TERRESTRIAL HABITAT MANAGEMENT RECOMMENDATIONS FOR MARBLED MURRELETS

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Marbled Murrelet Technical Committee

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GLOSSARY

Words and terms that appear in bold caps at first mention in this document (not including headers) are included in this glossary. The majority of these definitions are derived from *A Revised Protocol for Surveying Marbled Murrelets in Forests* (PSG Technical Publication 6, https://pacificseabirdgroup.org/psg-publications/technical-publications/; hereafter referred to as the *2024 Inland Survey Protocol*). It may help to refer to the *2024 Inland Survey Protocol* for additional details for some terms.

Audio-Visual Survey: The required method for determining murrelet use or occupancy in relation to proposed projects that may negatively impact murrelets or their terrestrial **Habitat (Nesting Habitat)**, primarily timber harvest-related projects. Audio-visual surveys can also be useful for monitoring murrelet activity levels, locating nests, establishing murrelet use patterns, or for research purposes such as characterizing habitat.

Breeding Season: the portion of the calendar year defined by the earliest known nesting and latest known fledging dates. The breeding season extends 24 March – 15 September in California, 1 April – 15 September in Oregon and Washington, 15 April – 15 September in British Columbia, and 15 May – 5 August in southeastern and south-central Alaska.

Canopy Height (Canopy): in relation to murrelet behaviors and weather conditions during surveys, is the height of the tallest tree within the station effective area. See *Appendix J: Data Forms and Instructions* in the *2024 Inland Survey Protocol*. The term canopy may also refer to the forest layer comprised of the crowns of the overstory trees.

Conservation Zone: Six conservation zones were established in the Marbled Murrelet Recovery Plan (USFWS 1997), for that part of the murrelet's range south of Canada. Zones 1 and 2 are in Washington (Puget Sound and western coast range, respectively), Zone 3 includes the northern and central Oregon coast range, Zone 4 includes southwestern Oregon and northern California (Siskiyou coast range), Zone 5 includes south of Cape Mendocino to San Francisco Bay (Mendocino), and Zone 6 includes the Santa Cruz Mountains. See Lorenz et al. (2021) and USFWS (1997) for maps of these zones.

Contiguous Habitat: For purposes of defining **Survey Areas**, within 402 m (0.25 mi) of the Project Footprint, contiguous habitat is all **Habitat** that is either connected to (within 200 m [656 ft] of) the **Project Footprint** or within 200 m (656 ft) of habitat connected to the project footprint. For any other purpose, contiguous habitat is all areas of habitat that are connected to (within 200 m [656 ft] of) each other.

Detection (Detection Type): Murrelet detections can be classified into three categories: occupied; presence; or no detections, depending on the types of behavior observed. **Presence Detection** and **Occupied Detection** are defined below.

False Omission Rate: The False Omission Rate (FOR) quantifies: If the decision was that the area is not occupied, what is the chance that it was in fact occupied? See *Appendices A and B* in the *2024 Inland Survey Protocol* for more details.

Forest Stand: a contiguous group of trees relatively uniform in composition, age class, location, origin, size class, structure, and distribution.

Habitat (Nesting Habitat): Coniferous forest with one or more **Platform Trees**, where the surrounding forest **Canopy** (surrounding trees or within the platform tree itself) provides some cover and functional protection.

Hard Edge: An edge created by the dissimilarity of two cover types, such as a recent clearcut next to older forest (van Rooyen et al. 2011). A hard edge in this study, in the southwestern British Columbia coastal western hemlock (*Tsuga heterophylla*) biogeoclimatic zone, occurred in instances where the heights of trees in adjacent areas differed by at least 7 m (23 feet). A forest edge with trees younger than approximately 15 years adjacent to older forest is also defined as a hard edge (Malt and Lank 2007, van Rooyen et al. 2011).

Hazard Tree: A live or dead tree with damage or defects that potentially could cause injury or death to people or damage to property.

Megafire: A wildfire of such exceptional intensity that it would not likely have occurred if the variables that determine fire severity had not been altered by climate change.

Natural Edge: A forest edge that has developed naturally within a stand, for example by a large tree falling creating a gap, a river, an avalanche chute, or a naturally occurring meadow (Malt and Lank 2007, van Rooyen et al. 2011). A natural edge, in the van Rooyen et al. (2011) southwestern British Columbia coastal western hemlock biogeoclimatic zone study, occurred in instances where the heights of trees in adjacent areas differed by approximately 4 m (13 ft).

Not Occupied Area: If none of the behaviors or conditions for occupancy designation were detected anywhere in the **Survey Area** after completing the required number of surveys, the **Survey Area** is designated as not occupied for a period of five years.

Occupancy Classification: An occupancy classification of occupied or **Not Occupied** (formerly unoccupied**)**, based on observed murrelet behaviors, applies at the scale of the entire **Survey Area**. Occupied results from one or more **Survey Strata** [site] within a **Survey Area** apply to the entire survey area. However, when delineating an **Occupied Area** from these results, all **Contiguous Habitat** within 402 m (0.25 mi) of the **Project Footprint** should be protected at a minimum, to maintain contiguity of **Habitat** for murrelet survival and recovery.

Occupied Area (Occupied Site): Survey Area where at least one occupied behavior or condition is detected or, if using the **Presence Approach**, three or more survey visits with at least one **Presence Detection** of any type, have been documented. Results from any **Survey Strata** [site] within a **Survey Area** apply to the entire **Survey Area**. Occupied area**s** include the survey area and all **Contiguous Habitat** within 402 m (0.25 mi) of the **Project Footprint** at a minimum. An occupied area is a nesting area which is delineated as such in perpetuity, so long as the area continues to support **Habitat**.

Occupied Detection: Behaviors indicative of occupancy, or occupied behaviors, are associated with visual **Detections** of murrelets below the forest **Canopy**, circling above the Canopy (≤3 canopy heights; see the *2024 Inland Survey Protocol* for more details), or audio detections indicating a murrelet is close to the surveyor or stationary in a tree.

Occupied Habitat: Habitat where one or more **Occupied Detections** or three or more survey visits with at least one **Presence Detection** were recorded.

Occupied Only Approach: A survey approach in which one **Detection** of an occupied behavior (e.g., subcanopy flights, circling, and landings) at any station within the **Survey Area** leads to an **Occupied Classification**. This approach requires more survey visits than the **Presence Approach**.

Platform (Nest Platform): A relatively flat surface >10 cm (4 in) in diameter created by a wide bare branch, a mistletoe infection or witch's broom, broken top trees, or other deformity, often with nesting substrate like moss, or lichen, needles, or other debris. Platforms are located on a branch or other surface >10 m (33 feet) high in the live crown of a tree.

Platform Tree: A tree of any age that provides a branch or branches with structures appropriate for murrelet nesting.

Presence Approach: A survey approach in which three or more survey visits with at least one **Presence Detection** or one **Detection** of occupied behavior leads to a **Survey Area** being classified as occupied. This approach requires fewer survey visits than the **Occupied Only Approach**.

Presence Detection: Murrelet **Detections** classified as presence detections include: (1) audio detections (except for below-**Canopy,** non-vocal detections of jet sounds or wingbeats, or stationary audio detections, which are classified as **Occupied Detections**); (2) visual detections of direct (straight line) flights above the **Canopy**; (3) visual detections of murrelets circling at greater than three **Canopy Heights**; or, (4) visual detections of murrelets flying in less than a 45-degree arc at a height greater than one **Canopy**. According to the *2024 Inland Survey Protocol*, if a murrelet is seen circling >3 **Canopy Height** with > 45 degree arc, consult your regulatory agency. See *2024 Inland Survey Protocol* for more explanation.

Project Footprint: Geographic boundary of the proposed action, including timber sales, planned new roads or quarries, etc.

Reiteration: A vertical stem that takes the form of a miniature tree and arises from a horizontal branch of a larger tree.

Site-potential Tree Height: The average maximum height of the tallest dominant trees (200 years old or more) for a given site class. Site class is a classification of the relative productive capacity of a forested area based on tree height or volume that is attained at a given age.

Soft Edge: A forest edge such as that which has developed with a regenerating forest (e.g., of about 15-40 years old; Malt and Lank 2007, van Rooyen et al. 2011) next to older-aged forest. A soft edge, in the van Rooyen et al. (2011) southwestern British Columbia coastal western hemlock biogeoclimatic zone study, occurred in instances where the heights of trees differed by less than 1 m (3 ft).

Survey Area: The fundamental unit at which surveys are conducted and **Occupancy Classification** is determined. See **Occupied Area** above and text below for how to apply the results in practice.

Survey Strata (singular Stratum): a survey area can be divided into one to three subunits, called strata, to ensure that the survey effort is distributed more evenly across the survey area. Comparable to survey sites in terminology of the 2003 version of the survey protocol.

INTRODUCTION

This document provides forest management and survey strategy recommendations intended to contribute to the conservation of Marbled Murrelets (*Brachyramphus marmoratus*; murrelet) and their terrestrial **Habitat (Nesting Habitat)**[1], based on the best available science and the collective knowledge of the authors. The Federal, State, and Provincial listings of the murrelet in Washington, Oregon, California, and British Columbia, coupled with continued habitat loss (Lorenz et al. 2021, Valente et al. 2021), emphasize the need for long-term retention of habitat for the conservation and recovery of the species. The loss and fragmentation of terrestrial habitat, both historically and contemporarily, is one of the biggest drivers of the species' status, negatively impacting reproduction, abundance, and recruitment (USFWS 1992, Raphael et al. 2002a). Timber harvest on nonfederal lands has been the majority source of that loss and fragmentation, particularly since the federal listing of the species in 1992 (Valente et al. 2023). Habitat loss and fragmentation directly impacts murrelets by reducing nest site availability and by displacing them from their nest sites, which, for site-faithful species such as murrelets can result in nest abandonment, delayed breeding, failure to breed in subsequent years, and nest failure due to egg, chick, or adult predation (Raphael et al. 2002a). Additionally, timber harvest-related activities within or adjacent to habitat which occur during the **Breeding Season** may lead to aborted, missed, or delayed feedings which can result in juvenile mortality, and increased energetic costs due to increased vigilance by adults, which can have negative impacts on reproductive success (Hébert and Golightly 2006, USFWS 2015).

So as not to exacerbate the impact that timber harvest has already had and is having on murrelets, this document describes specific measures that would minimize the future loss and fragmentation of terrestrial habitat, including strategies for conducting surveys, strategies for delineating **Occupied Areas,** maintaining or improving the integrity of the forested landscape, maintaining and buffering **Occupied Habitat**, enhancing and creating habitat, reducing impacts from human activities (e.g., timber harvest-related activities, construction or maintenance of human infrastructure, etc.), and minimizing disturbance and disruption to murrelets, particularly during the breeding season (e.g., recreation).

The habitat management recommendations contained in this document were initially drafted by the Pacific Seabird Group's Inland Survey Protocol Subcommittee (a subcommittee of the Marbled Murrelet Technical Committee), with the intent that they would be included as a chapter in the recently revised *A Revised Protocol for Surveying Marbled Murrelets in Forests* (PSG Technical Publication 6, https://pacificseabirdgroup.org/psg-publications/technical-publications/; hereafter referred to as the *2024 Inland Survey Protocol*). In 2023, the subcommittee agreed to separately publish recommendations for habitat management in this document, under the provision that both documents would reference each other. We consider this document to be a companion document to the survey protocol, each used in conjunction with the other. This document is intended for use by practitioners who are: (1) using the *2024 Inland Survey Protocol*; (2) using the 2003 survey protocol (Evans Mack et al. 2003) under temporary "legacy" scenarios; or (3) assuming occupancy of murrelet habitat on their managed lands and foregoing

[1] Terms used in this document are bolded and capitalized at first mention and are defined in the Glossary. These terms appear in normal fonts in all subsequent uses.

surveys. It is intended to provide recommendations for all who are responsible for managing inland murrelet habitat.

This document builds from the following sources: the Marbled Murrelet Recovery Plan (Recovery Plan; USFWS 1997), the U.S. Fish and Wildlife Service (USFWS) listing decision (USFWS 1992), Critical Habitat Rules (USFWS 1996, 2011, 2016), the 5-year review (USFWS 2019), the *2024 Inland Survey Protocol*, input from species experts, and relevant scientific literature. The Recovery Plan included the following objectives: "(1) stabilizing and then recovering the population by maintaining or increasing productivity and removing or minimizing threats to survivorship, and by maintaining or increasing nesting success by maintaining or increasing marine and terrestrial habitat; (2) providing habitat conditions in the future that will allow the continued existence of viable populations; and (3) gathering data for developing scientific delisting criteria." The Recovery Plan identified stabilizing and increasing habitat quality and quantity as the key to stopping population decline. In the listing decision, the USFWS recognized habitat loss and fragmentation as the major factors causing the decline of murrelet populations (USFWS 1992; also see Chapter 1: *Species Status* in the *2024 Inland Survey Protocol*). Threats identified in the Recovery Plan and listing decision in the 1990's remain today.

Marbled Murrelets, like most seabirds, have a habitat-split strategy where they nest and forage in two different habitat types during the breeding phase of their life cycle. Because they depend on more than one habitat type, especially during the breeding season, seabirds are believed to be more sensitive (than non-habitat-split species) to changes in their nesting and foraging habitats (Betts et al. 2020). Their marine and terrestrial ecosystems collectively support murrelet populations, such that maintaining both functional forests and functional marine ecosystems is critical to the species' survival and recovery.

Murrelets have high fidelity to their nesting sites; forested areas throughout their range first found to be occupied in the 1980s are still occupied today (e.g., Bradley 2002, Nelson and Wilson 2002, Barbaree et al. 2014). Within nesting sites, murrelets can use multiple nest trees within and among years and co-occur with other murrelets. Social information (vocalizations of other murrelets) appears to influence breeding site selection and likely contributes to long-term stand occupancy (Valente et al. 2021). Because of these factors, an occupied stand is considered occupied in perpetuity, so long as the area continues to support habitat. Protecting entire areas of habitat is imperative for successful reproduction, and improving the quality and/or increasing the quantity of habitat at a nest site may help improve that success.

The following actions are essential for the conservation of the murrelet and the terrestrial habitats upon which the species depends:

- delineate occupied areas;
- protect all habitat;
- maintain and enhance (improve the quality and/or increase the size of) forested areas adjacent to habitat (see *Minimizing Edge Effects Through Buffers*);

- maintain and enhance large blocks of contiguous forest cover (maximize stand size and minimize fragmentation; USFWS 1997);

- minimize predation and predator numbers in and near habitat (see *Minimizing Edge Effects Through Buffers*);

- minimize the effects of disturbance near habitat (see *Minimizing Disturbance and Disruption*; USFWS 1997, USFWS 2015, USFWS 2020); and

- avoid or minimize adverse impacts to murrelet habitat due to forest fires, for example by preventing **Megafires** (see *Managing and Reducing Threats of Megafires*).

While this document focuses on inland habitat, it must be recognized that the conservation of marine habitat is also central to the conservation and recovery of murrelet populations (Lorenz et al. 2016, 2017). Therefore, strategies to protect and enhance marine resources to maintain healthy marine food webs will also be critical to ensure murrelet persistence (see details on marine reserves and other marine protected areas here: https://nmsmarineprotectedareas.blob.core.windows.net/marineprotectedareas-prod/media/archive/pdf/helpful-resources/factsheets/mpa_classification_may2011.pdf).

HABITAT MANAGEMENT RECOMMENDATIONS

Selecting Habitat and Conducting Surveys

The *2024 Inland Survey Protocol* includes a suite of recommendations for conducting inland Marbled Murrelet surveys. In Chapter 2 of the *2024 Inland Survey Protocol*, options for implementing certain aspects of the survey method strategy are offered. In other places, the *2024 Inland Survey Protocol* is clear regarding its recommendations for a single survey strategy, such as using a **False Omission Rate** (FOR) of 0.05 (see *Statistical Analysis Overview* and *Appendix A* in the *2024 Inland Survey Protocol*). Where strategy options are mentioned, the decision to adopt one versus another strategy should be made in consultation with the appropriate regulatory agency.

This document clarifies when one strategy has a higher likelihood of achieving PSG's Marbled Murrelet conservation goals. These strategies include: (1) always using the definition of habitat from Chapter 1 of the *2024 Inland Survey Protocol*; (2) conducting additional surveys in certain situations, described in more detail below; and (3) managing unsurveyed habitat as if it were occupied.

We recommend using the definition of habitat from Chapter 1 of the *2024 Inland Survey Protocol* (coniferous forest with one or more platform trees, where the surrounding forest canopy [surrounding trees or within the platform tree itself] provides some cover and functional protection) and not using alternative criteria to define habitat; See the *Nesting Habitat* section in the *2024 Inland Survey Protocol*), as that may lead to omitting habitat from the survey. Failure to identify and survey all murrelet habitat could lead to missed **Detections** and misclassification of survey areas, which in turn may lead to harvest of occupied habitat. The more occupied habitat that is retained now, the greater the likelihood of species conservation in the future, particularly considering the fact that climate change is predicted to lead to significant losses of terrestrial murrelet habitat (USFWS 2019).

Similar to using the above habitat definition, we recommend the use of a 0.05 FOR (or lower) as is recommended in the *2024 Inland Survey Protocol*. Using it ensures an accurate survey area classification at least 95% of the time, while also achieving survey efficiency. In this manner, only 5% or fewer determinations of **Not Occupied** would be in error, and occupied habitat would be conserved. The 5% value is a common statistical criterion, which in this instance balances error rate and required survey effort.

To improve the chances of accurately determining the occupancy status of a survey area, additional surveys within a season or even additional years of survey may be needed. For example, under the *2024 Inland Survey Protocol*, if an observer only saw a partial arc (<45-degree arc at >1 canopy) of a murrelet on the last visit of a season, and no detections were recorded on other visits, only presence will have been documented in that survey area. Similarly, if fewer than three surveys with presence are recorded over the two years of surveys, only presence will have been recorded. In such circumstances, we recommend following up with additional surveys in the current and/or subsequent year(s) and contacting your regulatory agencies. An area with murrelet presence could in fact be occupied and follow up surveys could help verify the area's actual status. Poor ocean years and other factors (e.g., murrelet health, habitat changes) can affect activity of murrelets at inland sites (Betts et al. 2020), resulting in inaccurate area status. We recommend postponing surveys during and in the year following poor ocean years or adding years of surveys (i.e., a total of 3 or more consecutive years) to determine the true occupancy status of survey areas. In situations such as the examples given above, but not limited to only these examples, we recommend land managers add additional surveys or survey years and/or consult with their regulatory agencies.

Because both retaining and growing habitat are key to murrelet conservation, the management of unsurveyed habitat is also key. Any areas of habitat that have yet to be surveyed should be managed as though they are occupied, for purposes of species conservation and avoidance of take under the Endangered Species Act. Land managers can avoid survey costs entirely, simply by assuming unsurveyed habitat is occupied. This is a strategy employed by at least one large Federal landowner within the range of the murrelet today. By planning projects in this way, both time and money are saved, and murrelet habitat is conserved.

Application of Survey Results to Designate Occupied Areas

Delineating Occupied Areas

The *2024 Inland Survey Protocol* provides a statistically valid method, through the use of **Audio-Visual Surveys**, for detecting murrelets and determining the **Occupancy Classification** of a survey area with high confidence (see discussion of 0.05 FOR in the previous section, above). The results from the protocol surveys should then guide the protection, conservation, and management of murrelets and their habitat. When a survey area has been determined to be occupied, we recommend delineating **Occupied Areas** that encompass the survey area and all **Contiguous Habitat** within 402 m (0.25 mi) of the **Project Footprint**, at a minimum, to maintain contiguity of habitat for murrelet survival and recovery. As stated earlier, we do not recommend using an alternate definition of habitat; instead we recommend that the occupied area include all coniferous forests with one or more platform trees, where the surrounding forest canopy (surrounding trees or within the platform tree itself) provides some cover and functional protection (canopy cover, canopy layers, complex canopy structure; Nelson and Hamer 1995, Hamer et al 2021). Contiguous habitat is all areas of habitat that are connected to (within 200 m [656 ft] of) each other.

As stated in Chapter 1 of the *2024 Inland Survey Protocol*, larger, contiguous blocks of habitat provide critical, higher quality nesting habitat for murrelets by allowing co-occurrence (multiple pairs of birds using the same **Forest Stands** within the same year) and by providing multiple options for nest tree selection within and between years (pairs will use multiple trees in a stand and not nest in the same tree every year; Nelson and Peck 1995, Burger et al. 2009; Nelson unpublished data). Larger blocks not only increase the amount of interior core habitat at the stand level by providing more cover (canopy cover, canopy layers, complex canopy structure), but also help reduce predation and prevent microclimate impacts (see *Minimizing Edge Effects through Buffers*) such as increased temperatures and changes in moss abundance (e.g., USFWS 1997, Van Rooyen et al. 2011, Frey et al. 2016, Betts et al. 2017, Valente et al. 2021; see below). The importance of social information (vocalizations of other murrelets) and conspecific attraction in nest site selection also indicate that larger blocks of nesting habitat are key to supporting murrelet populations (Valente et al. 2021).

Based on the biology of the species, we recommend the following when delineating an occupied area:

- delineate all the habitat in the survey area plus all contiguous habitat within 402 m (0.25 mi) of the project footprint (or other proposed activities), at a minimum (Figure 1A-F);

- include all habitat up to the stand edge even if platform trees do not extend to the edge (Figure 1D). In some cases, it may not be obvious where the stand edge is, in which case land managers should consult with their regulatory agencies to delineate the occupied area;

- include a 100-m (328-ft) buffer around all occupied areas (see *Minimizing Edge Effects through Buffers* below; Figure 1E-F)*;*

- if all platform trees in an occupied area form a linear feature (e.g. riparian strip), include portions of the surrounding forest, in addition to a 100-m (328-ft) buffer, to create a broader delineation of habitat (e.g., more forest adjacent to the riparian area). See *Minimizing Edge Effects through Buffers*; and

- consider topographic boundaries and extend the delineation of an occupied area out to a ridge, a road, or a river rather than ending at the stand edge to maintain the integrity and function of the contiguous habitat and to make the occupied area easily identifiable for managers and regulators.

In some situations, land managers may choose to extend the delineation of an occupied area to include habitat that has not been surveyed or that has been surveyed and not determined to be occupied. Following are examples of situations where including habitat beyond the survey area and the habitat within 402 m (0.25 mi) may contribute to habitat quality within an occupied area survey area that has been determined to be:

- where contiguous habitat (unsurveyed or not occupied) continues beyond 402 m (0.25 mile) from the project footprint (Figure 1F);

- where including discontiguous habitat would contribute to the functionality and integrity of the occupied area, by maintaining a larger forested area on the landscape;

- where survey areas overlap but not all survey areas are classified as occupied; and

- where the size of a project footprint prompts the need to establish two or more survey areas, but not all survey areas are determined to be occupied based on survey results. In these situations, consider the landscape context and the contiguity of habitat when delineating the extent of the occupied area, so as to protect the integrity of habitat at the landscape scale. For the purpose of murrelet conservation, the maximum amount of habitat should be retained on the landscape.

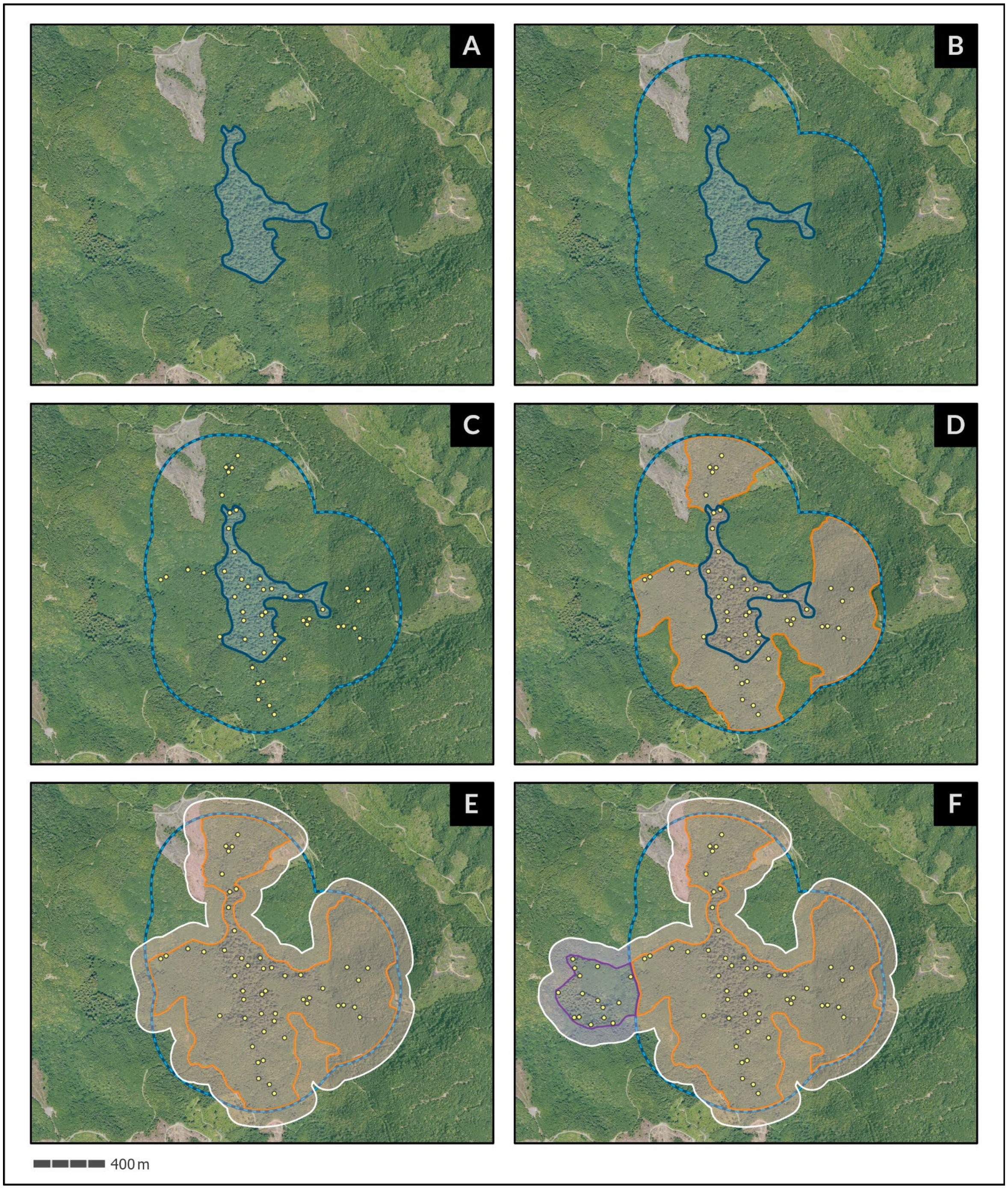

Figure 1. Hypothetical proposed timber harvest, showing: (A) project area (timber harvest unit) [blue line]; (B) 406-m (0.25-mi) boundary around project area [dashed blue line]; (C) platform trees [yellow dots] within the project area and the 406-m boundary; (D) contiguous forested habitat within the project area and the 406-m boundary, delineating the survey area [orange line]; (E) assuming occupancy by murrelets, 100-m (328-ft) buffer around survey area, delineating the occupied area [white line]; and (F) habitat that is contiguous with the occupied area, occurring beyond the 406-m boundary [purple line] and 100-m buffer [white line].; this area could include habitat that has not been surveyed or that has been surveyed and not determined to be occupied.

Determining whether to include additional habitat in the delineation of the occupied area will be informed by many factors, including:

- murrelet observations (the number, type, and location of detections) within the survey area and in nearby areas (e.g., adjacent survey areas, contiguous habitat outside of survey area or between occupied survey areas);
- limitations to visibility or audibility caused by survey station location;
- the quantity and quality of habitat in the surrounding forested landscape;
- topography; and
- land ownership patterns.

The relevant regulatory agency should be consulted for further guidance.

Additionally, while occupied areas include nest sites, they may also include additional terrestrial habitat used by murrelets as part of their life history (Nelson 1997, 2020). For example, in British Columbia, Oregon, and California, murrelets have been observed repeatedly landing in trees without **Platforms (Nest Platforms)** or in areas otherwise unsuitable for nesting that are contiguous with or near habitat (J. Deal, S.E. McAllister, S.K. Nelson, S.W. Singer, pers. comm.). These landings involved more than one murrelet, occurred on multiple occasions at the same locations, and birds remained in these trees for a period of time (a few seconds to about 45 minutes). Such landings may occur outside the nesting season. Thus, places such as these, where birds engage in courtship or other breeding-related activities, or in activities that otherwise serve to maintain a bird or birds' connection to habitat, are important to the species' life history and likely to contribute to increased nesting success. Similar to the *2024 Inland Survey Protocol* (see *Occupancy Classification* section in that document), where landing in trees is an occupied behavior, we recommend occupied habitat delineations in these areas be applied using the same methods.

To improve murrelet conservation, it is important to expand the distribution of large blocks of contiguous older forest (≥80 years) throughout the listed range (USFWS 1997). This will allow for an improved population distribution within each **Conservation Zone** and may help mitigate current and future climate change impacts to terrestrial murrelet habitat, including fire, landslides, drought, windthrow, forest diseases, and insect infestations. Climate change is altering, and predicted to further alter, western forests within the range of the murrelet due to increased temperatures, changes in precipitation timing and amount, extended fire seasons, increased fire severity, increased episodes of flooding and landslides, increased forest disease and insect outbreaks, and changes in tree species composition (e.g., Littell et al. 2014). Working now to improve the distribution, abundance, and quality of nesting habitat will help mitigate current and future impacts of climate change and improve the likelihood of conservation of the murrelet. Resisting the effects of climate change may not always be successful; resist-adapt-direct (RAD) management (Schuurman et al. 2020) may be needed to fully contribute to long-term murrelet survival and recovery.

Delineating Not Occupied Areas

Follow guidance in the *2024 Inland Survey Protocol* under *Classification of Survey Areas* to determine if the survey area is occupied or not occupied. To best conserve murrelets and their habitat, a determination of not occupied based on surveys should only apply to the area surveyed. This is especially important if an alternative definition of habitat was used during protocol-level surveys (i.e., not using one tree with one platform in a stand as the definition of habitat; See *2024 Inland Survey Protocol*).

How Long Do Survey Results Apply?

If a survey area is determined to be occupied then it should be classified as occupied indefinitely to provide habitat in the long term, so long as the area continues to support nesting habitat (see *Occupancy Classification* in Chapter 2 of the *2024 Inland Survey Protocol*). The designation of occupied habitat in a forest implies that the area serves as a breeding location for murrelets. Murrelets have high breeding site fidelity; occupied areas monitored for more than 30 years have remained occupied (e.g., Bradley 2002, Nelson and Wilson 2002, Barbaree et al. 2014). Land managers should consult with regulatory agencies if conditions within an occupied area have changed significantly such that it no longer functions as habitat (e.g., due to fire or catastrophic wind events).

To account for variability in availability of forage fish in marine foraging habitats and associated impacts on breeding efforts on land (e.g., Betts et al. 2020), survey areas designated as not occupied under the survey protocol reflect the status of the survey area only within five years of when the surveys were conducted. If five or more years have passed since surveys resulted in a not occupied designation, then habitat needs to be resurveyed before a timber harvest or planned management activity (e.g., blasting, building infrastructure) can proceed. If murrelets are detected in the survey area any time during or after the five-year period following a not occupied classification, then the survey area and all contiguous habitat within 402 m (0.25 mi) of the timber sale/project boundary warrants a change in classification from not occupied to occupied. Consult with your regulatory agencies regarding any changes in occupied area designation.

Data Sharing and Coordination with Adjacent Land Managers

Sharing survey results (occupied, presence, no detections) and coordinating with adjacent land managers to delineate and appropriately manage occupied areas are highly recommended. Data sharing can maximize protection of murrelets and occupied habitat and can minimize and/or lead to efficiencies and cost savings in survey and management efforts. As the *2024 Inland Survey Protocol* is implemented, consistent data collection and consolidation of Federal, State, and private data into shared databases (for all surveys including occupied, presence, and no detections) will allow for detailed and up to date statistical analysis in the future, which will inform the next iteration of the protocol (see *Data Collection and Reporting* in Chapter 2 of the *2024 Inland Survey Protocol*), as well as improve management of murrelet habitat and species status. A data template and information about where to submit data can be found at https://pacificseabirdgroup.org/psg-publications/technical-publications/. Similarly, data collected at sea on the distribution and abundance of murrelets nearshore from California to Washington should be archived in the North Pacific Pelagic Seabird Database (NPPSD; https://www.usgs.gov/centers/alaska-science-center/science/north-pacific-pelagic-seabird-database), the largest repository of at-sea marine bird data in North America, where it can be used to assess changes in abundance and distribution with respect to changes in marine habitat quality (Drew et al. 2005). It is also expected that the next iteration of the protocol will benefit from continued research on ocean conditions, specifically the effect of multiple years of poor ocean conditions on inland breeding and the ability to determine occupancy with increased climate change effects (Betts et al. 2020).

Maintaining and Managing Occupied Areas and the Integrity of the Landscape

This section will review techniques for managing existing Marbled Murrelet habitat and developing new habitat. Human activities and infrastructure often result in predictable effects on murrelet habitat, while stochastic events, such as wildfires and windstorms, can cause changes to habitat unexpectedly. By incorporating considerations for the Marbled Murrelet into habitat management decisions, whether occurring proactively or reactively, we expect the landscape would better support murrelet nesting in the long term. The topics in this section highlight certain aspects of murrelet habitat whose importance has been emphasized by the USFWS in both their listing rule and critical habitat rules including platform trees and the forested areas surrounding them (USFWS 1992, 1996, 2011, 2016).

Across forest land ownerships within the range of the murrelet, maintaining and creating large blocks of functional, contiguous habitat is important for murrelet survival and recovery (USFWS 1997). Forested areas containing habitat should be managed to maintain the integrity of the older-tree component and to minimize predation, blowdown, and microclimate effects (Burger 2002, Raphael et al. 2002a, Meyer and Miller 2002, McShane et al. 2004, Nelson et al. 2006, Raphael et al. 2015, 2016; Wilk et al. 2016). Key to these goals are avoiding harvest within occupied areas, minimizing fragmentation of habitat throughout watersheds containing occupied sites, maximizing the canopy cover of mature and young forest areas adjacent to occupied areas, and incorporating no-cut buffers adjacent to occupied sites. Land acquisitions and consolidating land ownership to separate logging activities from existing and future older-aged forests could facilitate the development of larger blocks of habitat (see *Protecting and Managing Residual Old-growth within Second-growth Forests*). Techniques for accelerating growth of new habitat have yet to be proven, but more research is warranted (see *Developing New Habitat*).

Where management of large contiguous blocks of mature forest is not possible, land managers should strive to protect habitat within large heterogeneous (mixed age) landscapes. These landscapes and habitat patches should have **Natural Edges** or buffers of simple-structured mature forests (Raphael et al. 2002a, 2002b; Ripple et al. 2003). Murrelets are most vulnerable when unbuffered habitat is adjacent to clearcuts and regenerating forests with berry-producing plants, which is optimal habitat for predators (Masselink 2001, Marzluff et al. 2004, Marzluff and Neatherlin 2006). To reduce predation pressure, predator management measures may be necessary (Halbert and Singer 2017). In addition, habitat in close proximity to human habitation or areas of high human use has higher predator densities and therefore lower nest success (Miller et al. 1998, Raphael et al. 2002a, Marzluff and Neatherlin 2006). Therefore, it is important to buffer (i.e. add areas of no-cut and no development) any current or future habitat from clearcuts or areas of high human use (see *Minimizing Edge Effects Through Buffers*).

Managing the forested landscape in ways that reduce the threat of wildfires, as well as hazard tree management, are important to the maintenance of murrelet habitat. Wildfire is a significant source of murrelet habitat loss in some conservation zones, with megafires becoming more common in this era of climate change. Proactive techniques for wildfire prevention should be used to curb human-caused fire ignitions, which account for the majority of fire ignitions (see *Managing and Reducing Threats of Megafires*). Wildfire, windstorms, construction, and natural succession can all result in designation of **Hazard Trees** that are cut or removed without consideration for effects to murrelet habitat. As hazard tree removal can eliminate current and future nesting trees and platforms, measures should be taken that would allow these trees to remain on the landscape whenever possible (see *Hazard Trees*).

Various anthropogenic activities can affect the ability of murrelets to nest successfully. Increases in nest predator densities have been tied to the availability of human food waste in recreation sites, but effective strategies exist to protect against this (see *Reducing Impacts from Recreation and Other Human Activities*). Construction and ongoing maintenance of infrastructure such as power lines, roads, and inland wind power developments can lead to direct mortality of murrelets, loss of habitat, or loss of access to habitat. Additionally, murrelets can experience visual or noise disturbance from certain activities occurring in habitat. For many activities, there are alternative methods, locations, or timing that could be incorporated into project design and maintenance that would minimize negative impacts to murrelets (see *Construction and Maintenance of Power Lines, Roads, and Inland Wind Power Developments* and *Minimizing Disturbance and Disruption*).

Forest land managers, particularly Federal land managers or those whose projects are funded, authorized, or carried out by a federal agency, should be aware that the USFWS has designated critical habitat for the Marbled Murrelet (USFWS 1996, 2011, 2016). The designation of critical habitat is intended to highlight the value of a particular area to the recovery of a federally listed species, as well as the important characteristics of that habitat for the species. According to Federal regulations (50 Code of Federal Regulations 424.12(b)), designated critical habitat identifies the physical or biological features essential to the conservation of a species, focusing on the "primary constituent elements" of those features. The USFWS considers the following to be primary constituent elements specific to the murrelet: (1) individual trees with potential nest platforms, and (2) forested areas within 0.8 km (0.5 mi) of individual trees with potential nest platforms, and with a canopy height of at least one-half the **Site-potential Tree Height** (USFWS 1996, 2016). This 2nd primary constituent element includes all such forested areas, regardless of contiguity [with the tree or each other]. These characteristics are considered not only important to the biology of the species, but essential to the conservation of the species. For that reason you'll see them discussed directly or indirectly in this *Maintaining and Managing Occupied Areas and the Integrity of the Landscape* section. Activities that may affect critical habitat, when carried out, funded, or authorized by a Federal agency, should involve a consultation with the USFWS (USFWS 1996). Therefore, for any activities that may affect federally designated critical habitat, and that are carried out, funded, or authorized by a Federal agency, land managers should consult with the USFWS on the possible effects of their proposed projects on these primary constituent elements.

Protecting and Managing Residual Old-growth within Second-growth Forests

Federal efforts to protect old-growth forests from logging began in the late 19th Century in Washington State, when President Cleveland designated most of the forested land on the Olympic Peninsula as the Olympic Forest Reserve. President Theodore Roosevelt designated part of this reserve as Mount Olympus National Monument in 1909, and in 1938, President Franklin Roosevelt signed legislation that established Olympic National Park. Legislation was introduced as early as 1911 to create a redwood national park; in 1968, President Johnson signed a bill creating Redwood National Park. In the early 20th century, private citizens also initiated efforts to protect old-growth forests, when conservation organizations such as the Sempervirens Fund (formed ca. 1900, then the Sempervirens Club) and Save the Redwoods League (formed ca. 1918) were formed to purchase and/or manage land parcels or conservation easements on parcels containing primarily old-growth trees. In California, several State Parks were established through the initial acquisition of redwood groves by businesspersons and the aforementioned conservation organizations, and subsequent acquisitions during the 20th Century enlarged the acreage of these parks. In addition to the efforts of private conservation groups, older-aged or occupied forest parcels within the range of the murrelet have been purchased through restoration settlement funds from oil spill mitigation.

In Washington, Oregon and California, the majority of contiguous murrelet nesting habitat occurs within State and National parks and forests. Possibly due to a dearth in availability of old-growth parcels for purchase, and for mitigation purposes, in recent years, conservation organizations have begun to consider the purchase and protection of parcels with residual old-growth trees among second-growth trees, with the goal to manage these forests to eventually attain late-seral forest characteristics (e.g., Carey et al. 2003, for coastal redwood). For example, in 2018 in Mendocino County, California, a 235-ha (580-acre) parcel of second-growth redwood forest containing residual old-growth redwood trees was purchased by a power company and transferred to Save the Redwoods League (W. McIver pers. comm.). In 2007, 1,725 ha (4,263 acres) acres of occupied residual old-growth and second growth was purchased in Oregon as mitigation for the New Carissa oil spill (Kramer et al. 2010). Most of this property will be managed for murrelets in perpetuity by the Confederated Tribes of the Siletz Indians. Federal and State wildlife agencies should coordinate with conservation organizations and others to identify land parcels containing residual old-growth trees within variable-aged second-growth forests, which could be purchased (or on which conservation easements could be purchased) especially in locations in close proximity to known or suspected occupied habitat.

Developing New Habitat

Considering the scale of negative impacts that contemporary and historical habitat loss and fragmentation have on distribution and abundance of murrelets, managers should carefully analyze the potential risks to this listed species when seeking to develop new habitat or to attract birds to unused habitat. Over time a number of techniques have been proposed ranging from stand-wide thinning to individual tree manipulation. Some of these techniques seem promising, while others may be ineffective or counter-productive. None have been thoroughly tested as of yet.

Some land managers may aim to accelerate development of murrelet habitat by thinning young, even-aged, overly dense forested areas not known to be occupied (e.g., those <50 years in age), but there may be substantial short-term risks to murrelets if forest treatments occur in close proximity to areas of occupancy. Reductions in forest cover can create openings in the canopy, which can lead to change in microclimate conditions and increased access to murrelet habitat by predators, especially jays and ravens (e.g., Masselink 2001, Hagar et al. 2024).

Although silvicultural research shows that forest thinning can accelerate the development of larger diameter trees (e.g., Carey et al. 2003, Comfort et al. 2010), it has not been shown to greatly enhance the development of platforms large enough for murrelet nesting (Carey et al. 2003, Franklin et al. 2007, Plummer et al. 2012, Sillett et al. 2018). Unless carefully planned beforehand and monitored onsite, silvicultural thinning and associated soil disturbance can also lead to increased storm runoff, increased soil erosion, increased flooding, and an increased risk of slope failures (Elliott et al. 1992, U.S. Environmental Protection Agency 1993, Ice et al. 2004, Rice et al. 2004).

Stand-level responses to silvicultural treatments have not been measured long enough in/near murrelet habitat that demonstrate direct benefits to murrelets. Therefore, in general, we do not recommend thinning activities in habitat or in buffers adjacent to habitat. If any treatments are conducted adjacent to murrelet habitat, adequate no-cut buffers are needed to protect the integrity of habitat and to protect murrelets from disturbance, particularly in instances where habitat is known to be occupied (See *Minimizing Edge Effects through Buffers* above and *Minimizing Disturbance and Disruption* below).

On a much smaller scale, individual tree manipulation or manipulation of very small clusters of trees can be done to accelerate the formation of large nest branches in otherwise suitable trees (Carey et al. 2003, Franklin et al. 2007, Sillett et al. 2018). This approach is largely untested but strongly supported by our knowledge of how tree canopies develop. Individual tree manipulation is accomplished by topping an otherwise suitable tree to accelerate the development of branches with **Reiterations**. Murrelets are known to favor branches with reiterations in both redwoods and Douglas-firs, and topping has been shown to accelerate their formation although it will take decades or longer to see results (Sillett et al. 2018). Small cluster tree manipulation is done by increasing sunlight availability to a selected branch or few branches of a heavily shaded tree. This can be done by pruning back or removing a neighboring tree that is blocking sunlight from reaching the target tree. The “released” branch(es) on the target tree will then grow rapidly into the new window of light, growing in both length and girth. This technique can quickly accelerate branch growth in contrast to stand-wide thinning that primarily increases trunk diameter (Carey et al. 2003, Franklin et al. 2007, Sillett et al. 2018).

Another technique that has been suggested is the placement of artificial nest platforms into trees without nest platforms that otherwise would be suitable murrelet nest sites (e.g., trees with sufficient cover) or that lost platforms due to fire or other disturbance. However, this has never been tested and there is no guarantee that murrelets would find or utilize these artificial nest platforms.

In an effort to attract murrelets to unused habitat it has been suggested that recorded murrelet calls be broadcast in such areas during the dawn and dusk activity periods in the nesting season. This type of social attraction has been tried in Oregon with encouraging results (Valente et al. 2021) but is not yet proven to result in nesting attempts by murrelets. It also includes the risk of attracting murrelets to nest in areas that look appropriate for nesting, but which may have high predator densities or other adverse conditions not known to the project manager, which could act as sink habitat and result in reproductive failure.

Given the paucity of information about all of these techniques, we do not currently recommend their use, unless they are implemented as scientific experiments by qualified researchers who have approval from all appropriate regulatory agencies, including the appropriate federal permits.

Minimizing Edge Effects Through Buffers

The effects to murrelets from anthropogenically created forest edges are well documented in the literature, and edge effects have been identified as a factor threatening murrelet survival (USFWS 1997, 2021). To minimize the effects of forest edges on breeding murrelets, we recommend surrounding all occupied murrelet nesting habitat with a minimum 100 m (328 ft) wide no-cut buffer. A visual example of buffer designation is provided in Figure 1E-F. Several studies have documented consistent below-canopy flight corridors of murrelets to nest sites (Nelson and Peck 1995, Singer et al. 1995). Use of below-canopy flight corridors may provide murrelets with predation protection for both the adults and nests, and these corridors are important to maintain around nest sites. Our recommendation of a 100 m (328 ft) buffer width is based on a study conducted at nest sites that identified under-canopy flight routes used by murrelets of at least 100 m (328 ft) in length (Singer et al. 1995). The remainder of this section is focused on the effects of anthropogenically created forest edges on murrelet nest success.

Research has characterized murrelet nesting failure as a result of nest proximity to edges of all types: hard, natural, and soft. For murrelets, those effects were greatest in proximity to anthropogenically created **Hard Edges** versus natural edges or soft edges. These effects to nest success are likely caused by one or more of the following: loss of epiphyte cover at hard and soft edges (van Rooyen et al. 2011), lower densities of platform trees at hard-edged forest sites (van Rooyen et al. 2011), and increased predation rates at hard edges (Malt and Lank 2007, 2009), particularly when forests are in proximity to human settlements and recreation sites (Raphael et al. 2002a).

Buffers maintain favorable microclimate for epiphytes and platform creation (van Rooyen et al. 2011) and potentially aid in proper thermoregulation of adults and chicks. The term "microclimate" in this context refers to environmental conditions of the canopy within habitat, such as temperature, humidity, and wind speed that differ from those in surrounding areas. Murrelets nest on large mossy limbs within most of their range (Ralph et al. 1995, McShane et al. 2004), except on coast redwood (*Sequoia sempervirens*) where they often nest on bare branches (Singer et al. 1995). Mosses (a type of epiphyte) often contribute positively to the formation and availability of murrelet nest platforms. Bryophytes (mosses and liverworts – also epiphytes) are known to be sensitive to microclimate and are generally positively associated with moisture (Sillett and Antoine 2004). Hard-edged forested areas have lower epiphyte cover and platform tree density than natural-edged forested areas, and this effect occurs at least 50 m (164 ft) into forest stands (Van Rooyen et al. 2011). Such effects would therefore be reduced under our recommendation of a 100 m buffer. Microclimate is often affected by hard edges, with air and soil temperatures, wind velocity, and solar radiation greater in recent clearcuts (10-15 years old) and adjacent forest edges than in nearby forest interiors. Older-aged contiguous forests, with their multi-layered canopies, are known to buffer climate change by maintaining cooler summer temperatures compared to plantations and younger forests (Frey et al. 2016, Betts et al. 2017, Kim et al. 2022). In addition, air and soil moisture levels are higher inside the older forest (Chen et al. 1993, 1999), including higher up in the canopy where murrelets nest (van Rooyen et al. 2011, Aubrey et al. 2013). Providing buffers to all murrelet habitat will help protect against microclimate changes.

Buffers can also help maintain murrelet habitat integrity by reducing the risk of windthrow or blowdown of habitat, which is often increased by clearcutting (i.e., creating hard edges) adjacent to habitat (Ruel 1995, Sinton et al. 2000). Blowdown risk is affected by a suite of factors, including topography (e.g., risk is greater on ridges exposed to high winds), soils, and other factors (Sinton et al. 2000, Gratowski 1956, Mitchell et al. 2001). Forested areas that do not meet the definition of habitat but are adjacent to habitat and that are identified for treatment (e.g., silviculture and/or fuels management) should be managed to reduce blowdown risk in ways that will support development of future platform trees. If blowdown does occur despite buffers and best management efforts, fallen trees should be left in place to maximize stand recovery and minimize effects to the restoration objectives (Lindenmayer et al. 2004). In addition to minimizing risk of windthrow or blowdown, buffer zones upslope of occupied habitat can reduce the risk of landslides, debris-flows, and channel erosion, all of which can cause loss of trees (Rice et al. 2004) within habitat.

Predation of eggs and nestlings is identified as a primary cause of nest failure and a limiting factor in murrelet populations (Nelson and Hamer 1995, McShane et al. 2004, Peery et al. 2006, Piatt et al. 2007, USFWS 2012, Halbert and Singer 2017). Studies of both real and artificial murrelet nests have found nest success tends to be greater when nests are farther from forest edges (reviewed in Raphael et al. 2018). High predation rates are recorded at least 50 m (164 ft) into forest stands, and areas with nearby human activity experience increased predation within at least 200 m (656 ft; Raphael et al. 2002a). One explanation for increased predation rates in such areas is that increased human presence and recreation activities can attract corvids which are important murrelet nest predators (Webb 2017; see *Reducing Impacts from Recreation and Other Human Activities* below). Another explanation is that edge areas with more sunlight and therefore more berry-producing plants are favorable habitats for some murrelet predators (Masselink 2001, Carey et al. 2003, Marzluff et al. 2004, Marzluff and Neatherlin 2006). For example, Steller's Jays (*Cyanocitta stelleri*) tend to be most abundant in fragmented forests and along edges (Vigallon and Marzluff 2005, Walker et al. 2020). Reducing overstory density or creating canopy gaps increases the probability and abundance of fruiting in some understory shrub species, based on studies in western Oregon and Washington (Wender et al. 2004). No-cut buffers would reduce or avoid the creation of new predator-friendly edges adjacent to or near occupied habitat.

The studies mentioned above provide support for a minimum 100 m (328 ft) buffer, if not wider (see USFWS 1997), based on demonstrated edge effects, because in actuality edge effects may vary continuously over a range of distances from an edge, including distances longer than those studied. Land managers should consult with their regulatory agency to determine an appropriate buffer width that considers site-specific factors such as slope, aspect, and topography, proximity to recreation areas or human settlements, and the objectives of buffers listed above. Buffers greater than 100 m (328 ft) would further minimize risk of windthrow, reduce the risk of nest depredation, and promote the development of larger blocks of interior habitat. Raphael et al.

(2008) recommended that 100% of buffer areas consist of, at a minimum, young pole-sized trees with a single canopy layer. Landscape analyses have shown that even the presence of younger, simple-structured stands adjacent to nesting areas may decrease predation at nests (Raphael et al. 2002a, Ripple et al. 2003), demonstrating the potential benefit of no-cut and no-entry buffers to murrelet nest success.

As of the publication of this document, no studies have been conducted that show thinning buffers improves the effectiveness of the buffer or provides benefits to murrelets or their habitat. In addition, there are no studies that demonstrate how to minimize threats (e.g., attracting corvids) to murrelets when thinning or other types of forest management occur adjacent to occupied sites. However, light to heavy thinning resulting in tree densities between 125-275 trees per hectare (51-111 trees per acre), and clearcut logging in conifer forests, increase corvid abundance (e.g., Masselink 2001, Cahall et al. 2013, Hagar et al. 2024). Increased amounts of edge cause undesirable effects on forest microclimate characteristics as well (e.g., Chen et al. 1995). The same effects could occur if buffers are thinned. For this reason, we do not recommend thinning or other types of forest management within buffers, or other forested areas adjacent to habitat, without first consulting your regulatory agency. See *Managing and Reducing Threats of Megafires* section for information on wildfire considerations.

Edge effects can result from forest management activities occurring within habitat and its buffers as well as outside of habitat and its buffers. Any forest management occurring outside of and adjacent to habitat or its buffers should attempt to maximize retention of canopy cover, minimize anthropogenic gap creation, and minimize ground disturbance associated with roads, landings, skid roads/trails, cable yarding corridors, etc., so that forest management is consistent with the protection and development of platform trees and murrelet habitat characteristics. It is important to note that thinning in multiple younger stands within a single watershed containing occupied habitat can lead to increased negative effects on murrelets (increased predation, microclimate effects, fire hazard; e.g., Chen et al. 1995, Masselink 2001, Vigallon and Marzluff 2005, Van Rooyen et al. 2011). The amount of hard edge and canopy openings present within a watershed at any one time should be minimized. This will serve to maintain the amount and contiguity of habitat across the landscape. Site-specific conditions should inform what approaches are taken. For example, consider these concerns: (1) how soils, geology, and slope steepness contribute to landslides or erosion risk; (2) how or if slope and aspect may contribute to the risk of windthrow, and how to minimize that risk; (3) how the understory composition may contribute to the risk of increased predator densities; (4) how multiple thinnings in younger stands within a watershed with occupied sites can decrease canopy cover in those stands, thereby increasing predation throughout the watershed; (5) how current or future predator response may influence murrelet survival and nest success; and (6) how nearby recreation sites may be negatively affecting murrelets in the area due either to disturbance or increased predator densities (see *Reducing Impacts from Recreation and Other Human Activities)*. We recommend that research be conducted to determine the efficacy of any type of management within or adjacent to buffers that may impact buffer performance. These actions should be done in consultation with regulatory agencies.

These buffer recommendations are particularly imperative for conservation of murrelets in the short term as species declines are continuing in some areas and habitat gains are expected to only slowly accumulate over the next 100 years. Evidence indicates murrelet nest-site fidelity occurs at multiple spatial scales (Plissner et al. 2015), which is similar to many alcid species that are philopatric, with offspring returning to their natal areas to breed (e.g., Gaston and Jones 1998, Frederiksen and Petersen 1999). While there is evidence of philopatry in Marbled Murrelets (i.e., marked birds re-nesting at the same location or stand within or between years in Alaska, British Columbia, and Oregon; Burger et al. 2009, Barbaree et al. 2014; Rivers et al. unpublished data), sample sizes are small. Assuming murrelets are philopatric like other members of their family, then actions contributing to successful nesting, such as reducing risk of predation, are likely to help maintain occupancy of habitat through time. Although some forestry techniques may yet prove to provide long-term habitat benefits (see *Developing New Habitat*), the need to conserve habitat in the short term should take precedence in order to contribute to a precautionary approach to species conservation.

Key buffer recommendations:

- surround all murrelet habitat with a 100 m (328 ft) wide no-cut buffer, at minimum;
- do not conduct forest management in buffers unless special circumstances exist that warrant their use and permission has been obtained from regulatory agencies;
- seek to create and maintain large, contiguous areas of murrelet habitat. Effects to murrelets due to hard edges decrease in larger, more circular areas of habitat;
- when harvesting timber adjacent to occupied habitat and buffers, avoid or reduce negative effects to murrelets or their habitat by minimizing the extent of hard edge present at any given time; and
- reduce the risk of blowdown and landslides due to activities in forested areas adjacent to murrelet habitat and buffers.

Managing and Reducing Threats of Megafires

Managers of suitable murrelet habitat should be cognizant of the threat posed by **Megafires**. Although murrelet habitat was historically subject to lower severity fires, megafires are an entirely new type of fire that pose a very serious threat to murrelet habitat. Megafires burn hotter, kill or damage a greater number of trees within the burn perimeter, and are projected to recur more frequently than historic fires (Rogers et al. 2011, Abatzoglou and Williams 2016, Westerling 2016, Kitzberger et al. 2017, Halofsky et al. 2018, Williams et al. 2019, Halofsky et al. 2020, Robbins 2021, Potter 2023, Turco et al. 2023). They can occur throughout the forested range of murrelets (Rogers et al. 2011, COSEWIC 2012, Environment Canada 2014, Parks et al. 2015, Steel et al. 2015, Westerling 2016, Kitzberger et al. 2017, Williams et al. 2019, Halofsky et al. 2020, Robbins 2021, Singer and Rinkert, in prep.; Alaska Wildlife Fire information https://blm-egis.maps.arcgis.com/apps/instant/portfolio/index.html?appid=4841da6a16804c07849c27ea7db2a26b). The primary driver of these fires is human-induced climate stressors (such as increasing temperatures, decreasing precipitation, longer dry seasons, more erratic winds, etc.), while forest fuel levels are a much lesser consideration (van Mantgem et al. 2013, Halofsky et al. 2020, Steel et al. 2015, Abatzoglou et al. 2021, Robbins 2021, and Turco et al. 2023), with the possible exception of the southernmost coast redwood forests where forest fuel levels may play a bigger role, although conflicting study results suggest that further research is needed (Norman et al. 2009, Steel et al. 2015, Turco et al. 2023).

An example of the damage that a megafire can inflict on an important murrelet nesting area is the 2020 CZU Lightning Complex Fire that burned Big Basin Redwoods State Park, Conservation Zone 6, in northern California. Big Basin contains the largest amount of old-growth redwood–Douglas-fir forest within the Zone and 98% of the park was burned, mostly at a high intensity level (Potter 2023, SCMBC 2020). During the fire, 85% of all Douglas-fir trees larger than 4 cm (1.6 in) dbh were killed (Mahdizadeh and Russell 2021) and although almost all mature redwoods survived the fire by sprouting new branches from base or bole, most of the large branches used by nesting murrelets were consumed by the fire. After the fire, the number of trees remaining with suitable nest platforms was reduced by an estimated 83% (Singer and Rinkert, in prep.). Megafires in Oregon and Washington in recent years (2017-2020), fueled by strong east winds, have also destroyed tens of thousands of acres of murrelet habitat (e.g., Robbins 2021). Where habitat losses are so severe, managers may want to experiment with methods for creating new murrelet habitat, in cooperation with regulatory agencies (see *Developing New Habitat*).

Megafires, being driven by high velocity winds, ultra-dry fuels, and heat waves, are nearly impossible to control by traditional fire-fighting measures unless there is a change to more favorable weather (SCMBC 2020, Potter 2023). Forest fuel reduction treatments, as typically used to prevent historical-fire-regime fires, are largely ineffective against megafires that occur within the forested portion of the murrelet breeding range (Halofsky et al. 2020, Abatzoglou et al. 2021, Robbins 2021, Turco et al. 2023). Forest fuel reduction treatments targeting prevention of megafires should never be used in occupied stands and should not be used in buffers unless special circumstances exist that warrant their use, and even then such use should be approved and permitted by regulatory agencies. Any type of entry (e.g., timber harvest, roads, etc.) into forested murrelet habitat has the potential to negatively modify physical conditions that support murrelet nesting, as well as to damage ecosystem services provided by the forested area if efforts are not made to avoid it.

In the dryer southern part of the redwood region, further research is needed to determine the relative importance of forest fuel levels versus climate change factors in promoting megafires (Noss 2000, Norman et al. 2009, Steel et al. 2015, and Turco et al. 2023). Until that question is resolved, fuel reduction efforts in southern redwood forests should be undertaken only with great caution and performed in consultation with regulatory agencies.

Regardless of their cause, megafires can be controlled in their initial stage when small, and better yet, they can be prevented by blocking human-caused fire ignitions. The vast majority of fire ignitions are caused by human activity (Nagy et al. 2018), so preventative efforts in areas of high human use can be helpful. Managers of forest lands, especially parks and recreation areas, should consider implementing these fire-prevention practices:

- remove grass and flash fuels from road edges in the dry season;

- prohibit any use of fireworks or other incendiary devices;

- use fire tools associated with forest management (e.g., slash pile burning, prescribed burning) only when the risk of escaped fires occurring is very low.

- construct shaded fuel breaks along the margins of campfires, picnic areas, and other areas of concentrated human use;

- ban campfires or restrict them to improved campsites with fire rings;

- conduct regular fire-safety patrols by rangers or park staff in remote areas of the park to prevent illegal camping and illegal campfires;

- during "red flag" fire weather conditions, consider closing the area to all human entry; and

- require public utilities to use wind-safe power lines that cut power off instantaneously when the line is broken, such as by a falling tree, or to bury power lines underground. Recommendations to reduce adverse impacts by burying of power lines can be found in the section below, *Power Lines, Roads, and Inland Wind Power Developments*.

Where habitat loss from a megafire has occurred, we recommend land managers consider creating new murrelet nesting opportunities as discussed in the *Developing New Habitat* section above.

Reducing Impacts from Recreation and Other Human Activities

The presence of late-seral and old-growth forests is one of the primary features that attract visitors to recreation areas, including, but not limited to, Olympic and Mount Rainier national parks in northern Washington, Redwood National and State Parks in northern California, and Big Basin Redwoods State Park in central California. In addition to the potential for directly disturbing breeding murrelets (see *Minimizing Disturbance and Disruption* section, below), recreation and other human activities can directly or indirectly impact murrelets by attracting predators, removing or fragmenting habitat, impeding development of habitat, and causing mortality of murrelets.

Campgrounds and associated food sources within murrelet habitat have been shown to greatly increase the density of known murrelet nest predators such as Steller's Jays, both within campgrounds and in a large surrounding area (Singer et al. 1991, West et al. 2016, 2019). Predation on murrelet eggs and chicks is a major cause of nest failure and low reproductive success, and human actions can increase the density of potential nest predators (See Chapter 1 in *2024 Inland Survey Protocol*). Predators are attracted to human presence, human provisioning of artificial food resources (Marzluff et al. 1994), and human-related noise (Miller et al. 1998). Roads also can attract and concentrate nest predators such as Common Ravens (Scarpignato and George 2013). These factors can cause an increase in predator numbers and increase the potential risk to murrelets or murrelet nests (Hébert and Golightly 2006, 2007, Scarpignato and George 2013). In areas where campgrounds occur in or near murrelet habitat, nesting success is usually low (e.g., the Santa Cruz Mountains; Peery et al. 2004). While campgrounds are a known problem, other developments such as trailheads, off-highway vehicle staging areas, target shooting lanes, and picnic areas are also of concern. The presence of loose garbage, open trash cans, and other human food sources, such as feeding of wildlife by recreationists, should be eliminated or minimized within and adjacent to habitat and habitat development sites.

Emphasizing the need for garbage management (e.g., wildlife-proof garbage cans) and preventing wildlife feeding by campers and others through education will help reduce predation risk. Because point food sources can affect nest predator abundance for a large surrounding area (West et al. 2016), communication and cooperation with adjacent land managers are especially important where multiple ownerships occur within or near (e.g., within 1-2 km [about 1 mi]) patches of occupied or unsurveyed habitat. Human presence and human-made structures of a wide variety appear to attract or increase the number of ravens, jays, and crows (Liebezeit and George 2002, Rosenberg et al. 2004).

Construction of new campgrounds and other recreation-related features or developments (e.g., trails, stores with food) where people concentrate within or adjacent to habitat should be avoided to help prevent an increase in predators. Where alternative routes exist, trails should not be built through murrelet habitat. For existing campgrounds and other features that occur in or near habitat, detailed signage about rules, including not feeding wildlife (intentionally or otherwise), minimizing garbage and food consumption while on the trails, and reducing noise should be posted. The "Crumb Clean Campaign" of the California Department of Parks and Recreation and National Park Service in redwood forest parks is an effective example of one such effort (https://www.parks.ca.gov/?page_id=29905). If any habitat within 0.8 km (0.5 mile) of existing campgrounds or other recreational developments becomes occupied by murrelets, a re-evaluation of the use and location of those developments is recommended, taking into consideration the potential for negatively impacting nesting murrelets. Where campgrounds and other people-concentrating features are constructed within close proximity to known occupied areas, long-term monitoring of predator densities and mitigation measures for minimizing predator increases should be implemented as part of the project, along with an adaptive management plan to address any increase that occurs (Halbert and Singer 2017).

In summary, we recommend implementing the following measures within and near habitat to reduce the risk of murrelet predation:

- install wildlife-proof trash cans at all campgrounds, day use areas, trailheads, and other areas of concentrated recreational use;
- install wildlife-proof food lockers or other storage containers at campgrounds;
- install dishwashing stations or wastewater drains to collect and allow removal of food particles at all campgrounds;
- educate the public about the negative effects of feeding wildlife on murrelets through the use of signs, displays, videos, or one-to-one contacts by staff at all campgrounds, visitor centers, day use areas, and other areas of concentrated human presence;
- whenever possible, educate campers and other visitors, by reinforcing the message and addressing non-compliance;

- reduce, and where possible avoid, the placement of recreational features within and near (e.g., within 0.8 km [0.5 mi] of) habitat, including but not limited to construction of new campgrounds, picnic areas, off-highway vehicle staging areas, trailheads, and trails;

- inform the public about reducing noise, especially during dawn and dusk (key murrelet activity periods);

- do not create new human settlements, youth camps, recreation areas, and waste management sites in proximity to habitat, as they increase predation rates; and

- relocate or eliminate existing recreation areas and food and waste management sites in proximity to occupied habitat, and if relocation or elimination is not possible, implement methods of limiting impacts to murrelets that are caused by such infrastructure (see above and consider wildlife-proof trash and food management, public education, predator management, adding buffers, etc.).

Hazard trees

Periodically, mature and old-growth trees, that may serve as murrelet nest trees, are designated by land managers as **Hazard Trees** when they might be in danger of falling on structures such as buildings, powerlines, roads, campsites, or other human infrastructure (e.g., Mount Rainier National Park 2010, Angwin et al. 2022). In such circumstances, they are often removed or their large branches are pruned off. We are concerned about their removal as these hazard trees may contain or contribute to suitable murrelet nest sites. We recommend an approach whereby the risks of potential hazard trees are duly evaluated, including whether the resources at risk can be relocated or removed, whether potential hazard trees can be left untouched, or large branches pruned off rather than felling the tree. In this way, habitat features essential to nesting murrelets can be retained. An example of guidelines pertaining to hazard trees along roads is the Forest Service's Hazard Tree Guidelines (Angwin et al. 2022). While such guidelines focus on removal of hazard trees, and not the retention of murrelet habitat, we favor an approach whereby the trees are evaluated for their perceived risk to infrastructure and human life, instead of a blanket approach that removes trees without such an evaluation.

We recommend implementing the following measures within and near habitat to reduce the risk of negative impacts to murrelets and their habitat due to hazard tree management-related activities:

- ensure that a wildlife biologist participates in the design, implementation, and monitoring of proposed hazard tree activities in murrelet habitat. The purpose of this involvement is to ensure the project avoids and minimizes impacts to listed species and that the project is carried out as described in supporting documents;

- require that all trees proposed to be removed or pruned in or adjacent to murrelet habitat be inspected by a qualified forest health protection pathologist or certified arborist to determine whether they are truly hazard trees;

- avoid the removal of active or historic murrelet nest trees. This includes trees with nesting structure and adjacent trees with branches that intertwine the branches of any tree with nesting structure. This also includes potential or known nest limbs or structures that may contribute to nesting;

- avoid and/or minimize the removal of large trees or large branches that may later support nests or nest sites, or contribute to habitat characteristics;

- immediately notify park or agency staff and a qualified wildlife biologist if an active murrelet nest is found, followed immediately with notification to the USFWS. Protecting the site from disturbance while the nest is active is imperative;

- in instances where hazard trees in or adjacent to habitat are being felled or may be felled for purposes of protecting human infrastructure, determine if the infrastructure can be relocated or removed, instead;

- to minimize conflicts between hazard tree management and conservation of murrelet habitat, transition high-use areas, such as campgrounds, out of murrelet habitat or change them to areas with lower human use, such as day-use areas;

- close campgrounds (or trailheads, etc.) or portions thereof during the nesting season, instead of felling or pruning hazard trees (or any trees) during the nesting season, to minimize the potential for disturbance to murrelets;

- consider Natural Resource Damage and Assessment programs (e.g., from oil spills) or USFWS's Endangered Species Conservation and Recovery Grants as appropriate sources of funding for projects such as those that move or eliminate infrastructures when hazard tree management programs may be interfering with maintenance and creation of murrelet habitat;

- avoid or minimize physical impacts to surrounding trees when felling hazard trees. Ensure you are felling hazard trees away from murrelet habitat; and

- experiment with cutting the top off of potential hazard trees to create snag habitat, and/or trimming off some hazard tree limbs, rather than felling them entirely. Although not yet fully proven, this approach could potentially support or help create old-forest habitat characteristics (see *Developing New Habitat*).

Construction and Maintenance of Power Lines, Roads, and Inland Wind Power Developments
Power lines are known to be a source of murrelet mortality through direct collision of murrelets with these structures, especially when they occur adjacent to nesting habitat or otherwise along the flight path between their at-sea habitat and their inland habitat. Since 2015, at least three murrelets were found below power lines with fatal injuries that were indicative of high-speed strikes (e.g., wings sheared off) in northern California (W. McIver pers. comm.). Other powerline deaths are known from Oregon and Washington (one in each state). It is likely additional murrelets have perished in this same way. At Prairie Creek Redwoods State Park, in a meadow adjacent to occupied habitat, approximately 0.8 km (0.5 mi) of power line was buried in 2016, after two murrelets were documented to have died when they struck power lines near their nest (W. McIver pers. comm.). We recommend that utility agencies:

- bury (or "underground") power lines adjacent to murrelet habitat so as to avoid, minimize, or mitigate impacts to murrelets. Burying power lines will also reduce the risk of megafires (see *Managing and Reducing the Impacts of Megafires*).

Murrelet habitat has the potential to be removed or degraded during maintenance and construction of power line corridors, often in relation to tree removal activities implemented to reduce the risk of fire, power interruptions, or power outages due to trees or branches falling across power lines. We recommend that utility agencies:

- give consideration to the best methods for avoiding destabilization of the soil and disturbance of tree roots;

- use trained wildlife biologists to survey for the presence of platforms or platform trees adjacent to power line corridors, and avoid removal of such habitat; and

- incorporate systems which shut off electricity when there is a break in the power line. This may be as effective as or more effective than removing nearby trees in terms of preventing fire, power interruptions, or power outages.

Watson (2005) described roads as a major contributor to habitat fragmentation on the landscape because roads divide large landscapes into smaller patches and convert interior habitat into edge habitat. Gucinski et al. (2001) provided a synthesis on the scientific information about the physical and biological effects of forest roads. They reported that animal species are affected by habitat fragmentation caused by the presence of forest roads, and that some species avoid roads while others are attracted to them. Those that are most affected by forest roads were often displaced, such as the Northern Spotted Owl (*Strix occidentalis*). Golightly et al. (2009) found that murrelets were more likely to nest farther away from paved roads, which was consistent with findings from other studies that found murrelets avoid edges or fragmented areas (e.g., Meyer et al. 2004). Though likely to a lesser extent than clearcuts, roads contribute to an increase in windthrow events, due to an increase in the wind exposure of remaining trees (Sinton et al. 2000).

Terrestrial wind power projects have the potential to impact murrelets flying to and from terrestrial habitat. To avoid impacts to murrelets, we recommend that terrestrial wind power projects not be located within or near murrelet terrestrial habitat or within or near flight corridors by which murrelets access their inland nest sites. If impacts cannot be avoided, they should be minimized and mitigated (e.g., protection of additional unimpacted terrestrial habitat through purchase or conservation easements). All terrestrial wind power project planning should be done in consultation with regulatory agencies.

Minimizing Disturbance and Disruption

Anthropogenic activities at or near occupied habitat may cause visual and/or noise disturbance to murrelets, including disruption of incubation, brooding, and feeding of chicks. In extreme cases, chicks may be caused to flush from their nests before they are capable of flight (e.g., a grounded chick was discovered following a low helicopter flight in British Columbia, Canada; J. Cragg pers comm.). The degree of disturbance to murrelets from anthropogenic activities varies based on the distance between the disturbance and murrelet(s), along with considerations of topography, vegetation, and other mitigating factors (e.g., Hebert and Golightly 2006, USFWS 2020). Ambient noise levels in the environment play a role in determining if a specific source of noise will have a negative impact on murrelets (e.g., USFWS 2020).

Below, we provide general guidance for minimizing disturbance or disruption to murrelets. Specific guidance for assessing and avoiding significant noise and visual disturbance is provided by USFWS (e.g., USFWS 2013, 2015, 2020) and may vary regionally. Contact your state's USFWS office for locally relevant guidance.

It is important to recognize that the potential disturbance effects of some activities, which may or may not be associated with timber harvest, such as construction, blasting, pile driving, and use of helicopters, may result in impacts to murrelets that extend beyond 402 m (0.25 mile) from the project footprint. Therefore, audio-visual surveys may need to extend farther out to encompass all areas where, if present, murrelets may be impacted by the project. The project footprint should include the areas within which impacts to murrelets or their habitat may be caused by a project, including but not limited to timber harvest, road construction, reconstruction, or improvement, rock blasting and placement, log or rock hauling, etc. Land managers should consult with their regulatory agencies as project footprint boundaries and subsequent survey areas are established to identify if this might be an issue for their proposed activities.

Projects should be designed such that: (1) activities occur at times of year and/or times of day, and in locations and at times that avoid and minimize the potential for noise or visual disturbance to murrelets (for example, outside of the breeding season or outside of the dawn and dusk high activity periods); (2) activities occur in the area farthest from murrelet habitat during the nesting season; and (3) activity locations and types are adjusted to use topographic and vegetative buffers to minimize noise or visual disturbance to murrelets. Anthropogenic noise above the ambient level should be avoided in occupied habitat during the breeding season. If habitat is unsurveyed, assume occupancy.

The following noise management recommendations are based on those found in Chapter 5 of the Marbled Murrelet Landscape Management Plan for Zone 6 (Golightly 2017) but are applicable for other conservation zones as well:

- project planners should consider not only amplitude (loudness), but also, the type of sound and associated characteristics, such as attenuation, duration, novelty, amplitude compared to ambient sound levels, sudden sounds, and frequency (low frequency sounds travel further), which have the potential to cause flushing and could be fatal to murrelets;

- loud impulsive noises that quickly reach maximum amplitude (e.g., gun shots, explosions, felling of large trees) should be completely avoided at any time during the nesting season and year-round for approximately 2 hours before to 2 hours after sunrise.

Land managers may use several types of fire tools, such as slash pile burning and prescribed fire when managing forested areas. The following recommendations should be considered when fire is being used near murrelet habitat:

- do not burn near murrelet habitat during the nesting season, to minimize the chance that adults, eggs, nestlings, or fledglings are injured by smoke or flames; and
- consult regulatory agencies for additional guidelines for reducing prescribed fire impacts to habitat. Smoke can sometimes be managed with respect to direction of flow and amount.

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