Biological Assessment of the Marbled Murrelet (*Brachyramphus marmoratus*) in Oregon and Evaluation of Criteria to Reclassify the Species from Threatened to Endangered under the Oregon Endangered Species Act

Oregon Department of Fish and Wildlife

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Foreword

The Oregon Department of Fish and Wildlife prepared this report for the Oregon Fish and Wildlife Commission, as an assessment of the biological status of the species and as a guide to the requirements of the Oregon Endangered Species Act to consider reclassifying a species. Prior Marbled Murrelet status reviews by the department (ODFW 1995, 2013, 2018) served as the initial basis for this report.

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Executive Summary

The Marbled Murrelet (*Brachyramphus marmoratus*) is a small seabird that breeds along the Pacific Coast from Alaska to central California. Marbled Murrelets spend most of their lives at sea and forage on small fish and invertebrates in nearshore marine waters. Throughout much of their range, they fly inland for nesting in old-growth, late-successional, and older forests. Marbled Murrelets do not construct nests, per se, but instead lay their single egg in a depression in moss, lichen, or tree litter on a large or deformed tree branch, generally high in the live canopy.

The Marbled Murrelet in Washington, Oregon, and California was listed as threatened under the federal Endangered Species Act in 1992, and were subsequently listed as state-threatened in Oregon under the Oregon Endangered Species Act (OESA) in 1995. The species is listed as state-endangered in both Washington and California. The 2019 Status Review of Marbled Murrelets by the USFWS maintained their Threatened status across the listed range (Distinct Population Segment) of the species under the federal ESA.

This status review, initiated at the end of 2019, is part of a process to consider reclassification of the species from threatened to endangered (uplist) under the OESA by the Oregon Fish and Wildlife Commission (Commission). In 2019, the Lane County Circuit Court issued a summary judgement of a lawsuit against the Commission's decision in June 2018 to decline uplisting the Marbled Murrelets in June 2018. As a result, the Commission, in December 2019, decided to reconsider its review of the species status and determine whether circumstances meet specific legal criteria to warrant reclassification to uplist the Marbled Murrelet from threatened to endangered under the OESA. Due to impacts of the COVID-19 pandemic, the Lane County Circuit Court granted a stipulated motion brought by both the petitioners and the Commission to modify the judgment and delay the status review until no later than July 31, 2021. The 2021 Marbled Murrelet biological assessment focuses on verifiable scientific information and other data relevant to the species' biological and legal status in Oregon, and will help to inform the Commission's decision. The definition of "verifiable" is "scientific information reviewed by a scientific peer review panel of outside experts who do not otherwise have a vested interest in the process" (ORS 496.171(4)).

In order to reclassify the Marbled Murrelet to endangered under the OESA, the Commission must first determine that the likelihood of survival of the species has diminished such that the species is in danger of extinction throughout any significant portion of its range within Oregon. The Commission must also determine that one or more of the following three factors exist: 1) that most populations of the species are undergoing imminent or active deterioration of their range or primary habitat; 2) that overutilization of the species or its habitat for commercial, recreational, scientific, or educational purposes is occurring or is likely to occur; or 3) that existing state or federal programs or regulations are inadequate to protect the species and its habitat.

In developing this biological assessment, ODFW reviewed and considered documented and verifiable scientific information and other best available data on the Marbled Murrelet. The following biological assessment reviewed many aspects of the species' biology, life history, population trends and demographics, marine and terrestrial habitat conditions, threats, and the adequacy of state and federal programs and regulations. Our 2021 evaluation resulted in the following conclusions:

- Marbled Murrelets have narrow habitat requirements and limited geographic distribution. The Marbled Murrelet's life history strategy (e.g., long-lived, low annual reproductive potential, delayed reproductive maturity) requires high survivorship of adults, subadults, and young for breeding birds to successfully "replace" themselves over the course of their lifetimes to yield a stable or increasing population. Occupied landscapes tend to have large amounts of unfragmented older forest nesting habitat. Once nesting habitat is lost, high breeding site fidelity and limited flight range from the coast to inland forests may further restrict distribution. Contemporary events that remove old-growth, late-successional, or older forests may be difficult for the species to compensate in the short-term because suitable habitat takes many decades or more to develop.

- Changes in quantity and quality of late-successional forests in Oregon occurred since European settlement, due to timber harvest, fire, wind, and other factors, which substantially reduced Marbled Murrelet nesting habitat from historical levels resulting in federal (1992) and state (1995) listing as a threatened species. Since 1993, higher probability nesting habitat increases have occurred, mainly due to habitat protections for listed species and as forests mature. Based on Northwest Forest Plan's Marbled Murrelet Effectiveness Monitoring Program results, higher probability nesting habitat increased in Oregon from approximately 471,220 acres in 1993 to 517,686 acres in 2017, a net increase of 46,466 acres (+9.9% net change). Higher probability nesting habitat was quantified as core (amount of contiguous habitat), edge (amount of habitat adjacent to core habitat) and scatter (habitat scattered in small forest fragments) nesting habitat. Across all landownerships, core higher probability nesting habitat increased from approximately 14,397 acres in 1993 to 15,065 acres in 2017 (+4.6% net change); edge higher probability nesting habitat increased from approximately 52,254 acres in 1993 to 53,559 acres in 2017 (+2.5% net change); scatter higher probability nesting habitat increased from approximately 404,569 acres in 1993 to 449,063 acres in 2017 (+11.0% net change).

- Despite net increases in higher probability nesting habitat across all landownerships in Oregon, some losses of habitat were masked when considering only net change. Specifically, increases in nesting habitat have occurred on federal (13.0% net change) and state (43.4% net change) landowners, whereas higher probability nesting habitat losses (-10.2% net change) have occurred on other lands (private, tribal, county, and municipal).

- Most of the higher probability Marbled Murrelet nesting habitat currently persists on federal (312,027 acres) and state (81,092 acres) lands in, including the Siuslaw and Rogue River-Siskiyou National Forests, forests owned by the Bureau of Land Management, and the state-owned and managed Tillamook, Clatsop, and Elliott State Research forests.

- The Northwest Forest Plan's Marbled Murrelet Effectiveness Monitoring Program surveyed murrelets at sea in Oregon from 2000-2019. During this time period, the Oregon population was increasing at an annual rate of 2.2% (95% CI: 0.9 to 3.4%). Based on this monitoring program, the Oregon population was estimated at 10,339 birds in 2019 and was likely somewhere between a range of 7,070 and 13,607 birds. The wide confidence limits for these population estimates reflect the challenges of monitoring a highly mobile seabird that is sparsely and patchily distributed in the nearshore environment, as well as constraints on survey effort.

- Forest fragmentation and “edge effects” can increase predation rates. Predation, particularly by corvids (e.g., jays, crows, ravens), is a leading proximate cause of Marbled Murrelet nest failure. Higher predator numbers and predation rates are generally associated with habitat edges, human activities, and anthropogenic food sources. Predation pressure is expected to remain at current levels or increase in the future and is of particular concern where parks, trails, or campgrounds overlap with murrelet habitat.

- Marbled Murrelets require sufficient prey resources in the marine environment for survival and successful reproduction. Oceanic conditions influence the abundance, distribution, and timing of prey available to murrelets, and prey quality and availability in turn affect breeding propensity and success. A centennial shift in murrelet diet to lower (poorer quality) trophic levels has been documented in central California and the Salish Sea in Washington (Zone 1). As with many other seabirds, low reproductive success has also been linked, in part, to El Niño years and other warm water events (e.g. Pacific Decadal Oscillation, and upwelling).

- The potential for oil spills remains a serious threat and could kill hundreds or thousands of Marbled Murrelets in Oregon. For example, the New Carissa oil spill in 1999 released over 70,000 gallons of fuel into the marine environment near Coos Bay, Oregon, killing an estimated 262 Marbled Murrelets.

- While natural disturbances have always shaped Oregon forests, climate change is expected to increase potential for habitat loss from catastrophic wildfires, insect infestations, disease outbreaks, and severe storms, and to exacerbate conditions unfavorable to murrelets in the marine environment. There are currently few indications that Marbled Murrelets south of Canada will see benefits from a warming climate based largely on the Intergovernmental Panel on Climate Change. The best available information signals increasing stressors and threats that are largely unfavorable to the species. Given their low reproductive potential, narrow habitat requirements in both terrestrial and marine systems, breeding site fidelity, and restricted distribution, Marbled Murrelets are not as resilient as some other species to changing conditions. One published assessment described the Marbled Murrelet as highly sensitive to climate change; out of 114 Pacific Northwest bird species analyzed, the Marbled Murrelet had the highest climate-sensitivity score.

- Other emerging natural or anthropogenic threats to the species include, but are not limited to, energy development projects; harmful algal blooms that produce biotoxins, feather-fouling surfactants, or low-oxygen “dead zones” in the ocean; and contaminants in prey that can biomagnify through the food chain.

- The threat posed by inadequate state and federal programs and regulations has decreased since federal listing of the Marbled Murrelet in 1992 and state listing in 1995. For example, implementation of the Northwest Forest Plan greatly reduced the rate of habitat loss due to timber harvest on federal lands. Nonetheless, existing state and federal programs and regulations have failed to prevent continued rates of murrelet habitat loss on landownerships other than public lands. Fisheries management is another example of state and federal programs and regulations that have been strengthened since the listing of the Marbled Murrelet, with greater management protections for its prey resources in Oregon.

Standard and Metric Equivalents

Standard Unit	Metric Unit
1 inch (in)	2.54 centimeters (cm) or 25.4 millimeters (mm)
1 foot (ft)	0.31 meters (m)
1 mile (mi)	1.61 kilometers (km)
1 acre (ac)	0.41 hectares (ha)
1 square mile (mi^2)	2.59 square kilometers (km^2)
1 ounce (oz)	28 grams (g)
Interval of 1 degree Fahrenheit (°F)	0.56 degrees Celsius (°C)

Key Acronyms

BLM	Bureau of Land Management
CCR	California Code of Regulations
CCS	California Current System
CFR	Code of Federal Regulations
CI	confidence intervals
CSF	Common School Fund
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DBH	diameter at breast height
DSL	Oregon Department of State Lands
EEZ	Exclusive Economic Zone
ENSO	El Niño Southern Oscillation
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
FPA	Oregon Forest Practices Act
FR	Federal Register
GIS	geographic information system
HCP	Habitat Conservation Plan
MMMA	Marbled Murrelet Management Area
MSA	Magnuson-Stevens Fishery Conservation and Management Act
NWFP	Northwest Forest Plan
OAR	Oregon Administrative Rule

ODF	Oregon Department of Forestry
ODFW	Oregon Department of Fish and Wildlife
OESA	Oregon Endangered Species Act
ORS	Oregon Revised Statute
PDO	Pacific Decadal Oscillation
PCB	polychlorinated biphenyl
PSG	Pacific Seabird Group
RIT	Recovery Implementation Team
RMP	Resource Management Plan
SD	standard deviation
USC	United States Code
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
WAC	Washington Administrative Code

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Chapter 1: Introduction

Why Update the 2018 Status Review?

At the December 6, 2019 meeting, the Oregon Fish and Wildlife Commission (Commission) directed Oregon Department of Fish and Wildlife (ODFW, department) staff to evaluate the status of the Marbled Murrelet *(Brachyramphus marmoratus)* in Oregon. The Commission's request was in response to a Lane County Circuit Court judgement related to the Commission's June 2018 decision to not uplist the Marbled Murrelet from threatened to endangered under the Oregon Endangered Species Act (OESA). Due to impacts of the COVID-19 pandemic, the plaintiffs and Commission were granted a stipulated motion in September 2020 by Lane County Circuit Court to modify the judgment and delay the review until no later than July 31, 2021. The 2021 Marbled Murrelet biological assessment focuses on information relevant to the species' biological and legal status in Oregon, and will help to inform the Commission's decision on whether current circumstances meet legal requirements to justify reclassification of the Marbled Murrelet as state-endangered or that the seabird remain listed as a threatened species.

This chapter outlines the legal criteria for a reclassification determination and the implications of an uplisting decision. It also summarizes the species' current legal status.

Criteria for Reclassifying Species and Procedural Requirements of the Oregon Endangered Species Act

The OESA (ORS 496.171-496.192) and its implementing rules (OAR Chapter 635 Division 100) set out criteria and procedural requirements that apply to the Commission's determination on whether to reclassify a species from threatened to endangered. Specifically, the Commission must determine, based on documented and verifiable scientific information, that the likelihood of survival of the species has diminished such that the species is in danger of extinction throughout any significant portion of its range within Oregon (OAR 635-100-0111(1)). In addition, the Commission must determine that at least one of the following factors exists:

1) that most populations are undergoing imminent or active deterioration of their range or primary habitat; or
2) that overutilization of the species or its habitat for commercial, recreational, scientific, or educational purposes is occurring or is likely to occur; or
3) that existing state or federal programs or regulations are inadequate to protect the species or its habitat (ORS 496.176(3), OAR 635-100-0105(6), OAR 635-100-0111(1)).

In making a reclassification determination, the Commission is required to consult with affected state and federal agencies, affected cities and counties, affected federally-recognized Indian tribes, the Oregon Natural Heritage Advisory Council, other states having a common interest in the species, and the interested public (ORS 496.176(4), OAR 635-100-0105(10)).

Effects of the Oregon Endangered Species Act

The most direct effect of listing a species as threatened or endangered under the OESA is through management decisions on state-owned, managed, or leased lands. Private lands are not directly affected by the OESA (ORS 496.192) except that no person is allowed to “take” a listed species anywhere in the state. Under the OESA, “take” is defined as “to kill or obtain possession or control of any wildlife” (ORS 496.004(16)).

State agencies work together to implement conservation measures adopted by the Oregon Fish and Wildlife Commission. ODFW biologists act as scientific consultants to other land and water managers to advise whether a management action can affect survival or recovery of a listed species.

The OESA requires particular state agencies to develop plans for the management and protection of endangered species, and to comply with survival guidelines adopted by the Oregon Fish and Wildlife Commission for threatened species and for endangered species until the endangered species management plan is in place (ORS 496.182(2), OAR 635-100-0130, OAR 635-100-0140). Survival guidelines are quantifiable and measurable guidelines that the commission considers necessary to ensure the survival of individual members of the species (OAR 635-100-0100(13)). They may include take avoidance and protecting resource sites such as nest sites or other sites critical to the survival of individual members of the species.

Implications of Reclassification to Endangered under the Oregon ESA

If the Oregon Fish and Wildlife Commission reclassifies Marbled Murrelet, the Commission would be required to establish survival guidelines for the species at the time it is uplisted from threatened to endangered and to work with state land-owning and managing agencies to determine if state lands can play a role in the conservation of the species[1] (ORS 496.182(2)(a), (8)(a)). Survival guidelines would serve as interim protection until endangered species management plans were developed and approved by applicable state agencies (required within 18 months of uplisting) and reviewed and approved by the Commission (required within 24 months of uplisting) (ORS 496.182(8)(a)(C), (D)). Further details on the timelines and requirements for the adoption of endangered species management plans are provided by ORS 496.182.

Marbled Murrelet Listing Status

Federal

The Washington, Oregon, and California distinct population segment of the Marbled Murrelet was listed as threatened under the federal Endangered Species Act (ESA) in September 1992 (57 FR

[1] Survival guidelines were not required for the Marbled Murrelet when it was first state-listed in May 1995.The survival guidelines requirement became effective in July 1995. The 2018 Commission added advisory survival guidelines for the Marbled Murrelet.

45328). The U.S. Fish and Wildlife Service (USFWS) determined that the species was threatened by loss and modification of older forest nesting habitat, mainly due to timber harvest, as well as mortality from gillnet fishing operations in Washington State and the effects of oil spills (57 FR 45328). The most recent 5-year status review of the Marbled Murrelet by the USFWS (2019) concluded that the Washington, Oregon, and California population of murrelets should remain listed but “no change is needed” from their current federally-threatened status. The USFWS (2019) highlighted the need for continued monitoring of reproductive success, population trends, and manmade and natural threat impacts to best assess if changing the listing status to endangered may be warranted in the future, and suggested revising the recovery criteria and updating the USFWS 1997 recovery plan for the Marbled Murrelet in Washington, Oregon, and California.

State

The Marbled Murrelet was listed as threatened under the OESA in 1995 (OAR 635-100-0125), also owing mainly to habitat loss (ODFW 1995). In both Washington (WAC 232-12-014) and California (14 CCR 670.5), the species is currently considered state-endangered. The Marbled Murrelet has no special status within the State of Alaska at this time.

Canada

In British Columbia, the Marbled Murrelet is listed as threatened under Canada’s Species at Risk Act (Schedule 1).

Summary

The Oregon Fish and Wildlife Commission will determine whether the Marbled Murrelet qualifies for reclassification from threatened to endangered under the OESA. In making this determination, the Commission must consider the strength of evidence in support of the reclassification criteria outlined in the Oregon Revised Statutes and Administrative Rules, and must consult with interested and affected parties. If the Commission decides to reclassify the species to state-endangered, the direct effects would be on state land-owning and managing agencies. State land-owning and managing agencies would be required to comply with survival guidelines that the Commission considers necessary to ensure protection of individual members of the species. These survival guidelines would serve as interim protection measures until endangered species management plans were developed by applicable state agencies and approved by the Commission. Although the Commission did not reclassify the species at the June 2018 Commission meeting, it did adopt voluntary survival guidelines into administrative rule in August 2018.

Chapter 2: General Biology and Ecology

Description

The Marbled Murrelet is a small Pacific seabird (24-25 cm [9.4-9.8 in] long, wing length 122-149 mm [4.8-5.9 in], adult mass 188-269 g [6.6-9.5 oz]) (Nelson 1997). It spends the greater part of its life in the marine environment but flies inland for nesting, mainly in mature, and old-growth, late-successional, or older coniferous trees. Adults are similar in both size and appearance (i.e., sexually monomorphic) but have distinct breeding and winter plumages (Nelson 1997). In breeding plumage, the Marbled Murrelet has sooty-brown upperparts with rusty-brown margins (Carter and Stein 1995). The underparts are light mottled brown, often with rufous-brown flecking. The head and front part of the body have white feathers edged with black. The flanks are almost entirely dark brown. This cryptic plumage is believed to be an adaptation to minimize predation in nesting areas (Binford et al. 1975, Piatt et al. 2007). In winter plumage, the bird is "dark above" and "light below" (i.e., dark brownish-gray on the back with white on the sides of the head, nape, and flanks) (Carter and Stein 1995). The underparts are white with some brown feathering on the side. Fledglings appear similar to adults in winter plumage, with subtle differences (Nelson 1997, Piatt et al. 2007). Newly-hatched chicks are covered with yellowish, speckled down (Binford et al. 1975).

Taxonomy

The Marbled Murrelet belongs to the Alcidae, or auk, family, generally referred to as alcids. The species was first described by Gmelin in 1789 as *Colymbus marmoratus*, but was reclassified by Brandt in 1837 as *Brachyramphus marmoratus* (American Ornithologists' Union 1998). Currently, there are three recognized species within the *Brachyramphus* genus: 1) the Marbled Murrelet, which breeds in western North America; 2) the Long-billed Murrelet (*B. perdix*), which breeds in eastern Asia; and 3) the Kittlitz's Murrelet (*B. brevirostris*), which breeds in Russia and Alaska (American Ornithologists' Union 1998).

Interestingly, the Long-billed Murrelet was originally classified as a separate species from the Marbled Murrelet in 1811 but was eventually lumped with *B. marmoratus* in the mid-1900s (reviewed in Friesen et al. 1995b). For much of the rest of the 20th century, the Long-billed Murrelet was considered a subspecies of the Marbled Murrelet. However, molecular research in the mid-1990s provided evidence that Marbled Murrelets and Long-billed Murrelets are genetically distinct (Zink et al. 1995, Friesen et al. 1996a, b), leading to recognition as separate species again in 1997 (American Ornithologists' Union 1997).

Geographic Range and Distribution

Marbled Murrelets breed along the Pacific Coast of North America from the Bering Sea (Attu Island in the Aleutian Archipelago) south to the Santa Cruz Mountains of California (Ralph et al. 1995a, Nelson 1997, Burger 2002, Piatt et al. 2007; see Fig. 1). The geographic center of the global population occurs in the northern part of southeast Alaska (Ralph et al. 1995a). Large numbers of murrelets are found in the

Kodiak Archipelago, Prince William Sound, and the Alexander Archipelago, and to the south along the coast to British Columbia (Piatt et al. 2007). In both directions from there, populations become more disjunct, with only sparse or small numbers of murrelets at the extreme ends of the range (Ralph et al. 1995a, McShane et al. 2004). Past habitat removal has also created large gaps that fragment population distribution within the core of the range (Ralph et al. 1995a, USFWS 1997, RIT 2012); in Oregon, large habitat gaps occur in the northwest portion of the state as well as the coastal strip between Reedsport and the Siskiyou Mountains (RIT 2012). Birds winter throughout the breeding range, and south to southern California or northern Baja California, Mexico (Nelson 1997, McShane et al. 2004, Piatt et al. 2007; Fig. 1).

Figure 1. Marbled Murrelet range in North America. Approximate breeding (dark gray) and at-sea (blue) distributions are indicated. Figure modeled after Piatt et al. (2007), Fig. 1, p. 5. Base map adapted from BlankMap-North America-Subdivisions/Wikimedia Commons/NuclearVacuum/CC-BY-SA-3.0.

The Marbled Murrelet is a native species in Oregon (American Ornithologists' Union 1998, Marshall et al. 2003, Oregon Biodiversity Information Center 2016). It is found mainly in the Coast Range and Klamath physiographic provinces. Marbled Murrelets have been detected up to 129 km [80 mi] inland in Oregon (Nelson 1997), but most breeding behaviors indicative of occupancy/nesting have been recorded within 65 km [40 mi] of salt water[2] (Evans Mack et al. 2003; Fig. 2). During the breeding season in Oregon (April through September), murrelets are generally concentrated within 2 km [1.2 mi] of the shore when at sea (Strong et al. 1995, Falxa et al. 2016).

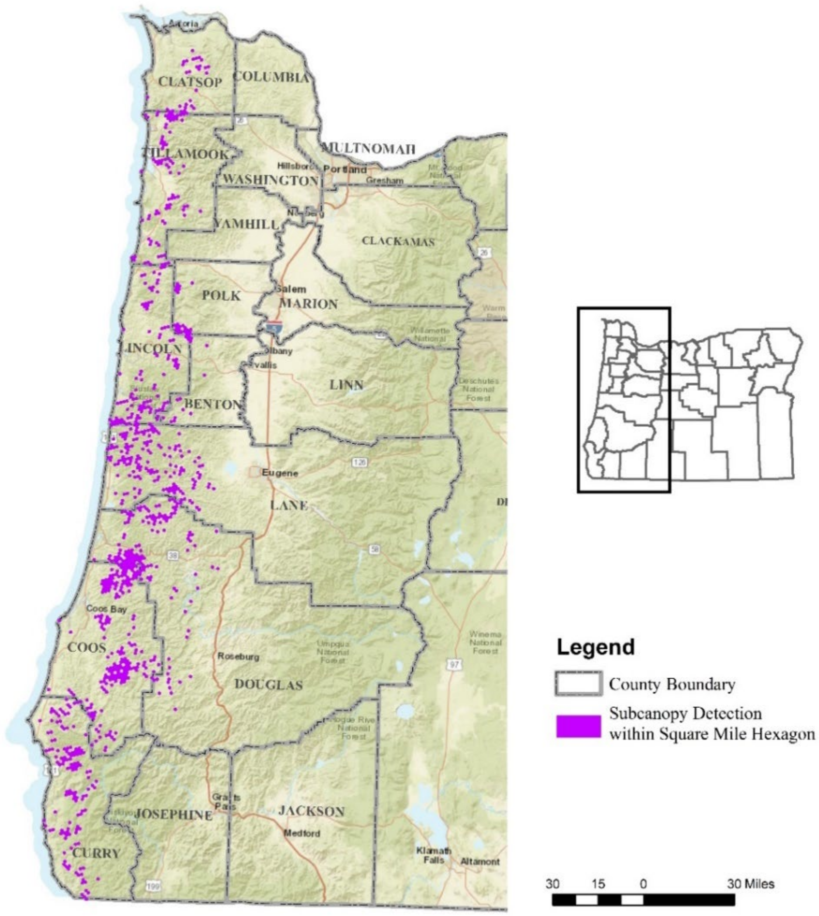

Figure 2. Approximate distribution of the Marbled Murrelet in Oregon based on available inland survey data gathered from 1988-2016. Inland survey data were provided by the Bureau of Land Management, Oregon Department of Forestry, and Oregon State University (note that surveys were not systematic across the state and covered various areas and time periods - see Inland Surveys in text for details). Subcanopy detections were selected from the survey results, and then summarized to indicate presence within a seamless 1 mi² hexagon dataset covering Oregon. County boundaries provided by Oregon Department of Administrative Services Geospatial Enterprise Office. Base map provided by Esri.

[2] In recent consultations concerning Marbled Murrelets, the USFWS considered "a tree with potential nesting structure" that "occurs within 50 mi of the coast (USFWS 1997)" as one of the typical characteristics of suitable habitat in Oregon (excerpt of biological opinion text provided to ODFW by R. Bown, USFWS, in March 2017).

Types of Habitat Used

Marbled Murrelets spend the majority of time in the marine environment, in nearshore waters along exposed coastlines throughout their range, and in sheltered sounds and estuaries in Alaska, British Columbia, and Washington. Foraging, courtship, loafing, molting, and preening occur at sea. Marbled Murrelets have also been recorded feeding in freshwater lakes (Carter and Sealy 1986).

In Oregon, Marbled Murrelets use older, late-successional, and old-growth forests almost exclusively for nesting. In Oregon, some nests have also been found in mature and younger trees (66-150 years) containing older forest characteristics, such as platforms created by mistletoe infections or other deformities (Nelson et al. 2006). Because murrelets do not construct a nest, per se, the presence of potential nest platforms provided by large or deformed tree branches with moss or lichen suitable to form a nest "cup" is a particularly important habitat feature (Nelson 1997, Burger 2002, McShane et al. 2004, Nelson et al. 2006). These tree-nesting habits are unique among North American alcids; most alcids nest colonially on islands or cliffs at the marine-terrestrial interface. Nesting on open ground (especially in western Alaska where trees are absent), on cliffs, in rock crevices, or rarely in deciduous trees has been documented in parts of the northern Marbled Murrelet range (Nelson 1997, McShane et al. 2004, Piatt et al. 2007), with the exception of a single cliff nest in Washington's Olympic Mountains (Bloxton and Raphael 2008, Wilk et al. 2016).

Migration and Movements

Marbled Murrelets in Oregon (and elsewhere in the southern portion of the range) are not known to undertake large migratory movements (McShane et al. 2004). However, studies of fall-winter movements are few, and there may be some seasonal shifts in murrelet distribution. Studies from other areas have reported seasonal movements of birds south from breeding areas in fall and winter, from coastal waters to more sheltered inshore waters, or from breeding areas to waters further offshore (e.g., Rodway et al. 1992, Speich and Wahl 1995, Beauchamp et al. 1999). Bertram et al. (2016), including reported a bird that moved almost 1,181 mi to Alaska after breeding in British Columbia.

Marbled Murrelets have been heard and observed over nesting areas throughout the year (Carter and Erickson 1992, Naslund 1993, O'Donnell et al. 1995). Inland detections are greatest during spring and summer, when activity is greatest and when attendance at inland sites is more consistent, and longer in duration. In most years, Marbled Murrelet detections reach a peak in the summer (Paton et al. 1990, O'Donnell et al. 1995, Nelson et al. 2006). In southeast Alaska, periods of no or reduced visitation to inland sites coincided with timing of murrelets' complete pre-basic molt in the fall (in which birds are flightless for 1-2 months at sea) and the pre-alternate (partial) molt in the spring (reviewed in Piatt et al. 2007). Reasons for visitation to inland sites during the non-breeding season are poorly understood, but birds may be maintaining pair bonds, examining future nesting areas, or engaging in other social activities (Carter and Sealy 1986, Naslund 1993).

Telemetry studies across the range have found high variability in home range sizes and nest-sea commuting distances for Marbled Murrelets (Whitworth and Nelson 2000, Hull et al. 2001, Kuletz 2005, Hébert and Golightly 2008, Barbaree et al. 2015, Lorenz et al. 2017). Differences probably reflect the distribution of suitable marine forage and terrestrial nesting habitat (Barbaree et al. 2015, Lorenz et al. 2017). In general, larger marine home ranges and commuting distances have been reported in the federally-listed range compared to Alaska (Lorenz et al. 2017).

In Washington, Lorenz et al. (2017) documented the greatest nest-sea commuting distances reported to date for breeding Marbled Murrelets (mean distance: 33.2 ± 17.6 mi, range: 10.4-90.3 mi). They found lengthy travel distances over land and over water. They suggested that declines in nesting habitat, combined with poor marine conditions in the Salish Sea, may be forcing murrelets to travel further in this region. One failed breeder in their study nested within 2.9 mi of sea on Vancouver Island but often foraged in the San Juan Islands (1-way commute of 85.9 mi).

Foraging Behavior and Diet

Like other alcids, Marbled Murrelets are wing-propelled pursuit divers. They capture small schooling fish and marine invertebrates beneath the surface by "flying" underwater (Nelson 1997, Burger 2002). Foraging depths are largely unknown, though an alcid the size of a murrelet is likely to have a maximum diving depth of 47 m [154 ft] (Mathews and Burger 1998). Murrelets forage during the day and at dawn or dusk, solitarily or in groups (Carter and Sealy 1990, Strachan et al. 1995, Speckman et al. 2003); there is little direct evidence of feeding at night (reviewed in Haynes et al. 2010). Off the coast of Oregon, groups of 2-3 murrelets are typically seen at sea (Strong et al. 1995), though extended aggregations comprised of thousands of murrelets have been observed in northern parts of the range where populations are much larger (Burkett 1995, Strachan et al. 1995). Marbled Murrelets prefer shallow, nearshore (within 3.1 mi of shore) marine waters less than 98 ft deep off the Oregon coast, but may be found farther offshore during the non-breeding season and in Alaska during any season (Nelson et al. 2006).

Marbled Murrelets are "flexible" foragers, feeding on the most abundant, suitable prey items (Burkett 1995, Nelson 1997). Prey quality and availability are affected by a combination of local and large-scale oceanographic processes (see Marine Habitat below). While little information is available on murrelet diet in coastal Washington and Oregon, several reviews have broadly characterized seasonal and geographic variation in diet across the murrelet range, and differences between adult and chick diet.

During the breeding season, fish prey dominate the diet (Sealy 1975, Carter 1984, Burkett 1995, Nelson 1997, Piatt et al. 2007). In contrast, during winter and spring, invertebrate species (e.g., euphausiids and mysids – shrimp-like crustaceans) may be taken in greater numbers (Burkett 1995, Piatt et al. 2007). Freshwater prey may also be important in some areas, particularly where large lakes with abundant salmonids occur near inland nesting habitat (Carter and Sealy 1986, Hobson 1990, McShane et al. 2004).

Pacific sand lance (*Ammodytes hexapterus*), Pacific herring (*Clupea pallassii*), and capelin (*Mallotus villosus*) are thought to be the main prey items north of Washington, whereas diet south of Canada is likely dominated by northern anchovy (*Engraulis mordax*), smelt (Osmeridae), and herring, with mysids and euphausiids also important in both regions (Burkett 1995, McShane et al. 2004). Most fish taken by murrelet adults and subadults are small larval or juvenile fish classes (30.1-60.0 mm [1.19-2.36 in] in size), whereas those fed to nestlings are larger subadult or adult fish (Burkett 1995, Piatt et al. 2007). Adults generally deliver a single fish to nestlings per feeding trip (Nelson 1997), and chicks may be fed larger fish due to their higher energy values needed for growth and development and/or the lessened transport costs or predation risks associated with fewer provisioning trips by parents to the nest site (see Piatt et al. 2007).

There is evidence that marine forage communities important to seabirds change in response to “regime shifts” and climate variability in the ocean, such as the Pacific Decadal Oscillation (PDO) (e.g., Anderson and Piatt 1999, Chavez et al. 2003, Miller and Sydeman 2004). As summarized by Piatt et al. (2007), various changes in Marbled Murrelet diet among years and across regions in Alaska were linked to a regime shift in the North Pacific Ocean that began in the late 1970s and continued into the 1990s. Capelin were common in the summer diets of murrelets collected from the Alaska Peninsula and Kodiak Island in the 1970s and 1980s, but were largely absent from murrelets collected from this same region in the early 1990s. Similarly, poor marine conditions in Prince William Sound were thought to be responsible for the disappearance of capelin from the Marbled Murrelet diet there and for a dietary switch to mostly sand lance in the late 1970s and to lipid-poor gadids from 1989-1991.

Several recent studies in the Salish Sea and in California indicate that the diet quality of Marbled Murrelets has declined over the last century due to regional changes in climate, overfishing, or both (Becker and Beissinger 2006, Norris et al. 2007, Gutowsky et al. 2009). Becker and Beissinger (2006) compared stable-carbon and -nitrogen isotope signatures in feathers from museum specimens (collected from 1895-1911) and birds caught at sea (collected 1998-2002) in central California. They found evidence of a 38% trophic level decline in pre-breeding diet over the last 100 years. They suggested that many murrelets forego breeding in years with insufficient food resources, particularly since egg formation is such an energetically expensive function. Using similar methods, Norris et al. (2007) and Gutowsky et al. (2009) reported declines in the trophic level of the murrelet diet in their Salish Sea study areas over the last 150 years, and concluded that murrelets have been limited, in part, by available food resources there. Because prey types vary in caloric content and energy density, reliance on less nutritious, energetically-poor prey items (e.g., krill) may be a major factor in reduced breeding propensity and low reproductive output also reported in these areas (Peery et al. 2004, Becker and Beissinger 2006, Becker et al. 2007, Lorenz et al. 2017).

Issues of prey distribution, abundance, timing, and quality are discussed further in Chapter 3.

Reproduction and Nesting Biology

For many years, the Marbled Murrelet represented what was perhaps the greatest ornithological mystery in the Pacific Northwest (Binford et al. 1975). Although it had long been suspected that murrelets nested in inland forest areas (Gabrielson and Jewett 1940), the first well-described Marbled Murrelet tree nest was not found until 1974 (in California) (Carter and Sealy 2005).

Intensive search efforts and improved survey techniques have led to the discovery of 89 Marbled Murrelet nests in Oregon since 1990 (S. K. Nelson, pers. comm. 2021). Of those, 34 were active at the time of discovery. The other nests (55) were old nests found by tree climbing after the nesting season.

Marbled Murrelet nests are extremely difficult to locate and monitor because they are hidden high in the forest canopy. In addition, murrelets exhibit secretive behavior and rapid flight, further challenging observers. In Oregon, the search effort for nests has been mostly limited to research study sites and those found during surveys conducted as part of timber sale planning. The nests found do not represent the total number of nests in Oregon, but rather underscore the extreme difficulty in finding nests.

Timing, Clutch Size, and Re-nesting

Compared to other alcids, Marbled Murrelets have a long and asynchronous breeding season (Hamer and Nelson 1995a). Hamer and Nelson (1995a) found that the breeding period in Oregon lasts up to 149 days, beginning in April and ending in September. Across the range, timing of breeding varies with latitude and may be affected by food availability, weather, and ocean conditions. There are also indications that birds breed later or forego breeding altogether when food availability is poor (Peery et al. 2004; see also Foraging Behavior and Diet above).

Marbled Murrelets lay only one, large (16-19% of body weight) egg per clutch (Nelson 1997). Renesting after early nest failure has been documented (McFarlane Tranquilla et al. 2003a, Barbaree et al. 2014). However, there is no evidence of second brooding (laying a second egg after successfully fledging a first chick) (McShane et al. 2004). Some eggs are laid as late as July (McFarlane Tranquilla et al. 2003b).

Nests

Marbled Murrelets nest primarily in old-growth, late-successional, or older coniferous forest stands but may also use mature or younger stands with characteristics typically found in older forest types. Nests are normally well hidden beneath overhanging branches, and are usually close to the tree trunk (Hamer and Nelson 1995b, Nelson and Wilson 2002). Nests are not constructed; instead, the egg is laid in a depression (nest cup) in moss, lichen, forest duff, or other suitable substrate on a natural platform on a large branch or on a deformity (e.g., mistletoe or "witches broom") high in the canopy. Marbled Murrelet breeding ecology reflects an evolutionary strategy of predator avoidance that is inherent for birds nesting in inland habitats. The presence of large platforms with adequate nesting substrate (e.g., moss) is particularly important (Nelson 1997, Burger 2002, McShane et al. 2004, Nelson et al. 2006). Foliage cover above and around the nest, tree size, nest height, and proximity to openings in the canopy are among other factors positively associated with nest sites (McShane et al. 2004, Nelson et al. 2006). There is also evidence to suggest that murrelets select distinctive trees for nesting from among trees available within a stand (Silvergieter and Lank 2011). Predation risk to adults and nests, and energetic constraints associated with commuting to inland nest sites are likely important factors related to nest-site selection for Marbled Murrelets.

Courtship

Courtship behavior has been frequently observed on the sea during early spring, throughout the summer, and in winter, but little is known about how and when Marbled Murrelets actually form pair bonds (Sealy 1975, Carter 1984, Carter and Stein 1995, Nelson 1997). Marbled Murrelets are commonly seen as pairs at sea throughout the year, but it is unclear whether they are necessarily breeding mates or perhaps temporarily foraging cooperatively (Sealy 1975, Strachan et al. 1995, McShane et al. 2004). In Oregon, pairs have been observed “prospecting” or visiting nest trees prior to egg laying (Nelson and Hamer 1995a, Nelson and Wilson 2002). Copulation has been observed in trees and on the water (Nelson 1997).

Incubation

After the female lays the single egg, the pair begins shared incubation in 24-hour shifts; exchanges of incubation duties generally occur before dawn, with one parent taking over incubation and the other leaving to forage at sea (Nelson 1997). Incubation lasts 28-30 days (Nelson 1997).

Chick-rearing

The chick is semi-precocial at hatching and is covered in cryptic down (Nelson 1997). It is brooded for 1 or 2 days by the adults, and then left alone at the nest for most of the chick-rearing period while both parents forage at sea (McShane et al. 2004). Murrelet chicks grow rapidly compared to other alcids (De Santo and Nelson 1995, Nelson 1997), which is consistent with a strategy to reduce time-dependent predation risk at the nest site (Lawonn et al. 2018).

Adults make up to eight visits a day to the nest, typically bringing just one large fish to the chick each trip (Nelson 1997). Adults approach the nest below tree canopy height and usually ascend steeply to the nest in “stall out” fashion (Nelson and Peck 1995, Nelson and Hamer 1995a), landing on a moss-covered “pad” near the nest. Most feedings take place around dawn or dusk, though some occur throughout the day (Nelson 1997).

Fledging

Just prior to fledging, the murrelet chick plucks off remaining down, revealing the juvenile plumage (Nelson 1997). Chicks fledge between 27 and 40 days, or 58-71% of adult mass (Nelson 1997). This variation is likely due to provisioning rates and prey quality, which are presumably associated with the availability of different prey species. At fledging, young are thought to fly alone directly from the nest to the ocean (Nelson 1997, Nelson et al. 2006). After departing the nest, there is no evidence of further parental care (Nelson 1997, Nelson et al. 2006).

An unknown percentage of recently-fledged Marbled Murrelets do not make it to the ocean, as evidenced by the fact that fledglings have been found on the forest floor at varying distances from the ocean (Hamer and Nelson 1995a, Nelson and Hamer 1995a, Halbert and Singer 2017). Because these young still had their egg tooth and some down feathers on the neck and back, they were known to have recently fledged. Young birds may experience difficulties in navigating through the forest to the ocean because they have no prior flight experience, muscle development may be inadequate, and they are not accompanied or guided by adults. Once on the ground, murrelets likely are not able to take flight again or get to the ocean by other means.

Breeding Site Fidelity

Marbled Murrelets are thought to have high fidelity to nesting sites (Divoky and Horton 1995), though there are few data from individually-marked birds (Nelson et al. 2006, Plissner et al. 2015). Based on inland surveys, there is evidence of reuse of the same nesting stands, with some stands supporting decades of known murrelet use (Divoky and Horton 1995). Findings of multiple nests of different ages within the same tree, reuse of the same nest platform in different years, and replacement laying following initial failure (e.g., Nelson and Peck 1995, Nelson and Wilson 2002, Hébert et al. 2003, Burger et al. 2009, Golightly and Schneider 2011) provide some of the best support for fidelity at the smallest (tree or nest platform) spatial scales (reviewed in Plissner et al. 2015 and Halbert and Singer 2017). Interestingly, a nest platform monitored using remote video by Golightly and Schneider (2011) in northern California was reused by a banded female in 7 of 10 years, even though the nest failed due to predation in 5 of those 7 years.

In their recent review, Plissner et al. (2015) examined evidence of breeding site fidelity in Marbled Murrelets at watershed-, stand-, tree-, and nest platform- levels. They concluded that areas (at various scales) used for nesting in one year are often occupied in subsequent years, but it is unknown whether these are the same birds or different individuals. They also found some indications that fidelity at the tree or nest platform scale may be lower where habitat is more continuous and where suitable sites are less limited (see Burger et al. 2009). They underscored the need for additional studies using marked birds to further investigate these relationships.

Social Behavior

Unlike many other seabirds, Marbled Murrelets do not form dense colonies. They have been described as solitary or semi-colonial breeders (Simons 1980, Divoky and Horton 1995, Nelson 1997). In Oregon, two active nests were only 30 m [98 ft] apart at one site in the Coast Range (Nelson and Wilson 2002), but in general, there is little information on densities of concurrently active nests (reviewed in Plissner et al. 2015). Solitary nests are likely grouped within suitable habitat, and birds are commonly seen interacting socially in flight over nesting areas (Nelson and Hamer 1995a). Like other alcids that nest solitarily or in small groups (e.g., Kittlitz's Murrelet, Pigeon Guillemot (*Cepphus columba*)), Marbled Murrelets actively engage in flights, chases, displays, and vocalizations over nesting habitat (Nelson 1997). Nelson (1997) characterized Marbled Murrelets at sea as highly social, particularly during winter and in British Columbia and Alaska where densities are high; secrecy to avoid predation is presumably less important on the water than at the nest site (Nelson 1997, Speckman et al. 2003). Valente et al. (2021) found that Marbled Murrelets appear to be attracted to potential nesting areas based upon the presence of other Marbled Murrelets in the area. They suggest that social information influences murrelet breeding sites selection and the importance of safeguarding occupied sites over time and maintaining nesting populations.

Terrestrial Nesting Habitat

Marbled Murrelet habitat associations have been examined at various scales. We briefly summarize tree, stand, and landscape characteristics below, relying heavily on reviews by Burger (2002), McShane et al. (2004), and Nelson et al. (2006), and emphasizing findings from Oregon. We include selected variables for all nests found to date in Oregon (Table 1) from S. K. Nelson (pers. comm. 2018).

Tree Species

All but one known tree nest in Washington, Oregon, and California have been in conifers (Burger 2002, Nelson et al. 2006). One Marbled Murrelet nest was however found in a bigleaf maple (*Acer macrophylum*) in the Siuslaw National Forest in 2019 (S. Kim. Nelson pers comm. 2021). Nesting has also been documented very occasionally in deciduous trees (red alder (*Alnus rubra)* and bigleaf maple) in British Columbia (Bradley and Cooke 2001, Ryder et al. 2012). In Oregon, all nests otherwise have been located in western hemlock (*Tsuga heterophylla*), Douglas-fir (*Pseudotsuga menziesii*), Sitka spruce (*Picea sitchensis*), and western red cedar (*Thuja plicata*) (Hamer and Nelson 1995b; Nelson and Wilson 2002; S. K. Nelson, unpubl. data 2020). However, Marbled Murrelets do not seem to select particular tree species, and combined with other states/provinces, they have been found nesting in a wide range of coniferous tree species. Nest tree species are usually the dominant or abundant species found within the range that provide suitable nest platforms and other preferred characteristics (Burger 2002, Nelson et al. 2006, Silvergieter and Lank 2011).

Tree Size and Age

Nest trees used by Marbled Murrelets are primarily large, tall old-growth, late-successional, or older trees (>49 cm [19 in] dbh, >33 m [108 ft] tall, Table 1a; Nelson 1997, Burger 2002, McShane et al. 2004, Nelson et al. 2006). Nelson and Wilson (2002) reviewed the ages of 33 nest trees on state lands in the Clatsop, Tillamook and Elliott state forests. A 107-year old tree in the Tillamook State Forest had 5 nests. Overall, the ages of the 33 trees ranged from 66 to 400+ years old: one tree was less than 80 years old; 21 were between 80 and 165 years old; and 11 were greater than 165 years old. The younger and mature trees had structural elements (deformities or dwarf mistletoe infestations) characteristic of older trees.

Platforms and Nesting Substrate

Nests are typically on large limbs (mean limb diameter at the trunk: 22 cm [8.7 in], mean limb diameter at the nest: 23 cm [9.1 in], Table 1b; Nelson 1997, Burger 2002, McShane et al. 2004, Nelson et al. 2006) and high in the live canopy (>10 m [33 ft] above ground, Table 1b; Nelson 1997). Measured platform widths were all >7 cm [2.8 in] (Table 1b). In most areas, these platforms supported thick mats of moss, other epiphytes, or forest duff/litter; mean moss and duff/litter depth were 4.3 cm [1.7 in] and 2.3 cm [0.91 in], respectively (Table 1b). Because the nest cup is merely a depression, this substrate on the nest limb helps to hold the egg in place and keep it from falling (Nelson et al. 2006).

Cover

Most nests have high amounts of protective foliage above (vertical cover) or to the side (horizontal cover, (mean vertical cover: 83%, mean horizontal cover: 53%, Table 1b; Nelson et al. 2006). Nest cover may help to reduce detection by predators and/or provide protection from inclement weather (Hamer and Nelson 1995b, Burger 2002, Nelson et al. 2006).

Stand Characteristics

Occupied stands in Oregon are mostly old-growth, late-successional, older forests dominated by Douglas-fir, western hemlock, or Sitka spruce (Grenier and Nelson 1995, Nelson and Wilson 2002). High densities of large trees with platforms, multiple canopy layers, and canopy gaps that provide murrelets flight access to nest sites appear important (Nelson et al. 2006). Such structure and complexity are most often found in old-growth, late-successional forests, and some mature or younger forest types with structural elements (deformities or dwarf mistletoe infestations) characteristic of older trees.

Platform Density

Nest trees found in Oregon have contained from 8-92 platforms (Table 1a). Based on an analysis of platform use as a function of number of platforms per tree in British Columbia, Silvergieter and Lank (2011) suggested that murrelets do not select trees with more platforms, but rather select platforms based on their individual characteristics.

Stand Age and Tree Density

Grenier and Nelson (1995) compared habitat characteristics of sites occupied by murrelets in Oregon to random sites. They found that occupied sites tended to be in older stands, with larger midstory trees, larger dominant or remnant trees, and higher densities of dominant or remnant trees. As noted above, Nelson and Wilson (2002) reported nesting in some younger forest stands in Oregon (limited to the Sitka spruce/western hemlock forest type) where platforms had been created by deformities and mistletoe. These and other studies support the idea that stand structure is more important in determining use by murrelets than stand age or size, but further research is needed to fully investigate the combination of physical conditions that constitute an optimal nest site (Halbert and Singer 2017).

Access

Marbled Murrelets have high wing loading (ratio of body mass to wing area). This helps to reduce drag underwater, but requires that they fly at high speeds (often >70 kph [44 mph]) to remain airborne (Nelson 1997, Burger 2002). Consequently, murrelets have low maneuverability relative to many other birds, making take-offs and landings more difficult. This constraint has likely influenced nest-site choice; natural gaps in the canopy that provide unobstructed flight access to nests, and nest platforms that are high enough to allow for stalled landings and jump-off departures, are important habitat features (Burger 2002, Nelson et al. 2006). Sites with multiple canopy layers or with openings near the nest site may provide such access, though there may be a tradeoff between selecting easily accessible sites and those that might be too open, attracting predators (Hamer and Nelson 1995b, Nelson and Wilson 2002, Nelson et al. 2006).

Landscape Characteristics

Throughout their range, Marbled Murrelets nest primarily in low-elevation coniferous forests within 52 mi of the coast (McShane et al. 2004, Nelson et al. 2006). At a landscape scale, murrelets use habitats (based on various survey methods and definitions) that are generally associated with large amounts of unfragmented old-growth or mature forests (Burger 2002, Raphael et al. 2002, Meyer and Miller 2002, McShane et al. 2004, Nelson et al. 2006, Burger and Waterhouse 2009, Raphael et al. 2015, Raphael et al. 2016b, Wilk et al. 2016, Raphael et al. 2018). The importance of slope, aspect, or other topographical features is more equivocal (Plissner et al. 2015). It is likely that a combination of factors, both terrestrial and marine, contribute to resource use and habitat selection by murrelets during the breeding season (see Lorenz et al. 2016).

Elevation

Marbled Murrelet nests have been found at elevations from sea level up to 1,500 m [4,921 ft] throughout their range (Burger 2002). All nests found in Oregon have been located at 617 m [2,024 ft] or less (Table 1a). The use of mostly low-elevation, moist forests by murrelets in Washington, Oregon, and California could be because high elevations are not present throughout much of their southern range, and where they occur, suitable nesting habitat is lacking (Hamer and Nelson 1995b, McShane et al. 2004, Nelson et al. 2006).

Distance to Coast

Proximity to the coast was an important predictor of murrelet occupancy in some studies (e.g., Meyer and Miller 2002, Meyer et al. 2002), but not others (reviewed in Burger 2002). All nests found in Oregon have been located within 30 mi of the coast (Table 1a), and most audio-visual detections indicative of nesting have been recorded within 40 mi (Evans Mack et al. 2003; Fig. 2). Proximity to productive marine foraging areas may also affect bird movement, commute distance, and home range size (see Lorenz et al. 2017). Lorenz et al. (2017) assumed that elevation, as well as distance to the coast, constituted an energetic cost to murrelets traveling to inland nest sites.

Murrelets seem to avoid nesting directly adjacent to the ocean in the southern portion of the range (Hamer and Nelson 1995b, Nelson et al. 2006). Nelson et al. (2006) concluded that distance inland may be determined by a combination of energetic constraints, habitat availability, site fidelity, predation pressure, or other factors.

Table 1. Selected Marbled Murrelet nest tree (Table 1a) and nest characteristics (Table 1b) for Oregon. Data were provided by S. K. Nelson (pers. comm. 2018) for 75 nests found in Oregon from 1990 and up to 2018. Mean values are shown for variables measured, along with standard deviation (SD), range, and sample size (n, number of nests).

Table 1a. Nest tree characteristics

	Tree DBH (cm)	**Tree Height (m)**	**No. Platforms in Nest Tree**	**Distance from Ocean (km)**	**Distance to Edge (m)**	**Elevation (m)**
Mean	141	56	26	22	51	330
SD	48	14	19	10	45	150
Range	49-279	33-85	8-92	1-49	0-185	53-617
n	70	70	46	75	75	75

Table 1b. Nest characteristics

	Nest Limb Height Above Ground (m)	**Nest Limb Diameter at Trunk (cm)**	**Limb Diameter at Nest (cm)**	**Distance from Trunk (cm)**	**Nest Platform Width (cm)**	**Moss Depth Adjacent to Nest (cm)**	**Duff & Litter Depth in Nest Cup (cm)**	**% Horizontal Cover (Side)**	**% Vertical Cover (Overhead)**
Mean	36	22	23	110	25	4.3	2.3	53	83
SD	14	10	9	116	10	2.4	1.9	19	21
Range	10-75	7-56	10-47	0-762	7-51	0.0-11.0	0.0-8.4	13-85	25-100
n	66	67	35	67	65	65	54	53	56

Slope, Aspect, and Moisture

There is no evidence that murrelets prefer a particular aspect for nesting, though aspect or other topographical features could affect moisture levels or other conditions conducive to platform creation or epiphyte growth (McShane et al. 2004, Nelson et al. 2006).

There is some evidence that slope is important in nest-site selection, and that steep slopes are usually avoided within Washington, Oregon, and California (reviewed in Nelson et al. 2006). Use of slopes may be tied to factors other than the slope itself, such as local predation pressure or timber harvest patterns (see discussion in Nelson et al. 2006). The average slope of 65 nest sites from Oregon was 39% and ranged from 5-97% (S. K. Nelson, pers comm.).

Habitat Fragmentation

Major changes have occurred in forested lands over the last 150-200 years, including considerable loss of late-successional forest and fragmentation of remaining forest into smaller or more isolated patches (Harris 1984). Fragmentation can result from timber harvest, fire, development, agriculture, or other natural or anthropogenic forms of habitat modification. Fragmentation can affect a multitude of ecological phenomena, including forest microclimates (e.g., temperature, light, wind, moisture), movement and dispersal of organisms, plant and animal community composition, and forest resiliency to future disturbances or stressors (Lehmkul and Ruggiero 1991, Halpern and Spies 1995, Chen et al. 1999). Fragmentation alters the pattern and configuration of the original forest, exposing remnant patches to increased “edge effects” (Lehmkul and Ruggiero 1991, Murcia 1995).

While habitat loss could be expected to result in the displacement of nesting birds, fragmentation could lead to both displacement and reduced breeding success (Divoky and Horton 1995). If all available nest sites in adjacent habitat are occupied, then displaced birds could attempt to breed in suboptimal sites with reduced success, forego breeding altogether, or prospect for new nest sites elsewhere (Divoky and Horton 1995). However, few murrelets are thought to disperse to new areas for nesting or to “pack” into remaining habitat in higher densities (Burger 2001, Raphael et al. 2002, Burger and Waterhouse 2009), an idea that is further supported by central California genetics research. Peery et al. (2010) found evidence of recent genetic discreteness in the central California murrelet population that may be tied to increasing habitat fragmentation over the last century. Strong fidelity to nesting sites may hamper colonization of new areas, even where suitable habitat remains (Divoky and Horton 1995).

Disturbed areas and edges may convey poorer breeding success or survival for those murrelets that do nest. Adverse edge effects may be due, in part, to higher predator densities or predation rates along edges as opposed to interior habitat (Nelson and Hamer 1995b). One important nest predator of murrelets, the Steller’s Jay (*Cyanocitta stelleri*), is known to concentrate in “patchy” or “edgy” areas and near human activities (Raphael et al. 2002, Marzluff et al. 2004). Windthrow, exposure to the elements, or other disturbances may be more pronounced at forest edges (McShane et al. 2004). Differences in sunlight, temperature, or moisture at clearcut edges may also reduce epiphyte growth and survival important for murrelet nest platforms (van Rooyen et al. 2011).

Edge effects are not static and can change over time (Malt and Lank 2007, 2009; van Rooyen et al. 2011). The type of adjacent habitat can also influence edge effects and may explain why some studies have failed to detect such effects (e.g., Marzluff and Restani 1999, Bradley 2002). Based on studies in British Columbia, “hard” edges (recent clearcuts) tend to produce detrimental effects, whereas “soft” edges (e.g., regenerating forest) or natural (e.g., riparian) edges appear to have lessened or no edge effects, respectively (Bradley 2002; Malt and Lank 2007, 2009; van Rooyen et al. 2011). As discussed earlier, proximity to human habitation or activities is also important for predator-prey dynamics. Campgrounds, picnic areas, and other sources of human-supplied food tend to support elevated levels of corvids (e.g., jays, crows, ravens), which can lead to higher nest depredation for nearby murrelets (Marzluff and Neatherlin 2006, Bensen 2017, Goldenberg et al. 2016), and perhaps for murrelets nesting further away (West and Peery 2017).

Based on modeling and limited observations, Marbled Murrelet nest sites are, in general, negatively associated with increasing amounts of forest fragmentation (reviewed in Burger 2002, McShane et al. 2004, Nelson et al. 2006). Aspects of landscape pattern and configuration (e.g., adjacent habitat, proximity to human activities, type of edge) are also important due to their influence on edge effects and predator-prey dynamics (see Fragmentation of Habitat below). In southern Oregon, Meyer et al. (2002) found that murrelets were most abundant in unfragmented old-growth forest patches located within a matrix of mature second-growth forests. In western Oregon, Ripple et al. (2003) found that the proportion of old-growth forest was a key predictor of murrelet nest sites, and that edge-related habitat variables (i.e., edge-perimeter density, nest-patch perimeter, high-contrast edge at nest patches) were lower at murrelet nest sites than random sites. These findings are consistent with recent results reported in Raphael et al. (2016b), that nesting habitat cohesion (the inverse of habitat fragmentation) was a strong predictor of murrelet abundance and trends along the Pacific Northwest Coast, including Oregon.

Amount and Distribution of Terrestrial Habitat

There have been many efforts to quantify the extent of the loss of older forests across different time periods. Such estimates can vary depending upon the definitions used for suitable habitat, reliability of mapping and GIS data, assumptions, and algorithms used (Piatt et al. 2007, COSEWIC 2012, Raphael et al. 2016a, Lorenz et al. In press). We review historical and current habitat conditions below.

Habitat in the Pacific Northwest

Historical Summary

Historically, Marbled Murrelets are believed to have inhabited coastal old-growth forests throughout the Pacific Northwest and northwestern California (USFWS 1997, McShane et al. 2004). Field-survey data are lacking for historical conditions, but estimates derived from early mapping and vegetation reconstruction efforts and simulations indicate large-scale declines in old-growth in recent history (last 100-200 years) (Booth 1991, Teensma et al. 1991, Bolsinger and Waddell 1993, Ripple 1994, Perry 1995, Wimberly et al. 2000, Strittholt et al. 2006, Ohmann et al. 2007). According to Strittholt et al. (2006), old-growth forests across the Pacific Northwest once covered about two-thirds of the land base; today, only about 28% of old-growth remains due mainly to timber harvest and other land use changes. Strittholt et al. (2006) estimated that 95% of old conifer Puget Lowland Forests (in Washington) and 82% of old conifer Central Pacific Coastal Forests (in Washington and Oregon) have been lost since the time of European settlement, much of which was likely murrelet habitat. Similar estimates of remaining old-growth (5-20%), depending on the region, have been reported by others within the federally-listed range of the Marbled Murrelet (see Falxa et al. 2016).

Habitat in Oregon

Patterns of forest age and structure in western Oregon are strongly tied to type of landownership due to varying policy, regulatory, and/or management regimes (Ohmann et al. 2007, Raphael et al. 2016a, Lorenz et al. In press). State and federal landownership within the Marbled Murrelet range in Oregon is shown in Fig. 3. In the Oregon Coast Range, most forest lands have been intensively managed for timber since the early 1900s and have had a complex fire history as well. Thus, the landscape today consists of a mosaic of young and older forests. Many older forests have been reduced to small, isolated patches (Spies and Franklin 1988), and the historical fire regime has been largely replaced by short-rotation (30-60 year) timber harvest on private lands (Wimberly et al. 2000).

In the mid-1800s and early 1900s, large human-caused wildfires burned extensive areas of Oregon Coast Range forests (Teensma et al. 1991, Ripple 1994, Perry 1995). Teensma et al. (1991), as cited by Perry (1995), estimated that stands 200 years of age and older represented 40-50% of Coast Range forests between 1850 and 1920, and declined to 20% by 1940 following large fires in the Tillamook area. If trees between 100 and 200 years old were considered in these estimates, potential Marbled Murrelet habitat might have comprised 70% of the Coast Range forests in 1920 and 50% in 1940 (Perry 1995). Perry (1995) also reported that considerable old-growth acreage (565,000-900,000 ac) had already been logged in the Oregon Coast Range by the 1930s.

In another analysis, Ripple (1994) traced the history and extent of old-growth forests in western Oregon in the context of fire cycles, size class distribution, the amount of pre-logging old-growth, and spatial forest patterns of western Oregon. He showed that by the early 1900s, 71% of all conifer forests were in the large forest class (large old-growth, small old-growth, and large second-growth), of which 89% was spatially connected as one patch. Similar to Teensma et al. (1991), Ripple (1994) found that the amount of old-growth in the Coast Range was 61% before the large fires of the late 1840s, and approximately 43% in the 1930s.

Recent simulation models integrating historical surveys, disturbance data, and maps with contemporary satellite imagery and GIS data corroborate and expand upon the findings by Teensma et al. (1991), Perry (1995), and Ripple (1994) of extensive forest cover change in the Oregon Coast Range (Wimberly et al. 2000, Wimberly and Ohmann 2004, Ohmann et al. 2007). Wimberly et al. (2000) quantified the range of historical variability in the amount of old forests in the Oregon Coast Range and estimated that late-successional forests covered 52-85% of the landscape over the 1,000 years prior to Euro-American

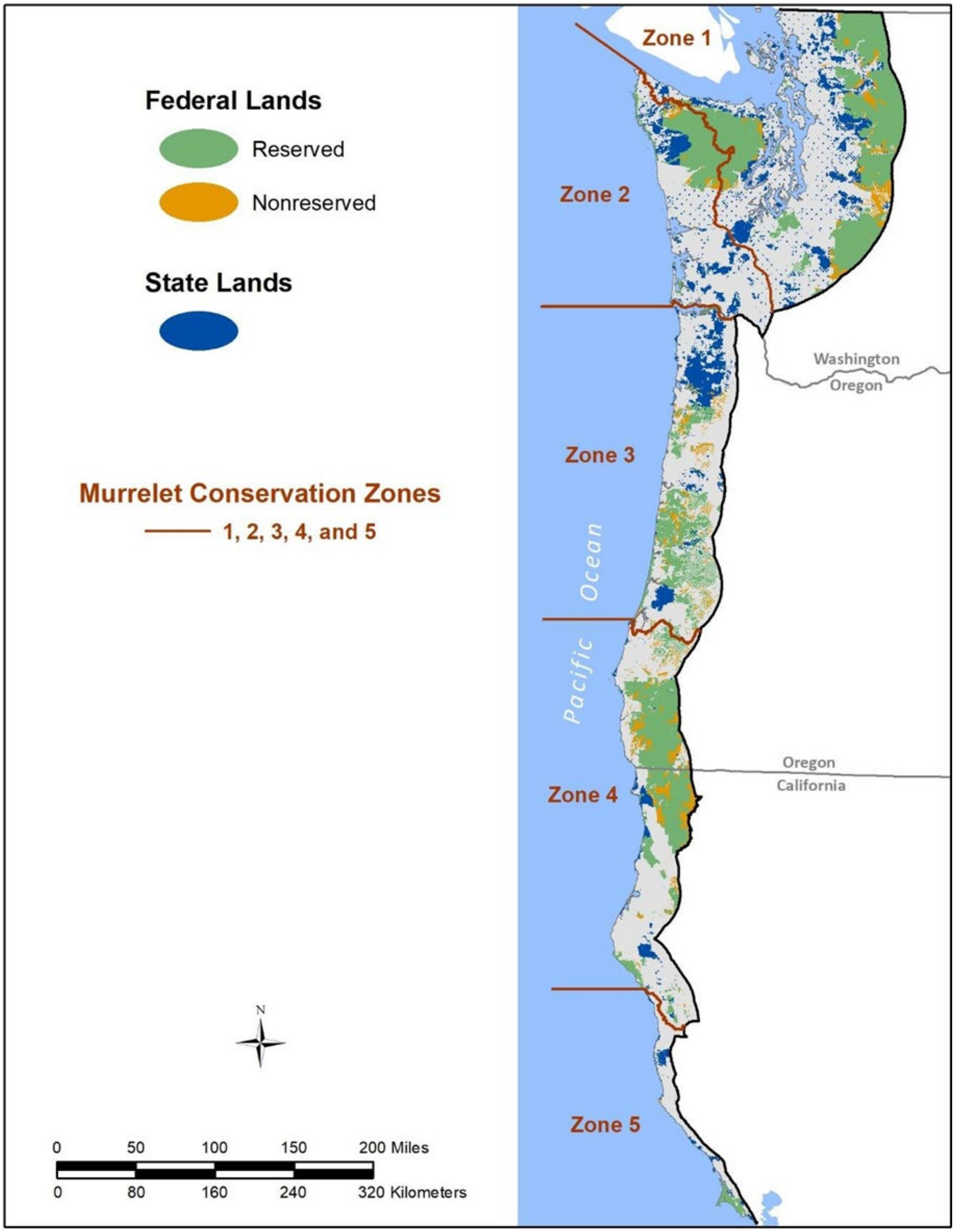

Figure 3. Northwest Forest Plan reserved (for late successional forest habitat) and nonreserved land use allocations on federal lands within the range of the Marbled Murrelet. Also depicted are state lands and locations of Marbled Murrelet Conservation Zones (Lorenz et al. In press).

settlement. Wimberly and Ohmann (2004) subsequently found that large-conifer forests decreased from 42% of the landscape in 1936 to 17% in 1996, while small-conifer forests increased from 21% of the landscape in 1936 to 39% in 1996. The change in large-conifer forests represented a loss of 1,533,536 ac, or 58% of the total area of large-conifer forests in 1996.

Northwest Forest Plan Habitat Effectiveness Monitoring

Lorenz et al. (In press) conducted the most recent habitat change analysis specific to Marbled Murrelets within the Northwest Forest Plan (NWFP) area (complete description of the USFS NWFP components is provided in Chapter 4). In Oregon, the NWFP area includes lands within 35 mi of the entire coast. These analyses excluded lands beyond 35 mi from the coast because of the scarcity or lack of known murrelet nest and occupied sites from those areas, which were required by the habitat probability models used. Similar to previous NWFP effectiveness monitoring reports (Raphael et al. 2011, 2016a), maximum entropy (Maxent) models were used to identify Marbled Murrelet nesting habitat, as well as to compare and identify gains/losses in the amount and distribution of nesting habitat between 1993 and 2017. They used murrelet nest locations from federal and state agency records currently maintained in a database by the Oregon State University as presence sites for training Maxent models.

To assess the status and trend of nesting habitat for Marbled Murrelets in the NWFP area, Lorenz et al. (In press) defined and modeled forests for the relative probability of occurrence (of a murrelet nest). They defined thresholds that separated lower, moderate, and higher probabilities of nesting habitat. Forested areas that were modeled as "higher probability nesting habitat" denoted the best representation of Marbled Murrelet nesting habitat. Within the higher probability nesting habitat, Lorenz et al. (In press) estimated the amount of contiguous habitat (core) versus the amount of habitat adjacent to core habitat (edge) and habitat scattered in small forest fragments (scatter). "Core" represented unfragmented patches of nesting habitat in forest interiors, which provided better quality habitat compared to forest edges and small scattered patches. The minimum patch size for core habitat was 5.56 acres. Core habitat was assumed to provide the highest quality habitat where moss for platforms was more abundant and nest failure would be lowest. "Edge" represented higher probability nesting habitat that was adjacent to core habitat on one side, but which may make murrelet nests more susceptible to failure than core habitat because it is adjacent to non-habitat on at least one side. Edge was considered higher probability nesting habitat of intermediate quality. "Scatter" represented higher probability nesting habitat that was too small or narrow to be classified as core habitat, and fragmented patches that were the poorest quality habitat for murrelets because nests were considered the most vulnerable to predation.

Lorenz et al. (In press) estimated that there were 6,609,499 acres of "habitat-capable" lands within the NWFP area in Oregon in 2017. Habitat-capable lands were defined as areas capable of growing forest, and they excluded urban areas, major roads, water, land above tree line, agricultural areas, and other non-forested features. Importantly, habitat-capable lands included 517,686 ac (7.8% of habitat-capable lands) of higher probability nesting habitat (i.e., murrelet nesting habitat) (Fig. 4).

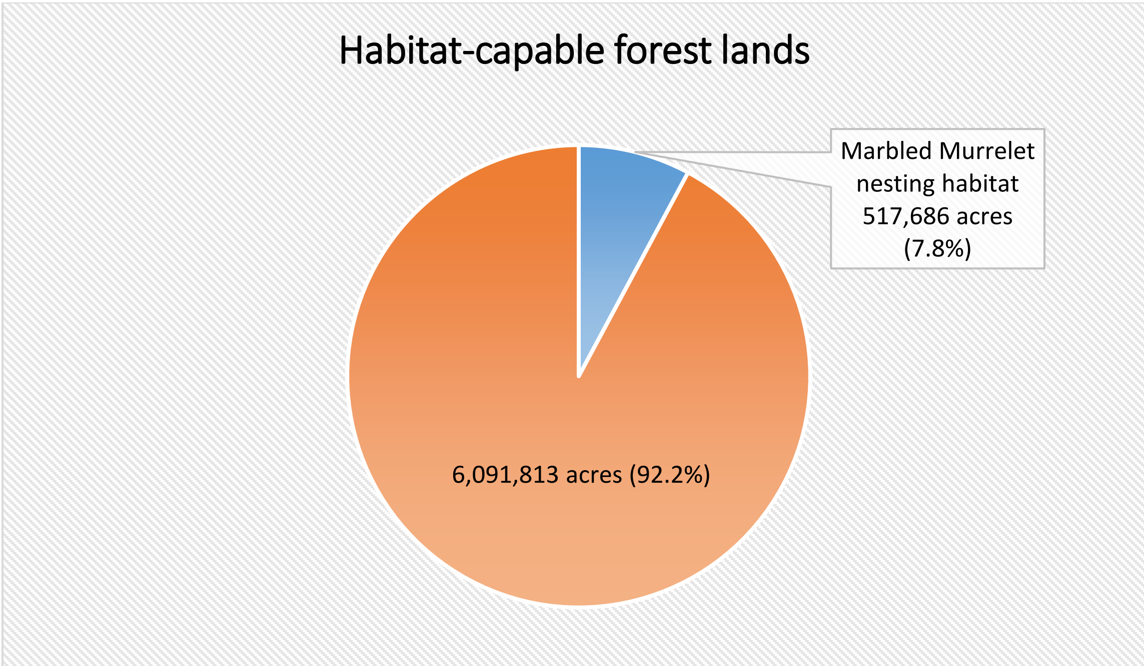

Figure 4. Proportion of Marbled Murrelet nesting habitat, among all habitat-capable forest lands, in Oregon (data from Lorenz et al. In press).

Most higher probability Marbled Murrelet nesting habitat currently persists on public (federal and state) lands in Oregon. Of the 517,686 ac of higher probability nesting habitat in Oregon, 312,027 acres (60.3%) occurred on federal lands, including 273,755 ac in reserved and 38,272 ac in nonreserved land allocations. In addition, 81,092 ac (15.6%) of higher probability nesting habitat occurred on state lands, and 124,567 ac (24.1%) of higher probability nesting habitat occurred on other lands (private, tribal, county, and municipal). Lorenz at al. (In press) further broke down the results by nesting habitat quality category and landownership:

- 15,065 ac (2.9%) were modeled as core nesting habitat
  - 13,172 ac (87.4%) occurred on federal lands, including 12,132 ac in reserved and 1,040 ac in nonreserved land allocations
  - 1,333 ac (8.8%) occurred on state lands
  - 560 ac (3.7%) occurred on other lands
- 53,559 ac (10.3%) were modeled as edge nesting habitat
  - 45,640 ac (85.2%) occurred on federal lands, including 41,675 ac in reserved and 3,965 ac in non-reserved land allocations
  - 4,750 ac (8.9%) occurred on state lands
  - 3,169 ac (5.9%) occurred on other lands
- 449,063 ac (86.8%) were modeled as scatter nesting habitat
  - 253,213 ac (56.4%) occurred on federal lands, including 219,947 ac in reserved and 33,266 ac in nonreserved land allocations
  - 75,009 ac (16.7%) occurred on state lands
  - 120,841 ac (26.9%) occurred on other lands.

In federal reserved lands, commercial timber harvest is generally not permitted, and younger stands, if managed, are managed to attain tree size and stand structure resembling old-growth. Reserved lands include such areas as national forests and BLM lands designated as late-successional reserves and designated wilderness areas. In most cases, commercial timber harvest is permitted on nonreserved federal lands.

Habitat changes since the 1990s

Lorenz et al. (In press) found that higher probability nesting habitat increased from 471,220 ac in 1993 to 517,686 ac in 2017; an overall net increase of 46,466 ac (+9.9% change) across all landownerships within the murrelet's range in Oregon (Table 2, Fig. 4 and 5). Specifically, net increases in core, edge, and scatter, which are components of higher probability nesting habitat, occurred during this period across all landownerships:

- +668 ac of core nesting were gained (4.6% net change);
- +1,305 ac of edge nesting were gained (2.5% net change); and
- +44,494 ac of scatter nesting habitat were gained (11.0% net change).

Most of the nesting habitat gains in Oregon were due to increases in scatter habitat (a component of higher probability nesting habitat), which represents fragmented patches that are lesser quality nesting habitat for murrelets because nests are the most vulnerable to predation (Lorenz et al. In press). Despite these overall net increases in nesting habitat in Oregon, some losses of habitat were masked when considering only net change. Specifically, all categories of Marbled Murrelet nesting habitat were gained on federal and state lands, whereas all categories of nesting habitat were lost on other landownerships (private, tribal, county, and municipal) during this period (Table 2, Fig. 5).

Table 2. Acres of higher probability nesting habitat; acres of core, edge, and scatter categories of higher probability nesting habitat; and net change by landownership from 1993 to 2017 in Oregon (data from Lorenz et al. In press).

Landowner	Higher Probability Nesting Habitat			
	1993 (ac)	2017 (ac)	Net Change[1] (ac)	(%)
Federal (total)	276,041	312,027	35,986	13.0
Federal reserved	248,182	273,755	25,573	10.3
Federal nonreserved	27,859	38,272	10,413	37.4
State	56,539	81,092	24,553	43.4
Other landownership	138,640	124,567	-14,073	-10.2
Total	**471,220**	**517,686**	**46,466**	**9.9**

[1] *See Lorenz et al. In press for specific gain and loss acreages in overall higher probability nesting habitat and core habitat*

Table 2 (continued). Acres of higher probability nesting habitat; acres of core, edge, and scatter categories of higher probability nesting habitat; and net change by landownership from 1993 to 2017 in Oregon (data from Lorenz et al. In press).

	Higher Probability Nesting Habitats			
	Core Habitat			
Landowner	**1993 (ac)**	**2017 (ac)**	**Net Change (ac)**	**(%)**
Federal (total)	12,262	13,172	910	7.4
Federal reserved	11,476	12,132	656	5.7
Federal nonreserved	786	1,040	254	32.3
State	503	1,333	830	165.1
Other landownership	1,632	560	-1,072	-65.7
Total	**14,397**	**15,065**	**668**	**4.6**
	Edge Habitat			
Landowner	**1993 (ac)**	**2017 (ac)**	**Net Change (ac)**	**(%)**
Federal (total)	42,541	45,640	3,099	7.3
Federal reserved	39,424	41,675	2,251	5.7
Federal nonreserved	3,117	3,965	848	27.2
State	2,893	4,750	1,857	41.9
Other landownership	6,820	3,169	-3,651	-53.5
Total	**52,254**	**53,559**	**1,305**	**2.5**
	Scatter Habitat			
Landowner	**1993 (ac)**	**2017 (ac)**	**Net Change (ac)**	**(%)**
Federal (total)	221,238	253,213	31,975	14.5
Federal reserved	197,282	219,947	22,665	11.5
Federal nonreserved	23,956	33,266	9,310	38.9
State	53,143	75,009	21,866	41.4
Other landownership	130,188	120,841	-9,347	-7.2
Total	**404,569**	**449,063**	**44,494**	**11.0**

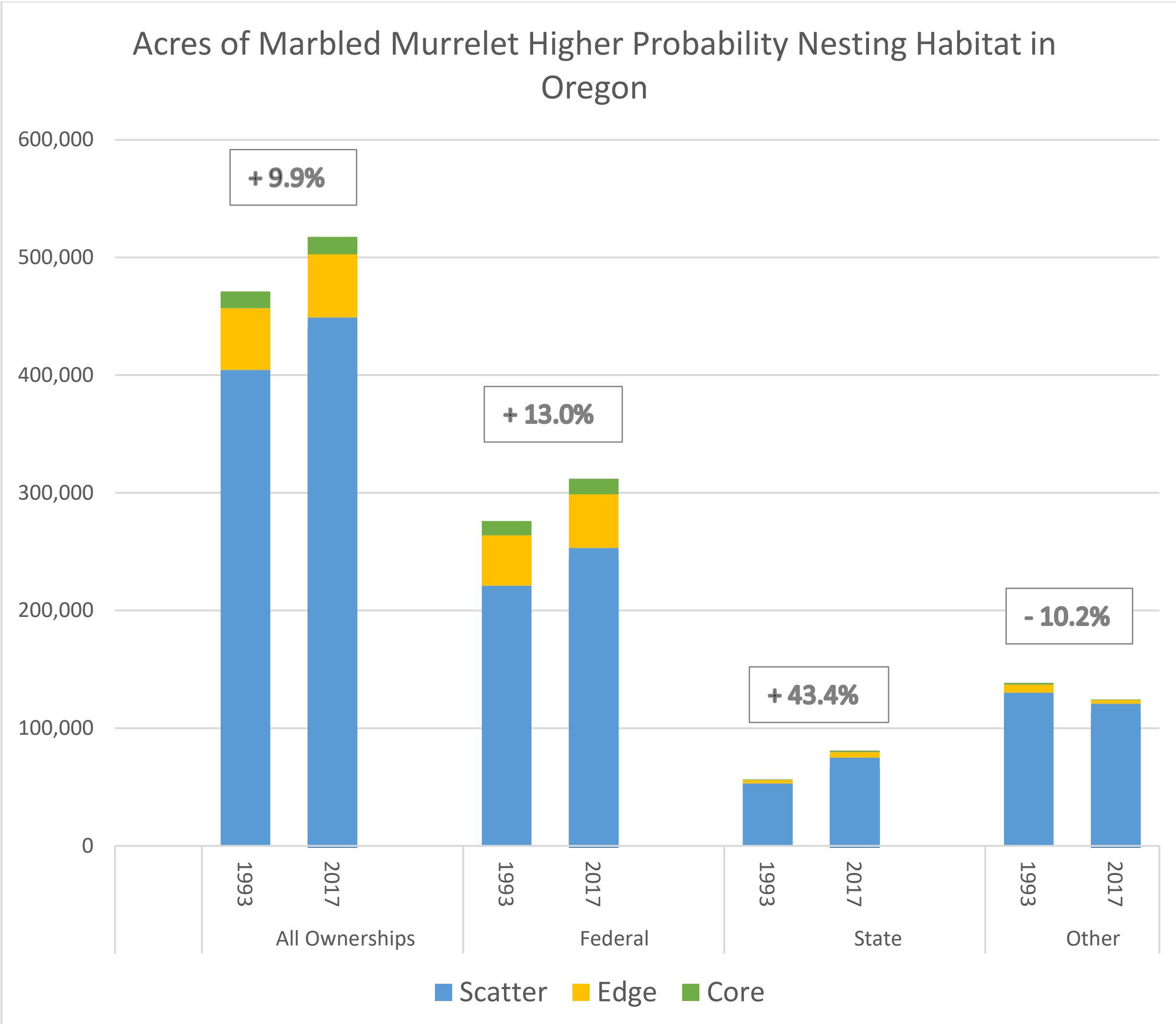

Figure 5. Acres of higher probability nesting habitat; acres of core, edge, and scatter habitat categories of higher probability nesting habitat, and net change in acres of higher probability Marbled Murrelet nesting habitat from 1993 (left bars) to 2017 (right bars) in Oregon on 1) all landownerships combined, 2) federal (reserved and nonreserved) lands only, 3) state lands only, and 4) other (private, tribal, county, and municipal) lands only. Habitat change estimates considered both habitat gains and losses during this period (Data from Lorenz et al. In press).

Lorenz et al. (In press) reported that habitat losses were due to timber harvest, windthrow, wildfire, insects, disease, and natural disturbances. They found that the majority of habitat losses were attributed to timber harvest (78,649 acres), primarily on other (private, tribal, county, and municipal) landownerships (Table 3). Losses in core nesting habitat were similarly attributed mostly to timber harvest (1,554 acres); however, 1,445 acres of losses in core habitat could not be assigned to a disturbance factor (Table 3). Attribution of losses in edge and scatter nesting habitat categories were not included in the analyses by Lorenz et al. (In press). Lorenz et al. (In press) noted that the 2002 Biscuit Fire in Oregon was included in the analyses, but most of the area within the fire footprint was not classified as higher probability nesting habitat in 1993. In addition, the Chetco Bar fire of late summer/autumn 2017 occurred after the analysis period. Therefore, only 77 acres of higher probability nesting habitat was lost to wildfire and no core nesting habitat was lost to wildfire from 1993-2017 (Table 3).

Table 3. Attribution of loss (in acres) of Marbled Murrelet higher probability nesting habitat in Oregon from 1993 to 2017 by landownership. (Data from Lorenz et al. In press).

Landowner	**Higher Probability Nesting Habitat**				
	Timber harvest	**Wildfire**	**Insect Damage**	**Other [1]**	**Unattributable loss**
Federal (total)	2,826	38	2	31	14,548
Federal reserved	1,774	38	2	30	12,788
Federal nonreserved	1,052	0	0	1	1,760
State	10,331	-	10	-	3,034
Other landownership	65,492	39	137	0	5,023
Total	**78,649**	**77**	**149**	**31**	**22,606**

[1] *includes other natural disturbances such as blowdown, floods, and landslides*

Inland Surveys and Habitat Occupancy

Systematic surveys of Marbled Murrelets in nesting habitat are not available. To date, most inland surveys for the species have been concentrated in areas proposed for timber sales or for specific research projects. Audio-visual surveys using the Pacific Seabird Group (PSG) methodology (described below) is used most extensively for all potentially suitable habitat that is within or adjacent to an operation or activity on state owned and managed lands in Oregon (ODF 2018).

A primary goal is often to determine whether a project site is “occupied” or not by Marbled Murrelets; evidence of occupancy generally confers a level of protection. Audio-visual surveys are widely used for this purpose, and in Washington, Oregon, and California, they typically follow a standardized protocol developed by the Pacific Seabird Group (current protocol is Evans Mack et al. 2003; a revised survey protocol is under development). These surveys rely on a sampling design and repeated site visits to determine murrelet presence, probable absence, and occupancy with a high degree of confidence. Evans Mack et al. (2003) defines an occupied site as one “where murrelets have been observed exhibiting subcanopy behaviors, which are behaviors that occur at or below the forest canopy and that strongly indicate that the site has some importance for breeding. Occupied sites include nest sites. A nest site is a site with an active nest or evidence of a nest, including eggs, eggshell fragments, or a downy chick.” The definition of occupancy and other terms will be revised by the PSG in the future survey protocols to include circling above the canopy, a nesting behavior exhibited by all alcids above nesting sites.

The limitations of audio-visual surveys have been reviewed by various authors (e.g., Burger 2002, McShane et al. 2004). Burger (2002) summarized the following key limitations:

- detections do not give reliable and accurate indicators of the actual numbers of murrelets present in a particular stand;
- detections show high diurnal and seasonal variability and are strongly affected by weather, especially cloud cover and rain;
- they do not show the actual sites used for nesting;
- visibility (canopy opening) and to a lesser extent noise (streams, etc.) can affect detections;
- differences among observers adds variability to the data, despite efforts to standardize training and observation techniques;
- ground-based observers cannot access all the forests accessible to murrelets.

In addition, by conducting radar and audio-visual surveys simultaneously, Bigger et al. (2006) documented that audio-visual surveys missed a high percentage of murrelets flying over an area.

Nevertheless, in the absence of other information, audio-visual survey data from several key land-managing agencies provide some indication of inland distribution and areas that may be particularly important to murrelets in Oregon (Fig. 2). Most surveys have been limited to BLM-, USFS-, and ODF-managed lands to date (Table 4).

Table 4. Summary of Marbled Murrelet survey stations and detections by landownership/management area. Data spanned various timeframes and were provided by the Bureau of Land Management (1997-2019), Oregon Department of Forestry (included Oregon Department of State Lands; 1989-2019), and Oregon State University (included U.S. Forest Service and all other non-federal ownerships; 1988-2019).

Landownership or Managing Entity	Total No. of Survey Stations	Total No. of Survey Stations with Murrelet Detections (Total No. of Survey Stations with Subcanopy Detections)
Bureau of Land Management	7,488	699 (305)
U.S. Forest Service	7,520	1,970 (534)
Other Federal Agency	54	3 (2)
Oregon Dept. of Forestry	7,201	772 (206)
Oregon Dept. of State Lands	3,723	1,147 (289)
Oregon Parks & Recreation Dept.	273	113 (45)
Other State Agency	64	1 (0)
Private	1,383	371 (116)
Tribes	56	37 (11)
Other	4	0 (0)

State Lands

The extent of potentially suitable Marbled Murrelet habitat on state lands is mostly restricted to state forest lands managed by the ODF and Oregon Department of State Lands (DSL), as well as some state parks managed by the Oregon Parks and Recreation Department (OPRD) (Fig. 3). The ODF manages

Board of Forestry-owned lands, including the Tillamook and Clatsop State Forests located in the northern Oregon Coast Range and smaller tracts of state forest land scattered in western Oregon. The DSL manages the Common School Fund (CSF) forest lands in the Elliott State Research Forest (most of which is currently owned by the State Land Board) located in the southern end of the Oregon Coast Range.

ODF manages approximately 563,200 acres of state forest lands within the range of the Marbled Murrelet. ODF currently has 109 Marbled Murrelet Management Areas (MMMAs), or areas containing designated occupied habitat based on audio-visual surveys and nests found. These MMMAs (and associated buffers) encompass 18,670 acres of forest land (ODF, unpubl. data 2020; Table 5).

Table 5. Number and size of Marbled Murrelet Management Areas (MMMAs) by county on Oregon Department of Forestry-managed lands in February 2020 (data provided by M. Gostin and N. Palazzotto, ODF). Values in this table reflect MMMAs that are in various stages of alignment with current ODF policy, as well as "draft" MMMAs still pending approval (see State Forest Plans below for further information on the designation and delineation of MMMAs).

County	Number of MMMAs	Total Acreage
Benton	2	526
Clatsop	21	3,404
Coos	10	1,262
Douglas	3	71
Lane	17	2,790
Lincoln	12	2,314
Polk	12	1,851
Tillamook	39	6,451
Total	**116**[1]	**18,670**

[1]*As of February 10, 2020, ODF has a total of 109 unique MMMAs, including 17 in Astoria, 37 in Tillamook, 25 in West Oregon, 17 in Western Lane, and 13 in Coos Districts. Some MMMAs span more than one county, which is why a simple count of MMMAs by county exceeds 109 in this table.*

The forest conditions on state lands are the result of a combination of natural events and past forest management. ODF- and DSL-managed lands have been inventoried in terms of forest age class and stand type. A general analysis in 2010indicated that the majority of coniferous stands in northwest Oregon state forests (which include the Clatsop and Tillamook State Forests) are were less than 85 years old (ODF 2010, p. S-8 and Table 2-9, p 2-82). In these north coast forests, murrelet nesting habitat included older stands that naturally regenerated following fire or logging, younger, naturally-regenerated Sitka spruce/western hemlock stands with dwarf mistletoe, and old-growth remnant trees or patches (Nelson and Wilson 2002). About half of the conifer stands in the Elliott State Forest were more than 85 years old (DSL and ODF 2011, p. 2-73 and Fig. 2-4, p. 2-74 and Table 2-8, p. 2-74).

Marbled Murrelets are known to occupy some forests owned and managed by the OPRD, though systematic surveys across the park land base have not been undertaken (V. Blackstone, pers. comm. 2018). A 2017 evaluation of LiDAR (remote-sensing) data by OPRD yielded approximately 5,901 ac of "potential habitat" on state park lands, or forest showing trees from 150 ft and taller with canopy openings that suggest a late-seral structure; no ground-truthing has been performed. Based on available survey data collected at various points over the last two decades, there are at least 1,745 ac of occupied murrelet habitat under OPRD management (OPRD, unpubl. data 2018). An additional 271 ac are considered “suitable habitat” by OPRD, as determined by walking the area and identifying potential nesting platforms (OPRD, unpubl. data 2018).

Other Lands

McShane et al. (2004) estimated that there were about 2,709,516 acres of commercial forest lands within 50 mi of the coast in Oregon, 87% of which was within 35 mi of the coast. In the Oregon Coast Range, Ohmann et al. (2007) estimated that private forest lands represented about 6% of old-growth and about 12% of very large tree structural conditions found on the landscape. These other lands are mostly privately-owned, though small amounts of county, tribal, and municipal lands are also represented. While there are several known occupied sites on private lands, the full extent of occupied habitat on private lands in Oregon is unknown. State regulations for forest practices do not require surveys for murrelets on all proposed project areas by private landowners (see the Oregon Forest Practices Act below for more details), although the federal ESA prohibits the take of Marbled Murrelets.

Federal Lands

These Federal lands are administered primarily by the USFS and BLM. Most of this habitat is within designated reserved areas and is unlikely to be harvested under current federal regulations of the NWFP (Table 2). The two major areas of Marbled Murrelet habitat remaining in Oregon are the Siuslaw National Forest and the Rogue River-Siskiyou National Forest. The Siuslaw National Forest is a particularly important area for murrelets along the central coast. In the 1930s, this forest had over 375,000 acres of older forests (USFS 2014). In 1993, there were about 337,000 acres with an old-growth structure index (OGSI) threshold of $\geq$80 years average stand age (OGSI 80) and 211,000 ac with an OGSI threshold of $\geq$200 years average stand age (OGSI 200) (USFS 2014). In 2012, there were about 340,000 acres with an OGSI threshold of $\geq$80 and 244,000 ac with an OGSI threshold of $\geq$200, suggesting that older forests have largely been restored or maintained on the Siuslaw National Forest during this period (USFS 2014).

More recently, preliminary USFS estimates indicate that more than 20,000 ac of federally-designated Marbled Murrelet habitat (in units OR-07-c and OR-07-d) experienced canopy-replacing fire effects as a result of the Chetco Bar Fire (Vaughn 2017). In 2018, the Klondike Fire burned 175,258 ac in southern Oregon, but the number of acres of Marbled Murrelet higher probability nesting habitat that were impacted has not been analyzed.

Other States in the Federal Distinct Population Segment

Washington

In Washington, Lorenz et al. (In press) estimated that there were 1,000,018 acres of higher probability nesting habitat in 1993 compared to 935,980 acres in 2017, a net loss of about -64,037 acres (-6.4% change). Within the higher probability nesting habitat, core habitat also decreased from 112,605 acres in 1993 to 109,455 acres in 2017; a net decrease of -3,151 acres (-2.8% change) over all landowners in the murrelet's range in Washington (Lorenz et al. In Press). Losses of higher probability nesting habitat during this period in Washington included -43,481 acres (-30.5% change) on other lands, -15,107 acres (-13.7% change) on state lands, and -5,449 acres (-0.7% change) on federal lands; of that, there were also losses in core habitat across all lands in Washington, including -2,585 acres (-2.4% change) on federal lands, -129 acres (-3.2% change) on state lands, and -437 acres (-18.6% change) on other lands (Lorenz et al. In press). Habitat losses on state and other (private, tribal, county, and municipal) lands in Washington were attributed to timber harvest; whereas habitat losses on federal lands was attributed to timber harvest and wildfire (Lorenz et al. In Press).

California

Carter and Erickson (1992) reviewed the loss of coastal old-growth forest in California since the early 1800s. By 1978, less than 15% of the original 1.9 million acres remained and about 30% of the remaining old-growth redwood acreage (or 4% of the original acres) was preserved in parks. In central California (Santa Cruz Mountains), there is approximately 10,000 acres of old-growth nesting habitat remaining, 77% of which is contained in 5 main areas (Halbert and Singer 2017). The remaining patches are dispersed and mostly under 100 ac in size (Halbert and Singer 2017). More recently, within California north of San Francisco Bay, Lorenz et al. (In Press) reported there were 41,840 acres of higher probability nesting habitat in 1993 compared to 38,564 acres in 2017, a net loss of about -3,276 acres (-7.8% change). Within the higher probability nesting habitat, core habitat also decreased from 13,089 acres in 1993 to 13,049 acres in 2017; a net decrease of -40 acres (-0.3% change) for all lands in the murrelet's range in California (Lorenz et al. In Press). Losses of higher probability nesting habitat during this period in California included -3,059 acres (-31.5% change) on other (private, tribal, county, and municipal) lands, -52 acres (-0.3% change) on state lands, and -165 acres (-1.4% change) on federal lands; of that, there were only very small amounts of losses in core habitat across all lands in California, including -6 acres (-0.2% change) on federal lands, -18 acres (-0.2% change) on state lands, and -16 acres (-0.2% change) on other (private, tribal, county, and municipal) lands (Lorenz et al. In Press). Habitat losses on other (private, tribal, county, and municipal) lands in California were attributed to timber harvest (Lorenz et al. In press).

Marine Habitat

California Current System

The nearshore marine environment along the Oregon coast is strongly influenced by the California Current System (CCS). The CCS is an eastern boundary current known for its high productivity. As described in Pacific Fishery Management Council (2013), the CCS flows along the West Coast from southern British Columbia to Baja California and is composed of a complex system of currents and processes. The main CCS surface current is massive and flows southward 31 to 311 mi offshore, moving cold water from the North Pacific toward the equator. The California Undercurrent flows northward, moving water toward the pole beneath the surface current in the summer, then surfaces near the continental shelf break where it is known as the Davidson Current in the winter. This is a much narrower band of water. The CCS is also characterized by strong, localized wind-driven coastal upwelling, particularly in spring-summer. Upwelling brings cold, nutrient-rich waters from depth to the surface along the coast, supporting primary productivity that serves as the base for the food chain. The locally-driven coastal upwelling processes vary on much smaller temporal and spatial scales than offshore processes. Underwater canyons, coastal headlands, and offshore banks as well as regional differences in winds and freshwater input are all important factors affecting these coastal upwelling processes and resulting productivity. The northern portion of the CCS, including much of the coastal waters off Oregon, has a relatively wide continental shelf, several banks that facilitate retention processes, numerous underwater canyons that intensify upwelling, more freshwater input, and generally weaker and more intermittent upwelling-favorable winds during spring-summer and strong downwelling-favorable winds in winter. The shelf narrows near Cape Blanco, and some of the strongest upwelling-favorable coastal winds occur from here down to Cape Mendocino in California. This transition area also marks the southern boundary for the oil-rich subarctic zooplankton species (Pacific Fishery Management Council 2013).

Variability in winds, sea surface temperatures, and sea level pressures affect upwelling and marine productivity in the CCS. Year-to-year variability (e.g., El Niño) and longer-term regime shifts (e.g., PDO) can have consequences for seabird diet and foraging areas. During strong El Niño events, coastal upwelling winds are reduced, there is an intrusion of offshore subtropical water, surface waters are warmer and more nutrient-poor than usual, and there can be dramatic declines in primary and secondary production that can lead to poor recruitment, growth, and survival for many resident species. It is common to have northward range extensions of many tropical species during El Niño events. During La Niña events, the reverse is generally true, with colder, more nutrient-rich waters present. Many studies have shown that reliance on different suites of prey species due to environmental conditions can impact seabird productivity (e.g., Ainley et al. 1995, Sydeman et al. 2006, Wells et al. 2008, Wolf et al. 2009, Cury et al. 2011, Thompson et al. 2012). In general, cold water events or cold ocean phases have been linked to greater prey availability for breeding seabirds (Ainley et al. 1995, Veit et al. 1997, Hyrenbach and Veit 2003, Ainley and Hyrenbach 2010), though a combination of ocean processes operating at various temporal and spatial scales ultimately determine foraging opportunities (see Climate Change Effects on Terrestrial and Marine Habitat in Chapter 3 for further discussion of climate factors).

Marine Habitat Associations

During the breeding season, most Marbled Murrelets in Oregon are found in nearshore marine waters along the central coast (Strong 1995, Strong et al. 1995, Strong 2003, Falxa et al. 2016). In recent years (2009-2014), highest densities of murrelets were detected in inshore sampling units just south of Yaquina Bay to Winchester Bay (Marbled Murrelet Effectiveness Monitoring Module 2015).

Recent modeling studies indicate that at-sea murrelet distribution during the breeding season is positively associated with the amount of unfragmented nesting habitat directly inland. Raphael et al. (2015 and 2016b) examined terrestrial and marine factors influencing murrelet densities at-sea throughout the NWFP area. They found that murrelet densities were best explained by terrestrial factors; murrelets were concentrated in areas with the most abundant and cohesive terrestrial habitat nearby. The authors cautioned that these results do not imply that ocean conditions are unimportant to murrelets and could reflect chosen variables or scaling issues (Raphael et al. 2016b) or the fact that the small numbers of murrelets in the study area underutilize much of the available foraging habitat (Raphael et al. 2015). Similarly, Lorenz et al. (2016) examined marine resource selection of Marbled Murrelets in Washington. Locations with higher amounts of nesting habitat close to shore, in cool waters, and with low human footprint were used most. Prey availability undoubtedly plays a role in murrelet distribution at sea, but in the absence of widespread temporal and spatial prey occurrence data, these studies relied heavily on indirect measures of marine productivity (e.g., sea surface temperature, chlorophyll-a, oceanic or upwelling indices) as proxies for murrelet prey resources, which the authors acknowledged may not fully capture complex relationships between murrelets and their prey.

Little is known about Marbled Murrelet habitat use during winter (Nelson 1997). Murrelets may be more dispersed and farther from shore outside the breeding season (Strachan et al. 1995).

Population Status

Genetic Population Structure

Varying degrees of demographic isolation or genetic diversity can have implications for adaptability and extinction risk. Piatt et al. (2007) completed the first analysis of population genetic structure based on neutral genetic markers that included murrelets sampled throughout the range, including Oregon and Washington. They confirmed that Marbled Murrelets in the western and central Aleutian Islands and central California differ significantly from those in central parts of the range, and that Marbled Murrelets comprise three genetically distinct units: 1) western and central Aleutian Islands, 2) eastern Aleutian Islands to northern California, and 3) central California. While birds in Washington and Oregon are assumed to have less restricted gene flow than those on the periphery of the range, Piatt et al. (2007) concluded that loss of any one of the above three genetically distinct units could compromise the long-term viability of the global population if an essential portion of the species' genetic resources and/or local adaptations are lost.

The genetic differentiation of the central California population appears to be a recent phenomenon possibly due to habitat fragmentation over the last century. Peery et al. (2010) found that the murrelet population in central California lost alleles at 3 of 9 microsatellite loci over the last century, a 6.9% decline in allelic richness. They tied this loss in genetic resources to habitat loss and fragmentation that reduced and isolated the resident breeding population. While immigration does occur, dispersing birds breed so little and contribute so few offspring that they fail to produce a "rescue" effect. Peery et al. (2010) concluded that additional habitat fragmentation may further isolate populations both demographically and genetically.

Recent work by Vásquez-Carrillo et al. (2014) indicated that there was at least some population-level genetic differentiation within the core of the range. They detected differences in major histocompatibility complex (MHC)-derived peptide frequencies between southeast Alaska and Oregon murrelets, as well as low allele and peptide richness at individual and population levels in Oregon. They suggested that Marbled Murrelets in Oregon may be especially vulnerable to novel diseases or pathogens (since MHC diversity has been linked to disease resistance and fitness in some other bird species) and could be considered of special conservation concern. Overall, the findings of Vásquez-Carrillo et al. (2014) support the idea that maintenance of conservation units across the Marbled Murrelet range is important for preserving this species' genetic diversity and future adaptive capacity.

The USFWS (2019) concluded that current information on Marbled Murrelet genetics indicates:

1) there is clinal genetic variation in the species from the Aleutian Islands to Central California;
2) murrelets appear to compromise three genetic units, including the western and central Aleutian Islands, eastern Aleutian Islands to Northern California, and central California, with moderate genetic differentiation;
3) The genetic discreteness of the central California population appears to be a relatively recent phenomenon tied to habitat fragmentation;
4) there are unique alleles and peptides in population segments sampled across the species range; and
5) there is lower allele and peptide richness at both the individual and population level in the murrelets sampled from Oregon.

Population Size and Trend

North American Population

There is limited information on the historical distribution and numbers of Marbled Murrelets. Historical information has been summarized by many authors, including Marshall (1988), Carter and Erickson (1992), Leschner and Cummins (1992), Mendenhall (1992), Nelson et al. (1992), Piatt and Ford (1993), Rodway et al. (1992), Speich et al. (1992), and Ralph (1994). Anecdotal evidence and available quantitative data all suggest major population declines over the last 150 years or so (Ralph 1994, McShane et al. 2004, Piatt et al. 2007). Steepest declines are suspected during the period of industrial logging of most murrelet habitat from 1850-1980 (McShane et al. 2004).

Recent assessments suggest that the global Marbled Murrelet population is on the order of 300,000-400,000 individuals today, with roughly 70% in Alaska, 25% in British Columbia, and 5% in Washington, Oregon, and California combined (COSEWIC 2012, Environment Canada 2014). While murrelets in Washington, Oregon, and California together represent only a small proportion of the current global population, this area accounts for about 18% of the total linear range of the species and likely supported larger populations in the past (McShane et al. 2004).

Oregon and NWFP Populations

Historical population status and trend information prior to implementation of the NWFP Effectiveness Monitoring Program at-sea surveys in 2000 is very limited. Available population estimates generated for Oregon in the early-mid 1990s varied widely due to differences in survey techniques, timing, area covered, and assumptions (Table 6). The USFWS Recovery Plan (USFWS 1997, p. 17-18) underscored "the need for further development of consistent survey methods for the entire range, without which comparable estimates cannot be obtained".

Table 6. *Summary of studies estimating statewide Marbled Murrelet population size in Oregon in the 1990s (prior to implementation of standardized Northwest Forest Plan at-sea surveys in 2000). These figures do not reflect population trends, but rather various independent estimates. They should not be compared directly to current Northwest Forest Plan population estimates due to differences in methodology (see Raphael et al. 2007).*

Study	**Technique**	**Year**	**Estimate**
Nelson et al. 1992	Shore-based	1988-1992	1,000 breeding pairs
Strong et al. 1995	Shore-based, aerial, and boat	1992, 1993	2,500 (shore-based)-22,250 (boat) individuals
Varoujean and Williams 1995	Aerial	1995	6,400-6,800 individuals

Boat-based surveys were ultimately found to be more reliable than aerial or shore-based counts due to more thorough coverage, proximity to birds, more observers, and longer scanning time (Strong et al. 1995). Strong (2003) conducted the first systematic at-sea surveys over many years (from 1992-1999) and reported a significant decline in murrelets along a section of the central Oregon coast. Within the study area, Strong (2003) reported that murrelets declined in that section by >50%, from roughly 9,750 birds (95% CI: 4,030, 14,870) in 1992-93 to 4,100 birds (95% CI: 870, 6,440) in 1997-99. Sampling effort and potentially poor marine forage conditions in 1996-1997 were factors that Strong (2003) speculated could have contributed to an abrupt rather than a steady decline.

For monitoring and management purposes, the USFWS Recovery Plan (USFWS 1997) recognized six recovery units or "Conservation Zones" across the federally-listed range in Washington, Oregon, and California where Marbled Murrelets are found on land or at sea (Fig. 3). These include: 1) Puget Sound (Conservation Zone 1), 2) Western Washington Coast Range (Conservation Zone 2), 3) Oregon Coast Range (Conservation Zone 3), 4) Siskiyou Coast Range (Conservation Zone 4), 5) Mendocino (Conservation Zone 5), and 6) Santa Cruz Mountains (Conservation Zone 6).

Conservation Zones 3 and the northern portion of Conservation Zone 4 occur in Oregon. Conservation Zone 3 begins at the Columbia River and runs south to North Bend, Coos County, Oregon (USFWS 1997). Conservation Zone 4 spans North Bend, Coos County, Oregon, south to the southern end of Humboldt County, California (USFWS 1997). Both zones include marine waters within 1.2 mi of the ocean shoreline and lands up to 35 mi from the coast plus any designated critical habitat units beyond that point.

Due to the difficulty of locating and monitoring Marbled Murrelets on land, population estimates for Washington, Oregon, and California are based entirely on at-sea surveys. Through the NWFP Effectiveness Monitoring Program, standardized boat surveys have been conducted since 2000 during the breeding season in Conservation Zones 1-5. Conservation Zone 6 in central California is sampled independently of the NWFP Program and has supported a small population in recent years (Henry 2017). The marine distribution and abundance of murrelets derived from monitoring efforts correlate with the amount and extent of adjacent onshore murrelet nesting habitat (Yen et al. 2004, Lorenz et al. 2016, Raphael et al. 2015, 2016b). The population estimates may include locally breeding birds, non-breeders, and transients, and the ratio of these different groups of birds likely changes among years.

Population estimates from at-sea surveys are derived from murrelet densities in the area of coastal waters sampled (Raphael et al. 2007). The population monitoring effort uses boat-based transects laid out in the nearshore ocean in each Conservation Zone. The monitoring program has estimated population size and trends for each Conservation Zone, for each state, and for all zones combined (Raphael et al. 2018). From when the surveys began in the 1990s through 2013, the entire Northwest Forest Plan area was surveyed each year. However, starting in 2014, a reduced sampling design was instituted, due to funding constraints. Conservation Zones 1 through 4 (including Oregon) are sampled every other year. Zones 1 and 3 are sampled in even-numbered years, Zones 2 and 4 in odd-numbered years, and Zone 5 (southern California) every fourth year (Lynch et al 2017, Falxa et al. 2016, Raphael et al. 2018). The 20-year Marbled Murrelet status and trends report (Falxa et al. 2016) provided estimates through 2013. Estimates from 2015 through 2020 estimates have been made available in annual reports (Lynch et al 2017, Pearson et al. 2018, McIver et al. 2019, McIver et al. 2020, McIver et al. 2021). The most recent year of surveys with state-level estimates for all of Oregon is 2019 because Conservation Zones 3 and 4 are surveyed in alternate years.

An All-Zones population estimate for 2018 revealed a total of 21,200 Marbled Murrelets (95% CI: 16,400, 26,000) (McIver et al. 2021). McIver et al. (2021) estimated the Oregon population in 2019 was approximately 10,339 murrelets (95% CI:7,070, 13,607) (Table 7 and Fig. 6). In 2020, approximately 8,400 Marbled Murrelets (95% CI: 5,600, 11,300) were estimated in Conservation Zone 3 (Columbia River south to Coos Bay, Oregon). In their 2019 survey, McIver et al. (2020) showed approximately 6,800 murrelets (95% CI: 5,600, 11,100) in Conservation Zone 4 (Coos Bay to the southern boundary of Humboldt County, California).

McIver et al. (2021) estimated that the All-Zones annual rate of population change (or “trend”) for years 2001 through 2019 indicated a 0.5% increase per year (95% CI: -0.5% to 1.5%) (Table 8). However, since the confidence interval (CI) is fairly ‘tight’ around zero, however, McIver et al. (2021) concluded that there is no overall trend. According to McIver et al. (2021), Oregon exhibited an overall significant increasing population trend from 2000 through 2019 of 2.2% per year (95% CI: 0.9% to 3.4%). At the Conservation Zone scale, Conservation Zone 3 showed a positive trend estimate (1.5% increase per year, 95% CI: 0.02% to 3.1%) for years 2000 through 2020. Conservation Zone 4 was not surveyed in 2020 but analysis was last completed for 2019 survey data (2021 survey data has not been analyzed and released yet). Conservation Zone 4 showed significant evidence of a positive increasing trend (3.5% increase per year, 95% CI: 1.6% to 5.5%) for years 2000 through 2019.

Table 7. *Annual Marbled Murrelet population size and density estimates for Oregon based on at-sea surveys from 2000 through 2019 (data from McIver et al. (2021), Table 4, with addendum denoting corrections to original report). Numbers in some years may differ slightly from those in previous summary reports, as a result of additional data quality reviews performed in 2019.*

Year	Density (Murrelets per km^2)	Total Murrelets	Total Murrelets 95% CI Lower	Total Murrelets 95% CI Upper	Area (km^2)
2000	3.85	7,983	4,992	10,974	2,071
2001	4.43	9,168	6,537	11,800	2,071
2002	3.64	7,530	4,727	10,332	2,071
2003	3.56	7,380	5,370	9,390	2,075
2004	4.40	9,112	6,833	11,391	2,071
2005	3.36	6,966	4,812	9,121	2,071
2006	3.68	7,617	5,916	9,318	2,071
2007	2.59	5,357	3,332	7,381	2,071
2008	3.64	7,541	5,682	9,400	2,071
2009	3.58	7,423	5,208	9,638	2,071
2010	3.95	8,182	5,743	10,622	2,071
2011	4.05	8,379	5,943	10,816	2,071
2012	3.76	7,780	5,605	9,956	2,071
2013	4.74	9,819	7,195	12,443	2,071
2014	5.50	11,384	8,188	13,930	2,071
2015	5.30	10,975	8,188	13,762	2,071
2016	4.46	10,060	7,541	12,579	2,071
2017	5.29	10,959	8,044	13,874	2,071
2018	5.34	11,063	7,610	14,515	2,071
2019	4.99	10,339	7,070	13,607	2,071

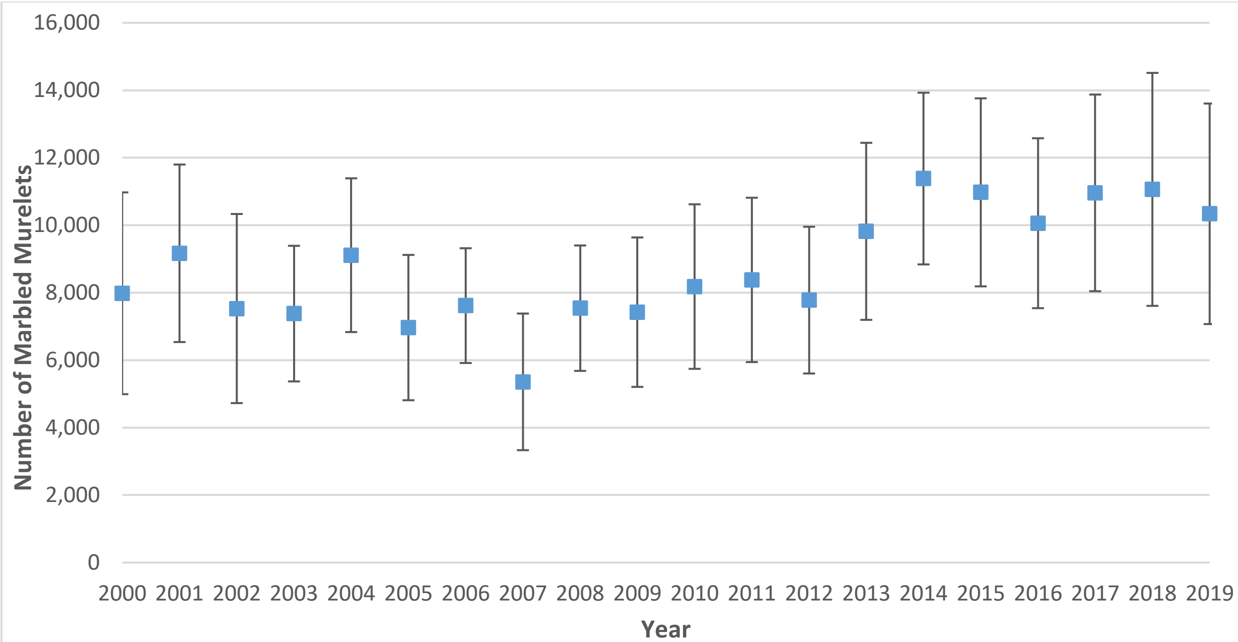

Figure 6. Annual Marbled Murrelet population estimates and 95% confidence intervals from Oregon at-sea surveys, 2000-2019 (McIver et al. 2021).

Table 8. *Annual rates of population change based on Marbled Murrelet at-sea surveys. Ninety-five percent confidence intervals are for the estimates of percent annual change. Adjusted R^2 values and P-values (for a 2-tailed test of whether the annual rate of change is different than zero[3]) are also indicated (McIver et al. 2020).*

Zone or State	Period of Analysis	Annual rate of change (%)	95% CI Lower	95% CI Upper	Adjusted R^2	P-value
Zone 3*	2000-2020	1.5	0.02	3.1	0.175	0.047
Zone 4**	2000-2019	3.5	1.6	5.5	0.470	0.001
Oregon	2000-2019	2.2	0.9	3.4	0.382	0.002
All Zones	2001- 2019	0.5	-0.5	1.5	0.000	0.346

As with any sampling design, power to detect a change when one actually exists is an important consideration. A study with low statistical power has a reduced chance of detecting a true effect because of low sample size, small effects, or both. In their power analysis for the Marbled Murrelet at-sea surveys, Falxa and Raphael (2016) concluded that 95% or greater power to detect a 4% annual

[3] For the purposes of evaluating the evidence for a linear trend, Falxa et al. (2016) considered: (1) the magnitude of the annual trend estimate, particularly in relation to zero, where zero represents a stable population, and (2) the width and location of the 95 percent confidence intervals surrounding that trend estimate, also in relation to zero. The evidence for a population trend, versus a stable population, is stronger when the trend estimate and its 95 percent confidence interval do not overlap zero, and when the trend estimate is farther from zero.

change has been achieved for Zones 3 and 4, as has 80% or greater power to detect a 3% annual change for those zones[4]. However, given the variability in estimates and current reduced sampling effort, they do not expect to achieve 80% or greater power to detect $\leq$2% annual population change until 2021 for Zone 4; 95% or greater power to detect a $\leq$2% annual change will not be achieved until 2024 and 2025 for Zones 3 and 4, respectively.

It is unclear to what degree dispersing birds may be affecting at-sea densities. Birds may be moving following early nest failures elsewhere or to more productive winter foraging areas; this idea is supported by preliminary results from an ongoing Oregon State University telemetry study. In 2017, researchers found that marked murrelets from Zone 3 in Oregon moved long distances within the breeding season into Zones 4 and 5 (in California), likely due to poor ocean conditions that reduced prey availability in Northwest waters (S. K. Nelson, pers. comm. 2018). These murrelets were failed breeders or non-breeders that will presumably return to nest in Oregon in future years, but they would have been counted in at-sea surveys as part of the California population and not in Oregon. If such movements are representative, these results suggest that temporary shifts in murrelet distribution during the breeding season could complicate conclusions about population size or trend from at-sea surveys, at least in some years.

Other States in the Federal Distinct Population Segment

Washington

Historically, Marbled Murrelets in Puget Sound and the San Juan Islands were described as “common” or “numerous” by Rathbun (1915) and Miller (1935), as summarized by Speich et al. (1992). Puget Sound has experienced profound anthropogenic changes over the last 200 years, including widespread removal of lowland old-growth forests (Perry 1995) and high rates of land use conversion, urbanization, and nearshore habitat modification (Azous and Horner 1997, Fresh et al. 2011, Simenstad et al. 2011). McIver et al. (2021) estimated that Washington exhibited a significant declining population trend (-3.9%; 95% CI: -5.4% to -2.4%,) between 2001 and 2019.

California

Little nesting habitat remains in California, and contemporary rates of habitat loss are lower than in the past, so high nest predation, changes in ocean conditions that affect marine forage, and post-fledging mortality are thought to be the main mechanisms affecting murrelet recruitment in this part of the range (RIT 2012). McIver et al. (2021) reported a significant increasing trend in California between 2000 and 2019 (4.6% per year; 95% CI: 2.7% to 6.5%). The 2019 California population estimate was approximately 5,700 Marbled Murrelets (95% CI: 3,894, 7,588) (McIver et al. 2020).

[4] These estimates from Falxa and Raphael (2016) are based on data from at-sea surveys starting in 2000 and continuing annually through 2013, then starting in 2014, switching to an every-other-year sampling frequency for Zones 3 and 4.

Demographics

Longevity, Age at First Breeding, Fecundity, and Sex Ratio

Marbled Murrelets are relatively long-lived and have delayed sexual maturity and low fecundity (Nelson 1997). Generation time (average age of parents in the population, as defined by COSEWIC 2012) has been estimated at about 10 years (Burger 2002, McShane et al. 2004, COSEWIC 2012), and maximum lifespan is not believed to exceed 25 years (McShane et al. 2004). Marbled Murrelets presumably begin nesting at 2-5 years of age (Beissinger 1995, De Santo and Nelson 1995, McShane et al. 2004). They lay only one egg per clutch and re-nesting rates are low, so nest success (number of fledglings produced per pair of adults that attempt breeding in a given year) has substantial influence on the demographic measure of fecundity (number of female offspring fledged per adult female per year) (Burger 2002, Peery and Henry 2010).

Survival

Early Marbled Murrelet population models relied on an adult survival value of 0.85-0.90 derived from other alcids (Beissinger 1995, Beissinger and Nur 1997). Subsequent field studies have supported the assumption of high adult survival. Cam et al. (2003) provided the first direct survival estimates of 0.93 (95% CI: 0.63, 0.99) and 0.83 (95% CI: 0.72, 0.90) from two samples in a Marbled Murrelet mark-recapture study in British Columbia. Peery et al. (2006) estimated annual survival rates for after-hatch-year Marbled Murrelets in central California and reported survival rates of 0.868 and 0.896 for untagged males and females, respectively, and 0.531 and 0.572 for radio-tagged males and females, respectively; the negative effect of radio-tagging on survival rates was highest during a domoic acid algal bloom.

Reproductive Success

Marbled Murrelet reproductive success and fecundity are determined by a combination of marine and terrestrial factors, such as nest predation, timing of breeding, foraging conditions, prey availability, and adult survival during the breeding season (McShane et al. 2004). While population growth may be most affected by adult survival, sustained low reproductive success can also limit populations (Burger 2002, McShane et al. 2004, COSEWIC 2012, RIT 2012). Breeding parameter estimates are derived from direct monitoring of located nests, telemetry, counts of juvenile birds at-sea, and population modeling. All have certain biases and assumptions. Telemetry estimates are thought to be the most reliable (McShane et al. 2004, Piatt et al. 2007), though the observation of a negative effect of radio-tagging on survival (Peery et al. 2006) suggests caution in interpreting results. Across the federally-listed range, nearly all available estimates indicate poor breeding success (McShane et al. 2004, Peery et al. 2004, Beissinger and Peery 2007, CCR 2008, 2013, Lorenz et al. 2017).

Juvenile:Adult Ratios

Due to the difficulty of finding murrelet nests, ratios of newly-fledged juveniles (hatch-year birds) to after-hatch-year birds (adults and subadults) at sea, or juvenile:adult ratios, are sometimes used as an indirect measure of breeding success. The reliability of juvenile:adult ratios measured at sea has long been debated (Ralph and Long 1995, Kuletz and Kendall 1998, Lougheed et al. 2002), and while adjustments are often applied in an attempt to reduce biases, such adjustments remain largely unverified (McShane et al. 2004, Piatt et al. 2007, Crescent Coastal Research 2013). Therefore, these ratios are best treated as indices of reproductive performance. It is also important to note that juvenile:adult ratios differ from nest/reproductive success estimates because the ratios incorporate early post-fledging mortality (Piatt et al. 2007). Estimated juvenile:adult ratios vary widely across the range, though all estimates within Washington, Oregon, and California suggest very low breeding success relative to British Columbia (USFWS 2009).

Nest Success, Breeding Propensity, and Other Measures of Fecundity

Of 22 nests with known outcomes in Oregon, 8 were successful (36%; S.K. Nelson, pers. comm. 2018). Nest predation, particularly by corvids, is widely recognized as a leading cause of murrelet nest failure in the federally-listed range (Nelson and Hamer 1995b, USFWS 1997, McShane et al. 2004, USFWS 2009). Other causes of nest failure include abandonment by parents, chicks falling from nests, and chick death (Nelson and Hamer 1995b). Extremely poor breeding success has been documented in Washington and California in recent years and may be linked to changes in the marine environment. No information from Oregon is available. In the most recent USFWS periodic review for the Marbled Murrelet, USFWS (2019) concluded that, “Since 2009, there is little or no additional data to suggest there has been an improvement in nesting success in Washington, Oregon, and California.”

Demographic Models

Models can be useful tools for understanding, explaining, and predicting the dynamics and persistence of populations. They can be designed to create predictions for stable, increasing, or declining populations based on the input values for fecundity and survival. Most demographic models published in the peer-reviewed literature for Marbled Murrelets have relied on relatively simple Leslie Matrix models. While these models have many assumptions and are limited by our understanding of vital rates and future conditions, they nonetheless can provide insights into the demographic, environmental, and stochastic factors affecting population viability and extinction risk. In order to validate models, it is important over time to verify and confirm whether the predictions are aligning with observed data.

Demographic modeling by McShane et al. (2004) used a series of female-only, multi-aged, discrete-time stochastic Leslie Matrix models to project population size by zone over 40 years. Among their assumptions were that annual adult survivorship was 83-92%, nest success was 0.324-0.460 for Zone 3 and 0.230-0.324 in Zone 4, juvenile:adult ratios were 0.080 for Zone 3 and 0.084 for Zone 4, and that 90% of adults breed in most years (the latter was reduced to 50% in “severe El Niños”, modeled to occur in 3 of every 25 years).

McShane et al. (2004) reported extinction probabilities by zone over 100 years. They projected probabilities of extinction of: 1) 100% within 40 years for Zones 5 and 6, 2) 0% within 40 years and 100% within 100 years for Zones 2, 3, and 4, and 3) 0% within 40 years and 25% within 100 years for Zone 1. For the entire federally-listed population, the probability of extinction within 100 years was 16%, with a mean 3-state population size of 45 birds at the end of 100 years (all within Zone 1). For Oregon specifically (Zones 3-4), the probability of extinction exceeded 80% by 2060 for Zone 4 and exceeded 80% by 2100 for Zone 3. Projections were especially sensitive to immigration rates and fecundity. McShane et al. (2004) stated, "Although the approach we used for examining extinction probabilities was rough, we could not devise a more reasonable approach with available information." They forecasted mean annual rates of decline of 2-6% across all zones initially. Earlier modeling efforts produced similar rates of decline of 4-7% per year for the federally-listed range (Beissinger 1995, Beissinger and Nur 1997). McShane et al. (2004) further stated that, "Over the next 20-40 years, new modeling efforts undoubtedly will occur and help refine the Zone Model, using additional information gathered in the future. In addition, annual survey data may show trends after 1 to 2 decades of effort (given high variability) for more direct verification."

Since the modeling effort by McShane et al. (2004), there has been no additional published research to provide updated data for the model variables that were originally used. However, population estimates based on annual at-sea surveys for murrelets can be used as a comparison to verify extinction model predictions. The extinction model from McShane et al. (2004) predicted a mean annual decline of 2.1 to 6.2% using the population estimate from 2001. However, at-sea survey estimates of trend during 2000-2019 after the extinction model estimates, have indicated a significant increasing population trend in Oregon. McIver et al. (2021) found that the All-Zones rate of change (or "trend") for years 2001 through 2019 indicated a 0.5% positive trend per year (95% CI: -0.5 to 1.5%). At the state scale, Oregon exhibited a significantly positive rate of population change (increasing trend) between 2000 and 2019 (2.2% per year; 95% CI: 0.9% to 3.4%). The McShane et al. (2004) modeling effort was based on the 2001 Conservation Zone population estimates. The Conservation Zone 3 population estimate grew from 7,396 (95%CI: 5,230, 9,075) in 2001 to 8,359 murrelets (95%CI: 5,560, 11,323) in 2020; and, the Conservation Zone 4 estimate grew from 3,807 (95% CI: 2,983, 6,425) in 2001 to 6,822 murrelets (95% CI: 5,576, 11,063) in 2019. The predictive outcomes of McShane et al. (2004) have not been validated with observed data. Further studies to obtain vital rate data for Oregon and elsewhere in the range will help to refine models in the future.

Mortality

Predation

Marbled Murrelets exhibit many strategies that likely evolved as antipredator defenses. Behavioral and morphological traits that may help murrelets avoid detection at or around nests include limited parental care at nests, nest visitation primarily at dawn or dusk (low light conditions), rapid flights to/from nests and within the nesting area, cryptic coloration of eggs, cryptic plumage of chicks and adults, minimal or muted vocalizations from nests, remaining still or flattening against tree branches in response to predators, and selection of sites with high amounts of cover above or adjacent to nests (reviewed in Nelson 1997). Moreover, murrelet nests appear to be dispersed on the landscape, and they are typically placed high in the upper canopy of older conifers.

All life stages of Marbled Murrelets are vulnerable to predation (Nelson and Hamer 1995b, Nelson 1997, Burger 2002, Piatt et al. 2007). As summarized by Piatt et al. (2007), known or suspected avian predators of adult murrelets include Bald Eagle (*Haliaeetus leucocephalus*), Peregrine Falcon (*Falco peregrinus*), Northern Goshawk (*Accipiter gentilis*), Sharp-shinned Hawk (*A. striatus*), and Common Raven (*Corvus corax*). Known or suspected avian nest predators include Common Raven, Steller's Jay, Sharp-shinned Hawk, Great-horned Owl (*Bubo virginianus*), Barred Owl (*Strix varia*), Cooper's Hawk (*A. cooperii*), Northwestern Crow (*C. caurinus*), American Crow (*C. brachyrhynchos*), and Gray Jay (*Perisoreus canadensis*) (reviewed in McShane et al. 2004), and corvids are the suspected cause of most nest losses (Nelson and Hamer 1995b, Raphael et al. 2002). Small mammals (e.g., mice, squirrels) are also suspected nest predators (Nelson 1997, Burger 2002, McShane et al. 2004). Occasional predators at sea may include Western Gull (*Larus occidentalis*), Steller sea lion (*Eumetopias jubatus*), California sea lion (*Zalophus californianus*), or even large fish (Nelson 1997, Burger 2002, McShane et al. 2004). Corvids are believed to have the greatest impact on the species (USFWS 2009), though recovering populations of Peregrine Falcons and Bald Eagles have been identified as an emerging concern (RIT 2012). Many of the above-named predators have seen significant increases in abundance in recent decades in regions where Marbled Murrelets nest (see Burger 2002, Piatt et al. 2007, Halbert and Singer 2017).

In addition to expanding predator populations, habitat fragmentation has been linked to greater nest predation risk for Marbled Murrelets. Nesting in marginal habitat, higher predator densities, and/or preferential predator foraging along edges in fragmented forests are among mechanisms that could result in heavier predation pressure (Marzluff and Restani 1999, Raphael et al. 2002, Marzluff et al. 2004). Several studies have reported higher rates of murrelet nest predation near forest edges (e.g., Nelson and Hamer 1995b, Manley and Nelson 1999). Corvids, in particular, have increased in many areas, benefitting from changes to the landscape, such as clearing that creates shrublands rich in berries and insects (Marzluff et al. 2004), and anthropogenic food sources (Marzluff et al. 2001, Marzluff and Neatherlin 2006). Campgrounds, picnic areas, and other sources of human-supplied food tend to support elevated levels of corvids, which can lead to higher nest depredation for nearby murrelets (Marzluff and Neatherlin 2006, Bensen 2017, Goldenberg et al. 2016), and perhaps for murrelets nesting further away (West and Peery 2017).

Disease/Parasites

Disease has not been identified as a major threat to the Marbled Murrelet (McShane et al. 2004). However, seabirds can be affected by a range of bacterial, fungal, parasitic, and viral diseases. Small or declining populations and/or those stressed by other factors may be especially vulnerable to disease impacts. Highly Pathogenic Avian Influenza (HPAI) and West Nile Virus have been detected in wild birds in Oregon and represent emerging concerns. Given their forest nesting habits and presumed increased exposure to mosquito vectors, Marbled Murrelets may be more susceptible to West Nile Virus than other seabirds (McShane et al. 2004).

Alcids are believed to be susceptible to aspergillosis in captivity (Muzaffar and Jones 2004; C. Gillin, pers. comm. 2018). While aspergillosis is not known to be a mortality factor for Marbled Murrelets in Oregon, available records from the USFWS indicate that at least five murrelets entered rehabilitation facilities in Oregon from the 1990s to 2018 (L. Henry, pers. comm. 2018), providing a potential avenue for exposure to aspergillosis. Parasites have also been reported in many alcids, including Marbled Murrelets (Muzaffar and Jones 2004).

Other Mortality

Starvation likely accounts for some birds discovered washed up on beaches (Nelson 1997). As discussed above, causes of chick mortality besides predation can include nest abandonment by parents, falling from the nest, or grounding of fledglings attempting to reach the ocean (Nelson and Hamer 1995b). Additional known or potential sources of mortality (e.g., entanglement, oiling, bird strikes, barotrauma, contaminants, and domoic acid poisoning from harmful algal blooms) are discussed in Chapter 3.

Summary

- The Marbled Murrelet has a unique life history in that it uses inland forests for nesting across much of its range and the ocean for foraging, loafing, courtship, molting, and preening.
- The species is primarily associated with old-growth, late-successional, and older forests with specific attributes (e.g., tree branch platforms with moss or other substrate). Nest-site selection has likely been influenced by predator avoidance and by the flight and energetic capabilities of murrelets.
- The Marbled Murrelet breeding range extends from Alaska to central California along the Pacific Coast. Within this range, there is evidence of three genetically distinct populations: 1) western and central Aleutian Islands, 2) eastern Aleutian Islands to northern California, and 3) central California. There is also evidence of some local genetic variation within the core of the species' range. In Oregon and elsewhere in the federally-listed range, large gaps in breeding distribution have been attributed to anthropogenic habitat loss.
- Marbled Murrelets feed on small schooling fish and marine invertebrates. Adults prefer mostly larval and juvenile fishes, but select larger fish to feed their chicks, presumably to maximize energetics or minimize predation risk since they must commute between inland nest sites and at-sea foraging locations.
- Variability in the marine environment can affect prey abundance, distribution, timing, and quality, with consequences for murrelet diet and breeding success.
- Marbled Murrelets are long-lived and have delayed sexual maturity. They have low fecundity and may not breed every year. Marbled Murrelets lay only one, large egg per clutch.
- Changes in late-successional forests in Oregon since European settlement, due to timber harvest, fire, wind, and other factors, have substantially reduced Marbled Murrelet nesting habitat. Since 1993, In Oregon, higher probability nesting habitat in Oregon increased from 471,220 acres to 517,686 acres in 2017; a net increase of 46,466 acres (+9.9% change). Higher probability nesting habitat was quantified as core (amount of contiguous habitat), edge (amount of habitat adjacent to core habitat) and scatter (habitat scattered in small forest fragments) nesting habitat. Across all landownerships, core higher probability nesting habitat increased from approximately 14,397 acres in 1993 to 15,065 acres in 2017 (+4.6% net change); edge higher probability nesting habitat increased from approximately 52,254 acres in 1993 to 53,559 acres in 2017 (+2.5% net change); scatter higher probability nesting habitat increased from approximately 404,569 acres in 1993 to 449,063 acres in 2017 (+11.0% net change).

- Despite net increases in higher probability nesting habitat across all landownerships in Oregon, some losses of habitat were masked when considering only net change. Specifically, increases in nesting habitat have occurred on federal (13.0% net change) and state (43.4% net change) lands, whereas higher probability nesting habitat losses (-10.2% net change) have occurred on other lands (private, tribal, county, and municipal).
- Most of the higher probability Marbled Murrelet nesting habitat currently persists on federal (312,027 acres) and state (81,092 acres) lands in Oregon, including the Siuslaw and Rogue River-Siskiyou National Forests, forests owned by the Bureau of Land Management, and the state-owned and managed Tillamook, Clatsop, and Elliott State Research forests.
- Most (76%, or 393,119 acres) higher probability Marbled Murrelet nesting habitat and core habitat (96.3%, or 14,505 acres) currently persists on public (federal and state) lands in Oregon.
- The majority (53%, or 253,000 acres) of higher probability nesting habitat and core habitat (81%, or 12,132 acres) in Oregon were found in federally reserved land use designations.
- Despite overall net increases in nesting habitat in Oregon, some losses of habitat were masked when considering only net change. Specifically, increases in nesting habitat occurred on federal and state landowners, whereas nesting habitat losses occurred on other landowners (private, tribal, county, and municipal) during this period: 35,986 acres (+13.0% change) of higher probability nesting habitat and 910 acres (+7.4% change) of core habitat were gained on federal lands; 24,553 acres (+43.4% change) of higher probability nesting habitat and 830 acres (+165.1% change) of core habitat were gained on state lands; and -14,073 acres (-10.2% change) of higher probability nesting habitat and -1,072 acres (-65.7% change) of core habitat were lost on other (private, tribal, county, and municipal) lands.
- Fragmentation of forest nesting habitat not only reduces the total amount of habitat available, but also the quality of areas that remain.
- The Northwest Forest Plan's Marbled Murrelet Effectiveness Monitoring Program surveyed murrelets at sea in Oregon from 2000-2019. During this time period, the Oregon population was increasing at an annual rate of 2.2% (95% CI: 0.9 to 3.4%). Based on this monitoring program, the Oregon population was estimated at 10,339 birds in 2019 and was likely somewhere between a range of 7,070 and 13,607 birds. The wide confidence limits for these population estimates reflect the challenges of monitoring a highly mobile seabird that is sparsely and patchily distributed in the nearshore environment, as well as constraints on survey effort.
- Observed population trend results from at-sea surveys in Oregon are not consistent with model predictions (McShane et al. 2004) that recruitment was insufficient for birds to replace themselves. Further studies to obtain vital rate data for Oregon and elsewhere in the range will help to refine demographic models in the future.

Chapter 3: Factors Influencing Survival and Reproductive Potential

Introduction

At the time that the Marbled Murrelet was listed as state-threatened in 1995, ODFW identified a variety of natural and human-induced factors that could affect the species' "natural reproductive potential[5]" and continued existence in Oregon. These were termed "influencing factors" and included:

- Limited geographic distribution
- Nesting habitat alteration (habitat loss and degradation)
- Natural large-scale disturbances (e.g., fires, wind storms)
- Small population size
- Declining population
- Predation
- Adverse ocean and weather conditions (effects of variability on prey resources)
- Gillnet fisheries (i.e., entanglement)
- Other fisheries (i.e., competition for prey resources with fisheries)
- Oil spills
- Pollution (mainly, effluent discharges from pulp and paper mills)

Small population size and declining population were understood to be results of other factors but were included because they themselves also affect the "natural reproductive potential" of the Marbled Murrelet. ODFW (1995) concluded that the most important influencing factors were nesting habitat alteration, small population size, declining population, and oil spill events.

Since 1995, some threats or risks to the Marbled Murrelet have increased, some have remained about the same, others have been reduced, and some new ones have been identified. In the 2004, 2009 and 2019 periodic reviews for the Marbled Murrelet federally-listed distinct population segment, the USFWS reported that threats from habitat loss, predation, and oil spill mortality were high (McShane et al. 2004, USFWS 2009, and 2019; Table 9). In their 2009 review, they also identified many new or increasing threats, including changes in prey availability and quality, harmful algal blooms and biotoxins, low-oxygen "dead zones" in the ocean, climate change effects, elevated levels of polychlorinated biphenyls (PCBs) in murrelet prey species (mainly a concern in the Salish Sea), entanglement from derelict fishing gear, energy development, and disturbance in the marine environment. In their most recent review, the USFWS (2019) identified various threats in the marine and terrestrial environments that had increased since 2009, including dead zones in the marine environment and climate change impacts, and those that

[5] In order to list a species as threatened or endangered under the Oregon Endangered Species Act, ORS 496.176(3) and OAR 635-100-0105 require a determination by the Commission that the natural reproductive potential of the species is in danger of failure. Natural reproductive failure is reached when a species or population is not replacing itself.

were reduced, such as inadequacy of regulations concerning fishing of forage fish, disease, and loss of timber on federal lands (Table 9).

In 2012, the Marbled Murrelet Recovery Implementation Team (RIT) convened by the USFWS identified the following top five mechanisms, in ranked order, for sustained low recruitment of murrelets in Oregon and the south coast of Washington: 1) loss of terrestrial habitat, 2) nest predation, 3) changes in marine forage, 4) cumulative and interactive effects, and 5) post-fledging mortality (RIT 2012). The purpose of this chapter is to examine these and other current “influencing factors” for the Marbled Murrelet in Oregon, with an emphasis on new scientific information or analysis since initial state-listing.

Discussion of Influencing Factors

Limited Geographic Distribution

At a broad scale, the distribution of the Marbled Murrelet is fairly continuous from the Aleutian Islands to California. There are, however, gaps within that distribution. At the extreme ends of the range (e.g., California and the Aleutian Islands), murrelets are sparse. Although Oregon is in the southern part of the species’ range, it is not at the extreme southern limits of the range.

The smaller populations at the limits of the species’ range may be particularly vulnerable to extirpation. There is also evidence that they have distinct genetic characteristics (Piatt et al. 2007, Peery et al. 2010). In central California, human-caused habitat fragmentation may be responsible for the recent genetic differentiation detected in that murrelet population (Peery et al. 2010). The loss of these peripheral populations could potentially reduce the capacity of the species overall to adapt to long-term environmental changes (see Piatt et al. 2007). Recent work by Vásquez-Carrillo et al. (2014) indicates that there is some population-level genetic differentiation within the core of the range as well.

Historically, it is likely that there were always small gaps within the species’ range due to effects of fire, wind, distribution or availability of prey, and other factors. However, large gaps in the species’ distribution today, particularly in southwest Washington, northwest Oregon, and central California, have been attributed to anthropogenic habitat loss and conversion (Ralph et al. 1995a, USFWS 1997, RIT 2012). Once suitable habitat is removed, there is no evidence that Marbled Murrelets find new sites for nesting. High breeding site fidelity and energetic and flight constraints may preclude colonization of new areas, though breeding in new areas may be more likely if other suitable habitat is nearby (RIT 2012).

Unlike many other seabirds, Marbled Murrelets also have a limited distribution in the ocean. They use nearshore marine waters for foraging, courtship, loafing, molting, and preening. During the breeding season, they have to make daily flights to and from the ocean to provision their chicks. Their at-sea distribution during the breeding season tends to be correlated with the amount and cohesion of suitable nesting habitat nearby, suggesting an important connection between high quality terrestrial and marine habitat (Raphael et al. 2015, Raphael et al. 2016b, Lorenz et al. 2016). More research is needed to determine the full extent of their wintering range, however.

Table 9. Summary of Marbled Murrelet threats and threat levels as assessed by the U.S. Fish and Wildlife Service. At the time of federal listing in 1992, loss and modification of older forest nesting habitat were identified as the primary threats to the Marbled Murrelet, with mortality from oil spills and gillnet fisheries (entanglement) identified as secondary threats. Since 1992, the U.S. Fish and Wildlife Service has conducted three status reviews for murrelets in Washington, Oregon, and California (McShane et al. 2004, USFWS 2009, USFWS 2019). Threats and threat levels evaluated in these reviews are briefly summarized below.

Review	**Threat Level Relative to 1992**			**New Threat(s) Identified**
	Greater	Similar or Unchanged	Reduced	
McShane et al. 2004	Predation	Ongoing and past habitat loss, oil spill mortality, unpredictable and stochastic events (e.g., fires, insect outbreaks, windstorms), Pacific Decadal Oscillation and El Niño/La Niña events, marine contaminants, noise disturbance, genetic viability, research impacts	Annual rate of habitat loss (due to regulatory mechanisms), loss of occupied sites due to survey error, gillnet mortality	Increased risk of disease (considered potential threat only)
Review	**Threat Level Relative to 2004**			**New Threat(s) Identified**
	Greater	Similar or Unchanged	Reduced	
USFWS 2009	Changes in the marine environment, particularly those that reduce prey availability and quality (see also new threats to right)	Habitat loss and degradation, predation, oil spill mortality, gillnet mortality, disturbance from boat traffic or noise, predation	Inadequacy of regulatory mechanisms	Energy development and production, entanglement from derelict fishing gear, exposure to elevated underwater sound levels, harmful algal blooms and biotoxins, oceanic "dead zones", climate change effects, elevated contaminant levels in murrelet prey, disease again acknowledged as potential threat (with addition of highly pathogenic avian influenza an emerging concern)

Review	Threat Level Relative to 2009			New Threat(s) Identified
	Greater	Similar or Unchanged	Reduced	
USFWS 2019	Marine environment and dead zones, terrestrial environment, climate change effects, overutilization for research, harmful algal blooms and biotoxins, oceanic “dead zones”, elevated contaminant levels in murrelet prey, increased shipping with increased human development	Habitat loss and degradation, predation, oil spill mortality, gillnet mortality, disturbance from boat traffic or noise, derelict fishing gear, localized energy developments, ocean acidification	Inadequacy of regulatory mechanisms, fishing pressure on forage fish, disease including avian influenza, rate of timber loss on federal lands	Trawl gear capture and mortality

Forest Habitat Alteration

Marbled Murrelets in Oregon are closely associated with forests with certain characteristics for nesting. Habitat loss and degradation were primary reasons for federal and state listings of the species in the 1990s, and several recent studies show a positive correlation between murrelet abundance and the amount and cohesion of suitable habitat (Raphael et al. 2015, 2016b, 2018; Lorenz et al. In press). Examples of alteration of forest habitats associated with human activities include:

- Direct elimination of habitat
- Conversion of habitat to other uses
- Fragmentation of habitat
- Direct or indirect changes in forest composition or characteristics
- Shrinkage of range or change in distribution of habitat, creating gaps in habitat

Marbled Murrelet old-growth and late-successional forest nesting habitat in the Pacific Northwest has been substantially reduced since European settlement (Perry 1995, USFWS 1997). However, higher probability murrelet nesting habitat in Oregon, including core, scatter, and edge nesting habitat, increased across all landownerships combined in Oregon since from 1993 to 2017 (Lorenz et al. In press) (Tables 2 and 3, Fig. 5). Despite these overall net increases in murrelet nesting habitat in Oregon, some losses of habitat were masked when considering only net change. Specifically, increases in nesting habitat occurred on federal and state lands, whereas nesting habitat losses occurred on other landownerships (private, tribal, county, and municipal) (Lorenz et al. In press).

It is not only the quantity of habitat available that may affect Marbled Murrelet breeding success or survival, but also the distribution and quality of this habitat which are important. Remaining habitat is highly fragmented in Oregon, and most of it persists on public lands. Lack of buffers and heavy thinning adjacent to murrelet habitat can also contribute to habitat loss and degradation (Raphael et al. 2016b, 2018). Edge effects can degrade otherwise suitable forest remnants through changes in abiotic or biotic conditions. Examples of adverse edge effects that could result from recent clearcuts (and logging/thinning adjacent to occupied sites) include elevated predator densities and predation levels, greater windthrow damage, and reduced epiphyte abundance needed for nesting substrate relative to forest interiors (Nelson and Hamer 1995b, McShane et al. 2004, van Rooyen et al. 2011). Maintaining and increasing the area and cohesion (e.g., creating larger blocks) of suitable nesting-habitat area on federal lands will likely contribute to stabilizing and eventually recovering murrelet populations (Raphael et al. 2018, Lorenz et al. In press). However, conservation of existing nesting habitat on federal lands may not be sufficient to conserve murrelet populations in the short term. Contributions from nonfederal lands will help the larger goal of murrelet conservation and recovery (Raphael et al. 2018, Lorenz et al. In press).

The creation and maintenance of large, unfragmented patches of higher probability suitable nesting habitat would likely augment future Marbled Murrelet conservation efforts (Raphael et al. 2016a, 2018, Lorenz et al. In press). Given the amount of habitat-capable lands in Oregon, there is great potential to create more murrelet habitat if losses can be reduced, and even greater potential for the development of core habitat. Notwithstanding, it may take many decades to see this potential realized. Late-successional and older forest characteristics, such as moss-covered platforms, may require about 175-200 years to develop in most forest types in the Pacific Northwest (Franklin et al. 1981).

Large-Scale Disturbances

Periodic wind, fire, tree disease, and insect infestations have always played a role in shaping forests within the range of the Marbled Murrelet. These events can destroy large areas of nesting habitat and increase forest fragmentation. On the other hand, in particular circumstances at the local level, disturbances sometimes create suitable nesting habitat by stimulating development of particular structural features or small, natural canopy gaps. In addition, old-growth trees can often survive low to moderate severity fires, unlike younger trees.

Because current habitat is now limited and disconnected, severe disturbances have the potential to remove key patches that cannot be replaced in the near-term. For example, the 2017 Chetco Bar Fire impacted over 20,000 ac of federally-designated Marbled Murrelet critical habitat with high to moderate severity burns (Vaughn 2017, p. 14).

While multiple factors (e.g., climate, weather, topography, vegetation structure/composition/fuels, fire suppression) affect the duration and intensity of fire across the landscape, many studies have concluded that fires are becoming larger and more frequent in the West (e.g., Stephens 2005, Westerling et al. 2006, Kitzberger et al. 2007, Littell et al. 2009, Miller et al. 2009, Westerling 2016). According to Westerling (2016), fire season length in the Pacific Northwest increased from 23 days in the 1970s to 116 days in the 2000s due to declining snowpack and earlier spring snowmelt.

Climate change is expected to increase potential for habitat loss due to wildfire, insect infestations, disease outbreaks, and severe storms (reviewed in Dalton et al. 2017). Oregon, unlike parts of California and Washington, is not generally subject to large-scale windstorms. However, there have been exceptions (e.g., the Columbus Day Storm of 1962), and fragmented forests may be more vulnerable to windthrow (Franklin and Forman 1987, Burton 2002). Habitat quality could also be impacted through changes in temperature, moisture, or other conditions that affect moss growth (RIT 2012, van Rooyen et al. 2011). The magnitude of these effects on murrelets in Oregon is uncertain at this time. While it is uncertain to what degree climate change will influence high-intensity, stand replacing fires within the range of the murrelet, warmer and drier summers are likely to produce more frequent and extensive fires, thus effecting the extent and connectivity of late-seral/old-growth forests and Marbled Murrelet nesting habitat (USFWS 2019).

Small Population Size

Small population size is itself a factor influencing the natural reproductive potential of the Marbled Murrelet. Marbled Murrelets were once “common” in Oregon, but it appeared that the population declined significantly since scientific observations began in the early 1900s (Nelson et al. 1992). Based on 2019 and 2020 at-sea surveys, the Oregon estimated population in 2019 was 10,339 birds, and likely somewhere between 7,070 and 13,607 birds (McIver et al. 2021).

Generally speaking, small populations within a limited area are more vulnerable to events such as storms, fires, oil spills, and natural, random variation in numbers (demographic stochasticity), and could even be entirely eliminated in large events. Small populations may take longer to recover from such events, if they are even able to recover. This is particularly true for a species like the Marbled Murrelet with a low fecundity, whose life history characteristics include elements such as: lays only one egg, does not breed every year, and does not become reproductively active until 2-5 years of age. In addition to vulnerability to catastrophic events, small populations are increasingly vulnerable to loss of genetic diversity, environmental and demographic variation, inbreeding depression, and possibly increased difficulty in finding mates. The combined effects of these risks has been likened to a vortex that tends to drive small populations to extinction (Gilpin and Soulé 1986).

It is not known whether recolonization would occur from populations outside Oregon if Oregon's population were to be extirpated, or if a catastrophic event were to significantly reduce Oregon's population. Current assumptions about high breeding site fidelity suggest recolonization is unlikely, at least in the short-term.

Although small population size is of concern, it is uncertain to what level Oregon's population can decline before it poses a significant threat to its natural reproductive potential and continued population viability. However, McIver et al. (2021) estimates the Oregon population trend has been increasing 2.2% per year (95% CI:0.9% to 3.4%) from 2000-2018/9. An earlier demographic model by McShane et al. (2004), predicted that extinction probability is high in Oregon (over 80% by 2060 for Zone 4, over 80% by 2100 for Zone 3). Observed population trend results from at-sea surveys in Oregon are not consistent with those model predictions. Recent genetics research suggests that there is at least some population-level differentiation in the core of the Marbled Murrelet range and that Oregon murrelets may be more vulnerable to novel diseases or pathogens (Vásquez-Carrillo et al. 2014).

Declining Population

At the time that the Marbled Murrelet was listed as state-threatened in 1995, ODFW identified declining population as an influencing factor that affected the species. However, since that time the at-sea abundance of murrelets has shown an increasing population trend for Oregon and California; and a decreasing trend in Washington (USFWS 2019, McIver 2020, McIver et al. 2021).

As discussed in Chapter 2, there is widespread agreement that Marbled Murrelet populations in Washington, Oregon, and California have undergone considerable declines since European settlement (Ralph 1994, McShane et al. 2004). Declines from historical levels have been largely inferred from anecdotal information. The population estimates calculated from at-sea surveys for the NWFP Effectiveness Monitoring Program from 2000-2019 showed Oregon exhibited a significant increasing trend of 2.2% per year (95% CI:0.9% to 3.4%) (McIver et al. 2021).

While overall there is uncertainty surrounding estimates of the current size and trend of the Marbled Murrelet population in Oregon, due in part to the difficulty of surveying for the species and the inadequacies of the current every-other-year sampling design to detect within season or interannual movements of murrelets between Conservation Zones.

Predation

Throughout the Marbled Murrelet's evolutionary history, the species has sustained its population with some level of predation. However, contemporary predation rates are considered high for a species that has low fecundity and delayed sexual maturity. Predation pressure is expected to remain high or even increase in the future.

Predation on eggs and nestlings, particularly by corvids, was recognized as a major cause of Marbled Murrelet nest failure in the 1990s. Recent reviews confirm the importance of predation in murrelet nesting outcomes (McShane et al. 2004, USFWS 2009, USFWS 2019). As discussed in Chapter 2, corvid and other generalist predator populations continue to increase as a result of human activities and land use changes. Forest fragmentation and "edge effects" may contribute to elevated predation rates by increasing predator densities, allowing them easier access into stands and/or influencing predator foraging behavior along edges. Anthropogenic food sources from campgrounds, trails, picnic areas, or other human settlements in or around murrelet nesting habitat can also support more predators and affect predator activity.

Recovering raptor (e.g., Bald Eagles, Peregrine Falcons) populations pose a new potential threat to adult and juvenile murrelet survival (Piatt et al. 2007, RIT 2012). This is of particular concern given that murrelet population growth is thought to be influenced most by adult and subadult survival (McShane et al. 2004). Depredation of adult murrelets by Peregrine Falcons, Sharp-shinned Hawks, Common Ravens, Northern Goshawks, and Bald Eagles has been documented, but there is no information on mortality rates (McShane et al. 2004).

Competition

Very little information is available on possible competitive interactions between Marbled Murrelets and other piscivorous species. Reviews by Burger (2002) and COSEWIC (2012) acknowledged potential for competition with Common Murres (*Uria aalge*) and Rhinocerous Auklets (*Cerorhinca monocerata*) due to similar diets. They speculated that invasions of warm water predatory fishes or other piscivores (e.g., Pacific mackerel, *Scomber japonicus*; jack mackerel, *Trachurus symmetricus*; Humboldt squid, *Dosidicus gigas*) might also reduce forage fish availability for murrelets in some years in British Columbia. In addition to feeding on lower trophic level prey, murrelets may be experiencing limitations in available foraging areas due to competition with other seabirds (USFWS 2019).

Human Disturbance

Boat Disturbance

Several studies have reported behavioral responses of Marbled Murrelets to boat traffic (reviewed in McShane et al. 2004, Piatt et al. 2007, USFWS 2009, COSEWIC 2012). Boat disturbance can disrupt foraging or resting birds on the water, potentially increasing energetic costs (Agness et al. 2013) or displacing them from preferred at-sea areas (USFWS 2009, 2019).

At Pacific Rim National Park Reserve, British Columbia, Bellefleur et al. (2009) observed murrelet-boat interactions. Most murrelets reacted (by diving or flying) to boats when they came within 40 m [131 ft]; murrelet age, boat speed, and boat density were important predictors of flushing response. Specifically, murrelets flushed at greater distances when boats were traveling at higher speeds, and they tended to fly out of the foraging area altogether when boats were traveling >28 kph [17 mph]. Juveniles also flushed more readily than adults. Flushing distances decreased in areas with high boat density, but more murrelets flushed in these areas, leading the authors to conclude that murrelets were less committed to feeding in areas with high boat traffic.

In another study in Auke Bay, Alaska, Speckman et al. (2004) observed that adult murrelets holding fish in their bills, presumably for later delivery to chicks, often dove and swallowed these fish when repeatedly approached by boat. They concluded that loss of prey from disturbance could incur energetic costs to breeding murrelets.

The degree to which Marbled Murrelets can habituate to repeated disturbances, and the extent to which vessel traffic has large-scale or long-term consequences on populations or fitness, remains largely unknown. However, some insights can be gained from studies of the closely-related Kittlitz's Murrelet. Agness et al. (2013) modeled the energetic costs of vessel disturbance to Kittlitz's Murrelets in Glacier Bay, Alaska, under average and peak vessel traffic scenarios. Due to their greater propensity to fly at the approach of vessels, the authors found that non-breeding birds expended more energy when disturbed (up to 30% and >50% under average and peak traffic scenarios, respectively) than breeding birds (up to 10% and 30% under average and peak traffic scenarios, respectively). In order to compensate for disturbance, they concluded that birds would need to find and capture additional prey (up to 11 additional sand lance per day for a non-breeding bird experiencing peak disturbance), which could ultimately affect reproduction, growth, or survival.

The above information suggests that many or fast-moving boats in Marbled Murrelet habitat can cause energetic impacts or force birds to feed in less productive areas. Areas outside of Oregon, such as Puget Sound or Monterey Bay, are of particular concern due to the high density of boats in nearshore waters (USFWS 2009). Ship-based tourism may also present localized problems in remote areas, as Marcella et al. (2017) estimated that 9.8-19.6% of all Kittlitz's and Marbled Murrelets in Glacier Bay, Alaska, are disturbed by the transit of a single cruise ship through Glacier Bay National Park.

Other Disturbance

In their review, the USFWS (2009, and 2019) identified "exposure to elevated sound levels" as a factor affecting the continued existence of the Marbled Murrelet. High underwater sound pressure levels, such as those produced by pile driving and underwater detonations, can cause mortality or sublethal injuries or impairment known as barotraumas to murrelets or other vertebrates. Barotrauma can include hemorrhage or rupture of internal organs, hemorrhaged eyes, ruptured eardrums, etc. Currently, this factor is of primary concern in Washington, mainly Puget Sound (USFWS 2009).

At nest sites, there is little information on the effects of human disturbance on Marbled Murrelets. Impacts are generally thought to be minimal, based largely on anecdotal observations, but McShane et al. (2004) emphasized that such disturbance cannot be dismissed. One study conducted by Hébert and Golightly (2006) in Redwood National and State Parks in northern California examined murrelet nest success and behavior in relation to disturbance trials. While they did not observe flushing by incubating adults or chicks in response to simulated trail maintenance (which included exposing nests to sounds of an operating chainsaw), they noted diminished resting behavior during the auditory stimulus of chainsaw operation. They found no correlation between murrelet nest success and distance from roads or trails. Golightly et al. (2009) subsequently reported that murrelets were more likely to nest further away from paved roads than random sites at this location and suggested that nesting birds may be avoiding more human or predator activity along roads, rather than noise, per se.

In their 5-Year Status Review for the Marbled Murrelet, the USFWS (2019) found that while the integrity of suitable habitat is important, so are the levels of human disturbance that impacts nesting habitat. Raphael et al. (2016a) found that nesting habitat was strongly correlated with areas of low human disturbance. Between 1993 and 2012, the mean rank for human disturbance went up in both Oregon and California (Raphael et al. 2016a).

Disease/Parasites

This topic is discussed in Chapter 2. Disease is not considered to pose a current threat to the Marbled Murrelet (USFWS 2019).

Energy Development

The potential for wave and offshore energy projects to impact seabirds, including murrelets, depends largely on their location and the type of equipment installed. If placed in sensitive areas, projects may adversely affect marine habitat through night-lighting, changes in prey abundance, and/or increased human disturbance (USFWS 2009, 2019). Projects may also degrade onshore habitat through construction and operation of ancillary facilities within or adjacent to forested onshore habitat. Bird strikes or entanglement (including collision with wind turbine blades), exhaustion due to attraction to night-lighting, reduced attentiveness to young at the nest, or other impacts to survival or fitness are possible. Conversely, in cases where projects are sited outside the species' foraging area or flight paths, there may be little or no impact to murrelets. Because the Marbled Murrelet's winter distribution (when they may be found further offshore) is largely unknown, some potential impacts cannot be ruled out at this time.

Wave Energy Projects

In Oregon, one wave energy test center was established in 2012 to test off-grid small-scale devices and has supported testing of one wave energy conversion device. This test center is located approximately 2 mi off of Newport within Oregon's Territorial Sea. A second test center received a Federal Energy Regulatory Commission (FERC) license in 2021 and, once constructed, will support testing of commercial-scale devices and arrays approximately 6 mi off of Newport on the outer continental shelf. Other short-term, small-scale tests have occurred within Oregon's Territorial Sea off of Warrenton, Newport, and Charleston, as authorized by state and federal permits.

Offshore Wind Projects

The department is not aware of any offshore wind energy projects currently proposed along the coast of Oregon. However, the Bureau of Ocean Energy Management is working with the state and the Oregon Intergovernmental Renewable Energy Taskforce to perform stakeholder outreach and data gathering to inform consideration of offshore wind siting off of Oregon. Federal and state governments are considering goals for offshore wind development that would accelerate marine energy development.

Onshore Wind Projects

We are not aware of any onshore wind energy projects currently proposed along the coast of Oregon.

Transmission Lines

Electrical transmission lines require permanent vegetation removal within their right-of-way, which can range from 100 to 1000 ft in width, depending on the voltage of the line. This could remove nesting habitat if the transmission line must go through late-successional forest within the range of the murrelet. There is currently a 115 kV transmission line proposed from Tillamook to Oceanside. This right-of-way would be permanently cleared of vegetation for 13 mi in a 100-ft width, some of which passes through forest habitat. However, the majority of the forests in this area are second-to-third growth timber production areas not likely to be used by nesting murrelets. There have been a small number of instances of Marbled Murrelets killed in collisions with transmission lines; this includes two murrelets found dead beneath a powerline adjacent to occupied nesting habitat in a park in northern California in spring 2015, for which necropsies indicated collision with the powerline as the likely cause of death.

Liquefied Natural Gas Terminals and Pipelines

There is currently one liquefied natural gas terminal and pipeline proposed in Oregon through the inland range of the Marbled Murrelet, the Jordan Cove Energy Project. The Jordan Cove Energy Project is a proposed liquefied natural gas export facility in Coos Bay, Oregon, and an associated Pacific Connector Gas Pipeline would run roughly 233 mi from Coos Bay across the Coast Range to Malin, Oregon, in the Klamath Range. The joint project was originally initiated with a notice of intent in November 2004. Since that time, the project has gone through two different iterations with FERC, which ended in March 2016 with a denial of the project by FERC, who cited a lack of a buyer for the export material, as well as insufficient agreement from affected landowners. In January 2017, the development company resubmitted a proposal to FERC with a modified plan for the export facility in Coos Bay, an established buyer in Asia, as well as a realigned plan for the pipeline approved by FERC in March 2020. FERC's decision has been appealed to the U.S. Circuit Court by multiple entities including the State of Oregon due to numerous procedural and substantive flaws at both the federal- and state level. This litigation is still pending. Biological surveys for the Pacific Connector Gas Pipeline project were conducted along the proposed routes by the development company's representatives in multiple years from 2007-2015, with some ground-truthing of presumed-occupied suitable habitat in 2017 and 2018. The pipeline route, as proposed by the applicant, would remove approximately 78 acres of known/presumed-occupied suitable habitat for Marbled Murrelets, with additional, indirect impacts to roughly 7,800 acres of suitable habitat. In May 2021, the project applicant requested that the federal permitting agencies cease their ESA Section 7 consultation with the USFWS Fish and Wildlife Service for impacts to Marbled Murrelet, citing the recent denial of other state and federal permit approvals as their reason to pause. All permitting work appears to have stopped on this project, and at this time its future remains uncertain.

Adverse Oceanic Conditions (Changes in Prey Distribution, Abundance, Timing, and Quality)

As described in Chapter 2, variability in ocean conditions (e.g., winds, temperatures, upwelling patterns) can affect marine productivity, and ultimately, the distribution, abundance, timing, and quality of prey available to murrelets. Marbled Murrelets consume a diverse group of prey, suggesting some degree of flexibility in prey choice and the capacity to switch when necessary. This makes sense from an adaptive standpoint because prey populations are naturally dynamic. Nevertheless, the evidence indicates that the flexibility to switch prey and alter their activity budget are not adequate to ensure reproductive success during years when ocean productivity is extremely poor (Ronconi and Burger 2008). Because murrelets are long-lived, short-term phenomena such as typical El Niño events or a year with poor ocean productivity would not be expected to adversely affect murrelet populations over the long-term. However, murrelets may not be able to compensate for long periods of unfavorable conditions or increased variability in prey resources (for example, during regime shifts associated with PDO), especially in combination with other anthropogenic threats and stressors. Climate change is expected to exacerbate these impacts.

A growing body of evidence indicates that low recruitment in the murrelet is linked, in part, to changes in the marine environment (Peery et al. 2004, Becker and Beissinger 2006, Becker et al. 2007, Norris et al. 2007, Gutowsky et al. 2009, USFWS 2009, Lorenz et al. 2017, USFWS 2019). During the breeding season, reductions in prey quality or quantity may lead to nest abandonment or failure. During the pre-breeding season, murrelets may fail to initiate nesting altogether without sufficient food resources. Centennial shifts toward lower quality prey types have been documented in both central California and the Salish Sea (Becker and Beissinger 2006, Norris et al. 2007, Gutowsky et al. 2009). Murrelet breeding success appears to be positively associated with an abundance of mid-trophic level prey and cooler ocean temperatures (Becker et al. 2007). Oregon's coastal surface waters have warmed an average of 0.5°F per decade over the latter half of the 20th century and are expected to increase by approximately an additional 2.2°F by the mid-21st century (Mote et al. 2010). The waters off Oregon are also becoming more stratified. The thermocline is 10-20 m [33-66 ft] deeper off Oregon in the early 21st century than it was in the middle of the 20th century (Huyer et al. 2007). Stronger stratification will make ocean mixing due to wind patterns less effective at bringing nutrients to the surface, thereby reducing primary productivity (Osgood 2008, Hoegh-Guldberg and Bruno 2010). Further information on climate change effects on marine habitat is discussed below (see Climate Change Effects on Terrestrial and Marine Habitat).

Habitat loss and degradation in coastal and nearshore areas may also affect Marbled Murrelets and their prey. For example, Lorenz et al. (2016) found that murrelets in Washington tended to avoid areas with higher human footprint, an index based on human population density, light pollution, and transportation infrastructure. In addition, many murrelet forage fish species depend on intact nearshore and estuarine habitat for successful spawning, rearing, or migration. Other threats and stressors in the marine environment, such as harmful algal blooms, dead zones, biotoxins, contaminants, and fishing pressures, are discussed elsewhere in this chapter.

The USFWS (2019) in their 5-Year Status Review for the Marbled Murrelet discuss low prey (forage fish species) availability and possible starvation. From 2009 through 2017, a total of 14 dead marbled murrelets were incidentally found and collected in Washington (8), Oregon (2), and California (4). Necropsies performed by the National Wildlife Health Center attributed emaciation as the primary or secondary cause of death of 10 murrelets. The findings were consistent with starvation as a possible cause of the deaths. No new information is available however, on the status of surf smelt, Pacific herring, or Pacific sand lance in Oregon (USFWS 2019).

Climate change is projected to result in changes throughout the marine food web, likely reducing prey quality and quantity. Reduced quality and quantity of prey can have physiological consequences to adults and/or chicks and result in reduced murrelet breeding success (USFWS 2019). The previous periodic review by USFWS (2009) indicated that murrelets may be constrained in their ability to respond to shifts in prey conditions, in particular during the breeding season, because of the reduced distribution of nesting habitat (USFWS 2009). New information indicates continued threats to murrelets in the marine environment and the impacts are projected to become greater in the future (USFWS 2019).

Piatt et al. (2020) documented the extreme mortality and breeding failure of common murres that resulted from the northeast Pacific heatwave from 2014 to 2016. The study in a related seabird species, indicates the risks of ocean conditions and the ecological consequences to forage fish and seabird populations in a wide geographic area.

Climate Change Effects on Terrestrial and Marine Habitat

While there will undoubtedly be species “winners” and “losers” in the context of climate change, there are currently few indications that Marbled Murrelets south of Canada will see benefits from a warming climate (USFWS 2009, 2019). Information was based largely on the Intergovernmental Panel on Climate Change (IPCC), Fourth Assessment Report (IPCC 2014a, b). The best available information signals increasing stressors and threats that are largely unfavorable to the species recovery. Given their low reproductive potential, narrow habitat requirements in both terrestrial and marine systems, breeding site fidelity, and restricted distribution, Marbled Murrelets may not be as resilient as some other species to changing conditions. An assessment by Case (2014) described the Marbled Murrelet as highly sensitive to climate change; of the 114 Pacific Northwest bird species analyzed, the Marbled Murrelet had the highest climate-sensitivity score.

There is already strong evidence that climate change is affecting ecosystems in the Pacific Northwest and globally (IPCC 2014, Blunden and Arndt 2016, Dalton et al. 2017). In their most recent climate assessment for Oregon, Dalton et al. (2017) reported that:

- From 1895 to 2015, Oregon’s mean temperature warmed 2.2°F per century.

- The winter of 2015 was the warmest on record and was characterized by a “snow drought”, in which most precipitation fell as rain instead of snow, resulting in record-low snow pack and altered hydrological regimes. Such conditions may occur regularly by mid-century.
- Under even the most optimistic scenarios, Oregon’s climate is expected to warm at least 2-5°F by the 2050s and 2-7°F by the 2080s.
- Projected impacts of further climate warming in Oregon include, increasing wildfire activity due to warmer, drier summers; wetter winters, reduced winter snow pack, and more frequent extreme rainfall events; spread of forest pests and pathogens; and vegetation shifts are among projected impacts of further climate warming in Oregon.

Though considerable uncertainty exists with respect to any regional-scale impacts of climate change due to the differences in trajectories of climate change scenarios, modeling results underscore the potentially large impacts on Pacific northwest ecosystems. In the Coast Range specifically, Dalton et al. (2017) noted that warmer, drier conditions may lead to conifer forests shifting to more drought-tolerant mixed forests and increasing impacts from wildfire and the fungal disease Swiss needle cast, which stunts Douglas-fir growth. Climate change effects that reduce growth of moss or other canopy epiphytes that provide nesting substrate for Marbled Murrelets could also impact the species (COSEWIC 2012).

For Marbled Murrelets, climate change effects in the marine environment may be especially important (USFWS 2009, 2019). Tillmann and Siemann (2011) reviewed climate change effects in marine and coastal systems within the North Pacific Landscape Conservation Cooperative, which extends from southcentral Alaska to northern California. Among their key findings are that ocean acidity is increasing, sea surface temperatures are rising, storm intensity and extreme wave heights are increasing, sea levels are rising (though effects vary by location), and anomalous hypoxic events in the California Current may be characteristic of future change. They underscored that these trends are expected to continue, with potential for increased coastal erosion, habitat loss, spread of invasive species, range shifts, and altered phenology (and likely decoupling of some predator-prey relationships due to mismatches in timing of biological and physical processes, see also Sydeman and Bograd 2009).

Effects on nutrient levels, primary productivity, and ultimately, the amount, distribution, and quality of food available to murrelets are of particular concern (USFWS 2009). While murrelets have likely adapted to some variability in ocean conditions, the cumulative or synergistic effects of more frequent, severe, or longer duration events such as El Niño could contribute to population declines or even extirpations (Burkett 1995, USFWS 2009, Tillmann and Siemann 2011). Climate models indicate that ocean warming is accelerating and will continue in the future, though changes in El Niño Southern Oscillation (ENSO) and PDO are less certain (Dalton et al. 2017). Nevertheless, a reconstruction of ENSO events from 1525 to 2002 found that although extreme ENSO events occurred throughout the 478 year period, there was an increase in strong, very strong, and extreme El Niño events beginning in the late 19th century, and 55% of the extreme El Niño events occurred in the 20th century (Gergis and Fowler 2009). Gergis and Fowler (2009) also found that 28% of all protracted ENSO events (those lasting more than 3 years) occurred during the 20th century and suggested that ENSO may operate differently under industrial age conditions of increased atmospheric carbon dioxide than it did previously. A strong El Niño event occurred in 2009-2010, and an even stronger El Niño occurred in 2014-2016, which suggests that the trends reported by Gergis and Fowler (2009) could be continuing in the 21st century. Similarly, Black et al. (2014) found that variability of winter upwelling in the CCS increased during the latter part of the 20^{th} century to levels only equaled twice over the last 600 years. This increase in variability was caused by an unprecedented succession of extreme downwelling-favorable winter climate conditions that reduced productivity for marine predators such as seabirds (Black et al. 2014). Results from a model by Zhang and Delworth (2016) showed that PDO amplitude was reduced and time scale shortened under a warming climate.

Bakun (1990) proposed that a warming climate would intensify upwelling-favorable winds, particularly during the warm season, in eastern boundary currents like the CCS, with potentially dramatic effects on these ecosystems. This theory has shaped scientific research and debate and was updated in 2015 (Bakun et al. 2015), but remains unresolved. A preponderance of published studies provide support for the theory that upwelling-favorable winds have increased in three of the five eastern boundary current systems, including the CCS (Sydeman et al. 2014). These authors noted that observational studies were more likely than modeling studies to show intensified upwelling-favorable winds, that seasonal patterns existed, and that the intensification was greater in higher latitudes, which was consistent with the patterns of warming. While increases in coastal upwelling could counter some anticipated effects of climate warming, they might also lead to more frequent hypoxic events, higher ocean acidity, and lower densities of appropriately-sized food particles for fish larvae, with cascading effects on higher trophic levels (Bakun et al. 2015). Another study also found a poleward shift in upwelling-favorable winds, but the majority of climate models examined projected future weakening of upwelling-favorable winds in the CCS by the end of this century under high emissions scenarios (Rykaczewski et al. 2015).

There is also evidence that the timing of the annual upwelling cycle may change with changes in climate, and that such changes can affect breeding success of the Marbled Murrelet. Barth et al. (2007) described the one month delay in the spring transition to upwelling-favorable winds during 2005 and the ecological changes observed in much of the food web. They noted that such a delay in the spring transition followed by stronger upwelling winds later in the year as occurred in 2005 is consistent with predictions of the influence of a warming climate (Bakun 1990, Snyder et al. 2003). Reproductive failures for the Cassin's Auklet and extremely poor reproductive success for the Marbled Murrelet in 2005 were attributed to the change in timing of the wind-driven upwelling, which resulted in low prey resources at a critical time of their reproductive cycle (Sydeman et al. 2006, Ronconi and Burger 2008).

Unusually warm ocean conditions from 2014-2016 provide additional insights into the ecological effects that a warmer future ocean along the Oregon coast might have. An anomalously warm water mass known as "The Blob" (Bond et al. 2015) formed in the Gulf of Alaska in fall 2013 and spread across the entire North Pacific by 2014. These warm waters combined with a strong El Niño the following year, keeping sea surface temperatures elevated off the Oregon coast through 2016. During "The Blob", the zooplankton community off the Oregon coast was dominated by small, lipid-poor tropical and subtropical copepods and gelatinous zooplankton, including new species not previously detected off Newport since sampling began in 1969, krill biomass was the lowest on record, and marine reptile and fish species were observed hundreds of miles outside of their usual ranges (Peterson et al. 2015). A number of forage fish species declined in abundance in 2013-2016, and a mass starvation of Common Murres was observed from southern California to the Aleutian Islands. Murre breeding success was also diminished off California and Oregon, and murres failed altogether in Alaska at many colonies in 2015 and 2016. Several other species of seabirds and marine mammals suffered starvation or breeding failures from southern California to the Bering Sea of Alaska during this period (Piatt et al. 2020).

In their analysis of Marbled Murrelet status and trend from 2000-2018 analysis, McIver et al. (In press) indicated caution in interpreting at-sea data, since their analysis coincided with years when there were dramatic shifts in marine conditions that likely exerted influence on murrelet distribution and abundance. The 'marine heatwave' presented record-high sea surface temperatures; 2014–2016 was the warmest 3-year period on record (Jacox et al. 2016). These anomalies initially compressed the zone of cold upwelled waters to the nearshore, which concentrated the forage species into these same nearshore areas (Jones et al. 2018). Unlike the lead-in to previous strong El Niño events however, effective upwelling in the central and northern regions occurred with upwelling-related species near the coast (such as rockfish juveniles), which were still found in relatively high abundance (Leising et al. 2015). The result was a system with overall moderate productivity (depending on location), extremely high prey species diversity, and overall changes in ecosystem structure (Leising et al. 2015 Peterson et al. 2018). During 2015 and 2017, McIver et al. (In press) recorded their greatest densities of Marbled Murrelets in Conservation Zone 4. They noted that when birds 'choose' not to breed or failed to breed, one might expect to find more birds on the ocean because fewer birds would be inland incubating eggs or feeding chicks. Furthermore, when murrelets and other small alcid species are no longer tied to nest areas, they are more likely to move to where food resources are more available (see Adams et al. 2004).

The exceptionally high sea surface temperature reached maximum values in spring/summer 2016 and declined thereafter, but there was considerable variation at smaller spatial scales (Wells et al. 2017, Thompson et al. 2018). Anomalously strong down welling occurred in the winter of 2015–16 (typical of El Niño winters). From January to May 2017, sea surface temperature anomalies north of 42˚N (California-Oregon border) were near the long-term average, (Wells et al. 2017, Thompson et al. 2018) and upwelling was close to normal throughout most of the CCS in 2017 and 2018. Even though the strength of upwelling was close to normal in 2017, its onset was delayed resulting in poor forage conditions until June 2017 (Thompson et al. 2018). Throughout the period that the marine heat wave impacted the CCS, the copepod composition off Newport, Oregon (Conservation Zone 3) remained in a warm water phase, with a high diversity of southern copepod species, but with lower caloric value than forage fish prey (Peterson et al. 2018). In May and June of 2017, there was an abrupt and late period of upwelling, and the copepod community switched back to larger, fewer species associated with boreal cold water conditions and generally better feeding conditions for predators of forage fish (salmon and seabirds) (Hooff and Peterson 2006; Peterson et al. 2018).

Given the complexity of these systems, it is clear that more research is needed to refine model projections and to improve our understanding of how climate change effects will influence biological communities. At this point, the environmental proxies utilized to characterize oceanographic changes at various scales and described in this section do not fully capture how oceanographic conditions affect Marbled Murrelet reproductive success. In the marine environment, the USFWS (2019) concluded that climate change is likely to reduce Marbled Murrelet breeding success through changes in prey abundance and availability. Further work is needed on direct measures of murrelet prey resources and their effects on recruitment of murrelets.

Harmful Algal Blooms and Dead Zones

Harmful algal blooms occur naturally and are likely becoming more frequent and severe due to human activities (Lopez et al. 2008, Diaz and Rosenberg 2008, Anderson 2009). Climate change is expected to exacerbate conditions that contribute to harmful algal blooms (Diaz and Rosenberg 2008, Lopez et al. 2008, McKibben et al. 2017). Many harmful algal blooms are caused by dinoflagellates, but some are caused by diatoms.

Impacts of harmful algal blooms vary widely, depending on the causative species (Horner et al. 1997, Lopez et al. 2008). Some microalgae produce potent neurotoxins that can bioaccumulate up the food web, causing neurological impairment, reproductive failure, or death in seabirds and marine mammals when contaminated prey are ingested (Gulland et al. 2002, Shumway et al. 2003, Lopez et al. 2008, Goldstein et al. 2009, Bodenstein et al. 2015). *Pseudo-nitzschia* blooms along the Pacific Coast have killed at least small numbers of Marbled Murrelets in the past due to domoic acid poisoning (USFWS 2009). The last couple of years have seen unprecedented closures of fisheries (e.g., Dungeness crab, *Metacarcinus magister*; razor clams, *Siliqua patula*) in Oregon nearshore waters and along the entire West Coast from Alaska to California due to domoic acid concerns for human health.

Other harmful algal blooms are nontoxic but can still have adverse effects on marine ecosystems. Some form large algae masses that later die and decompose, creating hypoxic or anoxic conditions that lead to fish kills or "dead zones" (Diaz and Rosenberg 2008, Lopez et al. 2008). Still others produce compounds that reduce feather waterproofing of seabirds (Jessup et al. 2009, Phillips et al. 2011). Anomalous upwelling conditions in 2009 led to the first recorded seabird mortality in Oregon from *Akashiwo sanguinea*, a dinoflagellate whose cellular breakdown created a proteinaceous foam that coated feathers much like oiling. Based on the hundreds of birds found stranded on public beaches in southern Washington and northern Oregon, at least seven seabird species (including one alcid, the Common Murre) were affected (Phillips et al. 2011). The USFWS (2019) reported harmful algal blooms (HABs) are becoming larger and longer on Puget Sound and the eastern Strait of Juan de Fuca increasing the risk of mortality of murrelet chicks to paralytic shellfish poisoning.

Seasonal hypoxic conditions off the Oregon coast are thought to be a recent phenomenon affecting Murrelet prey base, driven by climatic changes that affect primary productivity and upwelling intensity (Erhardt et al. 2014). Since 2002, this low-oxygen zone or "dead zone" has formed during the summer in nearshore waters along the continental shelf of the central Oregon coast. These extreme, low-oxygen conditions were especially severe and extensive in 2006, covering 1,158 mi^2 occupying up to 80% of the water column in shelf waters <197 ft deep, and persisting from June to October (Chan et al. 2008).

Entanglement

Gillnet Fisheries

During the federal listing of the Marbled Murrelet as a threatened species by the USFWS, mortality of Marbled Murrelets due to accidental capture in gillnets was identified as one of the major threats to murrelet populations (57 FR 45328). However, murrelet mortality due to gillnet fishing is not considered to be a problem in Oregon, since it has been prohibited in Oregon's estuaries, bays, and along the outer coast since 1942 (Nelson et al. 1992, Carter et al. 1995). Gillnet fishing is permitted in the Columbia River, but it is highly limited, and few murrelets occur there.

Derelict Fishing Gear

Impacts from derelict fishing nets are not believed to be significant for murrelets in Oregon due to lack of net fisheries along the Oregon coast, but may be greater in other parts of the range (USFWS 2009). There is, however, potential for adverse effects of derelict crab pots on some murrelet prey species (USFWS 2009).

Plastic and Marine Debris Ingestion

Ingestion of floating bits of plastic, fishing line, and marine debris has been documented in many seabirds, but is not known to be a problem for Marbled Murrelets (Fry 1995, Robards et al. 1995, Burger 2002). However, microplastics are being found in forage fish species and may be transferred up the food chain to murrelets (USFWS 2019).

Vulnerability to Prey Depletion (Other Fisheries and Climate)

Commercial and non-commercial harvest of herring, sardines, and other marine species important to Marbled Murrelets has potential to affect the species' survival and reproductive success (Burkett 1995, Becker and Beissinger 2006, McShane et al. 2004, USFWS 2009). Some forage fish species are not directly targeted by fisheries, but are still taken as bycatch. The shift in murrelet diet to lower-quality prey items (trophic level decline) in the Monterey Bay ecosystem over the last century may have been due, in part, to the collapse of the sardine fishery in the 1940s followed by heavy fishing pressure on other forage species since the 1980s (Becker and Beissinger 2006). In southern Washington and northern Oregon, the USFWS convened Marbled Murrelet RIT, expressed some concern over the sardine fishery in the Columbia River Plume due to possible effects on murrelet prey resources (RIT 2012).

There is little information on the relative importance of different prey species to Marbled Murrelets in Oregon, or where fisheries may overlap with murrelet diet and foraging areas. While landings of some commercially and recreationally harvested forage fish stocks have been tracked for decades, interpretation of such data is complicated by variable marine conditions, complex food webs, fishing effort, and uncertain availability to murrelets. Murrelets also prefer small larval and subadult fish, whereas fisheries tend to target larger adult fish (Burkett 1995, Piatt et al. 2007). Long-term data from Common Murres at the Yaquina Bay colony have shown that murre diet tends to be dominated by clupeids in warm water years and sand lance, northern anchovy, and flatfishes in cooler water years (Gladics et al. 2015). Common Murres have similar diet and foraging habits to murrelets, though they may feed further offshore (Burger et al. 2008, Materna et al. 2011) and can likely dive much deeper (see Ainley et al. 2002 for a review of Common Murre diving depths, which occasionally extend up to 180 m [591 ft]).

Environmental conditions are thought to be important drivers of abundance and distribution for many forage fish and other prey species of murrelets. There is evidence that changes in climate affects ocean productivity, that shifts in species spatial distributions and abundance are occurring that may affect not only yields from fisheries, but ecosystem structure and functioning including wildlife that depend on prey abundance and availability as well (Free et al. 2019, IPPC 2019).

A brief synopsis of available information on the status of forage fish in Oregon follows:

- For northern anchovy and surf smelt, population trends and abundance are largely unknown. However, there is some information that suggests a decline in the northern substock of northern anchovy from the 1970s to the mid-1990s (Emmett et al. 1997).
- For Pacific herring, the only assessment data available are for spawning stock surveys at Yaquina Bay; 2017 was the first commercial harvest in the roe fishery since 2003. Since the 1980s, most herring were landed in Newport, likely as part of the Yaquina Bay roe herring fishery (ODFW, unpubl. data 2020).
- The northern subpopulation of Pacific sardines occurs in Oregon. It has trended downward in recent years and the primary, directed commercial sardine fishery on the west coast, including Oregon, was closed beginning July 1, 2015. While directed sardine harvest has been closed, small sardine landings have been allowed in Coastal Pelagic Species (CPS) fisheries targeting other species such as anchovy and mackerel, as well as in non-CPS sectors, in order to enable continued operation of those fisheries while protecting the sardine resource. Coastwide sardine landings in these fisheries since the closure have totaled approximately 1-2% of the historical peak, and landings in Oregon are a very small fraction of this coastwide total.
- Spawning areas, abundance, and status are largely unknown for forage fish species not regularly harvested in Oregon (e.g., Pacific sand lance, osmerid smelts; ODFW 2016).
- The southern distinct population segment of the Pacific eulachon (*Thaleichthys pacificus*) was listed as threatened under the federal ESA in 2010 (75 FR 13012). Since the 1980s, nearly all eulachon were landed in the Columbia River rather than the ocean in Oregon (ODFW, unpubl. data 2020).
- Since the Marbled Murrelet state-listing in 1995, several protection measures have been implemented for forage fish in Oregon, including state (ORS 509.515) and federal (74 FR 33372) bans on directed krill harvest in waters off of Oregon in 2003 and 2009, respectively, the establishment of marine reserves and marine protected areas in 2012, and the adoption of a state-level management plan for six groups of forage fish in 2016. These topics are discussed further in Chapter 4.

At this time, there is insufficient information to determine whether prey depletion or competition with commercial or recreational fisheries for marine forage species in Oregon is impacting Marbled Murrelets. Forage fish are facing a multitude of their own threats and stressors, from habitat loss and degradation to ocean acidification. Separating out the roles of fishing pressures, changing ocean conditions, and other factors in murrelet diet will require much more study.

Oil Spills

Marbled Murrelets have one of the highest oil spill vulnerability ratings of any Pacific seabird because they feed in local concentrations close to shore and spend most of their time swimming on the sea surface (King and Sanger 1979, Wahl et al. 1981). The threat of oil spills was recognized as an important factor in the initial federal and state listings of the species in the 1990s and remains a significant concern today (USFWS 2009, 2019).

As summarized by Carter and Kuletz (1995), large oil spills may result from oil tanker, barge, or other large vessel accidents (e.g., groundings, collisions, explosions, accidental spillages), offshore oil wells (e.g., blow-outs, accidental spillages), unloading/loading cargo from onshore and offshore facilities, and onshore facility spills that enter the ocean. Small spills are due to cleaning of tanks at sea, bilge pumping, and various other accidental leaks or discharges. All types of boats and marine transportation vessels may be involved (Carter and Kuletz 1995). Both large spills and chronic oiling (from small or unreported spills) can impact seabirds (USFWS 2005).

Multiple large oil spills have occurred along the Pacific Coast (Carter and Kuletz 1995, USFWS 2005, USFWS 2009). Most of these have happened in shipping lanes or near ports (USFWS 2005). In Oregon, the higher vessel traffic and larger commercial shipping volume in the vicinity of the Columbia River put that area at particular risk for a large spill (RIT 2012).

Major oil spills in or around Oregon are summarized in Table 10 below. In 1999, the New Carissa cargo vessel that ran aground and split apart on the southern Oregon coast released over 70,000 gallons of fuel, killing or injuring an estimated 2,465 seabirds, including 262 Marbled Murrelets. This spill has had the greatest documented murrelet mortality in Oregon.

One of the largest spills in recent history, the 1989 Exxon Valdez oil spill in Prince William Sound, Alaska, is estimated to have killed about 8,400 *Brachyramphus* murrelets (Carter and Kuletz 1995, Piatt and Naslund 1995). This was the largest single murrelet mortality event in the world (Carter and Kuletz 1995). Of all species affected by that spill, alcids had the highest rate of mortality, and of the six alcid species affected, Marbled Murrelets suffered proportionally high mortality relative to their numbers (Piatt et al. 1990, Carter and Kuletz 1995).

A spill occurrence off the Oregon coast has the potential to have a major impact on Oregon's Marbled Murrelet population, depending on the location of the spill, its magnitude, season of occurrence, and speed and effectiveness of cleanup activities. Impacts would be greatest if spills occurred where Marbled Murrelets are in concentrations. Exposure to oil (e.g., ingestion during preening, fouling of plumage) can impair thermoregulation, flight ability, reproductive behavior, and/or physiological functions, with lethal or sub-lethal effects (USFWS 2005). A spill could also cause indirect mortality or effects (i.e., if prey base is negatively impacted) (Carter and Kuletz 1995, Peterson et al. 2003). For example, even low levels of oil can result in developmental defects and mortality in herring embryos (Incardona et al. 2007, 2015).

Table 10. Summary of Marbled Murrelet mortality from oil spills in or around Oregon (adapted from USFWS 2009, Table 11, p. 57 and McShane et al. 2004, Table 5.4-1, p. 5-18).

Month	Year	Oil Spill Name	No. Murrelets Recovered[1]	Estimated Mortality[2]
Feb	1979	Lincoln Co. Coast	[1-10]	[10-200]
Mar	1980	Lincoln Co. Coast	[1-10]	[10-200]
Nov	1983	Blue Magpie	2-4	[20-80]
Jul	1991	Tenyo Maru	[5]	[25-50]
Feb-Mar	1999	New Carissa	26	262
Mar	1999	Oregon/Washington Mystery Spill	2	[20]

[1]McShane et al. (2004) assumed minimal rates of 1 bird per year recovered.
[2]Numbers in square brackets were roughly estimated by McShane et al. (2004) using a correction factor of 10-20 times those recovered (Ford et al. 2002 in McShane et al. 2004).

Although large oil spill events do not have a high probability of occurring, history suggests that the likelihood of effective containment and recovery of oil from large spills is low. Depending on the location of the spill, and distribution, location, and concentration of Marbled Murrelets, these events could have a considerable impact on the survival and reproduction of the Marbled Murrelet in Oregon. Tanker and shipping traffic has increased since federal listing and is likely to increase further as the human population continues to grow on the West Coast (USFWS 1997, 2005, 2009). Crude oil transport off of Oregon (see Oil Spill Task Force 2017) remains a serious threat for a marine oil spill, as does other large vessel traffic moving back and forth along the West Coast (the New Carissa spill discussed above resulted from a cargo vessel that spilled its bunker fuel). Deep-draft ports in Oregon include Astoria, Newport, and Coos Bay. Trains carrying crude oil also now routinely operate along the Columbia River and other arterials within Oregon and Washington (Oil Spill Task Force 2017). A rail/marine oil terminal is located in Portland adjacent to the Willamette River, and another terminal with capacity to accommodate crude oil is located in the Clatskanie area. A major new crude oil facility is proposed in Vancouver, Washington, and a Final Environmental Impact Statement was completed in November 2017 for this project, known as the Tesoro Savage Vancouver Energy Distribution Terminal (Energy Facility Site Evaluation Council 2017). The Washington State Energy Facility Site Evaluation Council recommended disapproval of the proposed Vancouver facility in late fall 2017, but as of the writing of this report, a final decision on whether or not to approve the project is pending by the Governor. Refer to Energy Development above for information on other types of energy projects and facilities that could impact Marbled Murrelets in Oregon.

In their recent periodic review for the Marbled Murrelet, the USFWS (2019) determined that impacts from oil spills had not appeared to have increased since their 2009 status review. They concluded however, that the risk of a catastrophic oil spill impacting murrelets remains significant throughout the species' range. No additional regulations or changes to regulations have been introduced to address this threat, nor have recovery actions apparently reduced the risk.

Contaminants

The degree to which contaminants affect Marbled Murrelets is uncertain. Some contaminants can be transferred or biomagnified through trophic levels in the food chain, with the potential to increase morbidity or mortality and reduce fitness of top predators like piscivorous seabirds. In Puget Sound, with its high degree of hydrologic isolation and heavy urbanization, contaminants in murrelet prey species are of particular concern (USFWS 2009, RIT 2012). For example, West et al. (2008) found that Pacific herring in Puget Sound were 3 to 9 times more contaminated with PCBs compared to Strait of Georgia herring and 1.5 to 2.5 times more contaminated with levels of dichlorodiphenyl-trichloroethane and its isomers (DDTs).

In Oregon, the Columbia River and several sites in the Coos Bay estuary remain key sources of current and legacy contaminants (Buck 2004, USFWS 2005), but they are not known to be important foraging areas for murrelets. Elevated contaminant levels (e.g., PCBs, dichlorodiphenyl-dichloroethylene (DDE), mercury) were reported in eggs of most piscivorous birds sampled in the Columbia River estuary in the early 1990s relative to species lower in the food chain (Buck 2004). Concentrations in some piscivorous birds, such as Caspian Terns (*Hydroprogne caspia*), Double-crested Cormorants, and Bald Eagles, exceeded effect thresholds (Buck 2004).

Common Murres, a species with similar foraging habits to Marbled Murrelets, in Oregon are known to accumulate organic and inorganic contaminants in low concentrations that may produce sub-lethal or synergistic effects (Materna et al. 2011). Exposure pathways could come from point and/or non-point (e.g., from runoff or atmospheric deposition) sources.

Chlorinated organic effluent discharges from bleach pulp and paper mills identified by Fry (1995) as a potential threat to murrelets feeding in areas of effluent discharge are no longer a major concern. Since the 1990s, discharge from mills has been regulated, and industry has switched to non-chlorine bleaches, thereby reducing release of dioxins and furans into the environment (Buck 2004, USFWS 2005).

Overall Assessment of Influencing Factors

In this chapter, we examined a wide range of threats, stressors, and risk factors that could affect Marbled Murrelet survival and reproductive success in Oregon. Key threats first identified in 1995, including forest habitat alteration, large-scale disturbances, small population size, predation, changes in prey quality and availability, and oil spill mortality, have remained high, and new threats have been identified, particularly in the marine environment (Table 9). Competition, disease/parasites, human disturbance from boats, entanglement from gillnet fisheries or derelict fishing gear, and plastic and marine debris ingestion do not appear to pose a serious threat to murrelets in Oregon at this time. Changes in threat level posed by limited geographic distribution, declining population, prey depletion due to fisheries, and other pollution or contaminants are difficult to assess due to limited information. There are also indications that incidence or extent of harmful algal blooms, biotoxins, and dead zones is increasing, and that climate change may exacerbate conditions unfavorable to murrelets, but the magnitude of these effects is uncertain.

Individually, many of these influencing factors may represent a significant threat to the natural reproductive potential of the Marbled Murrelet. However, we have not been able to determine the significance of each factor relative to each of the others. It is likely that the cumulative or synergistic effects of these factors pose an even greater threat to the species (RIT 2012). Under the best of situations, a small population may be able to sustain itself, but if cumulative effects or even a single catastrophic event occurs, a smaller population may be unable to recover to previous levels. This is particularly true for a species like the Marbled Murrelet, whose life history characteristics include such things as: lays only one egg, does not breed every year, and does not become reproductively active until 2-5 years of age; these result in a low potential rate of population growth or recovery.

Recent monitoring and research continue to support the importance of habitat conservation for persistence of the Marbled Murrelet. Although Lorenz et al. (In press) did not detect an obvious correlation between recent murrelet population size and estimated amount of higher probability nesting habitat at the coarse scales of states and Conservation Zones, they did observe positive relationships between murrelet at-sea abundance and change in amount of higher probability nesting habitat at those coarse scales. This finding, although not direct evidence of a cause-effect relationship, does lend support to the idea that forest practices that conserve and restore habitat will likely contribute importantly to murrelet recovery (Lorenz et al. In press). It is also important to consider that the majority of higher probability nesting habitat in federal reserves, as well as on state and other (private, tribal, county, and municipal) landowners was classified as edge and scatter. For murrelet recovery, Lorenz et al. (In press) recommended that more core habitat is needed on all lands, and that the time needed to develop appreciable acreage of core habitat will take much longer across all ownerships. Further, conservation efforts that focus on protecting higher probability nesting habitat will benefit this species, as will management efforts that enlarge the size of tracts of core habitat (Lorenz et al. In press). This will help reduce the negative consequences of habitat fragmentation; enhancing higher probability nesting habitat will also produce more contiguous, unfragmented landscapes and should benefit Marbled Murrelets (Lorenz et al. In press).

Several authors have also recommended protection of marine habitat (Becker et al. 2007, Norris et al. 2007, Hazlitt et al. 2010, Lorenz et al. 2016). In a recent investigation of marine resource selection by Marbled Murrelets in Washington, Lorenz et al. (2016) found that areas with higher amounts of nesting habitat that were close to shore and in cool waters with low human footprint had greater probabilities of murrelet use. They called for prioritized protection of marine areas in close proximity to old-growth Marbled Murrelet nesting habitat.

Summary

- Marbled Murrelets have narrow habitat requirements and limited geographic distribution. Past and present habitat loss remains a threat to Marbled Murrelets in Oregon. Once nesting habitat is lost, it may require about 175-200 years to develop again. In addition, high breeding site fidelity and energetic and flight constraints are thought to further restrict distribution, and the ability for birds displaced by habitat loss to find new nesting habitat after nesting habitat is lost.

- Since 1993, higher probability nesting habitat (including core, edge, and scatter nesting habitat categories) habitat has increased across all landowners combined within the murrelet's range in Oregon. Despite these overall net increases in nesting habitat in Oregon, some losses of habitat were masked when considering only net change. Specifically, increases in nesting habitat occurred on federal and state landowners, whereas nesting habitat losses were noted on other landowners (private, tribal, county, and municipal). Additionally, the majority of net changes were in the scatter nesting habitat category.
- Remaining habitat is highly fragmented and contains a high proportion of edge components. Forest fragmentation and "edge effects" can increase predation rates and may result in other adverse effects to forest remnants (e.g., greater windthrow damage, microclimates less suitable to epiphyte growth).
- In general, Marbled Murrelets in Oregon are a small population relative to historical levels and may be more vulnerable to environmental and demographic stochasticity, catastrophic events, and loss of genetic diversity.
- Population estimates from at-sea surveys for Marbled Murrelet indicates that the population trend in Oregon increased 2.2% a year between 2000-2019, and the 2019 estimated Oregon at-sea population was 10,339 murrelets.
- Predation by corvids is the leading cause of nest failure.
- Murrelets may be vulnerable in localized areas to energy development projects. Depending on siting location and equipment, projects have potential to increase loss or fragmentation of nesting habitat, expand human activity and disturbance in sensitive areas, impact prey base, and/or cause mortality through bird strikes.
- Oceanic conditions influence the abundance, distribution, and timing of prey available to murrelets, and prey quality and availability in turn affect breeding success. A centennial shift in murrelet diet to lower (poorer quality) trophic levels has been documented in parts of the range. As with many other seabirds, low recruitment has been associated with El Niño or other warm water years. Effects of climate change will alter the marine environment potentially reducing forage quality and quantity.
- Climate change is expected to increase potential for habitat loss from wildfires, insect infestations, disease outbreaks, and severe storms. While natural disturbances have always shaped Oregon forests, climate change is expected to increase potential for habitat loss from catastrophic wildfires, insect infestations, disease outbreaks, and severe storms, and to exacerbate conditions unfavorable to murrelets in the marine environment. There are currently few indications that Marbled Murrelets south of Canada will see benefits from a warming climate. The best available information signals increasing stressors and threats that are largely unfavorable to the species. Given their low reproductive potential, narrow habitat requirements in both terrestrial and marine systems, breeding site fidelity, and restricted distribution, Marbled Murrelets are not as resilient as other species to changing conditions.
- Harmful algal blooms are now occurring frequently along the Pacific Coast. They can produce biotoxins, surfactant-like compounds, and low-oxygen "dead zones" that negatively affect seabirds and marine ecosystems. Entanglement in gillnets or in derelict fishing gear is not known to be a problem in Oregon.
- While prey depletion linked to commercial fisheries is of some concern, there is insufficient information to determine whether this is a problem for murrelets in Oregon.

- Potential for a catastrophic oil spill (e.g., Exxon Valdez, New Carissa) remains a serious threat.
- Contaminants have been shown to bioaccumulate in other seabirds in Oregon, but their effects on Marbled Murrelets have not been examined. Based on information from Common Murres in Oregon, sublethal or synergistic effects are possible.

Chapter 4: State Endangered Species Act Reclassification Criteria

This chapter presents the legal reclassification criteria which must be met in order to uplist the Marbled Murrelet to endangered status under the OESA, and biological or other information relevant to those criteria.

Summary of Criteria in Administrative Rule

To reclassify a wildlife species from threatened to endangered, the Commission must first determine whether the likelihood of survival of the species has diminished such that the species is in danger of extinction throughout any significant portion of its range within this state. (OAR 635-100-0105(3)(b); 635-100-0111(1)). In determining whether the risk of extinction criterion is met, regarding the range of the species, the commission shall consider (OAR 635-100-0105(5)):

(a) the total geographic area in this state used by the species for breeding, resting, or foraging, and the portion thereof in which the species is or is likely within the foreseeable future to become in danger of extinction;
(b) the nature of the species' habitat, including any unique or distinctive characteristics of the habitat the species' uses for breeding, resting, or foraging; and
(c) the extent to which the species habitually uses the geographic area.

Range of the Species (OAR 635-100-0105(5))

(a) Geographic Area

The geographic area used by the Marbled Murrelet in Oregon for breeding is generally restricted to that area along the entire coastline and inland about 50 mi (USFWS 1997), mainly within the Oregon Coast Range and Klamath physiographic provinces. Within that general range, murrelets use only those forested areas having specific characteristics, as described in Chapter 2.

There are gaps in the murrelet's breeding distribution, resulting from major changes in habitat availability. The disjointed distribution reflects the fact that the remaining nesting habitat, primarily old-growth and late- successional forests, is mostly found on public lands (see Chapter 2).

Marbled Murrelet old-growth and late-successional forest nesting habitat in the Pacific Northwest has been substantially reduced since European settlement (Perry 1995, USFWS 1997). As discussed in Chapter 2, most higher probability Marbled Murrelet nesting habitat currently persists on public (federal and state) lands in Oregon. Of the 517,686 ac of higher probability nesting habitat in Oregon, 312,027 acres (60.3%) occurred on federal lands, including 273,755 ac in reserved and 38,272 ac in nonreserved land allocations. In addition, 81,092 ac (15.6%) of higher probability nesting habitat occurred on state lands, and 124,567 ac (24.1%) of higher probability nesting habitat occurred on other (private, tribal, county, and municipal) lands (Lorenz et al. In press).

Based on Northwest Forest Plan's Marbled Murrelet Effectiveness Monitoring Program results (Lorenz et al. In press), higher probability nesting habitat increased in Oregon from approximately

471,220 acres in 1993 to 517,686 acres in 2017, a net increase of 46,466 acres (+9.9% net change). Higher probability nesting habitat was quantified as core (amount of contiguous habitat), edge (amount of habitat adjacent to core habitat) and scatter (habitat scattered in small forest fragments) (Table 2). Across all landownerships, core higher probability nesting habitat increased from approximately 14,397 acres in 1993 to 15,065 acres in 2017 (+4.6% net change); edge higher probability nesting habitat increased from approximately 52,254 acres in 1993 to 53,559 acres in 2017 (+2.5% net change); scatter higher probability nesting habitat increased from approximately 404,569 acres in 1993 to 449,063 acres in 2017 (+11.0% net change). Despite net increases in higher probability nesting habitat across all landownerships in Oregon, some losses of habitat were masked when considering only net change. Specifically, increases in nesting habitat have occurred on federal (13.0% net change) and state (43.4% net change) landowners, whereas higher probability nesting habitat losses (-10.2% net change) have occurred on other (private, tribal, county, and municipal) lands).

Federal lands with murrelet nesting habitat include primarily the Siuslaw and Rogue River-Siskiyou National Forests and lands managed by the BLM. The majority of murrelet nesting habitat on state lands occurs on the Clatsop and Tillamook State Forests and other state lands in western Oregon managed by ODF. Also included is the Elliott State Research Forest managed by DSL, and state parks managed by OPRD. Other landownerships (private, tribal, county, and municipal) could make important contributions to maintaining murrelet nesting habitat that is well-distributed, particularly where there are gaps in federal lands (e.g., between the Siuslaw and Rogue River-Siskiyou National Forests, north of the Siuslaw National Forest to the Columbia River, and on BLM lands fragmented by harvest and juxtaposed with other lands).

Marbled Murrelets' foraging and resting areas in Oregon are generally concentrated in the nearshore ocean (typically within 1.2 mi of the coastline during the breeding season) (Strong et al. 1995, Falxa et al. 2016). The species' energetic and flight capabilities help to determine the proximity of foraging and nesting areas, because adults must commute between nest sites and the ocean to obtain and deliver food to their chicks. Raphael et al. (2016b) found that murrelet distribution at sea during the breeding season is strongly correlated with the amount and cohesion of suitable nesting habitat nearby. However, large-scale marine conditions, such as the 'marine heat wave' which affected the California Current in 2014-2016, may have influenced Marbled Murrelet distribution at sea (see Chapter 2). The mechanisms for this change in distribution is not yet clear (McIver et al. In press).

(b) Nature of Habitat

As discussed in Chapter 2, the Marbled Murrelet has narrow habitat requirements. It is unique among North American alcids in that it nests primarily in coastal old-growth and late-successional forests. Marbled Murrelets do not construct a nest, per se, but rather lay their single egg on a large or deformed tree branch high in the canopy. Large platforms with moss or other substrate, foliage cover above and around the nest, high densities of large trees, multiple canopy layers, and proximity to openings in the canopy that provide flight access are among important habitat features. Marbled Murrelets use nearshore marine waters for resting and feeding.

(c) Extent of Use of Geographic Area

Marbled Murrelets are not known to undertake large migratory movements, and while there may be some seasonal shifts in distribution, murrelets occur in Oregon at all times of the year. They nest primarily in older coastal forests, and may visit nesting areas outside of the breeding season. They are assumed to have high nest-site fidelity, meaning that birds return to the same stand or perhaps even the same tree or platform year after year (Divoky and Horton 1995). Marbled Murrelets use nearshore marine waters year-round for resting and feeding.

Risk of Extinction in Oregon (OAR 635-100-0105(3)(b); 635-100-0111(1))

The large-scale decline in the distinct population segment (DPS) of Marbled Murrelets in Washington, Oregon, and California resulted in their listing as threatened under the federal endangered species act in 1992. The state of Oregon listed murrelets as threatened in 1995. These listings provided protections for the species on all landownerships throughout their range in Oregon. The nesting habitat requirements and life-history strategy evolved by this species provide little opportunity for the population to rapidly increase in number, even under optimal conditions. Much of the murrelet's historical old-growth and late-successional forest nesting habitat in Oregon was removed by timber harvest and wildfire during the last century. Since 1993, however, policies, plans, and regulations have resulted in overall increases of Marbled Murrelet nesting habitat in Oregon, most specifically on federal and state lands. Marbled Murrelet nesting habitat currently persists predominately on public lands in Oregon, including the Siuslaw and Rogue River-Siskiyou National Forests, forests owned and managed by the BLM, and the state-owned and managed Tillamook, Clatsop, and Elliott State Research forests.

An evaluation of the factors and threats that can influence the survival and breeding success of the Marbled Murrelet in Oregon, was presented in Chapter 3 (Table 9). Factors affecting the species are believed to be: forest habitat alteration; large-scale disturbances; small population size; predation; changes in prey quality, timing, and availability; and oil spills. In the 2019 USFWS Status Review of the DPS, the current threats were evaluated and determined that the species should remain as threatened under the federal ESA.

The ability to scientifically survey and estimate murrelet populations across the range of the DPS was not developed until 2000. Shortly thereafter, with limited data on many parameters of murrelet demographics, McShane et al. (2004) developed an extinction model for the Marbled Murrelet. The McShane et al. (2004) model was developed used the best information available at the time, however, the data used to build model assumptions was limited to projected recruitment rates obtained from small and disparate studies. Their extinction model produced probabilities of extinction for murrelets in the coming decades as well as predicted a 2-6% annual rate of decline. However, McIver et al. (2021) found that between 2000 and 2019 the murrelet population has shown a significant rate of increase of 2.2% per year (95% CI: 0.9 to 3.4%) in Oregon (Chapter 2). The relevance of predicted outcomes from the McShane et al. (2004) model is limited when compared to observed population data.

Although murrelets are long-lived birds with a low reproductive rate, longevity and the influence of possible migration from other states into Oregon does not likely explain the increasing trend. It is likely the protections of both occupied and higher probability nesting habitat have contributed to this increasing trend. Marbled Murrelet higher probability nesting habitat in Oregon has increased during the period from 1993-2017 (9.9% net change; Table 2), most specifically on federal and state land (Lorenz et al. In press). Lorenz et al. (In press) observed positive relationships between murrelet at-sea abundance and change in amount of higher probability nesting habitat, which lends support to the idea that forest management programs, policies, and regulations that conserve and restore habitat will likely contribute importantly to Marbled Murrelet recovery.

For recovery, large contiguous blocks of higher probability Marbled Murrelet nesting habitat and core habitat are needed across all landownerships in Oregon. This objective is on a long term trajectory of being attained over the next 100 years on federal and state lands. Notwithstanding, other landownerships (private, tribal, county, and municipal) lands also have the potential to make important contributions to Marbled Murrelet recovery, since they contain 52% of habitat-capable forest lands (Chapter 2) are found on these lands and may provide future potential Marbled Murrelet nesting habitat in Oregon (Lorenz et al. In press).

If the Commission determines the risk of extinction criterion is not met, uplisting is not warranted. No further analysis or determinations are necessary and no further rulemaking action is required.

If the Commission determines the risk of extinction criterion is met, the likelihood of survival of the marbled murrelet has diminished such that the species is in danger of extinction throughout any significant portion of its range in Oregon, the Commission must determine whether one or more of the factors set out in OAR 635-100-0105(6)(a) – (c) is met. The full text of OAR 635-100-0105(6) provides:

> *In listing a wildlife species as endangered or threatened, the commission shall determine that the natural reproductive potential of the species is in danger of failure due to limited population numbers, disease, predation or other natural or human actions affecting its continued existence and, to the extent possible, assess the relative impact of human actions. In addition, the commission shall determine that one or more of the following factors exist:*
>
> *(a) that most populations are undergoing imminent or active deterioration of their range or primary habitat;*
> *(b) that overutilization of the species or its habitat for commercial, recreational, scientific, or educational purposes is occurring or is likely to occur; or*
> *(c) that existing state or federal programs or regulations are inadequate to protect the species or its habitat.*

Additional Factors to Consider if Risk of Extinction is Determined

(a) Deterioration of Range or Habitat (OAR 635-100-0105(6)(a))

Terrestrial Habitat

Marbled Murrelets in Oregon are dependent upon coastal old-growth and late-successional forests for nesting. Marbled Murrelet nesting habitat in Oregon declined substantially from historical levels to

1993. Murrelets were federally listed in 1992. From 1993 to 2017, higher probability nesting habitat increased 9.9% (net change) within the murrelet's range in Oregon (Lorenz et al. In press). Despite this overall net increase, some losses of habitat were masked when considering only net change (Table 2). Specifically, increases in nesting habitat have occurred on federal (13.0% net change) and state (43.4% net change) lands, whereas nesting habitat decreased (-10.2% net change) on other (private, tribal, county, and municipal) lands (Lorenz et al. In press). The Marbled Murrelet nesting habitat that currently persists in Oregon is highly fragmented (Lorenz et al. In press), which suggests that increases in Marbled Murrelet nesting habitat quantity and quality is needed. Climate change is expected to exacerbate conditions (e.g., wildfire, insect/disease, drought, etc.) unfavorable to murrelets in the terrestrial environment (Chapter 3).

Ocean Habitat

Variability in ocean conditions and anthropogenic threats and stressors are also affecting marine habitat off of Oregon's coast. Marbled Murrelets use marine waters for foraging, loafing, courtship, molting, and preening. They require sufficient prey resources for survival and successful reproduction. While some recent government programs and regulations (e.g., establishment of marine reserves and marine protected areas, additional oversight of forage fish take) may help to protect certain marine areas and forage species, it is too soon to know their effectiveness; critical habitat in the marine environment has not been established for the Marbled Murrelet. Climate change is expected to exacerbate conditions unfavorable to murrelets in the marine environment (Chapter 3).

(b) Overutilization (OAR 635-100-0105(6)(b))

The Marbled Murrelet is a nongame species and is not hunted. No evidence suggests that the Marbled Murrelet has been subject to overcollecting for educational purposes, and the available information on scientific research indicates that impacts to murrelets are unlikely to have population-level effects in Oregon.

From 1992 to 2016, the USFWS issued four 10(a)(1)(A) recovery permits under the federal ESA that included Marbled Murrelet research activities in Oregon (C. Henson, pers. comm. 2018). The Service reported that 218 Marbled Murrelets were authorized to be taken (harassed) between 2009 and 2018 under those permits (USFWS 2019). Primary activities were capture, tagging, and handling at sea.

Prior rangewide assessments by the USFWS concluded that there may be some localized impacts of research on murrelets (McShane et al. 2004, USFWS 2009, USFWS 2019). Transmitter effects (e.g., higher underwater drag, increased predation risk) were identified as the greatest concern because effects on individual survival could impact a murrelet population, especially in small populations (USFWS 2009).

While there is little Oregon-specific information on impacts to murrelets from recreation, studies of corvid densities, foraging behavior, and predator-prey dynamics from California and Washington (e.g., Neatherlin and Marzluff 2004, Vigallon and Marzluff 2005, Marzluff and Neatherlin 2006, Golightly and

Chneider 2011, Scarpignato and George 2013, Goldenberg et al. 2016, West and Peery 2017) suggest that impacts are occurring or are likely to occur wherever murrelet habitat and recreational use overlap. Crows, jays, and other predators may be attracted by food and garbage litter, which could contribute to elevated predation rates of murrelets in those areas. Unauthorized, recreational tall tree climbing is also of concern in some parks or protected areas.

Commercial utilization of Marbled Murrelet habitat is mostly restricted to direct and indirect impacts from forest management activities. Overall changes in murrelet nesting habitat are described above for terrestrial lands in Deterioration of Range or Habitat.

While there are concerns about fishing pressure (past or present) and stressors faced by forage fish species, there is currently no direct evidence that overutilization of murrelet prey by commercial or recreational fishing is occurring in Oregon. Additionally, current state and federal fishery management practices prioritize sustainable fisheries.

(c) Adequacy of State and Federal Programs or Regulations (OAR 635-100-0105(6)(c))

The following is an overview of key state and federal programs and regulations pertinent to the status of the Marbled Murrelet and/or its habitat in Oregon. It is not a detailed or exhaustive list of all possible laws, regulations, plans, or programs that could possibly affect uses or natural resources in Oregon's forest lands, coastlines, or marine waters.

Federal Programs and Regulations

Federal Endangered Species Act

The purpose of the federal ESA (16 USC 1531-1544; 50 CFR 17) is to protect and recover threatened and endangered species and their habitats. As noted previously, Marbled Murrelets in Washington, Oregon, and California were listed as threatened under the federal ESA in 1992. One effect of this listing is that "take" is prohibited wherever the species occurs (across all landownerships) under Section 9, unless authorized by the USFWS. Take is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct" (16 USC 1532(19)). Through regulations, "harm" is defined 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 behavioral patterns, including breeding, feeding, or sheltering" (50 CFR 17.3).

There are various mechanisms for authorizing take of listed species under the federal ESA, including:

Incidental Take Permits in association with Habitat Conservation Plans: The USFWS may issue an Incidental Take Permit for take incidental to otherwise legal activities by nonfederal entities. To obtain a permit, the applicant must first develop a Habitat Conservation Plan (HCP) demonstrating that the activities will not appreciably reduce the likelihood of the survival and recovery of the species in the wild. The HCP must include measures to minimize and mitigate the effects of incidental take to the maximum extent practicable (16 USC 1539(a)(1)(B) [Section 10(a)(1)(B)]; endangered wildlife species: 50 CFR 17.22; threatened wildlife species: 50 CFR 17.32). We are not aware of any current Incidental Take Permits for Marbled Murrelets in Oregon. The ODF and DSL are pursuing such permits by preparing HCP's for the western Oregon state forests and Elliott State Research Forest, respectively that would provide coverage for multiple listed species.

Recovery and Interstate Commerce Permits: Recovery and Interstate Commerce Permits allow for take as part of efforts to recover a listed species. They may be issued for scientific research or to allow transport and sale of listed species across state lines for a breeding program or similar purpose (16 USC 1539(a)(1)(A) [Section 10(a)(1)(A)]; endangered wildlife species: 50 CFR 17.22; threatened wildlife species: 50 CFR 17.32). For details on take of Marbled Murrelets for scientific purposes in Oregon, see Overutilization (OAR 635-100-0105(6)(b)) above.

Enhancement of Survival Permits: Enhancement of Survival Permits are issued to nonfederal landowners participating in Safe Harbor Agreements (16 USC 1539(a)(1)(A) [Section 10(a)(1)(A)]; endangered wildlife species: 50 CFR 17.22; threatened wildlife species: 50 CFR 17.32). Such agreements allow landowners to improve habitat for listed species while protecting them from additional regulatory restrictions that could result from their conservation actions. We are not aware of any current Safe Harbor Agreements pertaining to Marbled Murrelets for nonfederal landowners in Oregon.

Interagency Cooperation: Under Section 7, federal agencies must consult with the USFWS to ensure that any action they authorize, fund, or carry out with potential to affect a federally-listed species or its federally-designated critical habitat is not likely to jeopardize the continued existence of the species or result in the destruction or adverse modification of its critical habitat (16 USC 1536(a) [Section 7(a)]; 50 CFR 402). After formal consultation, the USFWS writes a biological opinion, which describes the expected impacts of the project on the species, and makes a jeopardy determination. If a non-jeopardy determination is made, the USFWS may recommend measures to minimize adverse effects, set project terms and conditions, establish limits on allowable take, and issue an incidental take permit for a project.

Critical Habitat

The USFWS first designated 3,887,800 ac of critical habitat for the Marbled Murrelet in Washington, Oregon, and California in May 1996 (61 FR 26256). This designation included a description of the Primary Constituent Elements that support nesting, roosting, and other normal behaviors that are essential to the conservation of the Marbled Murrelet. The Primary Constituent Elements include: 1) forested stands containing large-sized trees, generally more than 32 in in diameter with potential nesting platforms at sufficient height, generally greater than or equal to 33 ft in height; and 2) the surrounding forested areas within 0.5 mi of these stands with a canopy height of at least half of the site potential tree height. Designated critical habitat also includes habitat that is currently unsuitable, but has the capability of becoming suitable habitat in the future. The 1996 designation was revised in 2011, removing approximately 189,671 ac in northern California and southern Oregon not considered essential for conservation of the species (76 FR 61599). The 2011 designation was reaffirmed in 2016

(81 FR 51348). There are currently 1,469,116 ac of critical habitat designated on federal and non-federal lands in Oregon. Critical habitat has not been designated in the marine environment.

Recovery Plan

The USFWS completed a recovery plan for the Marbled Murrelet in September 1997 (USFWS 1997). The main objective of the plan was to stabilize the population by maintaining and/or increasing productivity and removing and/or minimizing threats to survivorship (USFWS 1997). The recovery plan built upon the NWFP, an interagency Conservation Assessment sponsored by the USFS (see Ralph et al. 1995b), and earlier efforts by various organizations and researchers (USFWS 1997). It placed special emphasis on habitat-based conservation actions in the terrestrial environment.

Only interim delisting criteria were identified in the recovery plan, but these included: 1) trends in estimated population size, densities, and productivity have been stable or increasing in four of the six Conservation Zones over a 10-year period, and 2) management commitments and monitoring have been implemented in each of the six Conservation Zones to provide adequate protection of Marbled Murrelets for at least the near future (50 years) (USFWS 1997).

Status Reviews

Since federal listing, the USFWS has completed three 5-year reviews focused on new information and analysis relevant to the species' status (McShane et al. 2004, USFWS 2009, USFWS 2019). All of these reviews reaffirmed the federal threatened status of the Marbled Murrelet.

Migratory Bird Treaty Act

The Marbled Murrelet is protected under the Migratory Bird Treaty Act (16 USC 703-712; 50 CFR 20 and 21). The Migratory Bird Treaty Act and its associated regulations implement conventions between the United States and Canada, Mexico, Japan, and Russia, and address aspects of taking, possession, transportation, sale, purchase, barter, exportation, and importation of migratory birds. They prohibit take of certain migratory bird species as well as their eggs and nests, unless authorized by permit from the USFWS. Take is defined as "to pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to pursue, hunt, shoot, wound, kill, trap, capture, or collect" (50 CFR 10.12). Unlike the federal ESA, protections under the Migratory Bird Treaty Act do not generally extend to habitat (USFWS 2009).

Northwest Forest Plan

In the early 1990s, controversy over harvest of old-growth forests led to sweeping changes in management of federal forests in western Washington, Oregon, and northwest California. These changes were prompted by a series of lawsuits in the late 1980s and early 1990s that effectively shut down federal timber harvest in the Pacific Northwest. A team of scientists and technical experts were convened to conduct an assessment of management options for federal timberlands in the Pacific Northwest (FEMAT 1993). Their assessment provided the scientific basis for the environmental impact statement and record of decision (USDA and USDI 1994a, b) to amend USFS and BLM planning documents within the range of the Northern Spotted Owl under a new management plan, the NWFP (Thomas et al. 2006).

The NWFP includes strategies for conservation and restoration on federal lands, as well as mechanisms for subsequent research, learning, and adaptive management. Key elements of the NWFP include adoption of an ecosystem management approach, habitat protections for listed species, land use designations, monitoring programs, and adaptive-management. The NWFP affected about 24.4 million ac of federally-managed forests in 18 national forests and 7 BLM districts in northwestern California, western Oregon, and western Washington. To facilitate implementation of the NWFP, the federal land base was separated into land allocations: late-successional reserves, congressionally reserved areas, administratively withdrawn areas, managed late-successional areas, riparian reserves, adaptive management areas, and matrix land (lands outside the previous six designations) (USDA and USDI 1994a,b). Each land allocation had specific management objectives and requirements described in the standards and guidelines, which must be adhered to while implementing the NWFP. In reserved lands, commercial timber harvest is generally not permitted, and younger stands, if managed, are managed to attain tree size and stand structure resembling old-growth. Reserved lands include such areas as national forests and BLM lands designated as late-successional reserves and designated wilderness areas. In most cases, commercial timber harvest is permitted on nonreserved federal lands.

The NWFP identified several goals for murrelet nesting habitat, including providing substantially more habitat for Marbled Murrelets than existed at the start of the plan, providing large contiguous blocks of murrelet nesting habitat, and improving or maintaining the distribution of populations and habitat (Madsen et al. 1999). Ecological monitoring programs were established in 1993 to evaluate the effectiveness of the NWFP in meeting conservation objectives, and to inform management decisions (Mulder et al. 1999).

After 25 years of NWFP implementation, Lorenz et al. (In press) concluded that the NWFP has largely been successful at conserving Marbled Murrelet habitat on federal lands. The fundamental assumptions of the NWFP were that the rate of loss of murrelet nesting habitat in reserves would slow or stop, and that unsuitable forest cover types would recover. In the short term (less than 50 years), the availability of nesting habitat was expected to remain stable or decline from losses from fire and other natural disturbances. In addition, the rate of increase in the amount of nesting habitat was projected to be slow because trees do not develop structures suitable to support nests until they are large and old, often 150 or more years (USDA and USDI 1994a; USFWS 1997). Available data support this assumption and show that rates of net habitat gain on NWFP lands have occurred (Fig. 5). Forest stands in reserves are on a long term trajectory toward higher nesting habitat probability over the next 100 years, but many more decades will be needed to observe whether the NWFP is successful in achieving its goal to stabilize and increase murrelet populations (Raphael et al. 2018, Lorenz et al. In press).

Bureau of Land Management, Western Oregon Resource Management Plan

In 2016, the BLM signed the Records of Decisions (RODs) for the Resource Management Plans (RMPs) in Western Oregon (USDI BLM 2016a, b). This RMP revision replaced the 1995 RMPs developed for consistency with the 1994 NWFP, thereby also revising the NWFP for the management of BLM-administered lands in western Oregon. Out of 2.5 million ac in the BLM planning area, nearly three-quarters are protected in reserves for fish, water, wildlife, and other resource values. On July 20, 2016, the USFWS issued a biological opinion that found that the Proposed RMP was not likely to jeopardize the continued existence of any of the species (including Marbled Murrelet) under their jurisdiction, or adversely modify their critical habitat. In addition, the USFWS (2016) concluded:

> *Although there are likely to be some adverse effects to murrelets and murrelet critical habitat in portions of the species' range, the overall outcome of [Proposed RMP] implementation will be the protection of the vast majority of extant murrelet nesting habitat, and a large long-term net increase in total area and amount of murrelet habitat during the life of the plan. This approach builds on and continues the basic approach of the original conservation strategy for the murrelet first articulated in the NWFP and the recovery plan.*

The USFWS (2019) concluded that the BLM's 2016 RMPs now protect more Marbled Murrelet habitat. They found that changes from the NWFP included an additional 31,991 ac of habitat in Late Successional Reserves/Riparian Reserves, including an additional 18,034 ac of highly suitable habitat in Late Successional Reserves/Riparian Reserves. This change has reduced the potential for Marbled Murrelet habitat to be lost from timber sales.

The Oil Pollution Act of 1990

Following the 1989 Exxon Valdez oil spill in Prince William Sound, Alaska, U.S. Congress passed the Oil Pollution Act of 1990 (33 USC 2701-2761). This federal legislation amended the Clean Water Act and created an integrated prevention, response, liability, and compensation regime that addresses vessel- and facility-caused oil pollution in U.S. navigable waters (USFWS 2009). Since the 1990s, some additional measures further improve oil spill prevention. For example, the Oil Pollution Act required phase-out of single-hull tankers and tank barges carrying oil as cargo by 2015. However, this requirement does not apply to container ships, freighters, cruise ships, or other types of vessels.

Once a spill occurs, damages to natural resources (or the services they provide to humans or ecosystems) and restoration of injured resources are jointly guided by the Oil Pollution Act and the National Environmental Policy Act. The Oil Pollution Act provides the framework for natural resource damage assessment and restoration, whereas the National Environmental Policy Act lays out the process for impact analysis and public review (*M/V New Carissa* Natural Resource Trustees 2006, p. 83).

Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 USC 1801 et seq.) is the main law that governs management of marine fisheries in the United States. The MSA was amended and reauthorized in 1996 and 2006. The MSA establishes the United States' jurisdiction over marine fisheries management throughout the Exclusive Economic Zone (EEZ; offshore to 200 nautical mi), beyond the EEZ onto the continental shelf, and over anadromous fisheries throughout the migratory range of these species beyond the EEZ. The MSA also establishes an inner boundary for the U.S. EEZ that is coterminous with a coastal state's territorial sea. The MSA sets national standards for fishery resource conservation, fishery management, and the development of fishery management plans based on the best available science to achieve optimum yields while preventing overfishing. To manage U.S. fisheries by region and to promote the conservation of fish stocks, the MSA created eight regional fishery management councils authorized to develop and implement fishery management plans and policy. The Pacific Fishery Management Council is responsible for fisheries off the West Coast of the continental United States. The MSA gives the Secretary of Commerce authorization to evaluate, approve, and implement federal fishery management plans. The National Oceanic and Atmospheric Administration-National Marine Fisheries Service is the lead agency charged with implementing the MSA. The original Act promoted the development of a domestic fishing industry by phasing out foreign fishing fleets in the U.S. EEZ. The 1996 Sustainable Fisheries Act amendment to the MSA focused on defining measurable criteria for overfished stocks, rebuilding overfished species, protecting essential fish habitat, promoting recreational catch and release programs, and reducing bycatch. The 2006 amendment strengthens the mandate to end and prevent overfishing, promotes market-based management approaches, provides a larger role for science in decision making, and promotes enhanced international cooperation in fisheries management. Key provisions include annual catch limits based on scientific advice and accountability measures for all fishery management plan species. The Pacific Fishery Management Council has developed approved fishery management plans that include many of the species that make up the forage base for the Marbled Murrelet, such as anchovies, sardines, krill, osmerids, and many groundfish species. There has been a ban on directed krill harvest since 2009 (74 FR 33372). A ban on new commercial forage fish fisheries for several previously unmanaged forage species, including Pacific sand lance and osmerid smelts, took effect in 2016 (81 FR 4 19054).

State Programs and Regulations

Oregon Endangered Species Act and “Protected” Species

The Oregon Legislature enacted the OESA (ORS 496.171 to 496.192 and 498.026) in 1987 and amended it in 1995 through House Bill 2120. The Oregon Fish and Wildlife Commission adopted amendments to administrative rules to implement House Bill 2120 (OAR 635-100-0001 through 0180) in 1997.

ODFW is responsible for fish and wildlife under the OESA, and the Oregon Department of Agriculture is responsible for plants. Once a wildlife species is placed on the state list as threatened or endangered, Oregon statutes prohibit the “take” (kill or obtain possession or control, per ORS 496.004 (16)) of the listed species without a state permit. The Marbled Murrelet is listed as threatened under the OESA and is also a "protected" species under OAR 635-044-0430, meaning it is unlawful for any person to take, capture, hold, release, or have in possession, either dead or alive, whole or in part. The OESA provides the agency additional responsibility and authority for conservation of listed species.

The OESA primarily applies to actions of state agencies on state-owned, managed, or leased lands. Private lands are not directly affected by the OESA (ORS 496.192) except through applicable provisions of the Forest Practices Act (FPA) (ORS 527.610-527.610.992, OAR Chapter 629 Divisions 600-680). In contrast, the federal ESA directly affects federal, state, and private lands. In general, the OESA is much more limited in scope than the federal law.

Because the OESA primarily affects the actions of state agencies on state-owned, managed, or leased lands, and because less than 2% of Oregon's land base is state-owned, the burden of recovering threatened and endangered species is primarily associated with habitat protections on the federal landownerships in Oregon. However, because state lands are important to species recovery, the value of the OESA to species protection can be significant. Lorenz et al. (In press) estimated that 11% of potential Marbled Murrelet nesting habitat in Oregon is found on state-owned lands. Moreover, silvicultural practices and other land management activities on state forest lands can affect the viability of murrelets on adjacent federal lands.

The OESA sets a policy of encouraging cooperation and minimizing duplication between state and federal conservation efforts. It requires other state agencies to work with ODFW in an effort to make their management actions consistent with survival guidelines and endangered species management plans for listed species. Pursuant to ORS 496.172(4), an incidental take permit or statement issued by a federal agency for a species listed under the federal ESA can serve as "a waiver of any state protection measures or requirements otherwise applicable to the actions allowed under the federal permit".

The listing of a species by the Commission, in and of itself, does not automatically trigger any regulatory action by ODFW or other state agencies. At the time of listing, the Commission is required to establish "quantifiable and measurable guidelines" otherwise known as survival guidelines that it "considers necessary to ensure the survival of individual members of the species" (OAR 635-100-0100(13)). These guidelines may include protection of specific resource sites such as nest sites.

For threatened species, all state agencies are required to follow the survival guidelines established by the Commission. If an agency determines that its actions on state lands would violate the guidelines, it must notify the Oregon Fish and Wildlife Commission, which then has 90 days to recommend reasonable and prudent alternatives that are consistent with the Commission's guidelines. If the state agency does not adopt these recommendations, it must justify (after consultation with ODFW) that the potential public benefits of the action outweigh the potential harm of not adopting ODFW's recommendations, and that reasonable mitigation and enhancement measures will be taken.

For endangered species, the process is somewhat different. The Commission still must adopt survival guidelines when it lists a species, and affected state agencies are required to follow the survival guidelines described above for threatened species. However, within 4 months of listing an endangered species, the Commission must determine whether state land can play a role in the conservation of that species. If so, the land-owning or managing agency must determine (in consultation with ODFW) what role its lands will play in the conservation of the endangered species. To do so, the agency must consider the survival guidelines adopted by the Commission, additional information provided by the department on the conservation needs of the endangered species, the social and economic impacts of implementing needed conservation measures, and the agency's statutory obligations. The agency must then develop an endangered species management plan within 18 months of the species being listed as endangered and submit it to the Oregon Fish and Wildlife Commission for approval. Commission approval is based on whether the plan achieves the role defined by the agency.

Based on the biological needs of the species, and in consultation with state agencies, the Commission may modify the endangered species management plan to make it consistent with the agency's role. In any case, the Commission must approve the endangered species management plan within 24 months of listing the species as endangered. In the absence of an approved endangered species management plan, state land-owning or managing agencies will follow the procedure described above for threatened species. Other non-land-owning state agencies are not required to develop species management plans, but must ensure their actions are consistent with their identified role.

Besides the OESA, other state agency statutes and administrative rules may require protection for federal and state-listed species on private lands. For example, the FPA requires the Board of Forestry to adopt rules appropriate to protect the sites of federal and state-listed species on private lands (see Oregon Forest Practices Act below). ODFW works with ODF to provide advice on the development of such rules.

State Forest Plans

These state forest lands are actively managed under forest management plans to provide economic, environmental, and social benefits to Oregonians. Timber sales on these forests produce jobs and revenue that fund counties, local districts, and schools throughout the state. These forests also offer recreation and educational opportunities, and provide essential wildlife habitat and clean water.

State forests in Oregon were acquired in different ways, and the two types are owned by different entities within state government. Lands owned by the Board of Forestry are known as Board of Forestry lands. Some state parcels were granted to the state by the federal government when Oregon became a state in 1859. These lands are owned by the State Land Board and are known as Common School Fund (CSF) lands. Each landownership has its own set of legal and policy mandates. The goal for management of Board of Forestry Lands is to secure the Greatest Permanent Value (ORS 530.010 through 530.170 and OAR 629-035). The goal for management of CSF lands is the maximization of income to the CSF over the long-term (ORS 530.450 through 530.520).

The ODF Northwest Oregon State Forests Management Plan (ODF 2010) provides management direction for all Board of Forestry lands and CSF lands in northwest Oregon. The Board of Forestry owns 97% of these lands, and the State Land Board owns the other 3%. This plan takes a multi-resource approach to forest management, and presents guiding principles, a forest vision, and resource management goals that set the long-term direction for these lands. The resource management goals and strategies are intended to achieve a balance between the resources, and achieve the greatest permanent value through a system of integrated management that will likely benefit murrelets and other species of concern. The Board of Forestry and ODF State Forests Division initiated a multi-year project in 2017 to evaluate potential changes to the Northwest Oregon Forest Management Plan, which is ongoing and expected to be completed in 2022 concurrently with an HCP.

ODF currently manages approximately 556,000 ac of forest lands within the range of the Marbled Murrelet. Northwest Oregon state forests include two large blocks of land in the Tillamook and Clatsop State Forests. The Tillamook and Clatsop State Forests are in the northern end of the Oregon Coast Range. The Tillamook State Forest is 364,000 ac, and the Clatsop State Forest is 154,000 acres. Another 38,000 ac of smaller tracts of state forest land are scattered in western Oregon. The ODF Northwest Oregon State Forests Management Plan (ODF 2010) provides management direction for these lands, and is founded upon an approach called structure-based management. Structure-based management is designed to produce and maintain an array of forest stand structures across the landscape in a functional arrangement. The integrated management strategies are intended over time to result in habitat conditions on the landscape and in aquatic and riparian areas that will provide functional habitat conditions for native species. The long range desired future condition envisions 30-50% complex forest, which (this includes 15-25% of old forest structure and 15-25% layered forest structure; both stand types are expected to provide suitable habitat for Marbled Murrelets).

ODF has developed policies specific to Marbled Murrelets on state forest lands, which are intended to avoid "take" and protect suitable habitat around identified occupied sites. The ODF plans timber sales only after surveys for Marbled Murrelets have been conducted in potentially suitable habitat according to protocols established by the Pacific Seabird Group (Evans Mack et al. 2003), and the survey area was classified as unoccupied by nesting murrelets. The ODF has conducted over 32,000 individual surveys for Marbled Murrelets at more than 1,300 unique sites since 1992. This represents the largest survey effort for Marbled Murrelets by any land manager in Oregon, Washington, or California. The ODF, State Forests Division, designates protected Marbled Murrelet Management Areas (MMMAs), which includes “occupied habitat” identified through surveys and associated “buffers”. Under current ODF policy, MMMAs must be designated based on recommendations of Evans Mack et al. (2003) or as otherwise determined through consultation with the USFWS. Some activities, such as thinning, are conducted in buffers with seasonal restrictions for nesting and only after consultation and agreement from the USFWS that the activity as proposed has a low likelihood of take of Marbled Murrelets.

In 2018, the ODF began working on the Western Oregon State Forest HCP. The plan includes long-term protection for threatened species and allows for timber harvest. The ODF estimates the plan would increase the amount of Marbled Murrelet habitat by the end of the permit term (70 years). In October 2020, the Board of Forestry voted to advance the Draft HCP into the National Environmental Policy Act (NEPA) analysis and stakeholder engagement phase. The Western Oregon State Forests HCP is anticipated to be completed and approved by the Board of Forestry in 2022, and implemented in 2023.

Elliott State Research Forest

Since July 2017, ODF no longer manages the Elliott State Forest Common School Fund (CSF) forest lands. Of the 93,000 ac Elliott State Forest, DSL now manages approximately 84,200 ac of CSF forest lands, and ODF manages approximately 8,800 ac of Board of Forestry forest lands. Since July 2017, DSL has been contracting with a third-party forest manager for 'custodial management' only and has not been conducting any active timber harvesting on the property. In December 2018, the State Land Board directed DSL and OSU to begin examining the Elliott State Research Forest concept. The State Land Board voted in December 2020 to continue with this process. The DSL is also currently developing an HCP in close collaboration with OSU, which intends to acquire the forest and transform it into a research forest. The Elliott State Research Forest HCP is anticipated to be completed in 2022.

Oregon Forest Practices Act

The ODF is responsible for administering the FPA in Oregon. The FPA (ORS 527.610 to 527.992 and OAR Chapter 629, Divisions 600 to 665) lists protection measures specific to nonfederal (i.e., private and state-owned) forestlands in Oregon. These measures include specific rules for resource protection (OAR 629-665), including some threatened and endangered species such as the Northern Spotted Owl, but the rules do not address protection of Marbled Murrelet resource sites.

In November 2016, the Board of Forestry directed ODF to initiate a rule analysis for Marbled Murrelets. As specified in OAR 629-680-0100, the initial step in this process was to develop a Marbled Murrelet Technical Report. The technical report included additional background information on Marbled Murrelet ecology and habitat use, and explicitly addressed the required elements relating to the definition of resource sites and identification of potential forest practices conflicts and the consequences of those conflicts specified in (OAR 629-680-0100(1)(a)). In addition, a range of general protection strategies for this species was also identified. The final technical report was approved by the Board of Forestry in April 2019. The rulemaking process to address protection of Marbled Murrelet resource sites on nonfederal lands regulated by the Forest Practices rules is anticipated to be completed in 2023.

At the March 2017 Board of Forestry meeting, ODF staff provided a complete description of the FPA rule process relating to Marbled Murrelets and summary of existing ODF data on the species (Tucker and Weikel 2017a), excerpted as follows:

> *Although there are no rules specific to Marbled Murrelets in the FPA, ODF has data for known murrelet sites. Proposed forest operations near these sites are addressed through the notification and written plan processes. Marbled Murrelet protections are addressed under FPA rules for written plans for species on federal or state threatened and endangered species (T&E) lists. OAR 629-605-0170 (5)(d) requires statutory written plans for operations within 300 ft of nesting or roosting sites of threatened or endangered species. OAR 629-605-0190(2) requires non-statutory written plans for operations near habitat sites of any state-listed threatened or endangered species. OAR 629-605-0180 describes the process for addressing threatened and endangered species resource sites in written plans.*
>
> *Each situation is evaluated on a case-by-case basis to determine if the proposed operation will pose a conflict to the murrelet site. If a conflict is not likely, then a written plan is not needed. If a conflict is likely, then a written plan must be submitted. The written plan must describe reasonable*

measures to resolve the conflict in favor of the resource [i.e., the listed species]. There are no guidelines to use to evaluate written plans to determine if conflicts are likely. In general, written plans are evaluated to determine 1) if they are complete and 2) if they describe actions to be taken to protect murrelets. In general, conflicts are considered likely for operations within 0.25 mi of murrelet sites, however, local conditions such as topography, timing of the operation, and other factors are also considered. Comments are provided to the operator on the written plan, and the operator is notified that the murrelet is protected under the federal ESA and that compliance with the FPA does not ensure compliance with the federal ESA.

Enforcement authority is very limited for operations near Marbled Murrelet sites. Enforcement can only be taken if a complete written plan is not submitted. There is no ability for the Department [ODF] to take enforcement action if written plans are not followed during operations. Prior to 2003, when the Department [ODF] had the authority to approve or deny written plans, the Department [ODF] had greater ability to require specific protection standards on the ground and could take enforcement authority for an operator not following their written plan.

…The Department [ODF] does not have authority to authorize or to withhold authorization of forest operations. Oregon does not use a permit system for administration of the FPA. A notification system is used. Thus, landowners and operators do not apply for a permit, but instead notify the Department [ODF] prior to conducting forest operations. Administration and enforcement of the FPA is outcome based.

The Department [ODF] cannot require landowners or operators to conduct surveys for wildlife. The Department [ODF] could not conduct surveys on private land without the authorization of the landowner. As previously mentioned, the Department [ODF] cannot deny a landowner their ability to harvest or conduct other operations and thus cannot require that surveys are conducted as a condition prior to operating.

…The [ODF] Private Forest Program has data collected from other sources that can serve as an initial inventory. This data is what is currently used to screen notifications. The existing data contains known locations of nest sites and locations of occupied detections from 1) results from ODF State Forests Program Marbled Murrelet surveys and research studies, and 2) additional sites from unknown sources compiled from ODF district level resource site maps. These data include locations of occupied detections on BLM lands.

…Of the 797 sites [number of sites by ownership class is: Public-Federal = 48, Public-State = 712, Public-City, County, etc. = 5, and Private = 32]…, the large majority represent points on the ground where occupied behaviors were observed. Also included are 38 known nest trees; all located in the Public-State category.

Because the data summarized … is mostly from ODF-sponsored surveys, the distribution by land ownership class is biased towards the Public-State category. Thus, the values are not likely representative of the actual distribution of murrelet sites across the state.

Statewide Planning Goals

Oregon's land use planning program (ORS 197.005 et seq.) is founded upon 19 statewide planning goals covering a range of resources and topics (OAR Chapter 660, Division 015). The statewide planning goals are achieved through local comprehensive planning, whereby cities and counties adopt comprehensive plans consistent with the statewide goals, and zoning and land-division ordinances necessary to implement the plans. The Land Conservation and Development Commission reviews and approves local plans.

In addition to local governments, planning laws apply to special districts and state agencies, and emphasize coordination among different entities to keep plans and programs consistent with one another. Except as provided in ORS 197.277 or 197.180(2), or unless expressly exempted by another statute, ORS 197.180 requires state agencies with programs affecting land use to carry out these programs in accordance with statewide planning goals, and in a manner compatible with local comprehensive plans and land use regulations.

Several statewide planning goals specifically address coastal and ocean uses and resources (Goal 16: Estuarine Resources, Goal 17: Coastal Shorelands, Goal 18: Beaches and Dunes, and Goal 19: Ocean Resources). Under ORS 196, Oregon's Ocean Resources Management Plan and the Territorial Sea Plan relate to these goals and provide further clarification on how articulated policies will be implemented by government agencies. The Territorial Sea Plan was amended in 2013 to include policies governing offshore renewable energy siting in state waters.

In the terrestrial environment, Planning Goal 4 (Forest Lands) recognizes multiple values of Oregon's forest lands. It requires local governments to inventory, designate, and zone forest lands, and to conserve forest lands for forest uses. Planning Goal 5 (Open Spaces, Scenic and Historic Areas, and Natural Resources) requires local comprehensive plans to protect natural resources, including significant wildlife habitat, but ORS 197.277 specifically exempts forest practices under the FPA from any regulation under Goal 5.

State-level Forage Fishery Management

ODFW jointly manages commercial coastal pelagic species fisheries in the Pacific Ocean through the Pacific Fishery Management Council process. Administrative rules contained in OAR 635-004-0375 through 635-004-0379 apply to all fisheries in the Coastal Pelagic and Smelt Species section, and are in addition to and not in lieu of Division 004 General Regulations contained in OAR 635-004-0200 through 635-004-0265. The Coastal Pelagic and Smelt Species section includes regulations for the Sardine, Inland Waters Herring, Yaquina Bay Roe-Herring, Pacific Ocean Herring, Anchovy, and Smelt Fisheries. Market squid are managed under the Coastal Pelagic Species Fishery Management Plan and through the regulations adopted by reference in OAR 635-004-0375. However, market squid are managed as a shellfish when landed in Oregon, and are subject to regulations in the Squid Fishery section in OAR 635 Division 005. Some other marine forage species receive special protections in state waters (0-3 nautical mi offshore) through the *Oregon Forage Fish Management Plan*, and a network of marine reserves and marine protected areas restricts or prohibits take of all marine life in certain areas within Oregon's Territorial Sea (see below). Commercial harvest of krill has been banned in state waters since 2003 (ORS 509.515).

The Oregon Forage Fish Management Plan

In September 2016, the Oregon Fish and Wildlife Commission adopted a management plan for six groups of previously unmanaged forage fish, including Pacific sand lance and osmerid smelts, in state waters (ODFW 2016). The plan extends protections to these species through several approaches, including prohibition of new directed commercial harvest and limits on bycatch in other fisheries. As noted above, similar protections were established earlier in 2016 for federal waters by the Pacific Fishery Management Council and the National Oceanic and Atmospheric Administration-National Marine Fisheries Service.

Marine Reserves and Marine Protected Areas

Oregon completed designation of five marine reserve sites within state waters in 2012 (ORS 196.540 to 196.555, Senate Bill 1510). Each site has a no-take marine reserve, and most also have at least one less restrictive marine protected area. Marine reserves are closed to extractive activities and prohibit all take of fish, invertebrates, wildlife, seaweeds, and ocean development, except as necessary for research or monitoring. Marine protected areas have varying degrees of protection for take and ocean development.

If the Commission determines that any one or more of the three factors described above (OAR 635-100-0105(6)) exist, the Commission proceeds to reclassify the species from a threatened status to an endangered status (OAR 635-100-0111(1)). However, the Commission may choose to not list a species as either threatened or endangered even if it qualifies (see Other Options **below).**

If the Commission determines that none of those three factors exist, uplisting is not warranted and the species' status should remain listed as threatened.

Summary of Information Pertaining to Risk of Extinction

- Best available information indicates that Oregon's Marbled Murrelet population is considerably smaller than it was historically. Although there has been uncertainty regarding demographic model outcomes, current population monitoring from at-sea surveys indicates a variable but significant upward population trend (2.2% per year, 95% CI: 0.9 to 3.4%) during the 2000-2019 period in Oregon.
- The survival and reproduction of the Marbled Murrelet are thought to be most affected by forest habitat alteration; large-scale disturbances; small population size; predation; changes in forage fish populations; and oil spills. Uncertainty remains regarding impacts of climate change to Marbled Murrelet breeding success and population trends because of changes in the marine environment and forested habitat.
- Much of the Marbled Murrelet's historic older forest nesting habitat had been lost prior to 1992 when murrelets were federally listed. Since 1993, policies, plans, and regulations

implemented to protect listed species have resulted in overall increases of Marbled Murrelet nesting habitat. From 1993 to 2017, Marbled Murrelet nesting habitat in Oregon increased 9.9% (net change) across all landownerships combined; most specifically on federal (13.0% net change) and state (43.4% net change) lands. Despite these overall gains in nesting habitat for all landownerships combined in Oregon, losses of Marbled Murrelet nesting habitat (-10.2% net change) occurred on other (private, tribal, county, and municipal) lands from 1993 to 2017.
- Fragmentation of murrelet breeding habitat is shown by the majority of higher probability nesting habitat modeled as scatter and edge nesting habitat (97.1% combined).
- The geographic area used by the Marbled Murrelet in Oregon for breeding is generally restricted to that area of the entire coastline inland about 50 mi (USFWS 1997), mainly within the Oregon Coast Range and Klamath physiographic provinces.
- The Marbled Murrelet is listed as federally threatened in Washington, Oregon, and California. It is listed as threatened in British Columbia under Canada's Species at Risk Act, and state-endangered in Washington and California. In their most recent 5-year status review, the USFWS (2019) reaffirmed the threatened status of Marbled Murrelet across the listed range.

Summary of Factors to Consider if Risk of Extinction is Determined

- Deterioration of primary habitat has not continued since state listing. Since 1993, policies, plans, and regulations implemented to protect listed species have resulted in overall increases of Marbled Murrelet nesting habitat. From 1993 to 2017, Marbled Murrelet nesting habitat in Oregon increased 9.9% (net change) across all landownerships combined; most specifically on federal (13.0% net change) and state (43.4% net change) lands. Despite these overall gains in nesting habitat for all landownerships combined in Oregon, losses of Marbled Murrelet nesting habitat occurred on other (private, tribal, county, and municipal) lands (-10.2% net change) from 1993 to 2017.
- Overutilization of the species and/or its habitat for scientific or educational purposes is not occurring and is not likely to occur. There are some concerns about recreational use of murrelet habitat since campgrounds, trails, and other human activities in or near forests can attract predators, especially corvids, potentially leading to higher nest predation rates. There is currently no direct evidence that overutilization of murrelet prey by commercial or recreational fishing is occurring in Oregon.
- In their 5-year status review, the USFWS (2019) concluded that the threat posed by inadequacy of existing mechanisms have been reduced since Federal ESA listing in 1992. Our review also found that those threats have decreased since federal and state listing.

Other Options Not to List as Endangered

Pursuant to OAR 635-100-0105(7), the Commission may choose to not list a species as either threatened or endangered even if it qualifies for listing. In this current evaluation, even if the Commission determines that the risk of extinction criterion and at least of one of three additional factors is met, the Commission may still decide not to uplist a species from threatened to endangered. An analysis of OAR 635-100-0105(7) is presented below. That rule provision reads:

Notwithstanding any other provision of OAR 635-100-0100 to 635-100-0130, the Commission may decide not to list a wildlife species as threatened or endangered that would otherwise qualify to be so listed within this state if the Commission determines that:

(a) the future of the species is secure outside this state;
(b) the wildlife species is not of cultural, scientific, or commercial significance to the people of this state;
(c) the species has been listed as threatened or endangered pursuant to the federal ESA;
(d) the species is a candidate species under the federal ESA;
(e) the species has been petitioned for listing under the federal ESA;
(f) the responsible federal agency has determined that the species does not warrant listing as a threatened or endangered species under the federal ESA; or
(g) the species is currently on the Department's sensitive species list (OAR 635-100-0105(7)).

(a) Security of the Species Outside the State

The Marbled Murrelet is listed as threatened in Washington, Oregon, and California under the federal ESA. It is state-endangered in both Washington and California, and considered threatened by the Canadian Government where it occurs in British Columbia. The species is not currently listed in Alaska, but recent evidence suggests declines of that population by about 70% from the 1980s to 2006 (Piatt et al. 2007). The state of Washington has shown a declining population trend between 2001 and 2019 (-3.9% per year; 95% CI; -5.4% to -2.4%) (McIver et al. 2021).

The future of the species is not secure outside of Oregon.

(b) Cultural, Scientific, and Commercial Significance

It is the policy of the State of Oregon "that wildlife shall be managed to prevent the serious depletion of any indigenous species" (ORS 496.012). This is a recognition that all native species are important to the current and future citizens of Oregon.

Historically, the Marbled Murrelet represented what was perhaps the greatest enigma in Northwest ornithology because its nesting areas were unknown (Binford et al. 1975). The first well-described tree nest was not discovered until 1974 (Carter and Sealy 2005). No other North American bird has such a long and extensive history on the discovery of its breeding habits (Carter and Sealy 2005).

The Marbled Murrelet is still of great scientific interest because of its unique habitat requirements. While it is now one of the best-studied seabirds in North America (Burger 2002), it remains poorly understood in many aspects of its life history. There are numerous basic research questions remaining, among them why birds frequent nesting areas during the non-breeding season (Naslund 1993), many aspects of marine resource use (Lorenz et al. 2016), and the extent of wintering range (Nelson 1997). Due to their association with coastal old-growth and late-successional forests, Marbled Murrelets are also increasingly the focus of applied research and management efforts.

The former Pacific Northwest Bird and Mammal Society (now the Society for Northwestern Vertebrate Biology to address fishes, amphibians, and reptiles as well as birds and mammals) used the Marbled Murrelet as its logo for over 60 years, and its scientific journal was named *The Murrelet* (published three times a year from 1920-1988).

Seabirds feature prominently in the cultures of many indigenous peoples of the Pacific Northwest Coast. They are significant in subsistence, ceremonial, spiritual, and other cultural contexts (de Laguna 1972, Hunn et al. 2002, Moss 2007, COSEWIC 2012). The Marbled Murrelet is recognized as a particularly important figure in the history and mythology of the Tlingit of southeast Alaska (Swanton 1909 in Piatt et al. 2007, de Laguna 1972, Piatt et al. 2007). The murrelet is represented on clan regalia (including a ceremonial hat) and artwork and in the naming of Tlingit clan houses (de Laguna 1972, Piatt et al. 2007). According to de Laguna (1972), Tlingit did not eat the Marbled Murrelet because “it was Raven’s mother”.

The Marbled Murrelet is a focal species in the contemporary forest management and conservation plans of several Oregon tribes. For example, the Confederated Tribes of Siletz Indians and the Confederated Tribes of the Coos, Lower Umpqua, and Siuslaw Indians are designated natural resource trustees, along with state and federal agencies, for damages associated with the New Carissa oil spill that occurred in 1999. In 2007, the Confederated Tribes of Siletz Indians were selected to steward nearly 3,900 ac of Coast Range forest in perpetuity for the benefit of Marbled Murrelets and other values consistent with recovery goals. The property was transferred to the tribe as part of a court- approved settlement agreement to mitigate for resources lost to that spill. Funds to acquire property came from the U.S. Coast Guard’s National Pollution Fund Center through the OPA, and allowed the tribe to recover some ancestral lands.

While it is not a commercially valuable game animal, the Marbled Murrelet’s forest nesting habitat and some of its prey species are important economically. Outdoor or recreation-based industries and local communities may also derive benefits from the species through revenue generated by visitors engaging in wildlife viewing (see Dean Runyan Associates 2009). For example, several Oregon-based ecotourism companies advertise possible sightings of the Marbled Murrelet on guided birding tours. The murrelet is a sought-after bird species for birders, and ongoing pelagic birding trips make a point of showing murrelets to everyone on each tour (e.g., Oregon Pelagic Tours).

The Marbled Murrelet has cultural and scientific significance to the people of Oregon. Its attraction to birders may also contribute to local economies.

(c) Federal Status

The Marbled Murrelet is listed as threatened under the federal ESA.

In addition, before making a determination not to list pursuant to subsection (c), the Commission shall evaluate whether the federal listing, categorization, or other action regarding the species adequately protects that species in Oregon (OAR 635-100-0105(8)).

Under the federal ESA, take (to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct) of Marbled Murrelets is prohibited unless authorized by permit from the USFWS. This definition of take includes harm caused by significant habitat modification or degradation. It applies to federal, state, and other (private, tribal, county, and municipal) lands. Much of the Marbled Murrelet's historical older forest nesting habitat had already been lost prior to 1992 when murrelets were federally listed. Since 1993, however, policies, plans, and regulations implemented to protect listed species has resulted in overall increases of Marbled Murrelet nesting habitat in Oregon), most specifically on federal and state lands (Lorenz et al. In press). Despite these overall gains in nesting habitat for all landownerships combined in Oregon, losses of Marbled Murrelet nesting habitat occurred on other landownerships (private, tribal, county, and municipal) from 1993 to 2017, and impacts from fragmentation also occurred on all landownerships (Lorenz et al In press).

(OAR 635-100-0105(7) (d)-(g) Not Applicable

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