), as well as several shrimp species, as part of a major community reorganization following a climate regime shift from a cool phase to a warm phase in the 1970s. In the northeastern Pacific Ocean, capelin, sand lance (Ammodytidae family), and rockfish abundance are all negatively correlated with seasonal sea surface temperatures (Thayer et al. 2008, p. 1616). A model of multiple climate change effects (e.g., acidification and deoxygenation) to marine food webs in the Northeast Pacific consistently projects future declines in small pelagic fish abundance (Ainsworth et al. 2011, pp. 1219, 1224). Within Zone 1, abundance of surf smelt and Pacific herring in the Skagit River estuary are positively associated with coastal upwelling during the spring and early summer, likely because nutrient-rich upwelled water increases food availability (Reum et al. 2011, pp. 210-212). If projections of later, shorter upwelling seasons are correct (see above), the delays may lead to declines in these stocks of herring and surf smelt, as happened in 2005 (Reum et al. 2011, p. 212). Similarly, delayed upwelling in 2005 led to reduced growth rates, increased mortality, and recruitment failure of juvenile northern anchovies (*Engraulis mordax*) off of the Oregon and Washington coasts (Takahashi et al. 2012, pp. 397-403). In contrast, anchovy abundance in Zone 1 was unusually high in 2005, as it was in 2015 and 2016 following the marine heatwave, and is positively associated with sea surface temperature (Duguid et al. 2019, p. 38). In the northeastern Pacific, Chavez and coauthors (2003, pp. 217-220) have described a shift between an "anchovy regime" during the cool negative phase of the PDO and a "sardine regime" during the warm positive phase, where the two regimes are associated with contrasting physical and biological states. However, global warming may disrupt the ecological response to the naturally-occurring oscillation, or alter the pattern of the oscillation itself (Chavez et al. 2003, p. 221; Zhang and Delworth 2016, entire).

Marbled Murrelets

Marbled murrelets are likely to experience changes in foraging and breeding ecology as the climate continues to change. Although studies are not available that directly project the effects of marine climate change on marbled murrelets, several studies have been conducted within and outside the listed range regarding ocean conditions and marbled murrelet behavior and fitness. Additionally, numerous studies of other alcids from Mexico to British Columbia indicate that alcids as a group are vulnerable to climate change in the northeastern Pacific.

These studies suggest that the effects of climate change will be to reduce marbled murrelet reproductive success, likely mediated through climate change effects to prey. In British Columbia, there is a strong negative correlation between sea surface temperature and the number of marbled murrelets observed at inland sites displaying behaviors associated with nesting (Burger 2000, p. 728). In central California, marbled murrelet diets vary depending on ocean conditions, and there is a trend toward greater reproductive success during cool water years, likely due to the abundant availability of prey items such as euphausiids and juvenile rockfish (Becker et al. 2007, pp. 273-274). Across the northern border of the listed range, in the Georgia Basin, much of the yearly variation in marbled murrelet abundance from 1958 through 2000 can be explained by the proportion of fish (as opposed to euphausiids or amphipods) in the birds' diet (Norris et al. 2007, p. 879). If climate change leads to further declines in forage fish populations (see above), those declines are likely to be reflected in marbled murrelet populations.

The conclusion that climate change is likely to reduce marbled murrelet breeding success via changes in prey availability is further supported by several studies of other alcid species in British Columbia and California. Common murres, Cassin's auklets, rhinoceros auklets, and tufted puffins in British Columbia; pigeon guillemots (*Cepphus columba*), common murres, and Cassin's auklets in California; and even Cassin's auklets in Mexico all show altered reproductive rates, altered chick growth rates, or changes in the timing of the breeding season, depending on sea surface temperature or other climatic variables, prey abundance, prey type, or the timing of peaks in prey availability (Abraham and Sydeman 2004, pp. 239-243; Ainley et al. 1995, pp. 73-77; Albores-Barajas 2007, pp. 85-96; Bertram et al. 2001, pp. 292-301; Borstad et al. 2011, pp. 291-299; Gjerdrum et al. 2003, pp. 9378-9380; Hedd et al. 2006, pp. 266-275; Sydeman et al. 2006, pp. 2-4). The abundance of Cassin's auklets and rhinoceros auklets off southern California declined by 75 and 94 percent, respectively, over a period of ocean warming between 1987 and 1998 (Hyrenbach and Veit 2003, pp. 2546, 2551). Although the details of the relationships between climate variables, prey, and demography vary between bird species and locations, the consistent demonstration of such relationships indicates that alcids as a group are sensitive to climate-related changes in prey availability, prompting some researchers to consider them indicator species for climate change (Hedd et al. 2006, p. 275; Hyrenbach and Veit 2003, p. 2551).

In addition to effects on foraging ecology and breeding success, climate change may expose adult and juvenile marbled murrelets to health risks. For example, it is likely that they will experience more frequent domoic acid poisoning, as this toxin originates from harmful algae blooms in the genus *Pseudo-nitzchia*, which are expected to become more prevalent in the listed range (see above). In central California, domoic acid poisoning was determined to be the cause of death for at least two marbled murrelets recovered during a harmful algae bloom in 1998 (Peery et al. 2006, p. 84). During this study, which took place between 1997 and 2003, the mortality rate of radio-tagged marbled murrelets was highest during the algae bloom (Peery et al. 2006, p. 83). Domoic acid poisoning has previously been shown to travel through the food chain to seabirds via forage fish that feed on the toxic algae (Work et al. 1993, p. 59). Other types of harmful algae, including the *Alexandrium* genus, which is also likely to become more prevalent in the listed range (see above), produce saxitoxin, a neurotoxin that causes paralytic shellfish poisoning. Consumption of sand lance contaminated with saxitoxin was implicated in the deaths of seven out of eight (87.5 percent) of Kittlitz's murrelet (*Brachyramphus brevirostrus*) chicks that were tested following nest failure at a study site in Alaska in 2011 and 2012 (Lawonn et al. 2018, pp. 11-12; Shearn-Bochsker et al. 2014). Yet another species of harmful algae produces a foam that led to plumage fouling and subsequent mortality of common murres and other seabird species off of Oregon and Washington during October of 2009, and similar events may become more frequent with climate change (Phillips et al. 2011, pp. 120, 122-124). Due to changes in the Salish Sea food web, climate change is projected to increase mercury and, to a lesser extent, polychlorinated biphenyls (PCB) levels in forage fish and top marine predators (Alava et al. 2018, pp. 4); presumably marbled murrelets will experience a similar increase. Climate change may also promote conditions in which alcids become exposed to novel pathogens, as occurred in Alaska during 2013, when crested auklets (*Aethia cristatella*) and thick-billed murres (*Uria lomvia*) washed ashore after dying of avian cholera (Bodenstein et al. 2015, p. 935). Murrelets in Oregon may be especially susceptible to novel diseases, because these populations have lack diversity in genes related to immunity (Vásquez-Carrillo et al. 2014, p. 252). Counterintuitively, in the 1997-2003 study of radio tagged marbled murrelets in California, marbled murrelet adult survival was higher during warm-water years and lower during cold-water years, likely because they did not breed and therefore avoided the associated physiological stresses and additional predator risk (Peery et al. 2006, pp. 83-85).

Overall, the effects of climate change in marine ecosystems are likely to be complex, and will vary across the range. Alterations in the physical properties of the marine environment will affect the productivity and composition of food webs, which are likely to affect the abundance, quality, and availability of food resources for murrelets. These changes, in turn, will affect marbled murrelet reproductive performance. In addition, toxic algae and potentially disease organisms are expected to present increasing risks to murrelet health and survival. Different types of effects can be predicted with varying levels of certainty. For example, large increases in the prevalence of harmful algal blooms have already been observed, whereas the likely future magnitude and direction of overall changes in net primary productivity remain highly uncertain. Some changes may be positive (for example, the potential for a northward shift in anchovy abundance), but on the whole climate change is expected to have a detrimental effect to marbled murrelet foraging and health.

Summary of Climate Change Effects

In summary, marbled murrelets are expected to experience effects of climate change in both their nesting habitat and marine foraging habitat. Natural disturbances of nesting habitat are expected to become more frequent, leading to accelerated habitat losses that may outpace ingrowth even in protected landscapes. Marine food chains are likely to be altered, and the result may be a reduction in food resources for marbled murrelets. Even if food resources remain available, the timing and location of their availability may shift, which may alter marbled murrelet nesting seasons or locations. In addition, health risks from harmful algal blooms, anthropogenic toxins, and perhaps pathogens are likely to increase with climate change.

Within the marine environment, effects on the murrelet food supply (amount, distribution, quality) provide the most likely mechanism for climate change impacts to murrelets. Studies in British Columbia (Norris et al. 2007) and California (Becker and Beissinger 2006) have documented long-term declines in the quality of murrelet prey, and one of these studies (Becker and Beissinger 2006, p. 475) linked variation in coastal water temperatures, murrelet prey quality during pre-breeding, and murrelet reproductive success. These studies indicate that murrelet recovery may be affected as long-term trends in ocean climate conditions affect prey resources and murrelet reproductive rates. While seabirds such as the murrelet have life-history strategies adapted to variable marine environments, ongoing and future climate change could present changes of a rapidity and scope outside the adaptive range of murrelets (USFWS 2009, p. 46).

Conservation Needs of the Species

Reestablishing an abundant supply of high quality murrelet nesting habitat is a vital conservation need given the extensive removal during the 20th century. Even following the establishment of the NWFP, habitat continued to be lost between 1993 and 2012, and the rate of loss on non-federal lands has been 10 times greater than on federal lands (Raphael et al. 2016b, pp. 80-81). If this rate of loss continues, the conservation of the murrelet may not be possible because almost half of the higher-suitability nesting habitat is on non-federal lands (Raphael et al. 2016b, p. 86). Therefore, recovery of the murrelet will be aided if areas of currently suitable nesting habitat on non-federal lands are retained until ingrowth of habitat on federal lands provides replacement nesting opportunities (USFWS 2019, p. 21).

There are also other conservation imperatives. Foremost among the conservation needs are those in the marine and terrestrial environments to increase murrelet fecundity by increasing the number of breeding adults, improving murrelet nest success (due to low nestling survival and low fledging rates), and reducing anthropogenic stressors that reduce individual fitness or lead to mortality. The overall reproductive success (fecundity) of murrelets is directly influenced by nest predation rates (reducing nestling survival rates) in the terrestrial environment and an abundant supply of high quality prey in the marine environment before and during the breeding season (improving breeding rates, potential nestling survival, and fledging rates). Anthropogenic stressors affecting murrelet fitness and survival in the marine environment are associated with commercial and tribal gillnets, derelict fishing gear, oil spills, and high underwater sound pressure (energy) levels generated by pile-driving and underwater detonations (which can be lethal or reduce individual fitness). Anthropogenic activities, such as coastline modification and nutrient inputs in runoff, also affect prey availability and harmful algal blooms, which in turn affect murrelet fitness.

Further research regarding marine threats, general life history, and marbled murrelet population trends in the coastal redwood zone may illuminate additional conservation needs that are currently unknown (USFWS 2019, p. 66).

Recovery Plan

The Marbled Murrelet Recovery Plan outlines the conservation strategy with both short- and long-term objectives. The Plan places special emphasis on the terrestrial environment for habitat-based recovery actions due to nesting occurring in inland forests.

In the short-term, specific actions identified as necessary to stabilize the populations include protecting occupied habitat and minimizing the loss of unoccupied but suitable habitat (USFWS 1997, p. 119). Specific actions include maintaining large blocks of suitable habitat, maintaining and enhancing buffer habitat, decreasing risks of nesting habitat loss due to fire and windthrow, reducing predation, and minimizing disturbance. The designation of critical habitat also contributes towards the initial objective of stabilizing the population size through the maintenance and protection of occupied habitat and minimizing the loss of unoccupied but suitable habitat.

Long-term conservation needs identified in the Plan include:

- increasing productivity (abundance, the ratio of juveniles to adults, and nest success) and population size;
- increasing the amount (stand size and number of stands), quality, and distribution of suitable nesting habitat;
- protecting and improving the quality of the marine environment; and
- reducing or eliminating threats to survivorship by reducing predation in the terrestrial environment and anthropogenic sources of mortality at sea.

General criteria for murrelet recovery (delisting) were established at the inception of the Plan and they have not been met (USFWS 2019, p. 65). More specific delisting criteria are expected in the future to address population, demographic, and habitat based recovery criteria (USFWS 1997, p. 114-115). The general criteria include:

- documenting stable or increasing population trends in population size, density, and productivity in four of the six Conservation Zones for a 10-year period and
- implementing management and monitoring strategies in the marine and terrestrial environments to ensure protection of murrelets for at least 50 years.

Thus, increasing murrelet reproductive success and reducing the frequency, magnitude, or duration of any anthropogenic stressor that directly or indirectly affects murrelet fitness or survival in the marine and terrestrial environments are the priority conservation needs of the species. The Service estimates recovery of the murrelet will require at least 50 years (USFWS 1997).

Recovery Zones in Washington

Conservation Zones 1 and 2 extend inland 50 miles from marine waters. Conservation Zone 1 includes all the waters of Puget Sound and most waters of the Strait of Juan de Fuca south of the U.S.-Canadian border and the Puget Sound, including the north Cascade Mountains and the northern and eastern sections of the Olympic Peninsula. Conservation Zone 2 includes marine waters within 1.2 miles (2 km) off the Pacific Ocean shoreline, with the northern terminus immediately south of the U.S.-Canadian border near Cape Flattery along the midpoint of the Olympic Peninsula and extending to the southern border of Washington (the Columbia River) (USFWS 1997, pg. 126).

Lands considered essential for the recovery of the murrelet within Conservation Zones 1 and 2 are 1) any suitable habitat in a Late Successional Reserve (LSR), 2) all suitable habitat located in the Olympic Adaptive Management Area, 3) large areas of suitable nesting habitat outside of

LSRs on Federal lands, such as habitat located in the Olympic National Park, 4) suitable habitat on State lands within 40 miles off the coast, and 5) habitat within occupied murrelet sites on private lands (USFWS 1997).

Summary

At the range-wide scale, annual estimates of murrelet populations have fluctuated, with no conclusive evidence of a positive or negative trend since 2001(+0.34 percent per year, 95% CI: -0.9 to 1.6%) (McIver et al. 2018, p. 3). The most recent extrapolated population estimate for the entire NWFP area was 23,000 murrelets (95 percent CI: 18,500 to 27,600 birds) in 2017 (McIver et al. 2019, p. 3). The largest and most stable murrelet subpopulations now occur off the Oregon and northern California coasts, while subpopulations in Washington have steadily declined since 2001 (-3.9 percent per year; 95% CI: -5.8 to -2.0%) (McIver et al. 2019, p. 3).

Monitoring of murrelet nesting habitat within the NWFP area indicates nesting habitat declined from an estimated 2.53 million acres in 1993 to an estimated 2.23 million acres in 2012, a decline of about 12.1 percent (Raphael et al. 2016, p. 72). Murrelet population size is strongly and positively correlated with amount of nesting habitat, suggesting that conservation of remaining nesting habitat and restoration of currently unsuitable habitat is key to murrelet recovery (Raphael et al. 2011, p. iii). Given likely future increases in forest disturbances that can cause habitat loss, conservation of remaining nesting habitat is especially important.

The species decline has been largely caused by extensive removal of late-successional and old growth coastal forest which serves as nesting habitat for murrelets. Additional factors in its decline include high nest-site predation rates and human-induced mortality in the marine environment from disturbance, gillnets, and oil spills. In addition, murrelet reproductive success is strongly correlated with the abundance of marine prey species. Overfishing and oceanographic variation from climate events and long-term climate change have likely altered both the quality and quantity of murrelet prey species (USFWS 2009, p. 67).

Although some threats have been reduced (e.g., habitat loss on Federal lands), some threats continue and new threats now strain the ability of the murrelet to successfully reproduce. Threats continue to contribute to murrelet population declines through adult and juvenile mortality and reduced reproduction. Therefore, given the current status of the species and background risks facing the species, it is reasonable to assume that murrelet populations in Conservation Zones 1 and 2 and throughout the listed range have low resilience to deleterious population-level effects and are at high risk of continuing or renewed declines. Activities that degrade the existing conditions of occupied nest habitat or reduce adult survivorship or nest success of murrelets will be of greatest consequence to the species. Actions resulting in the loss of occupied nesting habitat, mortality to breeding adults, eggs, or nestlings will reduce productivity, contribute to continued population declines, and prolong population recovery within the listed range of the species in the coterminous United States.

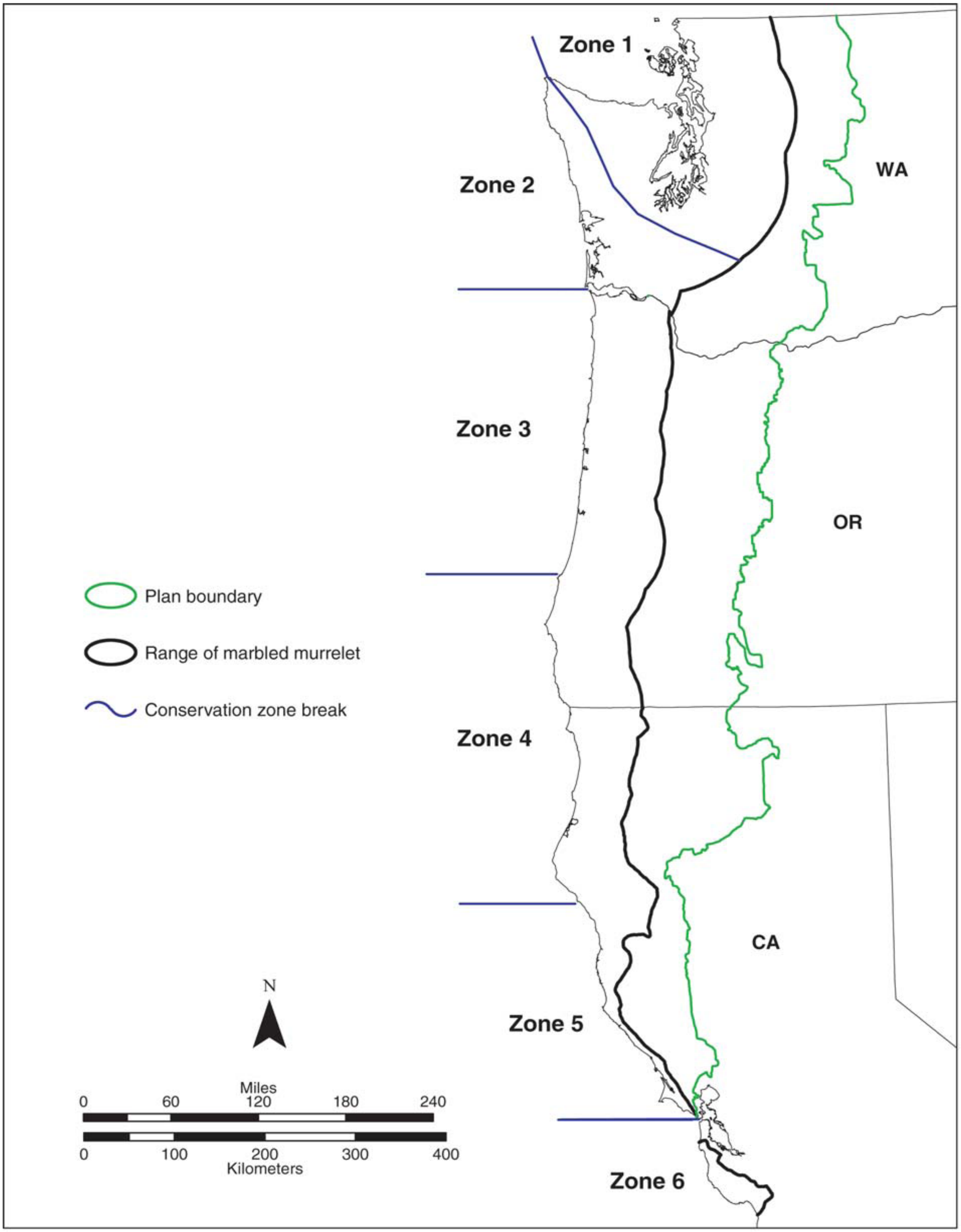

Figure 1. The six geographic areas identified as Conservation Zones in the recovery plan for the marbled murrelet (USFWS 1997). Note: “Plan boundary” refers to the NWFP. Figure adapted from Huff et al. (2006, p. 6).

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APPENDIX B
STATUS OF DESIGNATED CRITICAL HABITAT: MARBLED MURRELET

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Appendix B
Status of Designated Critical Habitat: Marbled Murrelet

Legal Status

The final rule designating critical habitat for the marbled murrelet (murrelet) (61 FR 26256 [May 24, 1996]) became effective on June 24, 1996. Critical habitat was designated for the murrelet to addresses the objective of stabilizing population size. The principle factors affecting the murrelet and the main cause of its population decline has been the loss of older forests and associated nest sites and habitat fragmentation (57 FR 45328:45330 [October 1, 1992]). The selection criteria considered in choosing areas for inclusion in murrelet critical habitat included 1) suitable nesting habitat, 2) survey data, 3) proximity to marine foraging habitat, 4) large, contiguous blocks of nesting habitat, 5) opportunities to maintain current distribution, and 6) adequacy of existing protection and management.

In the 1996 final rule, the U.S. Fish and Wildlife Service (Service) designated critical habitat for the murrelet within 32 Critical Habitat Units (CHUs) encompassing approximately 3.9 million acres across Washington, Oregon, and California. The final rule intended the scope of the section 7(a)(2) analysis to evaluate impacts of actions on critical habitat at the conservation zone(s) or even a major part of a conservation zone (61 FR 26256:26271 [May 24, 1996]). In 2011, the Service issued a revised final rule which removed approximately 189,671 acres in northern California and southern Oregon from critical habitat designated under the 1996 final rule based on new information indicating that these areas did not meet the definition of critical habitat (76 FR 61599:61604 [October 5, 2011]). No changes were made for critical habitat designations in Washington.

In 2016, the Service issued a final determination which confirmed that critical habitat for the murrelet as designated in 1996 and revised in 2011, meets the statutory definition of critical habitat under the Endangered Species Act of 1973, (81 FR 51348 [August 4, 2016]). This final determination did not propose any changes to the boundaries of the specific areas identified as critical habitat in the 2011 final rule. The current designation includes approximately 3,698,100 acres of critical habitat in Washington, Oregon, and California.

Physical or Biological Features and Primary Constituent Elements

Critical habitat is defined in section 3(5)(A) of the Act as " (i) the specific areas within the geographical area occupied by the species, at the time it is listed…, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by a species at the time it is listed…, upon a determination… that such areas are essential for the conservation of the species."

The Service defines ''physical or biological features'' as ''the features that support the life history needs of the species, including but not limited to water characteristics, soil type, geological features, sites, prey, vegetation, symbiotic species, or other features. A feature may be a single habitat characteristic, or a more complex combination of habitat characteristics. Features may include habitat characteristics that support ephemeral or dynamic habitat conditions. Features may also be expressed in terms relating to principles of conservation biology, such as patch size, distribution distances, and connectivity'' (81 FR 7414:7430 [February 11, 2016]).

The designation of critical habitat for the murrelet uses the term primary constituent elements (PCEs) or essential features. Primary constituent elements (PCEs) are the physical and biological features of critical habitat essential to a species' conservation and thus its recovery. Revised critical habitat regulations (81 FR 7214) replace this term with physical or biological features (PBFs). The shift in terminology does not change the approach used in conducting a ''destruction or adverse modification'' analysis, which is the same regardless of whether the original designation identified primary constituent elements, physical or biological features, or essential features. References to PCEs in this document should be viewed as synonymous with PBFs.

In the 1996 final rule designating critical habitat for the murrelet, the Service identified PCEs essential to provide and support suitable nesting habitat for successful reproduction. These are 1) individual trees with potential nesting platforms (PCE 1), and 2) forest lands of at least one half site-potential tree heights regardless of contiguity, within 0.8 km (0.5 miles) of individual trees with potential nesting platforms and that are used or potentially used by the murrelet for nesting or breeding (PCE 2)[1] (61 FR 26256:26264). Areas with only PCE 1, or both PCE 1 and 2, are considered, by definition, to be critical habitat. These PCEs were deemed essential for providing suitable nesting habitat for successful reproduction of the murrelet, and thus its conservation. PCEs require special management considerations.

<u>Conservation Role of Critical Habitat</u>

The conservation role of critical habitat is to provide nesting habitat to support successful murrelet reproduction (61 FR 26263-26264 [May 24, 1996]). To recover the species, it is also necessary to produce and maintain viable murrelet populations that are well distributed throughout the respective Conservation Zones (USFWS 1997, p. 116). Critical habitat helps focus conservation activities by identifying areas that contain essential habitat features (PCEs) thus alerting Federal agencies and the public to the importance of an area in the species' conservation. Critical habitat also identifies areas that may require special management or protection (61 FR 26256:26263 [May 24, 1996]).

<u>Activities that May Affect PCEs</u>

The final rule (61 FR 26256:26271[May 24, 1996]) states that "A variety of ongoing or proposed activities that disturb or remove primary constituent elements may adversely affect, though not necessarily 'adversely modify' murrelet critical habitat as that term is used in section 7 consultations. Examples of such activities include 1) forest management activities which greatly reduce stand canopy closure, appreciably alter the stand structure, or reduce the availability of nesting sites, 2) land disturbance activities such as mining, sand, and gravel extraction,

1 The Washington Fish and Wildlife Office has enumerated these as discrete PCEs for convenience; the Federal Register (1996 and 2011) does not identify these PCEs with discrete numbers.

construction of hydroelectric facilities and road building, and 3) harvest of certain types of commercial forest products (e.g., moss [Bryophyta] and salal [*Gaultheria shallon*])." Ultimately, actions may alter PCEs if they remove or degrade forest habitat, or prevent or delay future attainment of suitable habitat.

According to the revised final rule, proposed actions requiring section 7 consultations must be evaluated individually, in light of the baseline conditions of the critical habitat unit and Conservation Zone, unique history of the area, and effect of the impact on the critical habitat unit relative to its regional and range-wide role in the conservation of the species (76 FR 61599:61609 [October 5, 2011]).

Distribution of Critical Habitat

Approximately 3,698,100 acres are designated on Federal, state, county, city, and private lands in Washington, Oregon, and California in 101 subunits (81 FR 51359). These individual units are coded by the state in which they occur and are individually numbered by unit and sub-unit (e.g., WA-01-a, OR-01-a, CA-01-a). The majority of these CHUs (78 percent) occur on Federal lands (Table 1). In the selection of CHUs, there was a reliance on lands designated as Late-Successional Reserves (LSRs) on Federal lands. Most LSRs within the range of the murrelet in Washington, Oregon, and California were designated as critical habitat. LSRs, as described in the Northwest Forest Plan, are most likely to develop into large blocks of suitable murrelet nesting habitat given sufficient time.

Table 1. Designated critical habitat by state, ownership, and land allocation[†]

State	Ownership	Land Allocation	Designated Critical Habitat (hectares)(ha)	Designated Critical Habitat (acres)
Washington	Federal Lands	Congressionally Withdrawn Lands	740	1,800
		Late Successional Reserves	485,680	1,200,200
		Federal Total	**486,420**	**1,202,000**
	Non-Federal Lands	State Lands	172,720	426,800
		Private Lands	1,020	2,500
		Non-Federal Total	173,740	429,300
		Washington Total	**660,160**	**1,631,300**
Oregon	Federal Lands	Late Successional Reserves	541,530	1,338,200
		Withdrawn in 2011	*18,690*	*46,184*
		Federal Total	**522,840**	**1292,016**
	Non-Federal Lands	State Lands	70,880	175,100
		County Lands	440	1,100
		Private Lands	350	900
		Oregon Total	**594,510**	**1,469,116**
California (Northern)	Federal Lands	Late Successional Reserves	193,150	477,300
		Withdrawn in 2011	*58,068*	*143,487*
		Federal Total	**135,082**	**333,813**
	Non-Federal Lands	State Lands	71,040	175,500
		Private Lands	16,360	40,400
California (Central)	Non-Federal Lands	State Lands	14,080	34,800
		County Lands	3,230	8,000
		City Lands	400	1,000
		Private Lands	1,720	4,200
		CaliforniaTotal	**241,912**	**597,713**
		Overall Total	***1,496,582***	***3,698,129***

[†]These figures reflect the values from the 1996 final rule and 2011 revised final rule.

In 2011, the Service issued a revised final rule for critical habitat (76 FR 61599 [October 5, 2011]). In it, approximately 189,671 acres (76,758 ha) were removed from designated critical on Federal lands in Oregon and California. It was determined that these acreages were not essential to the conservation of the murrelet and did not meet the definition of critical habitat. The table above reflects this update.

Although most of the areas designated as murrelet critical habitat occur on Federal lands, the Service designated selected certain non-Federal lands that met the criteria for critical habitat. These lands occurred in areas where Federal lands were insufficient to provide suitable nesting habitat for the recovery of the species. On non-Federal lands, 21 percent of designated critical habitat acres occur on state lands, 1.2 percent on private lands, 0.2 percent on county lands, and 0.003 percent on city lands. In application, critical habitat does not include non-Federal lands covered by a legally operative incidental take permit for murrelets issued under section 10(a) of the Act (61 FR 26256:26278[May 24, 1996]). Therefore, critical habitat designations are excluded on non-Federal lands upon completion of an approved Habitat Conservation Plan that addresses conservation of the murrelet.

Critical Habitat in Washington

Designated critical habitat in Washington encompasses approximately 1,631,300 acres (Table 1, above). Over 1.2 million acres of critical habitat in Washington is located on National Forest lands that are designated as LSRs under the Northwest Forest Plan (74 percent).

The critical habitat designation in Washington also includes approximately 426,800 acres of state lands (26 percent) managed under the Washington Department of Natural Resources (WDNR) 1997 Habitat Conservation Plan (WDNR 1997). Because these lands are managed under an approved Habitat Conservation Plan issued under section 10(a) of the Act, these lands are excluded from critical habitat by description in the final rule. However, should their permit be revoked, terminated, or expire, WDNR lands would revert back to designated critical habitat. WDNR lands, therefore, continue to remain mapped and accounted for in the total designation acreage (81 FR 51365 [August 4, 2016]).

Critical habitat in Washington also includes a few subunits of private lands (~2,500 acres) in areas where Federal lands are limited and the lands contained occupied sites in southwestern Washington. These areas represent less than 0.2 percent of the critical habitat in Washington.

<u>Current Condition of Critical Habitat in Washington</u>

Much of the area included in the critical habitat designation in Washington includes young forest and previously-logged areas within LSRs that are expected to provide buffer habitat to existing mature forest stands, and future recruitment habitat to create large, contiguous blocks of suitable murrelet nesting habitat. Due to a combination of past timber harvest, wildfire history, and natural topography (e.g., subalpine, wetlands, etc.), only about 26 percent (311,000 acres) of the total area within the 1.2 million acres of designated murrelet critical habitat on Federal lands in Washington is mapped as potential nesting habitat for murrelets (Table 2).

Table 2. Summary of marbled murrelet Critical Habitat Units (CHUs) in Washington.

CHU Name	Total designated acres in CHU	Total acres of potential murrelet nesting habitat	Percent of CHU acres with potential murrelet habitat	Land Use Allocation
WA-01-a	60,477	25,391	42.0%	LSR
WA-01-b	8,172	5,566	68.1%	LSR
WA-02-a	15,955	11,429	71.6%	LSR
WA-02-b	1,982	1,017	51.3%	LSR
WA-02-c	46,342	23,515	50.7%	LSR
WA-02-d	412	238	57.8%	LSR
WA-03-a	97,847	43,665	44.6%	LSR
WA-03-b	65,027	17,330	26.7%	LSR
WA-05-b	401	195	48.8%	PRIVATE
WA-05-c	297	62	20.8%	PRIVATE
WA-05-d	327	109	33.3%	PRIVATE
WA-05-f	191	16	8.4%	PRIVATE
WA-05-g	218	50	22.8%	PRIVATE
WA-06-a	71,539	23,499	32.8%	LSR
WA-06-b	44,236	15,445	34.9%	LSR
WA-07-a	78,207	15,220	19.5%	LSR
WA-07-b	1,075	475	44.2%	PRIVATE
WA-07-c	88,759	20,234	22.8%	LSR
WA-07-d	24,112	6,653	27.6%	LSR
WA-08-a	85,254	21,853	25.6%	LSR
WA-08-b	20,410	3,934	19.3%	LSR
WA-09-a	1,826	787	43.1%	CWD (Navy)
WA-09-b	108,076	21,119	19.5%	LSR
WA-09-c	4,959	1,068	21.5%	LSR
WA-09-d	13,051	2,727	20.9%	LSR
WA-09-e	48,827	6,191	12.7%	LSR
WA-10-a	76,593	11,204	14.6%	LSR
WA-10-b	41,956	7,177	17.1%	LSR
WA-10-c	25,712	3,284	12.8%	LSR
WA-11-a	72,196	6,884	9.5%	LSR
WA-11-b	11,139	539	4.8%	LSR
WA-11-c	37,589	5,671	15.1%	LSR
WA-11-d	51,360	8,407	16.4%	LSR
Total	**1,204,524**	**310,954**	**25.8%**	

Notes: This table excludes state lands managed under the WDNR HCP; about 426,851 acres. Marbled murrelet habitat estimates are approximate values that represent conditions in 2012, as depicted by Raphael et al. (2016) map data, moderate (class 3) and highest (class 4) suitability. Due to limitations of the habitat model used, the habitat amounts listed above are estimates only, and are not considered to be absolute values.

Effects to Critical Habitat from prior Federal Actions

The Service maintains a database to summarize effects to critical habitat documented through consultations with Federal agencies under section 7 of the Act. In Washington, there has been almost no loss of suitable nesting habitat within designated critical habitat due to timber harvest or major fires. The majority of nesting habitat loss on federal lands in Washington has been through natural disturbance (Raphael et al. 2016, p. 80). The Service's Tracking and Integrated Logging System (TAILS) reports that within Conservation Zones 1 and 2 (zones within Washington which include the Olympic Peninsula and the Cascade Mountains, only 16 acres of critical habitat stands (PCE 1s) and 45 acres of PCE 2s are estimated to have been removed by federal actions since 2003 (Table 3).

At the range-wide scale, impacts to critical habitat from prior federal actions have been limited, and in total, less than 1,000 acres of nesting habitat (PCE 1s) are estimated to have been removed for purposes of timber harvest or other federal actions (Table 3). The amount of habitat loss due to natural disturbance within critical habitat is not known, as range-wide monitoring efforts have only been summarized at the scale of Federal reserves and non-reserved lands under the Northwest Forest Plan (Raphael et al. 2016). Monitoring of murrelet nesting habitat within the Northwest Forest Plan area indicates nesting habitat has declined from an estimated 2.53 million acres in 1993 to an estimated 2.23 million acres in 2012, a total decline of about 12.1 percent (Raphael et al. 2016, p. 72). These estimates are for all lands (Federal and non-federal) within the range of the murrelet. Habitat losses on Federal reserves have been substantially less, estimated at approximately 34,000 acres, representing a net loss of -2.5 percent of the potential murrelet nesting habitat within reserves (Raphael et al. 2016, p. 78). Most of this habitat loss is attributed to wildfires and other natural disturbances. Critical habitat does not include designated Wilderness or National Parks, and so the estimates of habitat loss on Federal reserves likely represents a reasonable estimate of total habitat losses that have occurred within designated critical habitat.

Table 3. Summary of murrelet critical habitat PCEs (acres) removed or downgraded as documented through section 7 consultations from 2003 to present (May 24, 2019).

Conservation Zones[1]	**Designated Acres**[2]	**Authorized Habitat Effects**[3]			**Reported Habitat Effects**[3]		
	Total CHU Acres	**Stands** 4	**Remnants** 5	**PCE2** 6	**Stands** 4	**Remnants** 5	**PCE2** 6
Puget Sound (Zone 1)	1,271,782	-16	0	-45	0	-1	0
Western Washington (Zone 2)	414,050	-1	0	-1	0	0	0
Oregon Coast Range (Zone 3)	1,024,122	-501	-4	-2,497	0	_1,186	0
Siskiyou Coast Range (Zone 4)	1,055,788	-4,900	0	-3,176	0	-97	0
Mendocino (Zone 5)	122,882	0	0	0	0	0	0
Santa Cruz Mountains (Zone 6)	47,993	0	0	0	0	0	0
Total	**3,936,617**	**-5,418**	**-4**	**-5,719**	**0**	**-1,284**	**0**

Notes:

1 <u>Conservation Zones</u>: Six zones were established by the Marbled Murrelet Recovery Plan (USFWS 1997) to guide terrestrial and marine management planning and monitoring for the species.

2 <u>Designated Acres</u>: Critical Habitat Unit (CHU) acres as designated in 1996, divided by Conservation Zones, as presented in the 1997 Marbled Murrelet Recovery Plan (USFWS 1997; Figure 8, p. 114).

3 <u>Authorized Habitat Effects</u>: Includes all known occupied sites, as well as other suitable habitat, though not necessarily occupied. Importantly, there is no single definition of suitable habitat. The Marbled Murrelet Effectiveness Monitoring Module is in the process of rectifying this. Some useable working definitions include the Primary Constituent Elements as defined in the Critical Habitat Final Rule or the criteria used for Washington State used by Raphael et al. (2002).

4 <u>Stands</u>: A patch of older forest in an area with potential platform trees.

5 <u>Remnants</u>: A residual or remnant stand is an area with scattered potential platform trees within a younger forest that generally lacks structures for marbled murrelet nesting.

6 <u>PCE2</u>: Trees with one half site-potential tree height within 0.5 miles of a potential nest tree.

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