United States Department of the Interior

FISH AND WILDLIFE SERVICE
Arcata Fish and Wildlife Office
1655 Heindon Road
Arcata, California, 95521
Phone: (707) 822-7201 FAX: (707) 822-8411

Memorandum

To: All Interested Parties

From: Field Supervisor, Arcata Fish and Wildlife Office, Arcata, California

DANIEL EVERSON Digitally signed by DANIEL EVERSON
Date: 2020.10.28 07:01:58 -07'00'

Subject: Revised Transmittal of Guidance: Estimating the Effects of Auditory and Visual Disturbance to Northern Spotted Owls and Marbled Murrelets in Northwestern California

This memorandum provides revised guidance from the Memorandum Transmittal of Guidance: Estimating the Effects of Auditory and Visual Disturbance to Northern Spotted Owls and Marbled Murrelets in Northwestern California dated July 31, 2006. This revised guidance addresses the effects of disturbance on the federally listed northern spotted owl (*Strix occidentalis caurina*) and marbled murrelet (*Brachyramphus marmoratus*), and applies to activities which have the potential to disturb these species as a result of elevated sound levels or human presence near nests during their breeding seasons. This guidance applies to activities occurring within the jurisdictional area of the Arcata Fish and Wildlife Office (AFWO): Humboldt, Del Norte, and Trinity counties, western Siskiyou County, and Mendocino County exclusive of the Russian River watershed. The purpose of the revised guidance is to incorporate the most recent published scientific literature on auditory and visual disturbance and update pertinent information. All ongoing or completed AFWO consultations or technical assistance following the 2006 Marbled Murrelet and Northern Spotted Owl Harassment Guidance are determined to be consistent with this guidance and will not be re-evaluated. Questions regarding implementation and interpretation of this guidance should be directed to AFWO Field Supervisor, Dan Everson at the above letterhead address.

Attachments

- Estimating the Effects of Auditory and Visual Disturbance to Northern Spotted Owls and Marbled Murrelets in Northwestern California, 2020
- Appendix A - Marbled Murrelet Auditory and Visual Disturbance Decision Support Tool Draft User Guide, 2020
- Appendix B - Northern Spotted Owl Auditory and Visual Disturbance Decision Support Tool Draft User Guide, 2020

Estimating the Effects of Auditory and Visual Disturbance to Northern Spotted Owls and Marbled Murrelets in Northwestern California

October 1, 2020

Executive Summary

The issue of human-generated disturbances to northern spotted owls and marbled murrelets has drawn increasing attention in recent years. The data available to assess impacts to terrestrial wildlife from these effects are limited, and fewer data are specific to these listed species. This guidance document builds upon and consolidates information (see Appendix A, Marbled Murrelet Sound and Visual Disturbance Decision Support Tool 2020 and Appendix B, Northern Spotted Owl Sound and Visual Disturbance Decision Support Tool 2020) to interpret the available data and draw objective conclusions about the potential for identified effects to rise to the level of take, as defined by the Endangered Species Act, during the breeding season for both species. The general breeding season for northern spotted owl is February 1 to July 31. The general breeding season for marbled murrelets is March 24 to September 15.

Through this guidance, the U.S. Fish and Wildlife Service describes behaviors of these two forest wildlife species that reasonably characterize when disturbance effects rise to the level of take (i.e. harm), as defined in the implementing regulations of the Endangered Species Act of 1973, as amended. These behaviors include but are not limited to:

- Flushing an adult or juvenile from an active nest during the reproductive period.
- Precluding adult feeding of the young for a daily feeding cycle.
- Precluding feeding attempts of the young during part of multiple feeding cycles.

These documents provide objective metrics based on a substantial review of the existing literature, as it pertains to these two wildlife species and appropriate surrogate wildlife species. Our recommended methodology relies on a comparison of sound levels generated by the proposed action to pre-project ambient conditions. Disturbance may reach the level of take when at least one of the following conditions is met:

- Project-generated sound exceeds ambient nesting conditions by 20-25 decibels (dB).
- Project-generated sound, when added to existing ambient conditions, exceeds 90 dB.
- Human activities occur within a visual line-of-sight distance of 330 feet or less from a nest.

To simplify the analysis of these potential effects, and to promote consistency in interpretation of the analytical results, we established sound level categories of 10-dB increments. The analysis relies on a comparison of project-generated sound levels against existing ambient conditions. The recommended analysis includes a simple comparison of project and pre-project sound levels within a matrix of estimated distances for which available data support a conclusion of harm by significantly impairing essential behavioral patterns in breeding and feeding. We also provide: real-world examples to assist the reader in understanding the correct application of the methodology, describe site-specific information that is important to include

in project analyses, and provide caution against inclusion of information and circumstances not relevant to the results to provide context to the project proponent analysis and final interpretation.

This current guidance is based, in large part, on the contents of Appendix A and Appendix B. Both appendices were compiled in 2004-2005. The original field evaluation process outlined in the two appendices required a two-phase process in which the user (a) selects one of ten environmental "scenarios" that best describe field conditions within their project area; and (b) follows a twelve-step process for initializing the spreadsheet auditory model to obtain an estimate of the threshold distance for noise effects. The evaluation process in this document is simplified into a five-step procedure. All probable auditory model outputs are integrated in Table 1, below, so users are not required to operate the spreadsheet model.

Introduction

The issue of elevated sound and visual disturbance of forest wildlife species, particularly as it affects the northern spotted owl (owl) and the marbled murrelet (murrelet) is important because of the federally listed status of these animals. The purposes of this guidance are: (a) to describe the scientific basis for considering the effects of auditory and visual disturbance to owls and murrelets, and (b) to provide a methodology to simplify the analysis of these effects for the large majority of project circumstances typically encountered in or near owl and/or murrelet habitat and occupied areas.

This guidance estimates the effects of elevated sound levels and visual proximity of human activities to owls and murrelets, and primarily applies to these species within their suitable forest habitats in northwestern California. This guidance applies to activities occurring within the jurisdictional area of the Arcata Fish and Wildlife Office: Humboldt, Del Norte, and Trinity counties; western Siskiyou County; and Mendocino County; exclusive of the Russian River watershed. This assessment tool may have some applicability to other forest nesting avian species, but was not developed with other species specifically in mind. Future updates of this guidance may address other forest birds and wildlife. This guidance has been developed through consideration of the available literature, incorporating species-specific information as available, but relying substantially on data from a variety of other surrogate avian species and local applications, as appropriate.

Behaviors Indicating Harm

The definition of "take" prescribed by the Endangered Species Act includes "harm". The Endangered Species Act's implementing regulations further define harm 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. Such an act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering." [50 CFR § 17.3]

Activities that create elevated sound levels or result in close visual proximity of human activities at or near sensitive locations (e.g., nest trees), have the potential to significantly disrupt essential behavior patterns. While owls and murrelets may be disturbed by many human activities, we anticipate that such disturbance rises to the level of impairing essential behavior patterns under a limited range of conditions. For purposes of this guidance, we assume disturbance to the level of harm may occur when owls or murrelets demonstrate behavior suggesting that the safety or survival of the individual is at significant risk, or that a reproductive effort is potentially lost or compromised. Examples of this behavior include, but are not limited to:

- An adult or juvenile is flushed from a nest during the incubation, brooding, or fledging period, that potentially results in egg failure or reduced juvenile survival.
- An adult abandons a feeding attempt of a dependent juvenile, which potentially results in malnutrition or starvation of the young.
- An adult delays feeding attempts of dependent birds on multiple occasions during the breeding season, potentially reducing the growth or likelihood of survival of young.

Other essential behaviors, if disrupted, may also indicate harm.

Based on our interpretation of the best available data, these behaviors that result in detriment may occur when owls or murrelets are subject to elevated sound levels or visual detection of human activities near their active nests or dependent offspring. We interpret the best available published data on owls, murrelets and appropriate surrogate species as indicating that the above behaviors may manifest when: (a) the action-generated sound level substantially exceeds (i.e., by 20-25 dB or more as experienced by the animal) ambient conditions existing prior to the project; (b) when the total sound level, including the combined existing ambient and action-generated sound, is very high (i.e., exceeds 90 dB, as experienced by the animal); or (c) when visual proximity of human activities occurs close to (i.e., within 330 feet) of) an active nest site. Sound levels of lesser amplitude or human presence at farther distances from active nests have the potential to disturb these species, but have not been clearly shown to cause behaviors that meet the definition of take. We estimate distances at which conditions (a) and (b) occur by calculating attenuation rates of sound across habitat conditions representative of the forest habitats occupied by owls and murrelets.

Some behaviors are difficult to witness or quantify under field conditions. The difficulty associated with documentation of these behaviors, especially in species such as the murrelet that rely on cryptic coloration and behavior to avoid detection, warrants a conservative interpretation of the best data available for the purposes of this document. At this time, we have identified only those behaviors associated with active nest sites during the breading season as potentially indicating harm.

Sound Level Categories

The analysis of auditory and visual disturbance provided herein relies substantially on a comparison of the sound level generated by sources (e.g., chainsaws, dozers, etc.) anticipated for use in a proposed action against ambient sound conditions prevalent in the action area prior to implementing the project. The analysis compares the sound level that an owl or murrelet is likely to be subject to as a result of implementing a proposed action against the sound levels to which the species may be exposed under existing, pre-project conditions.

Note that in this guidance we define the "ambient" sound level as that sound environment in existence prior to the implementation of the proposed action, and may include any and all human-generated sound sources when they constitute a long-term presence in the habitat being analyzed. Temporary, short-term sources, even if in effect during or immediately prior to the proposed action, would generally not be considered as part of the ambient sound level but would instead be considered as a separate effect, or considered in combination with the sources from the proposed action. A special case of ambient is the "natural ambient", which includes sound sources native to the forested habitat being considered, such as wind in trees, bird calls, and distant water flow. Human-generated, "white noise" sources, such as a distant highway, may also be part of the natural ambient if (a) relatively distant to the area being considered, (b) relatively low in volume (i.e., <50 dB), and (c) relatively uniform in sound level over the area of consideration. Ambient sound should be estimated based on typical sources experienced on a daily or more frequent basis. For other than "natural ambient", sources are generally located within or near the footprint of the proposed action.

The following subsections and Tables provide concise descriptions of sound levels typically encountered under pre-project ambient conditions or during project implementation (including post-project use, if future use of the project area results in a long-term alteration of the sound/visual environment). In Table 1, we created sound level categories of 10-dB increments as a means to simplify the analysis. Each sound level category is described in terms of the conditions, equipment, tools, and other sound sources common to the particular level. Each description includes the decibel range, a general description, and examples of equipment or tools that typify that sound environment. Measurements and estimates from a broad range of potential sound sources are provided for reference purposes in Table 2.

Many tools and equipment demonstrate a range of sound production substantially wider than the 10-dB sound level categories provided here. That range of sound production represents the inherent variability among similar sources, and the variation that typically occurs among measurements of even identical sources. This can be seen in a cursory examination of Table 2. When the range of sound measures for a source exceed the 10- dB range of a single sound level category, the analyst should consider the sound source in the context of other sources typical to the proposed activity. For example, chain saws used in timber harvest operations would include those in the higher sound measures, and would not include lower sound levels more representative of homeowner applications. Similarly, the sound of small trees being felled is not anticipated to be substantially higher than the sound of the saws and other activities. However, the felling of larger trees may exceed the sound of the equipment used to fall and yard them; we have addressed this situation in the sound level descriptions.

We have attempted to create categories that include similar sound sources, and have applied median values (that is, we have discounted outliers) where multiple values for similar sound sources are encountered. While there may be exceptions within and among these categories, we have attempted to address this variability through an otherwise conservative approach to estimating distances at which disturbance behaviors may manifest.

Natural Ambient: Refers to ambient sound levels (generally < 50 dB) typically experienced in owl or murrelet habitat and includes sources native to forest habitats.

Very Low: Typically 50-60 dB, and generally limited to conditions where human-generated sound would never include amplified or motorized sources. Includes forest habitats close to less-frequently encountered natural sources, such as rapids along large streams, or wind-exposure, and may include quiet human activities, such as nature trails and picnic areas.

Low: Typically 61-70 dB, and generally limited to sound from, non-gas-powered recreational activities, and residential activities, such as those associated with small parks, visitor centers, bike paths, and residences. Includes most hand tools and battery operated, hand-held tools.

Moderate: Typically 71-80 dB, generally characterized by the presence of passenger vehicles, small trail cycles (not racing), small gas-powered engines (e.g., lawn mowers, Stihl 025 chainsaws, 25 KVA or less generators, and power lines.)

High: Typically 81-90 dB, and would include medium- and large-sized construction equipment, such as backhoes, front end loaders, pumps and generators, road graders, dozers, dump trucks, drill rigs, and other moderate to large diesel engines. Would also include high speed highway traffic with passenger cars, medium trucks and sport vehicles, power saws, large chainsaws, pneumatic drills and impact wrenches, and large gasoline-powered tools.

Very High: Typically 91-100 dB, and is generally characterized by impacting devices, compression (“jake”) brakes, motor boats, heavy trucks and buses, large trees falling (e.g., trees larger than 75 feet tall), clam shovels, hydromulchers and pneumatic chippers.

Extreme: Typically 101-110 dB. Generally includes use of vibratory sonic pile driver, guardrail installation and pile driving, impact pile drivers, track hoes, and helicopter S-61.

Sound Levels Exceeding 110 dB: These sound levels, typified by sources such as jet engines and military over flights, rock blasting, exterior cone blast with sand bags, and treetop blasts, heavy lift double rotor helicopters are special situations requiring operations up to one mile distance, and are not covered by the analytical methods provided herein.

Derivation of Disturbance Distances

Available data in Appendix A: Marbled Murrelet Auditory and Visual Disturbance Decision Support Tool Draft User Guide, 2020 and Appendix B: Northern Spotted Owl Auditory and Visual Disturbance Decision Support Tool Draft User Guide, 2020 suggest that disturbance occurs when sound levels resulting from project-based sound sources exceed ambient conditions by relatively substantial levels, or when those sound sources exceed a high absolute threshold. Since sound attenuates as a function of the distance from the source (within typical forest habitat, at a rate of approximately 6 dB per doubling of distance from a point source), the analyst can estimate the distance at which various sound sources exceed ambient conditions by anticipated threshold values. We estimated these distances using a spreadsheet model that simulates sound attenuation in typical forest habitats, reasonably accounting for ambient environmental conditions and sound source characteristics. We emphasize the importance that this guidance is to be used in typical forested habitats only. In instances where sound generated is not attenuated by forest, a separate distance calculation should be made based on the environment of the project area. As a means of simplifying the analysis process, we used median sound values within the above-described categories for both source and ambient sound conditions. Table 1 reports the distances within which elevated, project-generated sound is reasonably expected to exceed ambient conditions to such a degree as to result in disturbance of murrelets or owls. The reader is referred to Appendices A and B and their references for additional, detailed discussion of sound metrics and the model used to derive these distances.

The values in Table 1 were obtained directly from the spreadsheet auditory model. When disturbance distance (y-axis) is estimated from two variables -- ambient and action-generated sound (x1- and x2-axes) – the resulting graph is a three-dimensional response surface. Table 1 is the tabular representation of the response surface created after approximately 2,000 iterations of the spreadsheet auditory model. Each table intersection (e.g., low ambient sound combined with high action-generated noise) represents 100 model iterations with one-decibel increments on each x-axis. Each intersection value in the table represents the central tendency of the 100 model iterations, with consideration of the values in the adjacent intersections.

Time of Day Adjustment for the Marbled Murrelet

The take threshold distances provided in Table 1 are based on a comparison of project generated sound levels with existing (ambient) sound levels, which themselves represent average daytime sound conditions. It is recognized, however, that ambient sound level often has a substantial time-of-day component, with nighttime, dawn and dusk ambient sound levels generally 5-10 dB lower than typical midday levels (EPA 1974). It is also known that murrelet flights into nests to feed nestlings and for nest-tending exchanges are concentrated around dawn and dusk (Nelson and Hamer 1995), during the period when ambient noise levels tend to be lower than average daytime levels (EPA 1974). Therefore, for murrelets, the disturbance threshold distances provided in Table 1 apply to noise-generating activities occurring during the midday period, when the risk of disturbance is lower. Specifically, for murrelets, the disturbance distances in Table 1 apply to noise-generating activities that are not within 2 hours of sunrise or sunset. If proposed activities will occur within 2 hours of sunrise or sunset, and if the ambient sound environment during the dawn and dusk period can reasonably be expected to be 5 dB or more quieter than the midday sound environment, then the estimated disturbance distance threshold should be calculated based on an ambient level 10 dB lower (i.e., one row up in the table) compared to the normal ambient rating in Table 1.

In some cases, applying the time-of-day factor will result in a larger disturbance threshold distance. This time-of-day measure provides the threshold criteria to the known biology of the murrelet and the anticipated sound environment during dawn and dusk periods. In many situations, a prohibition on noise generating work within 2 hours of sunrise or sunset (also known as a “diurnal restriction”) is both operationally feasible and imposes minimal encumbrance during project implementation. Diurnal restrictions greatly reduce the likelihood of disturbance to murrelets during a sensitive portion of the day.

Similar time-of-day considerations and adjustments are not required for the owl.

Application of Disturbance Distances to Project Conditions

The following methodology may be used to estimate the approximate distance at which project-generated sound exceeds ambient conditions to such an extent that owls or murrelets may be subject to sound or visual disturbance.

Step 1: The analyst reviews the environment in the action area to determine the existing ambient sound level. The analyst should include any sound sources occurring in the action area, prior to and not part of the proposed action, that create ambient sound levels higher than the "natural" background. For example, if the proposed action would add a passing lane to a high-use major highway, the ambient condition should include the existing traffic and maintenance on the highway itself, in addition to other sounds native to the adjacent forest environment. As a second example, a proposed action to maintain a remote hiking trail would not include sound sources other than the "natural background" and infrequent human use as part of the existing ambient. Based on this review, the analyst assigns a sound level category to the ambient condition (equivalent to a row of Table 1).

Step 2: The analyst reviews the proposed action to determine the types of equipment, tools, etc., anticipated to be used during the project. Based on the descriptions of sound level categories, above, the analyst assigns a sound level category to the action-generated sound sources (corresponding to the columns in Table 1). Action-generated sound sources should include all major sources necessary to complete the proposed action. When project-specific sound measures are not available, the reader should refer to Table 2 for typical values for equipment, tools, and other sound sources. For projects where distinctly different sound environments (for either ambient or action-generated) may occur throughout the duration of the project implementation, the analyst may complete separate analyses for each distinct sound environment.

Step 3: From Table 1, the analyst finds the cell corresponding to the appropriate row and column for existing ambient sound and action-generated sound, respectively. This cell provides an estimate of the distance within which increased sound level may disturb an owl or murrelet. The cell values are generally reported as a distance from the outer edge of the project footprint into unsurveyed, occupied, or presumed occupied nesting habitat, unless site-specific information indicates sound sources may be more localized within the project footprint (see also "Other Considerations", below).

Step 4: When significant topographic features occur within the sound environment, appropriate consideration may be given to their sound amplifying or attenuating capabilities. Topographic features may attenuate or amplify effects on ambient noise (e.g., nearby road use) and project-generated noise. However, the analyst should have a full understanding of the effects of topography on sound amplification and attenuation, especially when the species involved typically nests at a substantial distance above the ground. That is, topography may substantially amplify or attenuate sound between the source and the receiver (i.e., owl or murrelet nest site) when that topographic barrier is sufficiently high to block line-of-sight transmission between the source and receiver.

Step 5: Consider the potential for human activities within 330 feet of potential nest trees of owls or murrelets. If there is a known or likely nest tree, or flight path to the nest itself within 330 feet of human activities, then the analyst would assume visual disturbance. Otherwise, no visual disturbance would be anticipated.

Table 1. Estimated disturbance distance (in feet) due to elevated action-generated sound levels affecting the northern spotted owl and marbled murrelet, by sound level.

Existing (Ambient) Pre-Project Sound Level (dB) [1, 2]	**Anticipated Action-Generated Sound Level (dB)** [2, 3]			
	Moderate (71-80)	**High (81-90)**	**Very High (91-100)**	**Extreme (101-110)**
"Natural Ambient" [4] **(< = 50)**	50 (165)[5,6]	150 (500)	400 (1,320)	400 (1,320)
Very Low (51-60)	0	100 (330)	250 (825)	400 (1,320)
Low (61-70)	0	50 (165)	250 (825)	400 (1,320)
Moderate (71-80)	0	50 (165)	100 (330)	400 (1,320)
High (81-90)	0	50 (165)	50 (165)	150 (500)

[1] Existing (ambient) sound level includes all natural and human-induced sounds occurring at the project site prior to the proposed action, and are not causally related to the proposed action.

[2] See text for full description of sound levels.

[3] Action-generated sound levels are given in decibels (dB) experienced by a receiver, when measured or estimated at 50 ft from the sound source.

[4] "Natural Ambient" refers to sound levels generally experienced in habitats not substantially influenced by human activities.

[5] All distances are given in meters, with rounded equivalent feet in parentheses.

[6] For murrelets, activities conducted during the dawn and dusk periods have special considerations for ambient sound level. Refer to page 7 for details.

Example Analysis

The following example is provided to assist the reader in understanding the application of this recommended methodology to a hypothetical yet typical project circumstance.

Proposed Project: A project proponent proposes to construct an informational kiosk, restroom, and six graveled parking slots at an existing, undeveloped, trailhead parking area along a low-speed (<45 mph), paved road closed to large trucks and buses. The footprint of the proposed project is a roughly circular area of approximately 75-foot diameter (about 1/10 acre). The surrounding forest is suitable nesting habitat for murrelets, and the agency proposes to do construction during the nest season. Topography in the action area is low rolling ridges less than 50 feet high. No other sound sources of significance are located nearby. The construction project will not remove any large trees, but will require the use of several pieces of equipment (e.g., backhoe, dump truck), as well as smaller power equipment (e.g., cement mixer, portable generator, small chain saw) and hand tools. No jackhammering, pile driving, or larger diesel equipment will be needed. The agency agrees to conduct all on-site noise-generating activities during the midday time period between 2 hours after sunrise to 2 hours before sunset (i.e. they will implement a diurnal restriction).

Analysis: The ambient sound level at the proposed kiosk includes the existing passenger vehicle/light truck traffic on a paved surface immediately adjacent to the work area, and existing human presence of hikers. Using the above-described sound level categories, this ambient sound level classifies as "low" (61-70 dB). The large construction equipment (i.e., the backhoe and truck) are the greatest sources of increased sound to be considered here, as they exceed the level of the other tools. From the above-described sound levels, the analyst anticipates that action-generated sound levels will fit into the "high" category (81-90 dB). Choosing the appropriate row (Ambient = Low) and column (Action-generated = High) in Table 1, the analyst will estimate that disturbance may rise to the level of disturbance over an area within 50 m (165 ft) from the footprint of the project. Since all activities will be conducted during the mid-day period, no further adjustment of the tabled value to account for murrelet activity periods is necessary. This 50 m distance, when used as a buffer around the project footprint, results in an estimate of 2.9 acres (1.2 ha) subject to auditory disturbance. Large potential nest trees exist immediately adjacent to the work area, so visual disturbance may also be a consideration. However, human presence already occurs at the trailhead on a daily basis, and the proposed project will not substantially alter that effect. The topographic features in the action area are unlikely to further attenuate any sound experienced by murrelets, which commonly nest more than 50 feet above ground level. Since construction of the kiosk and restroom would not appreciably change the effects of the existing roadway or parking area, the duration of effects would be for a single breeding season, and would not alter effects already at the site in future years.

Interpretation and Application of the Results

The estimated disturbance distance resulting from the analysis of any particular project conditions requires careful interpretation. Although seemingly precise, the reported distance represents a reasonable *approximation* of the distance wherein "the likelihood of injury" occurs, as supported by currently available data. That is, the resultant number estimates the distance within which available disturbance data on owls or murrelets (or surrogate species, as appropriate) show that at least some individuals would demonstrate one or more behaviors indicating disturbance as a result of anticipated sound levels or visual detection of human activities near nest sites. Given the many sources of variability in such an analysis, such as differences in individual bird response, variation in actual sound level produced by similar sources, variability in sound transmission during daily weather patterns, and non-standardization in sound metrics reported in the published literature, exact estimates of disturbance distances are currently infeasible, and likely will remain so.

It is reasonable to assume that owls or murrelets closer to sources of disturbance have a higher likelihood of significant disruption of normal behavior patterns than those at the outer limits of the estimated disturbance distance, due to louder sound levels or a visually closer perceived threat to the nest. Further, not all owls or murrelets, except those in the very closest proximity to the audio and visual activities, may respond to a degree indicating disturbance. Thus, the likelihood of injury for any particular individual would range from some low proportion to a higher value depending on its actual proximity to a particular sound/visual source. It is neither reasonable nor necessary for purposes of analysis and estimation of take to predict that all (or even a high proportion of) owls or murrelets within this distance show disturbance behaviors. Conversely, it is also unreasonable to conclude that owls or murrelets beyond this distance would never be disturbed. A more supportable interpretation is that currently available information does not support a conclusion that owls or murrelets more distant to the anticipated sound/visual disturbances are likely to suffer a significant disruption of normal behavior patterns.

The reporting of take associated with auditory and visual disturbances is necessary, even if somewhat imprecise. It is appropriate to consider all reasonable means to minimize take including, but not limited to, seasonal restrictions and substitution of equipment type to reduce the likelihood of injury. When considering measures to reduce the effects of disturbance, the analyst should bear in mind not only the spatial extent of the auditory and visual disturbance, but also the timing and duration of the disturbance.

Other Considerations

A site-specific assessment of topography should be considered. Steep slopes, ridges, and designed sound barriers may increase sound attenuation when they form barriers to the direct line of sound transmission between source and the location of the receiver (here, the actual location of the species). Small ridges or walls, not clearly blocking the sources from a highly elevated nest, would provide little or no attenuation. When clearly supported by site-specific information regarding topography, action-generated sound may be reduced by one or two levels in the analysis, when compared to existing ambient sound levels.

For some projects, elevated sound levels may cease following completion of the project. For example, sound level following the completion of timber harvest is likely to return to pre-harvest levels, and so would not result in long-term or permanent sound and visual disturbance to owls and murrelets. On the other hand, actions such as the creation of a new road may result in elevated sound levels both during construction and during future use and maintenance of the road. The analyst should carefully consider both spatial and temporal aspects of noise and visual disturbance for each project.

Activities producing sound levels of 70 dB or less (estimated at 50 feet from the sources), such as use of hand tools, small hand-held electric tools, or non-motorized recreation, would not generally rise to the level of disturbance, except in certain circumstances, such as when used in very close proximity (i.e., <82 feet) to an active nest. Under these circumstances, visual detection of human activities by the species near its nest is assumed to be of more consequence than auditory disturbance, and take should be described in such terms. Activities producing sound levels greater than 110 dB (estimated at 50 feet from the sources), such as open-air blasting, aircraft, or impact pile-driving, are not addressed in this analysis, and should be evaluated through a more detailed site-specific analysis. Some activities (i.e. heavy lift double rotor helicopters) warrant a large buffer including up to one mile.

This guidance does not address the direct effects of predation by corvids (e.g., ravens, crows and jays) and other predators as a result of human-mediated activities in murrelet and owl habitat. Distance estimates reported in this guidance reflect only the effects of sound attenuation and visual detection on behaviors appropriately interpreted as disturbance. We have considered predation only in the sense that detection of the nest as a result of owl or murrelet disturbance behavior (e.g., flushing from the nest) may increase the risk of predation, regardless of density of predators, and thus represents a "likelihood of injury."

This analytical method addresses most forest habitat conditions that affect the attenuation rate of sound (and thus the level of sound detected by the owl or murrelet at its location). These conditions include dampening effects of forest vegetation, variability in natural ambient sound typically encountered under forest conditions, use of multiple pieces of identical equipment, and the effect of elevated nest sites on sound attenuation. Departure from the tabled values in this guidance to account for special forest conditions (i.e. clearcut between the project and the habitat) is generally inappropriate except under highly unusual circumstances.

Table 2. Some Common Sound Levels for Equipment/Activities[1]

	Range of Reported dB Values @ Distance Measure *Distance Measure assumed to be 50 ft unless otherwise indicated.*	
Project Sound Sources	**Reported Decibel Level @ 50 ft.**	**Relative Noise Level [2]**
Conversation	34	Ambient
Speech (normal)	41	Ambient
Milling Machine	61	Low
Motorcycle on Trail (620 cc street legal, meter at ground level)	62	Low
Power Lawn Mower	68	Low
Yelling	70	Low
Generator (25 KVA or less)	70	Low
Gas Lawn Mower	72	Moderate
Chainsaw (Stihl 025)	73	Moderate
Welder	74[3]	Moderate
Pickup Truck (driving)	75[3]	Moderate
Flatbed Pickup Truck	77	Moderate
Powerline	78	Moderate
Cat-skidder	80	Moderate
Compressor (air)	80[3]	Moderate
Backhoe	80[3]	Moderate
Concrete Mixer (Vibratory)	80[3]	Moderate
Pumps	81[3]	High
Horizontal Boring Hydraulic Jack	82[3]	High
Slurry Machine	82[3]	High
Vacuum Street Sweeper	82[3]	High
Concrete Pump	82	High
Log Loader	83	High
Ground Compactor	83[3]	High
Concrete Batch Plant	83	High
Dump Truck	84	High
Flat Bed Truck	84	High
Roller	85[3]	High
Mowers, leaf blowers	85	High
Passenger Cars/Light Trucks (65 mph)	85	High
Auger Drill Rig	85	High

Project Sound Sources	**Reported Decibel Level @ 50 ft.**	**Relative Noise Level** [2]
Truck Horn (Warning)	85[3]	High
Equipment > 5 horsepower	85	High
Impact Wrench	85	High
Concrete Truck	85	High
Road Grader	85	High
Chain saws	85[3]	High
Highway-Traffic	85	High
Dozer	85[3]	High
Rock Drill	85[3]	High
Crane	85[3]	High
Paver	85[3]	High
Scraper	85[3]	High
Pneumatic tools	85[3]	High
Large Diesel Engine	86	High
Generator	87	High
Front-end Loader	87	High
Drill Rig	88	High
Medium Trucks & Sport Vehicles (65 mph)	89	High
General construction	89	High
Large Truck	89	High
Jackhammer	89[3]	High
Concrete Saw	90	High
Hydra Break Ram	90	High
Mounted Impact Hammer Hoe-Ram	90	High
Large Tree Falling	92	Very High
Clam Shovel	93	Very High
Jake Brake on Truck	94	Very High
Hydromulcher	94	Very High
Boat motors	95	Very High
RVs (large)	95	Very High
Pneumatic Chipper	95	Very High
Heavy Trucks and Buses	95	Very High
Heavy Construction	96	Very High
Logging Truck	97	Very High
Railroad	98	Very High
Vibratory (Sonic) Pile Driver	101[3]	Extreme
Impact Pile Driver	101	Extreme

Project Sound Sources	**Reported Decibel Level @ 50 ft.**	**Relative Noise Level** [2]
Guardrail Installation and Pile Driving	105	Extreme
23 ft Detonation Cord, on surface	106	Extreme
Track Hoe	106	Extreme
Helicopter S-61 (large, single rotor, loaded)	112	Extreme
Rock Blast	112	Extreme
12 ft Detonation Cord, buried	112	Extreme
Exterior Cone Blast w/ sand bags	120	Extreme
Jet Overflight	136	Extreme
Exterior Cone Blast (obstructed)	127	Extreme
Treetop Blast	137	Extreme

[1] Most values in this table are derived from U.S. Department of Transportation. FHA. 2017. Construction Noise Handbook. Table 9.1 RCNM Default Noise Emission Reference Levels and Usage Factors.
[2] Relative Noise Level: a general, subjective ranking of relative noise levels created by the sources considered here, when used for analysis of relative noise effects on species.
[3] Equipment decibel level has been revised from the 2003 guidance with data provided from U.S. Department of Transportation (2017)

Literature Cited

Environmental Protection Agency [EPA]. 1974. Information on levels of environmental noise requisite to protect public health and welfare with an adequate margin of safety. Prepared by the U.S. Environmental Protection Agency Office of Noise Abatement and Control. EPA/ONAC 550/9-74-004.

Nelson, S.K. and T.E. Hamer. 1995. Nesting biology and behavior of the marbled murrelet. *In*: Ralph, C.J., G.L. Hunt, M.G. Raphael, J.F. Priatt, eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-512. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. pp. 57-67.

U.S. Department of Transportation. FHA. 2017. Construction Noise Handbook. Table 9.1 RCNM Default Noise Emission Reference Levels and Usage Factors.

Appendix A
Marbled Murrelet
(*Brachyramphus marmoratus*)
Auditory and Visual Disturbance Decision Support Tool

User Guide
Version 9
U.S. Fish and Wildlife Service, Arcata, CA
October 1, 2020

Table of Contents

Overview

To facilitate use and understanding of these materials:

- This is an updated guidance from the 2006 Appendix A.
- We have placed instructions and scenarios within the beginning of this document and placed the explanatory and supportive materials within the appendices.
- We have embedded hyperlinks to allow the user quick access and navigation to sections and key terms.
- We have explained the assumptions underlying this decision support tool.

These materials will help users determine the distance within which an auditory or visual disturbance tolerance may rise to the level of take (i.e. harm), as defined in the implementing regulations of the Endangered Species Act of 1973, as amended and related to marbled murrelets (hereafter referred to as murrelets). This information will allow an analyst to use our decision support tools in conjunction with project-specific information to make an effects determination.

Marbled Murrelet Auditory and Visual Disturbance

We developed a summary of behaviors that indicate a reasonable likelihood that a murrelet has been harmed from sound or visual stimuli disturbances.

The Use of Scenarios

We created a set of scenarios that combines a range of possible activities with common existing environmental conditions. The user selects the scenario(s) that best fits their situation and then selects the sound and visual disturbance distances that are associated with the related activity.

Sound Attenuation Model for Estimating Harm Take Distance

We developed a Sound Attenuation Model and then incorporated it into an Excel spreadsheet to quantitatively and objectively estimate the extent and distance to which actions resulting in human activity or elevated sound levels near murrelet nest sites are likely to harm the species.

Auditory Disturbance Threshold Analysis

We conclude murrelets may be harmed from project-generated sound disturbance under one or both of two conditions:

1. *Tolerance Threshold*: species may be harmed at or above an absolute limit of sound in its habitat. This upper sound limit was set as 82 decibels (92 for aircraft), which includes the action-generated and all existing sound sources;
2. *Above-Existing Threshold*: the species may react to elevated sounds in relation to all existing sound sources. We determined this elevated decibel difference to be a 25 decibel difference between all existing noise (i.e., natural background ambient, line and point sound sources) and only the action-generated sound.

Visual Disturbance Threshold Analysis

We conclude murrelets may be harmed from project-generated visual disturbances if the project is within 100 meters of the base of nest tree or from nesting habitat.

Marbled Murrelet Auditory and Visual Disturbance

Three behaviors are considered to potentially indicate disturbance of a murrelet:

1. Flushing of an adult or juvenile murrelet from the nest site or a perch site in the immediate vicinity of the nest.
2. Aborted feeding(s) of a nestling, in which the adult abandons the feeding attempt, as in situations where the adult must return to foraging habitat to obtain new prey.
3. Multiple delayed feeding attempts, in which adult delivery of food to the nestling is delayed multiple times, either within a single day, or across multiple days, due to human-caused disturbance at or near the nest site.

The three behaviors may reach to the level of take (i.e. harm) of murrelets due to:

- Increased risk of predation
- Increased energetics cost
- Risk of decreased fledgling success
- Risk of reduced chick fitness (i.e. poor growth)
- Increase risk of nest abandonment
- Increase risk of mortality of chicks

Significant disturbance occurs when project noise or activity causes a murrelet to become so agitated that it flushes away from an active nest site or aborts a feeding attempt during incubation or brooding of nestlings. A flush from a nest site includes movement out of an actual nest, off of the nest branch, and away from a branch of a tree within habitat during the nesting season. Such events are considered significant because they impair an essential breeding or feeding behavior.

The murrelet is a secretive, solitary species with cryptic plumage (Carter and Stein 1995). The general breeding season for marbled murrelet is March 24 to September 15. Breeding adults usually fly inland before or at sunrise to attend nest sites and adults usually only give soft, or no vocalizations around the nest (Nelson and Hamer 1995a). Such passive defense behaviors and physical characteristics tend to decrease the visibility of a nesting murrelet. Due to the difficulties locating, and then monitoring, murrelet nests, there are no peer- reviewed, published articles providing empirical evidence on disturbance of murrelets. This analysis is based on observations in the field and published studies on other avian species. While different avian species react differently to auditory and visual disturbances, most birds have “very similar frequency ranges and thresholds,” due to the relatively simple construction of the avian ear (Awbrey and Bowles 1990). All birds, except pigeons, are less sensitive to low frequencies than humans, which should make them less sensitive to aircraft noise (Awbrey and Bowles 1990). Further, bird hearing can be damaged by continuous noise, e.g., high-amplitude pure-tone noise for long periods, such as 86-115 dB for several days (Awbrey and Bowles 1990).

Disruption of Normal Behavior

Hull et al. (2001) reports that murrelets spend 0.3 to 3.5 hours per day (mean 1.2 ± 0.7 hours per day) commuting to nests during the breeding season. The distance traveled between the nest site and foraging areas ranges from 12 to 102 km, and creates a substantial energy demand for adults. They estimate roughly 30 days are spent for incubation and 28 days for chick rearing, totaling 58 days for the breeding period. This entails 15 flights to and 15 flights from the nest/adult (i.e., 15 roundtrips) during the incubation period (i.e., 30 day duration with exchanges every 24 hours).

Nelson and Hamer (1995a) state, "Adults return to feed young up to eight times daily," with an average of 3.2 feedings/day (i.e., 1.6 roundtrips/day/adult). Hull et al. (2001) state the "Number of visits by each bird to nests during chick rearing varied from 1 to 1.7 per day (average 1.2)." Nelson and Peck (1995) state, "nestlings were fed up to 5 times a day in this study and up to 8 times a day elsewhere." They also state, "On many days, 2 feeding visits occurred at both dawn and dusk indicating that each adult carried a fish to the chick at least twice daily" (Nelson and Peck 1995). Based on a compilation of radio-telemetry data, several feedings occur during the mid-day portion the nestling phase (USFWS 2012b). Murrelets sometimes take up to an hour at the nest when delivering a prey item. Given the number of feedings and the amount of time an adult murrelet spends at the nest, the minimum percent time per midday period an adult would be in a forest stand attempting to feed its nestling would be 1 percent (using 12 hours in midday, 1 feeding per midday, 7 minutes per feeding) and the maximum percent would be >100% (using 8.5 hours in midday, 10 feedings per midday, 1 hour per feeding). A reasonable worse-case scenario would be 58 percent (using 9 hours in midday, 7 feedings per midday, and 45 minutes per feeding). A reasonable worse- case scenario indicates that, in an occupied murrelet stand, we would expect that one adult per nest could be present any time during the day. Therefore, there is a reasonable likelihood that the types of audio and visual activities addressed here would intersect with a prey delivery attempt at some point during each day in the nestling phase.

Likelihood of Harm to Breeding Murrelets

Increased Risk of Predation

The relationship between human activities and predators, and their potential impact on murrelet nesting success, has been identified as a significant threat to murrelets (Peery and Henry 2010). Murrelets have evolved several mechanisms to avoid predation: they have cryptic coloration, are silent around the nest, minimize movement at the nest, and limit incubation exchanges and chick feeding to occur primarily during twilight hours (Nelson 1997). Losses of eggs and chicks to avian predators have been determined to be an important cause of nest failure (McShane et al. 2004). The risk of predation by avian predators (especially corvids) appears to be highest in close proximity to forest edges (including roads), campgrounds, settlements, and human activity, where many corvid species (e.g., jays, crows, ravens) are in highest abundance (Raphael et al. 2002, McShane et al. 2004, Marzluff and Neatherlin 2006). Nest failure and predation were highest within 50 m from edges of clearcuts, especially in areas close to human activity, which were defined to be at least as large as "campgrounds or small human settlements" (Raphael et al.

2002). Steller's jays (*Cyanocitta stelleri*) were found to be abundant at "hard-edged sites" (edges of clear cuts 5 to 11 years old) and "soft-edged sites" (next to regenerating stands 17 to 39 years old) but rare at "natural-edged sites" (next to rivers and avalanche chutes) (Malt and Lank 2009). Simulated murrelet nests placed in hard edges had 2.5 times the probability of disturbance by avian predators relative to nests placed in adjacent interiors, whereas nests in soft edges were only one-third as likely to be disturbed as nests in adjacent interiors (Malt and Lank 2009). Nests in natural-edged sites showed little difference in risk of avian disturbance between edges and interiors (Malt and Lank 2009). Scaropignato and George (2013) found that murrelet nests occurred within the home ranges in 60% of the ravens they studied.

Murrelets appear to be most sensitive to noise or visual disturbances when they are approaching a nest site or delivering fish to a nestling. There are several documented instances where ground-based activities caused adult murrelets to abort or delay feedings of nestlings, caused adults to divert their flight paths into nesting habitat, or caused murrelets to vacate habitat (Hamer and Nelson 1998, USFWS 2012b). Disturbances that cause a murrelet to flush can advertise the nest's location, thereby creating a likelihood of predation of the eggs or nestlings (USFWS 2006). Nelson and Hamer (1995b) found that the single largest cause of murrelet nest failure was predation (56% of failed nests), due mostly to corvids. Consequently, activities that cause a breeding murrelet to flush may increase the likelihood of predation either by advertisement of the nest's location or through the increased time the adult is commuting.

If an adult conducts a single feeding, and that feeding is aborted, and it later returns with another prey item the same day, then its time spent commuting would increase by 100%. Likewise, on days when the adult would make two feeding roundtrips, commute time would increase by 50%. Ralph et al. (1995) states "predation on adult murrelets by raptors occurs in transit to nest sites…Given the small number of nest sites that have been monitored, observations of the taking of adult murrelets by predators raises the possibility that this is not a rare event." Ralph et al. (1995) list several observations of raptors killing adult murrelets and of murrelet wings and bones being found in peregrine falcon nests (*Falco peregrinus*) nests. Moreover, if logging and development (e.g., clearing land, creating patches of habitat, thinning stands) within the murrelet's range has resulted in increased numbers of predators or predation rates, and has made murrelet nests easier to locate because of increased amounts of edge and limited numbers of platforms with adequate hiding cover, then predation on murrelet nests could be significantly higher in such situations. (Long and Ralph 1998).

Effects of Increased Energetics Cost

Hull et al. (2001) estimate the energetic expenditure of commuting to the nests for murrelets for the entire breeding season to be 1,200 to 10,144 kJ (mean 3,883 ± 2,296 kJ). If we divide the mean energetic expenditure, 3,883 kJ, by the estimated 71 trips during the incubation and chick-rearing period, then each adult spends, on average, 54.69 kJ/trip on feeding trips during the breeding season. Hull et al. (2001) also estimate the daily field metabolic rate is 416.7 kJ during the breeding season. The field metabolic rate is estimated to be 3 times the basal metabolic rate and here includes daily activities, such as feeding, but not flying. So, as a percentage, each trip (of the assumed 71 during the incubation and chick-rearing period) requires an extra 13.12% kJ/day, in addition to the field metabolic rate. To use the range stated in Hull et al. (2001), "the added cost of commuting to nests was 1,200 to 10,144 kJ over the breeding season, or an additional 5 to 42% (mean 16%) above normal field metabolic-rates."

Each flight to the nest is energetically costly, increases the risk of predation from avian predators, and detracts from time spent in other activities such as foraging (Hull et al. 2001). Increases in prey capture and delivery efforts by adults result in reduced adult body condition by the end of the breeding season, and increases the predation risks to adults and chicks as more inland trips are required (Kuletz 2005).

If the adult aborts a single feeding and returns with another prey item that same day, the energy used per successful feeding attempt will increase by 100% (to 109.38 kJ/day, using the average daily rate) or 50% (to 164.07 kJ/day on those days when the adult would make two trips). Obst et al. (1995), in their study on least auklets (*Aethia pusilla*), stated an average inbound energetic cost per feeding attempt of 36.25 kJ/hour, and an average outbound cost of 31.76 kJ/hour. Using these numbers and the average commuting time stated in Hull et al. (2001) (0.3 to 3.5 h), a single aborted feeding would increase the energy expenditure per successful trip from 40.8 to 476.07 kJ, and when the adult would make two trips, this would increase the energy expenditure from 61.2 to 714.10 kJ. Hence, a single aborted feeding may increase the daily expenditure for feeding the chick to more than 100% of the adult's daily field metabolic rate of 416.7 kJ.

Ricklefs et al. (1986) suggested "that the period during which adults brood small chicks may be the most demanding energetically because parents can feed only half the time yet must support both themselves and their chick at best." Roby and Ricklefs (1986) state that 12% of an adult's daily energy cost spent on foraging and commuting is "substantial." They suggest "the one-chick broods of auklets and diving petrels are… a consequence of the high energy costs of foraging and transporting chick meals." Ricklefs et al. (1986) also found that "the foraging efficiency during both the incubation and chick-rearing periods is about 0.4 kJ returned per kJ expended." This efficiency will decrease by half as the time spent per successful feeding attempt doubles.

Hodum et al. (1998) state that Cassin's Auklets (*Ptychoramphus aleuticus*) need to consume approximately 67% of their body mass daily in order to meet their energy needs. Mehlum et al. (1993) have shown that Black Guillemots (*Cepphus grylle*) consume 61% of their body mass in prey per day, and Gabrielson et al. (1991) state Dovekie (*Alle alle*) need to consume 80% of their body mass daily to maintain their high field metabolic rate. While we do not know exactly how much time a chick-rearing adult spends foraging each day, if the average weight of an adult murrelet is 232 g and the average prey item is a 10 g Pacific sand lance (*Ammodytes hexapterus*) (Hull et al. 2001), then an adult will need to capture 14 fish each day to achieve 60% of its body mass. Such foraging requirements may be difficult to achieve if the adult is spending the upper end of the estimated time commuting, i.e., 7 hours for two feeding trips, or 10.5 hours for three trips, in effect, a 50 or 100% increase in the energy expended by the adult foraging and commuting may increase a likelihood of harm through a decrease in energy availability for the adult, and a decrease in available time for foraging.

Physiological Stress Effects

It is difficult to determine when human activities create negative physiological effects on murrelets, and currently the scientific data do not exist to determine the exact levels that auditory or visual disturbances may harm murrelets due to physiological stress.

The potential negative effects of corticosteroids are an example of physiological effects that are difficult to detect. Corticosterone is released by the hypothalamo-pituitary-adrenal gland to help animals respond to environmental stress. Except for the study by Wasser et al. (1997), corticosterone studies have not been conducted on murrelets, and it is not known at what levels and for what duration corticosterone needs to be elevated before the likelihood of harm is created. "However, chronic high levels may have negative consequences on reproduction or physical condition" (Marra and Holberton 1998). Kitaysky et al. (2001) reported that corticosterone implanted black-legged kittiwake (*Charadriiformes*, *laridae*) adults spent more time (nearly 20x) away from nest and less time brooding/guarding than sham-implanted adults. The proportion of corticosterone-implanted parents that failed to return to the breeding colony was significantly larger than its sham-implanted parents. They concluded their results do not demonstrate an effect of high corticosterone levels on the breeding success of adults.

Nestling mockingbirds (*Mimus polyglottos*) less than 10 days old showed little or no secretion of corticosterone, but late-stage nestlings showed elevated levels when they were about to fledge, indicating that young-stage nestlings may not be susceptible to corticosterone effects due to disturbance (Sims and Holberton 2000); it could also be that corticosterone is naturally produced to help in the fledging process. Blethoff and Dufty Jr. (1998) reported a correlation between an increase in serum corticosterone levels in young western screech owls (*Otus kennicottii*) and an increase in motor activities (jumping and wing flapping) in preparation for dispersal.

Whether such elevated levels of corticosterone would result in adverse effects of murrelets to a level of harm is unknown. Therefore, the possible effects of elevated corticosterone was not considered in this analysis given the lack of data for any avian species showing a clear correlation between elevated corticosterone levels and effects to feeding, breeding or sheltering.

Likelihood of Harm to Murrelet Nesting

Effects of Reduced Feedings to Chicks

Murrelets are most sensitive to noise or visual disturbances when they are approaching a nest site or delivering fish to a nestling. Murrelet nestlings are fed primarily during dawn and dusk periods, but also may be fed throughout the day (Nelson 1997). Even with morning and evening timing restrictions in place, murrelets exposed to noise or visual disturbances are susceptible to missed feedings during the day. Nelson and Hamer (1995b) reported that relatively few feedings take place during the daytime.

Hull et al. (2001) use a 10 g Pacific sand lance as a composite of the average payload an adult carries to the nest. Assuming an assimilation efficiency of 76% (Montevecchi et al. 1984, Hull et al. 2001), they also estimate that each 10 g sand lance has an energetic value of 54.3 kJ. If we use the average of 4 total daily adult feeding visits per nest, we get 217.2 kJ delivered per day. A single aborted feeding of one parent would constitute a loss of 25% of that day's kJ, or 13% of the daily field metabolic rate of 416.7 kJ (which we must assume is a high metabolic rate for the chick as it represents the estimated daily field metabolic rate of an adult during breeding season). Such a loss might be construed as a significant disruption of normal behavior given that, "Murrelet chicks grow rapidly compared to most alcids, gaining 5-15 g/day during the first 9 days after hatching" (Nelson and Hamer 1995a). The average daily increase for the first nine days of neonate development is 10.94%, while the percentage of increase for the next 16 days is 2.17% (Simons 1980).

Missing a single feeding may disrupt normal behavior and create the likelihood of harm by presenting a development risk to the chick. During chick rearing, adults feed the young 1 to 8 times per day (mean = 3.2 ±1.3 SD) (Nelson and Hamer 1995b). If we assume an average of 4 feedings per day, a single aborted feeding would constitute a loss of 25 percent of that day's food and water intake for the nestling. Such a loss is considered to be a significant disruption of normal behavior given that, "Murrelet chicks grow rapidly compared to most alcids, gaining 5 to 15 g/day during the first 9 days after hatching" (Nelson and Hamer 1995b). Considering such a fast growth rate and a low average number of daily feedings, missing a single feeding may disrupt normal growth and constitute harm by presenting a developmental risk to the chick. Simons (1980) documented negative daily growth rates of over 10%, but none of the days of negative growth occurred during the first nine days. Further, Ricklefs (1983) states in regards to avian postnatal development, "although daily food deprivation is easily compensated by increased feeding rate, chronic deprivation for periods of 1 out of 2 days or 2 out of 3 days cannot be fully compensated." Hebert and Golightly (2006) estimated that a single missed feed could deprive the chick of 25-50 percent of its daily energy and water intake, which could have a significant negative impact on fledging success.

Murrelets exhibit prioritizing wing and bill growth and delaying the development of fat stores to post-fledging development (Janssen et al. 2011). This is believed to be an adaptive strategy to reduce the length of the nestling period while maintaining a high probability of successful fledging and survival immediately after fledging (Janssen et al. 2011). Young murrelets that receive multiple daily feedings grow faster and fledge earlier than those with lower provisioning rates. Early fledging helps minimize nest mortality (Nelson and Hamer 1995b).

Forty-five fish-eating alcids (e.g., murrelets, *Brachyramphus* spp.; and puffins, *Fratercula* spp.) exhibit wide variations in nestling growth rates. The nestling stage of murrelet development can vary from 27 to 40 days before fledging (DeSanto and Nelson 1995). The variations in alcid development are attributed to constraints on feeding ecology, such as specialized foraging behaviors, unpredictable and patchy food distributions, and great distances between feeding and nesting sites (Øyan and Anker-Nilssen 1996). Food limitation often results in poor growth, delayed fledging, increased mortality of chicks, and nest abandonment by adults (Øyan and Anker-Nilssen 1996). Growth rates of body mass and skeletal elements in alcids are strongly affected by rates of food intake; and low rates of daily food intake result in a significant increase in the duration of chick development time (Kitaysky 1999). Some alcids respond to reduced provisioning by slowing their metabolic rates and allocating growth to the head and wings to facilitate successful fledging (Øyan and Anker-Nilssen 1996; Kitaysky 1999).

Contemporary studies of murrelet diets in the Puget Sound–Georgia Basin region indicate that Pacific sand lance (*Ammodytes hexapterus*) now comprise the majority of the murrelet diet

(Gutowsky et al. 2009). Historically, energy-rich fishes such as herring (*Clupeidae. spp.)* and northern anchovy (*Engraulis mordax*) comprised the majority of the murrelet diet (Becker and Beissinger 2006; Gutowsky et al. 2009). This is significant because sand lance have the lowest energetic value of the fishes that murrelets commonly feed on. A single northern anchovy has nearly six times the energetic value of a sand lance of the same size (Gutowsky et al. 2009), so a chick would have to eat six sand lance to get the equivalent energy of a single anchovy. This illustrates the significance that a single feeding can represent for a murrelet nestling. Assuming nestlings receive an average of three single-fish feedings per day (Nelson and Hamer 1995b), a nestling being fed a low-quality diet comprised primarily of sand lance may be on the edge of its energetic needs for successful development. Nestlings have minimum daily energetic demands to sustain life and development, and mortality from starvation occurs when nestlings do not receive sufficient food (Kitaysky 1999).

A study of 158 radio-tagged murrelets in Washington found that of 20 confirmed nesting attempts, only 4 nests were successful, indicating a very low nesting rate and low nesting success (Bloxton and Raphael 2009). The majority of the nest failures were attributed to nestling starvation or adults abandoning eggs during incubation (Bloxton and Raphael 2009). The findings from Bloxton and Raphael (2009) indicate that murrelets in Washington are not initiating nesting or are abandoning their nests during incubation or chick rearing, most likely in response to poor foraging conditions. For those murrelets that do initiate nesting and begin chick rearing, the implications of missed feedings due to noise or visual disturbance are significant, because each missed feeding represents a delay in the development of the chick, prolonging the time to fledging and increasing the risk of predation, accidental death from falling off the nest, or abandonment by the adults. If the disturbance at a nest site is prolonged, each successive day of disturbance represents an increasing risk that multiple missed feedings will trigger a significant delay in their growth and development processes, cause permanent stunting, or result in the mortality of a nestling due to malnourishment.

If one of the murrelet chicks exposed to disturbance is already receiving a low average number of daily feedings, it is reasonable to assume that a single missed feeding can disrupt normal growth and constitute harm by presenting a developmental risk to the chick. Hence, while the ability of an adult murrelet to increase feeding rates is unknown, a single missed feeding may represent deprivation for one day and may not be compensable.

Auditory Disturbance Threshold Analysis

How sounds disturb nesting murrelets are not well known. Typically, we have positive data (instances of reactions) but no negative data (number of times an action was done near a nesting murrelet with no reaction by the murrelet). We have assumed that murrelets would not detect a change in sound pressure until it was at least 4 dB above ambient levels. This is based on a study by (McFadden and Saunders 1989) that found that 16 species of birds had an average sensitivity of 4 dB to detect a sound. Therefore, in areas where sound pressure levels differ from ambient conditions, an effect to the species would not be anticipated until the sound pressure exceeded the ambient condition by at least 4 dB.

Documented Murrelet Response to Aircraft Activities

Long and Ralph (1998) noted that murrelets did not have a response to either airplanes or helicopters flying overhead, except when they passed at low altitudes. They noted that one chick did not respond to an airplane passing twice within 0.25 mile at 1,000 feet, but another chick lay flat on the branch "when an aircraft passed at low altitude ("low altitudes" was not defined). During incubation, we do not expect murrelets to flush in response to aircraft based on studies of other species as described by Grubb et al. 2010; Craig and Craig 1984; Fraser et al. 1984; and Delaney 1999, and based on observations of marbled murrelets (Long and Ralph 1998).

Documented Murrelet Response to Action-Generated Sound

Long and Ralph (1998) reported no visible reaction from a murrelet (the paper does not state if it was an adult or a chick) due to many rifle shots within 200 meters from the nest in the Mt. Baker Snoqualmie National Forest. Hébert and Golightly (2006) did not find a statistically significant difference in the responses of murrelet chicks exposed to chainsaw noise compared to pre- and post-disturbance trials. All three chicks exposed to chainsaw disturbance fledged. Hébert and Golightly conclude that chainsaw noise disturbance lasting 10 to 15 minutes at a distance greater than 25 m from the nest does not appear to induce long-term behavioral changes.

Documented Murrelet Responses to Action-Generated Sounds at Higher Ambient

We anticipate that murrelets that select nest sites in close proximity to heavily used roads are either undisturbed by or habituate to the sounds and activities associated with these roads (Hamer and Nelson 1998). Murrelet responses to abrupt noises, such as car doors slamming and gun shots vary. (Long and Ralph 1998). Murrelet responses (or lack of response) may be related to previous exposure. At three nests observed between 1991 and 1994 in Big Basin Redwoods State Park, murrelets showed no visible response to car doors slamming in a nearby public parking lot, where at least 20 cars parked on a daily basis. In contrast, most other nest sites were located away from public roads or parking areas and investigators were careful to close doors softly when they parked nearby (Hamer and Nelson 1998.). However, Nelson did observe one instance in 1990 at the Valley of the Giants when a car door was closed loudly about 150 m from the nest. The adult under observation jumped, but did not abandon the nest.

Murrelets appeared generally undisturbed by passing vehicles, or sharp or prolonged loud noise (Long and Ralph 1998). One instance of a chick jumping was recorded at the sound of a car door slamming 150 m from the nest, however this was in an area where roads are closed so car door sounds are unusual. Loud noises such as boom box portable radios, car doors slamming, and loud visitors hiking nearby at the Big Basin Redwoods State Park nests (California) did not disturb either the adults or chicks. However, this level of noise disturbance is unique to the park, and has not been observed at any other nests, and therefore cannot be translated as acceptable disturbance in other areas (Long and Ralph 1998).

Long and Ralph (1998) reported very little response by adults or chicks due to road-grading, logging operations within 0.5 mile, and loud radios. Murrelet chicks show little or no response to vehicles passing within 70 meters of the nest on lightly-used roads or heavily-used roads (Long and Ralph 1998). Typically, two large trucks needed to intersect in front of the Ruby Beach nest—the nest tree was located 8 meters from Highway 101—for the incubating adult to flush from the nest. The location of this nest indicates that the murrelets which chose to be so close to a busy highway were, apparently, relatively oblivious to vehicle traffic.

Hébert and Golightly (2006) documented few overt responses of nesting murrelets to chainsaw noise and the presence of people hiking on trails in Redwood National and State Parks in Northern California. They conducted chainsaw disturbance tests for 15-minute intervals at a distance of 25 meters from the base of occupied nest trees (n = 12). Adult and chick responses to chainsaw noise, vehicle traffic, and people walking on forest trails resulted in no flushing and no significant increase in corvid presence. However, adults exposed to chainsaw noise spent more time with their head raised, and their bill up in a posture of alert, vigilant behavior. When undisturbed, adult murrelets spent 95 percent of the time resting or motionless. Many adult murrelets exposed to an operating chainsaw ultimately experienced complete nest failure, but the authors caution that the relationship, if any, between the disturbance trials during the incubation period and fledgling success was unclear. They concluded that reproductive success was similar for control (13 percent) and experimental nests (30 percent).

Adult murrelets in nest trees located 10 meters and 25 meters from heavily used hiking trails and three nests overhanging a trail used by 25,000 visits per year "rarely showed behavior suggestion agitation from human presence or noise" or showed "no visible reaction to loud talking (or) yelling…near the nest tree" (Long and Ralph 1998).

Published Auditory Disturbance on Avian Species

Published studies on avian responses to various sound-generating activities (exceeding ambient conditions approximately 17-23 dB) varies from decrease in egg production, decrease in fledged chicks, increased corticosterone secretion, increased predation, avoidance of otherwise high quality habitat, change in vocal frequency (Halfwerk et al. 2010; Crino et al. 2013; Blickley et al. 2012; Schroeder et al. 2012; Francis et al. 2011). Thiessen and Shaw (1957) found that caged ring-billed gulls (*Larus delawarensis*) subjected to sounds at a range of frequencies and decibel levels reacted by cringing at 83-91 dB and by increased heart rates at 92 dB. Awbrey and Bowles (1990:21) stated that "what little published literature (on raptors) is available suggests that noise begins to disturb most birds at around 80-85 dB sound levels and that the threshold for the flight response is around 95 dB." Brown (1990) subjected crested terns to experimental noises imitating aircraft overflights in an area with 55-75 dB ambient noise levels, and found that, at 70 dB, about 55 percent were alert and, at 95 dB (the loudest they tested), approximately 15 percent were startled and 8 percent flushed. Delaney et al. (1999) found that Mexican spotted owls, during both the nesting season and the non-nesting season, did not flush from helicopter noise unless the noise was at least 92 dB(A). Due to results from all of these studies, we estimate the sound-only harm threshold to be 92-95 dB (rounded down to 92 dB)."

Table 1. Selected Auditory Disturbance References for Various Avian Species

Species	Response	Type of Disturbance	Action-Generated Sound Level (dB)	Existing (Ambient) (dB)	Distance	Reference
Great tit (*Parus maj)*	Reduction in reproductive success	Four-lane highway	67.8	46.5	400-700 m	Halfwerk et al. 2010.
White-crowned sparrows (*Zonotrichia leucophrys*)	Increased corticosterone secretion, increased predation	Noise and distance to road	59.53±0.94	42.74±0.34	5 m	Crino et al. 2013
Greater sage-grouse (*Centrocercus urophasianus*)	Increased corticosterone secretion, decline in occupancy	Road-noise	67.662.0	Natural Ambient <50	In leks (display grounds)	Blickley et al. 2012
Greater sage-grouse (*Centrocercus urophasianus*)	Increased corticosterone secretion, decline in occupancy	Drilling-noise recordings	71.4±1.7	Natural Ambient <50	In leks (display grounds)	Blickley et al. 2012
House sparrows (*Passer domestic)*	Reduction in reproduction and survival between hatching and fledging	Noise of large generators	68	Natural Ambient <50	Entrance of nest boxes	Schroeder et al. 2012
Grey flycatcher (*Empidonax wrightii*)	Decline in occupancy, vocal frequency did not change	Gas wells with compressors	46-68.2	32.1-45.8	50-150 m	Francis et al. 2011
Ash-throated flycatcher (*Myiarchus cinerascens*)	Occupancy uninfluenced, but vocal frequency increased	Gas wells with compressors	46-68.2	32.1-45.8	50-150 m	Francis et al. 2011

Auditory Disturbance Determination

Based on published avian studies in Table 1, we expect murrelets to have significant behavioral responses when project-generated sound exceed ambient nesting conditions by 20-25 dB based on differences between the recorded minimum ambient decibel levels. In addition, adult murrelets conducting an incubation exchange or delivering a prey item may alter their behavior in response to aircraft. We expect murrelets may abort or delay feedings in response to exposure to aircraft at sound levels exceeding 92 dB SEL based on observed response of Mexican spotted owls to helicopters (Delaney 1999). We also expect that nestlings would also respond to aircraft by lying flat on the nest branch.

Visual Disturbance Threshold Analysis

Documented Murrelet Response Visual Disturbance

In response to ground-based human activity, adult murrelets have delayed and aborted feedings (Hamer and Nelson 1998; Long and Ralph 1998), flushed from the nest limb (Hamer and Nelson 1998), diverted their flight paths (Hamer and Nelson 1998), and delayed entry to nesting habitat (Hamer and Nelson 1998). Chicks have responded to human presence by assuming defensive postures (Binford et al. 1975; Long and Ralph 1998; Simons 1980). For example:

- Hamer and Nelson (1998) report that a ground observer who moved from being out of sight to 35 meters away from the base of a nest tree caused an adult murrelet to fail at feeding its young and fly away. The same adult returned 1 hour 21 minutes later and fed the chick, although it took a different flight path to the nest. They also found that twenty-seven percent of the time (8 of 30 instances) in which people were within 40 meters of the Ruby Beach murrelet nest, the adult flushed the nest or postponed/aborted a feeding attempt. (Hamer and Nelson 1998). Hamer and Nelson (1998) noted that nest disturbances that shorten or interfere with feeding interchanges could be detrimental to young birds. They recommended a 125-meter buffer to allow for machinery noise to reach ambient noise levels, and a 150 m buffer for any type of blasting. The researchers recommend that the first concern in protecting nesting habitat from disturbances should be to visually screen any disturbances near areas where birds are nesting.

- Long and Ralph (1998) report that adult murrelets located in trees 10 and 25 meters from heavily used hiking trails (used by 25,000 visits per year) “rarely showed behavior suggesting agitation from human presence or noise” or showed “no visible reaction to loud talking (or) yelling…near the nest tree”. Nestlings also did not have a noticeable response when researchers were within 6-35 meters and they appeared to habituate to researchers changing camera batteries within 1 m (Long and Ralph 1998). In contrast, a radio-tagged male murrelet vocalized and then flew with another murrelet from limb to limb before they both flew from a stand when people arrived in a car, slammed the doors, and talked loudly within 30 meters of the tree. That male was preyed upon by a peregrine falcon (*Flaco peregrinus*) later that day, so it is unknown whether he would have nested there (Long and Ralph 1998).

- Hébert and Golightly (2006) suggest that the behaviors they observed are similar to those of an adult murrelet reacting to the presence of a nest predator, and that prolonged noise disturbance at nest sites could have unknown consequences.

We assume that a murrelet responding to a noise by moving or shifting position may increase the chance that it would be detected by a predator. Additionally, the energetic cost of increased vigilance to protracted disturbance could have negative consequences on nesting success. Adult murrelets feed their chicks throughout the day. Thus, operating equipment while an adult approaches a nest to feed a chick may cause sufficient disturbance to result in abortion or delay of the feeding. Nestlings appear more tolerant to potential disturbance than do adult murrelets.

Published Avian Response to Visual Disturbance

There are a number of studies on how disturbance affects a variety of birds (USFWS 2006). Rodgers and Smith (1995) recommended a distance of 100 meters for wading bird colonies and

180 meters for mixed tern/skimmer colonies to effectively buffer from human disturbance caused by approach of pedestrians. If we expand our criteria to include forest dwelling, branch-nesting birds, the great horned owl (*Bubo virginianus*) study (Bednarz and Hayden 1994) article is applicable. Bednarz and Hayden (1994) state that approaches by humans flushed 100 percent of great horned owls at a mean distance of 111.3 meters, with a range of 5-700 meters, and that owls did not return to initial site as long as humans were visible. Multiple studies on bald eagles (e.g., Knight and Knight 1984, McGarigal et al. 1991, Stalmaster and Kaiser 1997), for example, recommend limiting activities beyond 250 meters to reduce threats from visual disturbances.

Hayden and Bednarz (1991) studied the effects of human disturbance during the breeding season for great horned owls, Swainson's hawks (*Buteo swainsoni*), and Harris' hawks (*Parabuteo uncinctus*) in New Mexico. They found that approaches by humans flushed great horned owls at a mean distance of 65 m during incubation, and at a mean distance of 126 m during brood-rearing. All three species fled from nest sites with greater distances of human approach during brood-rearing then during incubation. The authors concluded that overall effects to reproductive success were subtle. Productivity was lower in human-disturbed areas during years when prey populations were depressed but these results were not significant. They recommended that for ease of implementation, to be inclusive of all three species' responses, and to minimize potential effects during years when prey availability was low, a 500 m buffer zone should be applied. It is worth noting that this study was done in an arid, open landscape where presumably the detectability of approaching pedestrians is greater than in a forested landscape.

Table 2: Avian Response Behaviors when exposed to human presence.

Species	Response	Exposure	Distance	Reference
Pelicans	Nest abandonment, predation and egg or nestling mortality	People in vicinity	600 m	Carney and Sydeman (1999)
Swans	Flushing	Vehicles	230 m	Henson and Grant (1991)
Swans	Flushing	People in vicinity	230 m	Henson and Grant (1991)
Pelicans	Flushing	People in vicinity	100 m	Carney and Sydeman (1999)
Terns and skimmers	Flushing	People in vicinity	80-142 m	Carney and Sydeman (1999)
Terns	Flushing	People in vicinity	106 m	Carney and Sydeman (1999)
Wading birds	Flushing	People and boats in vicinity	<100 m	Rodgers and Smith (1995)
Terns	Flushing	People and boats in vicinity	<180 m	Rodgers and Smith (1995)
Penguins	Flushing and nest abandonment	Helicopters	1,000 – 1,500 m	Carney and Sydeman (1999)
Great Horned Owls	Flushing	People in vicinity	111.3 m	Bednarz and Hayden (1994)

Delaney (1999) and Delaney and Grubb (2001) note that ground-based disturbance may have a greater effect than aerial disturbance on nesting success. Long and Ralph (1998) concluded that pedestrians had the greatest impacts to nesting birds, especially when there were no visual barriers between people and nests.

Visual Disturbance Distance Determination

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

The visual disturbance distance is the distance at which murrelets can detect humans and their activities from the species' nest site or flight approach path. Murrelet researchers advised buffers of greater than 100 meters to reduce potential noise and visual disturbance to murrelets (Hamer and Nelson 1998, USFWS 2012). Based on documented incidents provided from murrelet researchers and published reports on visual disturbance on a variety of avian species the visual disturbance distance is 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by murrelets on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area. There is enough variation and overlap in nest establishment, incubation, number of trips adult murrelets may make to nest sites, and hatching periods that we assume there is equal risk and similar responses to these exposures throughout the nesting season.

The Use of Scenarios

Determining whether human activities may harm nesting murrelets due to elevated sound levels and/or close visual proximity of human activities to an active nest includes a daunting array of factors. To simplify this task and facilitate a consistent application of available information, we have incorporated a range of scenarios into a decision support tool (see Table 3). These scenarios cover a range of conditions likely to be encountered during actions in or near murrelet nesting habitat. They also provide a reasonable approximation of the effects of sound and visual detection from human activity on murrelets under specified conditions. The physical formulae applied to sound attenuation are quite precise in theory, their application under field conditions may be subject to substantial error of estimation. Further, the available data on actual sound levels that might disturb wildlife species, especially the murrelet, are limited.

Each scenario includes two levels of natural background sound. The use of 35 dBA is appropriate for those project sites where the sound sources are predominantly quite low and are only occasionally elevated due to wind events and other similar natural sources. The use of 45 dBA is appropriate where natural background sound levels are slightly elevated due to commonly encountered sound sources that may be present at the site, such as afternoon winds, or distant human-generated sounds (e.g., airport, highway). In deciding on the appropriate scenario to use (described in greater detail in Step 6), choose 35 dBA or 45 dBA to reflect the predominant conditions encountered at the project site, not the rare or exceptional condition.

Derivation of Disturbance Distances

The values for auditory and visual disturbance were calculated from an Excel spreadsheet model described in detail in this appendix. For circumstances where more precise and credible data may become available, and for which the analyst may wish to "do the math", we have provided the model as part of this decision support tool. We encourage additional testing and refinement of the model, but discourage its use by those who are unwilling to devote the time to understanding its limitations, or who cannot meet the conditions for quality control of data collection as described in this appendix.

Table 4: Some Common Sound Levels for Equipment/Activities displays a summary of values for typical sound sources that we have used in the model to develop the scenarios. These values represent the most valid data we could find on sound sources, collected under reasonably controlled conditions, and for which source-receptor distances are recorded.

Other data may be available. The analyst is encouraged to use additional data provided the data have been collected using standardized and accepted methods, including a precise measure of the source-receptor distance, and indicate the metric used.

How to Use the Scenarios to Calculate Disturbance Distances

1. Review the list of scenarios and choose from the following pages which best matches the equipment used, the likely sound levels generated by the project, and the background sound levels expected in the affected habitat, i.e., the existing point and line sound sources.

2. Once a scenario is selected, use the values indicated for sound and visual distances to calculate the overall habitat area within which murrelets are disturbed by elevated sound levels or visual detection by murrelets of human activities near nests or potential nests. These distances are used to calculate the total area within which take due to harm is likely to occur due to the project.

As an example, we need to estimate the area of murrelet nesting habitat subject to auditory and visual disturbance from proposed maintenance of 2 miles of hiking trail through murrelet nesting habitat. No surveys have been done in this area, but this habitat is similar to nearby known occupied habitat, justifying our assumption that this habitat is also occupied. The maintenance involves the use of a chainsaw to clear windfalls. All other tools used in the maintenance are hand tools that produce lower sound levels. The natural background sound level along this trail is low, about 35 decibels, and there are no other existing point or line sources of sound. The only existing sound on the trail is from human speech and the sounds of hikers.

Scenario 1 estimates an auditory disturbance distance of 30 m and a visual disturbance distance of no more than 100 meters. One hectare is 10,000 square meters or 2.47 acres. Therefore, the area of habitat subject to auditory disturbance is (30 m x 2 (both sides of the trail) x 3220 m)/10,000 m^2 = 19.3 ha (47.6 acres). Calculate the area of visual disturbance as follows: (100 m x 2 x 3220 m)/10,000 m^2 = 64.4 ha (159.1 acres).

Now, let us suppose site-specific information suggests the visual detection distance is only 60 m (rather than the maximum default of 100 m) due to vegetation density along the trail. Our visual disturbance distance is now (60 m x 2 x 3220 m)/10,000 m^2 = 38.6 ha (95.4 acres). Finally, suppose topographic barriers (a sharp ridge, for instance) along one side of the trail preclude sound from being transmitted more than 15 m along that side of the trail. In this case, calculate the two sides of the trail independently to reflect this site- specific information—((30 m x 3220 m) + (15 m x 3220 m))/10,000 m^2 = 14.5 ha, or 35.8 acres. Based on this output, it may be appropriate to explore ways of reducing disturbance of murrelets by applying seasonal timing restrictions, or requiring use of hand saws, if feasible.

3. For some projects, it may be appropriate to apply different scenarios to different parts of the action area, when conditions vary across the action area. For example, a road construction project that includes work in both isolated areas and areas subject to existing sound sources might apply two different scenarios to account for these two different situations. Then, the total area affected is the sum of the two calculations.

4. The analyst should choose the scenario that *most closely approximates* the conditions encountered at the action site. If the analyst finds that conditions encountered in the proposed action seem to fall intermediate between two scenarios, it is appropriate to select the scenario that provides the greater protection to the species. That is, select the scenario that provides the wider zone of presumed disturbance tolerance, and report the area affected based on that distance. If avoidance of take is not possible, the distance values should be used to calculate the area within which take due to harm is likely to occur.

Scenarios for which disturbance is unlikely have not been included in this list. Examples would include those situations for which action-generated sound levels are below or barely exceed the ambient sound levels on or near the work area. Under these circumstances, action-generated sound levels would not result in harm of murrelets. Please also note, however, that visual disturbance of murrelets may occur under these circumstances, and the analyst should discuss the likelihood of visual disturbance in the absence of excessive noise. In addition, some potential scenarios involve action-generated sounds so extreme as to not be applicable to the methods described in this document. Actions involving these extreme sound sources cannot be analyzed using these scenarios and the model underlying these scenario outcomes. Those circumstances will need separate, action-specific analyses to determine their potential impacts to murrelets.

Table 3 below provides a summary of auditory disturbance distances estimated for various levels of sound generated by human activities, when considered in a range of existing conditions. The reader must refer to the following pages for detailed information pertinent to each scenario and its appropriate interpretation.

Table 3. Table of Scenarios

Action Scenario	Natural Background (dB)	Existing point sound sources [1]	Existing line sound sources [1]	Action-generated sound [1]	Disturbance Distance for Marbled Murrelet (m) (35 dBA/45 dBA)
Scenario 1	35/45	zero	zero	very low	30/10
Scenario 2	35/45	zero to very low	zero to very low	low	75/30
Scenario 3	35/45	zero	zero	medium	300/100
Scenario 4	35/45	very low to low	very low to low	medium	30/30
Scenario 5	35/45	zero to very low	zero	high	500/250
Scenario 6	35/45	low to moderate	very low to low	high	75/75
Scenario 7	35/45	low to moderate	moderate	high	100/100
Scenario 8	35/45	zero to low	zero to very low	very high	500/500
Scenario 9	35/45	moderate to high	low to moderate	very high	300/300
Scenario 10	35/45	moderate to high	high	very high	500/500

[1] The follow sound levels are used for the categories presented in this summary table: Zero: < 45 dBA.

- Very low: 46-65 dBA
- Low: 66-76 dBA
- Medium: 77-87 dBA
- High: 88-95 dBA
- Very High: 96-108 dBA
- Extreme: >108 dBA

Table 4. Some Common Sound Levels for Equipment/Activities[1]

	Range of Reported dB Values @ Distance Measure *Distance Measure assumed to be 50 ft unless otherwise indicated.*	
Project Sound Sources	**Reported Decibel Level @ 50 ft.**	**Relative Noise Level [2]**
Library (ambient sound level)	30	Ambient
Conversation	34	Ambient
Speech (normal)	41	Ambient
Milling Machine	61	Low
Motorcycle on Trail (620 cc street legal, meter at ground level)	62	Low
Power Lawn Mower	68	Low
Yelling	70	Low
Generator (25 KVA or less)	70	Low
Gas Lawn Mower	72	Moderate
Chainsaw (Stihl 025)	73	Moderate
Welder	74[3]	Moderate
Pickup Truck (driving)	75[3]	Moderate
Flatbed Pickup Truck	77	Moderate
BPA Powerline	78	Moderate
Cat-skidder	80	Moderate
Compressor (air)	80[3]	Moderate
Backhoe	80[3]	Moderate
Concrete Mixer (Vibratory)	80[3]	Moderate
Pumps	81[3]	High
Horizontal Boring Hydraulic Jack	82[3]	High
Slurry Machine	82[3]	High
Vacuum Street Sweeper	82[3]	High
Concrete Pump	82	High
Log Loader	83	High
Ground Compactor	83[3]	High
Concrete Batch Plant	83	High
Dump Truck	84	High
Flat Bed Truck	84	High
Roller	85[3]	High
Mowers, leaf blowers	85	High
Passenger Cars/Light Trucks (65 mph)	85	High

Project Sound Sources	Reported Decibel Level @ 50 ft.	Relative Noise Level [2]
Auger Drill Rig	85	High
Truck Horn (Warning)	85[3]	High
Equipment > 5 horsepower	85	High
Impact Wrench	85	High
Concrete Truck	85	High
Road Grader	85	High
Chain saws	85[3]	High
Highway-Traffic	85	High
Dozer	85[3]	High
Rock Drill	85[3]	High
Crane	85[3]	High
Gradall	85[3]	High
Paver	85[3]	High
Scraper	85[3]	High
Pneumatic tools	85[3]	High
Large Diesel Engine	86	High
Generator	87	High
Front-end Loader	87	High
Front-end loader	87	High
Drill Rig	88	High
Medium Trucks & Sport Vehicles (65 mph)	89	High
General construction	89	High
Large Truck	89	High
Jackhammer	89[3]	High
Concrete Saw	90	High
Hydra Break Ram	90	High
Mounted Impact Hammer Hoe-Ram	90	High
Large Tree Falling	92	Very High
Clam Shovel	93	Very High
Jake Brake on Truck	94	Very High
Hydromulcher	94	Very High
Boat motors	95	Very High
RVs (large)	95	Very High
Pneumatic Chipper	95	Very High
Heavy Trucks and Buses	95	Very High
Heavy Construction	96	Very High
Logging Truck	97	Very High
Railroad	98	Very High
Vibratory (Sonic) Pile Driver	101[3]	Extreme

Project Sound Sources	**Reported Decibel Level @ 50 ft.**	**Relative Noise Level [2]**
Impact Pile Driver	101	Extreme
Guardrail Installation and Pile Driving	105	Extreme
23 ft Detonation Cord, on surface	106	Extreme
Track Hoe	106	Extreme
Helicopter S-61 (large, single rotor, loaded)	112	Extreme
Rock Blast	112	Extreme
12 ft Detonation Cord, buried	112	Extreme
Exterior Cone Blast w/ sand bags	120	Extreme
Jet Overflight	136	Extreme
Exterior Cone Blast (obstructed)	127	Extreme
Treetop Blast	137	Extreme

[1] Most values in this table are derived from U.S. Department of Transportation. FHA. 2017. Construction Noise Handbook. Table 9.1 RCNM Default Noise Emission Reference Levels and Usage Factors.
[2] Relative Noise Level: a general, subjective ranking of relative noise levels created by the sources considered here, when used for analysis of relative noise effects on species.
[3] Equipment decibel level has been revised from the 2003 guidance with data provided from U.S. Department of Transportation (2017).

Scenario 1: Very low action-generated sounds in species habitat otherwise unaffected by human sound-generating activity.		
Sound Source	**Maximum Decibels** [1]	**Typical Sound Sources**
Natural Background Sound	35 - 45	Typical natural background sound level in species habitat for isolated sites on "average" day.
Existing Point Source Sound	0 - 45	No existing point sound sources at the site, or sounds equivalent to natural background.
Existing Line Source Sound	0 - 45	No existing line sound sources at the site, or sounds equivalent to natural background.
Action-Generated Sound	46 - 65	Very low action-generated sounds. Typical of activities limited to small hand tools, human speech, and other fairly inconsequential sounds only slightly higher than natural background.

Description of Existing Ambient Sound Conditions: The existing environment is characterized by the near absence of ambient sounds associated with human activities, and is typified by natural background sounds found in the species habitat (e.g., bird calls, light breezes through vegetation, distant stream flow). Human-generated sound is non-existent, extremely low, or very distant and makes no measurable contribution to ambient sound level at the site. These actions occur in habitats that are either isolated from human activities, or receive minimal human use, and only by the least obtrusive sound sources. Typical sites include isolated habitats, or may occur near hiking trails with relatively infrequent use. No existing sources of significant human-generated sound exists at the site.

Typical Action-Generated Sound Sources and Projects: Action-generated sound sources are typically very low, only slightly above existing ambient and natural background sound levels. Typical sources of sounds in this situation are hand tools and small electric tools, cordless drills, normal to somewhat loud human speech, non-amplified music, small appliances. A typical project covered by this scenario might be the use of hand tools during the maintenance of an infrequently used and isolated hiking trail.

Reported Disturbance Distances for:	**Auditory Disturbance Distance** [2]	**Visual Disturbance Distance** [3]
Low Natural Background Sound Level (~35 dB)[4]	30 m	*Maximum estimated detection distance or 100 m, whichever is lesser.*
Moderate Natural Background Sound Level (~45 dB)[4]	10 m	

[1] Maximum Decibels reports the maximum sound level attributable to these sources that are likely to be encountered in the habitat under most typical conditions for this scenario. Sound levels might exceed these maximum values only infrequently, and by a few decibels at most.
[2] The values reported here for Auditory Disturbance Distance are maximum distances. These values may be less under conditions where topographic breaks (e.g., ridge) may result in barriers to sound propagation, or slightly higher where topographic openings (e.g., intervening canyon) promote sound transmission.
[3] The Visual Disturbance Distance is the distance at which murrelets can detect humans and their activities from the species' nest site or flight approach path, up to a maximum of 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by murrelets on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area.
[4] Report appropriate results from low or moderate natural background sound level depending on normally encountered background sound conditions at the site. Habitat near areas with a Natural Background Sound Level significantly greater than 50 dB may need site-specific analysis.

Scenario 2: Low action-generated sounds in species habitat subject to very low to near zero human sound-generating activity.		
Sound Source	**Maximum Decibels [1]**	**Typical Sound Sources**
Natural Background Sound	35 - 45	Typical natural background sound level in species habitat for isolated sites on "average" day.
Existing Point Source Sound	0 - 65	Very low to non-existent line sound sources at the site
Existing Line Source Sound	0 - 65	Very low to non-existent line sound sources at the site
Action-Generated Sound	66 - 75	Low sound sources typical of milling machine, motorcycle on trail (620 cc), power lawn mower, generator (25 KVA or less), gas lawn mower, chainsaw (Stihl 025), welder.

Description of Existing Ambient Sound Conditions: The existing environment is characterized by very low to zero sources of existing ambient sounds associated with human activities, and is typified by natural background sounds found in the species habitat (e.g., bird calls, light breezes through vegetation, distant stream flow). Human-generated sound is non-existent or very low, and makes only a minor contribution to existing sound level at the site. These actions occur in habitats that are either isolated from human activities, or receive low human use with no sound amplifying tools or devices, and only by the least obtrusive sound sources. Typical sites include isolated habitats, or may occur near hiking trails with infrequent to moderate use levels, but do not include motorized use or motorized maintenance. No existing sources of significant human-generated sound exist at the site.

Typical Action-Generated Sound Sources and Projects: Action-generated sound sources are typically low, somewhat above existing ambient and natural background sound levels. Typical sources of sounds in this situation are hand tools, electric tools, small gas-powered engines with near-new mufflers (such as gas lawn mowers at typical mowing speed), generators (25 KVA or less), loud human speech, moderately-amplified music. A typical project covered by this scenario might be the use of small power tools during the maintenance of a more frequently used hiking trail with existing sources of sound of a low level.

Reported Disturbance Distances for:	**Auditory Disturbance Distance [2]**	**Visual Disturbance Distance [3]**
Low Natural Background Sound Level (~35 dB)[4]	75 m	*Maximum estimated detection distance or 100 m, whichever is lesser.*
Moderate Natural Background Sound Level (~45 dB)[4]	30 m	

[1] Maximum Decibels reports the maximum sound level attributable to these sources that are likely to be encountered in the habitat under most typical conditions for this scenario. Sound levels might exceed these maximum values only infrequently, and by a few decibels at most.

[2] The values reported here for Auditory Disturbance Distance are maximum distances. These values may be less under conditions where topographic breaks (e.g., ridge) may result in barriers to sound propagation, or slightly higher where topographic openings (e.g., intervening canyon) promote sound transmission.

[3] The Visual Disturbance Distance is the distance at which murrelets can detect humans and their activities from the species' nest site or flight approach path, up to a maximum of 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by murrelets on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area.

[4] Report appropriate results from low or moderate natural background sound level depending on normally encountered background sound conditions at the site. Habitat near areas with a Natural Background Sound Level significantly greater than 50 dB may need site-specific analysis.

Scenario 3: Moderate action-generated sounds in species habitat otherwise unaffected by human sound-generating activity.		
Sound Source	**Maximum Decibels [1]**	**Typical Sound Sources**
Natural Background Sound	35 - 45	Typical natural background sound level in species habitat for isolated sites on "average" day.
Existing Point Source Sound	0 - 45	No existing point sound sources at the site, or sounds equivalent to natural background.
Existing Line Source Sound	0 - 45	No existing line sound sources at the site, or sounds equivalent to natural background.
Action-Generated Sound	76 - 87	Most flatbed pick up trucks, cat-skidder, air compressor, backhoe, concrete mixer, pumps, horizontal boring hydraulic jack, concrete pumps, log loader, ground compactor
Description of Existing Ambient Sound Conditions: The existing environment is characterized by the near absence of sounds associated with human activities, and is typified by natural background sounds found in the species habitat (e.g., bird calls, light breezes through vegetation, distant stream flow). Human-generated sound is non-existent or very distant and makes no measurable contribution to ambient sound level at the site. These actions occur in habitats that are either isolated from human activities, or receive minimal human use, and only by the least obtrusive sound sources. Typical sites include isolated habitats, or may occur near hiking trails with relatively infrequent use. No existing sources of significant human-generated sound exist at the site. **Typical Action-Generated Sound Sources and Projects**: Action-generated sound sources are typically moderate, noticeably above existing ambient and natural background sound levels. Typical sources of sounds in this situation are flatbed pickup trucks, cat-skidder, air compressor, backhoe, concrete mixer, pumps, horizontal boring hydraulic jack, concrete pumps, log loader, ground compactor, dump truck, roller, mowers and lead blowers and improvement activities using small to moderate-sized chain saws and similar power tools, but would not include use of aircraft or felling of large trees.		
Reported Disturbance Distances for:	**Auditory Disturbance Distance [2]**	**Visual Disturbance Distance [3]**
Low Natural Background Sound Level (~35 dB)[4]	300 m	*Maximum estimated detection distance or 100 m, whichever is lesser.*
Moderate Natural Background Sound Level (~45 dB)[4]	100 m	

[1] Maximum Decibels reports the maximum sound level attributable to these sources that are likely to be encountered in the habitat under most typical conditions for this scenario. Sound levels might exceed these maximum values only infrequently, and by a few decibels at most.

[2] The values reported here for Auditory Disturbance Distance are maximum distances. These values may be less under conditions where topographic breaks (e.g., ridge) may result in barriers to sound propagation, or slightly higher where topographic openings (e.g., intervening canyon) promote sound transmission.

[3] The Visual Disturbance Distance is the distance at which murrelets can detect humans and their activities from the species' nest site or flight approach path, up to a maximum of 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by murrelets on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area.

[4] Report appropriate results from low or moderate natural background sound level depending on normally encountered background sound conditions at the site. Habitat near areas with a Natural Background Sound Level significantly greater than 50 dB may need site-specific analysis.

Scenario 4: Moderate action-generated sounds in species habitat subject to very low to low human sound-generating activity.		
Sound Source	**Maximum Decibels [1]**	**Typical Sound Sources**
Natural Background Sound	35 - 45	Typical natural background sound level in species habitat for isolated sites on “average” day.
Existing Point Source Sound	46 - 75	Very low to low level of existing ambient sound at the site, slightly above natural background.
Existing Line Source Sound	46 - 75	Very low to low level of existing ambient sound at the site, slightly above natural background.
Action-Generated Sound	76 - 87	Most flatbed pick up trucks, cat-skidder, air compressor, backhoe, concrete mixer, pumps, horizontal boring hydraulic jack, concrete pumps, log loader, ground compactor

Description of Existing Ambient Sound Conditions: The existing environment is characterized by the low to very low levels of sound associated with human activities, and is typified by small power tools, light vehicular traffic moving at slow speeds, recreational activities, and many urban and rural residential activities. In more isolated areas, sounds include those associated with small parks, visitor centers, bike paths, tour roads and residences.

Typical Action-Generated Sound Sources and Projects: Action-generated sound sources are typically moderate, noticeably above existing ambient and natural background sound levels. Typical sources of sounds in this situation are flatbed pickup trucks, cat-skidder, air compressor, backhoe, concrete mixer, pumps, horizontal boring hydraulic jack, concrete pumps, log loader, ground compactor, dump truck, roller, mowers and lead blowers and improvement activities using small to moderate-sized chain saws and similar power tools, but would not include use of aircraft or felling of large trees.

Reported Disturbance Distances for:	**Auditory Disturbance Distance [2]**	**Visual Disturbance Distance [3]**
Low Natural Background Sound Level (~35 dB)[4]	30 m	*Maximum estimated detection distance or 100 m, whichever is lesser.*
Moderate Natural Background Sound Level (~45 dB)[4]	30 m	

[1] Maximum Decibels reports the maximum sound level attributable to these sources that are likely to be encountered in the habitat under most typical conditions for this scenario. Sound levels might exceed these maximum values only infrequently, and by a few decibels at most.
[2] The values reported here for Auditory Disturbance Distance are maximum distances. These values may be less under conditions where topographic breaks (e.g., ridge) may result in barriers to sound propagation, or slightly higher where topographic openings (e.g., intervening canyon) promote sound transmission.
[3] The Visual Disturbance Distance is the distance at which murrelets can detect humans and their activities from the species’ nest site or flight approach path, up to a maximum of 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by murrelets on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area.
[4] Report appropriate results from low or moderate natural background sound level depending on normally encountered background sound conditions at the site. Habitat near areas with a Natural Background Sound Level significantly greater than 50 dB may need site-specific analysis.

Scenario 5: High action-generated sounds in species habitat otherwise subject to very low human sound-generating activity.		
Sound Source	**Maximum Decibels [1]**	**Typical Sound Sources**
Natural Background Sound	35 - 45	Typical natural background sound level in species habitat for isolated sites on "average" day.
Existing Point Source Sound	0 - 65	Very low to non-existent point sound sources at the site.
Existing Line Source Sound	0 - 45	No existing line sound sources at the site, or sounds equivalent to natural background.
Action-Generated Sound	88 - 95	Most large trucks, jackhammer, large falling trees, clam shovel, jake brake on truck, boat motors, large RVs, pneumatic chippers

Description of Existing Ambient Sound Conditions: The existing environment is characterized by very low to zero sources of sounds associated with human activities, and is typified by natural background sounds found in the species habitat (e.g., bird calls, light breezes through vegetation, distant stream flow). Human- generated sound is non-existent or very low, and makes only a minor contribution to existing sound level at the site. These actions occur in habitats that are either isolated from human activities, or receive low human use with no sound amplifying tools or devices, and only by the least obtrusive sound sources. Typical sites include isolated habitats, or may occur near hiking trails with infrequent to moderate use levels, but do not include motorized use or motorized maintenance. No existing sources of significant human-generated sound exist at the site.

Typical Action-Generated Sound Sources and Projects: Action-generated sound sources are typically high, much above existing ambient and natural background sound levels. Typical sources of sounds in this situation are large trucks, jackhammer, large falling trees, clam shovel, jake brake on truck, boat motors, large RVs, pneumatic chippers

Reported Disturbance Distances for:	**Auditory Disturbance Distance [2]**	**Visual Disturbance Distance [3]**
Low Natural Background Sound Level (~35 dB)[4]	500 m	*Maximum estimated detection distance or 100 m, whichever is lesser.*
Moderate Natural Background Sound Level (~45 dB)[4]	200 m	

[1] Maximum Decibels reports the maximum sound level attributable to these sources that are likely to be encountered in the habitat under most typical conditions for this scenario. Sound levels might exceed these maximum values only infrequently, and by a few decibels at most.

[2] The values reported here for Auditory Disturbance Distance are maximum distances. These values may be less under conditions where topographic breaks (e.g., ridge) may result in barriers to sound propagation, or slightly higher where topographic openings (e.g., intervening canyon) promote sound transmission.

[3] The Visual Disturbance Distance is the distance at which murrelets can detect humans and their activities from the species' nest site or flight approach path, up to a maximum of 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by murrelets on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area.

[4] Report appropriate results from low or moderate natural background sound level depending on normally encountered background sound conditions at the site. Habitat near areas with a Natural Background Sound Level significantly greater than 50 dB may need site-specific analysis.

Scenario 6: High action-generated sounds in species habitat subject to very low to moderate human sound-generating activity.		
Sound Source	**Maximum Decibels [1]**	**Typical Sound Sources**
Natural Background Sound	35 - 45	Typical natural background sound level in species habitat for isolated sites on "average" day.
Existing Point Source Sound	66 - 87	Low to moderate level of existing ambient sound at the site.
Existing Line Source Sound	46 - 75	Very low to low level of existing ambient sound at the site, slightly above natural background.
Action-Generated Sound	88 - 95	Most large trucks, jackhammer, large falling trees, clam shovel, jake brake on truck, boat motors, large RVs, pneumatic chippers

Description of Existing Ambient Sound Conditions: The existing environment is characterized by the medium to very low levels of existing ambient sound associated with human activities, and is typified by small power tools, light vehicular traffic moving at slow speeds, recreational activities, and many urban and rural residential and commercial activities. Where existing ambient sound levels approach medium levels, typical point sources include backhoes, ground compactors, road graders, generators, electric power tools, chain saws, and other similar stationary or slow moving, moderate sized equipment. In more isolated areas, sounds include those associated with larger parks, visitor centers, motorized recreational facilities (except loud sources, such as ATVs), businesses, small manufacturing sites, drill rigs, etc. This scenario would not include existing heavy equipment, high speed road traffic, or medium to heavy trucks except at fairly slow speeds and on paved roads (but no jake brakes).

Typical Action-Generated Sound Sources and Projects: Action-generated sound sources are typically high, somewhat above existing ambient and natural background sound levels. Typical sources of sounds in this situation are large trucks, jackhammer, large falling trees, clam shovel, jake brake on truck, boat motors, large RVs, pneumatic chippers

Reported Disturbance Distances for:	Auditory Disturbance Distance [2]	Visual Disturbance Distance [3]
Low Natural Background Sound Level (~35 dB)[4]	75 m	*Maximum estimated detection distance or 100 m, whichever is lesser.*
Moderate Natural Background Sound Level (~45 dB)[4]	75 m	

[1] Maximum Decibels reports the maximum sound level attributable to these sources that are likely to be encountered in the habitat under most typical conditions for this scenario. Sound levels might exceed these maximum values only infrequently, and by a few decibels at most.
[2] The values reported here for Auditory Disturbance Distance are maximum distances. These values may be less under conditions where topographic breaks (e.g., ridge) may result in barriers to sound propagation, or slightly higher where topographic openings (e.g., intervening canyon) promote sound transmission.
[3] The Visual Disturbance Distance is the distance at which murrelets can detect humans and their activities from the species' nest site or flight approach path, up to a maximum of 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by murrelets on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area.
[4] Report appropriate results from low or moderate natural background sound level depending on normally encountered background sound conditions at the site. Habitat near areas with a Natural Background Sound Level significantly greater than 50 dB may need site-specific analysis.

Scenario 7: High action-generated sounds in species habitat subject to moderate human sound-generating activity.		
Sound Source	**Maximum Decibels [1]**	**Typical Sound Sources**
Natural Background Sound	35 - 45	Typical natural background sound level in species habitat for isolated sites on "average" day.
Existing Point Source Sound	66 - 87	Low to moderate level of existing ambient sound at the site.
Existing Line Source Sound	76 - 87	Moderate level of existing ambient sound at the site.
Action-Generated Sound	88 - 95	Drill rig, medium trucks (65 mph), general construction, jackhammer, concrete saw, clam shovel

Description of Existing Ambient Sound Conditions: The existing environment is characterized by medium to very low levels of existing ambient sound associated with human activities, and is typified by small power tools, light to heavy vehicular traffic moving at slow to moderate speeds on improved roads, recreational activities, and many urban and rural residential and commercial activities. Where existing ambient sound levels approach medium levels, typical point sources include backhoes, ground compactors, road graders, generators, electric power tools, chain saws, and other similar stationary or moving equipment, and may include large street-legal trucks and buses but at low speeds. In more isolated areas, sounds include those associated with larger parks, visitor centers, motorized recreational facilities (except loud sources, such as unmuffled ATVs), businesses, small manufacturing sites, small generators, etc. This scenario would not include heavy equipment, high speed road traffic, or medium to heavy trucks except at slow to moderate speeds and on paved roads (but no jake brakes). The primary difference in existing ambient sound between this scenario and Scenario 6 is the slightly higher existing line source ambient sound, as demonstrated by the somewhat higher speeds of vehicular traffic.

Typical Action-Generated Sound Sources and Projects: Action-generated sound sources are typically high, above existing ambient and natural background sound levels. Typical sources of sounds in this situation are large to very large construction equipment, large gas-powered engines, and ATVs and small trucks at high speed or on rough surfaces. Would also include larger construction equipment such as the largest backhoes, large dozers, hoe-rams, large trucks using jake brakes or at moderate to high speeds, clam shovels, pavers, front-end loaders, and impact wrenches. A typical project covered by this scenario is similar to Scenario 6, but this scenario includes a higher level of existing ambient sound levels. These project would typically occur near sources of sound that are of higher level, such as along rural highways and other transportation facilities with moderate traffic and speeds, but not including peak sound sources such as the use of jake brakes.

Reported Disturbance Distances for:	**Auditory Disturbance Distance [2]**	**Visual Disturbance Distance [3]**
Low Natural Background Sound Level (~35 dB)[4]	100 m	*Maximum estimated detection distance or 100 m, whichever is lesser.*
Moderate Natural Background Sound Level (~45 dB)[4]	100 m	

[1] Maximum Decibels reports the maximum sound level attributable to these sources that are likely to be encountered in the habitat under most typical conditions for this scenario. Sound levels might exceed these maximum values only infrequently, and by a few decibels at most.
[2] The values reported here for Auditory Disturbance Distance are maximum distances. These values may be less under conditions where topographic breaks (e.g., ridge) may result in barriers to sound propagation, or slightly higher where topographic openings (e.g., intervening canyon) promote sound transmission.
[3] The Visual Disturbance Distance is the distance at which murrelets can detect humans and their activities from the species' nest site or flight approach path, up to a maximum of 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by murrelets on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area.
[4] Report appropriate results from low or moderate natural background sound level depending on normally encountered background sound conditions at the site. Habitat near areas with a Natural Background Sound Level significantly greater than 50 dB may need site-specific analysis.

Scenario 8: Very high action-generated sounds in species habitat subject to low to near zero human sound-generating activity.

Sound Source	Maximum Decibels [1]	Typical Sound Sources
Natural Background Sound	35 - 45	Typical natural background sound level in species habitat for isolated sites on "average" day.
Existing Point Source Sound	0 - 75	Low to near zero level of existing ambient sound at the site, above natural background.
Existing Line Source Sound	0 - 65	Very low to nonexistent line sound sources at the site, only slightly above natural background.
Action-Generated Sound	96 - 108	The largest construction equipment, logging trucks, railroads, large helicopters, impact pile driver, rock drills, vibratory pile driver, pneumatic tools in combination with other equipment.

Description of Existing Ambient Sound Conditions: The existing environment is characterized by the low to near zero levels of existing ambient sound associated with human activities, and is typified by small power tools, light vehicular traffic moving at slow speeds, non-powered recreational activities, and many urban and rural residential activities. In more isolated areas, sounds include those associated with small parks, visitor centers, bike paths, tour roads and residences, or may be completely removed from human sound sources. In these latter cases, ambient sound levels would be completely masked by natural background sounds. At worst, vehicular traffic is limited to small vehicles moving at relatively low speeds on paved road surfaces.

Typical Action-Generated Sound Sources and Projects: Action-generated sound sources are typically very high, much above existing ambient and natural background sound levels. Typical sources of sounds in this situation are very large construction equipment, railroads, impact and vibratory pile drivers, tractor mounted jackhammers, helicopters, rock drills, and pneumatic tools in combination with other large equipment. May also covered greatly amplified rock music, truck horns and other loud signals. Typical projects covered by this scenario might be the use of very large construction equipment, pile drivers and jackhammers in isolated sites, such as in the construction of new road, stream restoration projects, or mining activities that require very large equipment, rock removal, large tree felling, etc. Would also cover use of these types of equipment in other situations where human-generated ambient sound is very low to low, such as at near rural residences, outdoor natural park facilities, hiking trails, or nature interpretive trails. Would not cover situations with a higher existing ambient sound level, such as near existing rural highways or commercial facilities.

Reported Disturbance Distances for:	Auditory Disturbance Distance [2]	Visual Disturbance Distance [3]
Low Natural Background Sound Level (~35 dB)[4]	500 m	*Maximum estimated detection distance or 100 m, whichever is lesser.*
Moderate Natural Background Sound Level (~45 dB)[4]	500 m	

[1] Maximum Decibels reports the maximum sound level attributable to these sources that are likely to be encountered in the habitat under most typical conditions for this scenario. Sound levels might exceed these maximum values only infrequently, and by a few decibels at most.
[2] The values reported here for Auditory Disturbance Distance are maximum distances. These values may be less under conditions where topographic breaks (e.g., ridge) may result in barriers to sound propagation, or slightly higher where topographic openings (e.g., intervening canyon) promote sound transmission.
[3] The Visual Disturbance Distance is the distance at which murrelets can detect humans and their activities from the species' nest site or flight approach path, up to a maximum of 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by murrelets on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area.
[4] Report appropriate results from low or moderate natural background sound level depending on normally encountered background sound conditions at the site. Habitat near areas with a Natural Background Sound Level significantly greater than 50 dB may need site-specific analysis.

Scenario 9: Very high action-generated sounds in species habitat subject to moderate to high human sound-generating activity.

Sound Source	Maximum Decibels [1]	Typical Sound Sources
Natural Background Sound	35 - 45	Typical natural background sound level in species habitat for isolated sites on "average" day.
Existing Point Source Sound	0 - 75	Moderate to high level of existing point source ambient at the site.
Existing Line Source Sound	66-87	Low to moderate level of existing line source ambient at the site.
Action-Generated Sound	96 - 108	The largest construction equipment, large trucks at high speeds on rough roads, railroads, large helicopters, impact pile driver, rock drills, vibratory pile driver, pneumatic tools in combination with other equipment.

Description of Existing Ambient Sound Conditions: The existing environment is characterized by medium to high levels of existing ambient sound associated with human activities, and is typified by gas-powered tools, very large chain saws, medium to heavy vehicular traffic moving at slow to moderate speeds on improved roads, backhoes, generators, ground compactors, and many urban and rural commercial activities, and may include very large construction equipment such as dump trucks, dozers, cranes, front end loaders, and large drill rigs. May also include medium trucks, large RVs, and buses moving on improved roadways at moderate to low speeds. Does not include large trucks, buses and similar sources when moving at high speed or when jake braking on long downhill road segments. These sound levels are typical of commercial zones where manufacturing occurs, or along reduced speed roadways where traffic includes a broad range of vehicle types but is not subject to high speed or excessive grades.

Typical Action-Generated Sound Sources and Projects: Action-generated sound sources are typically very high, somewhat above existing ambient and natural background sound levels. Typical sources of sounds in this situation are very large construction equipment, railroads, impact and vibratory pile drivers, tractor mounted jackhammers, helicopters, rock drills, and pneumatic tools in combination with other large equipment. May also covered greatly amplified rock music, truck horns and other loud signals. Typical projects covered by this scenario might be the use of very large construction equipment, pile drivers and jackhammers in sites, such as in the construction of new road, stream restoration projects, or mining activities that require very large equipment, rock removal, etc., near rural low-volume, moderate speed highways, commercial facilities or other developed areas.

Reported Disturbance Distances for:	Auditory Disturbance Distance [2]	Visual Disturbance Distance [3]
Low Natural Background Sound Level (~35 dB)[4]	300 m	*Maximum estimated detection distance or 100 m, whichever is lesser.*
Moderate Natural Background Sound Level (~45 dB)[4]	300 m	

[1] Maximum Decibels reports the maximum sound level attributable to these sources that are likely to be encountered in the habitat under most typical conditions for this scenario. Sound levels might exceed these maximum values only infrequently, and by a few decibels at most.

[2] The values reported here for Auditory Disturbance Distance are maximum distances. These values may be less under conditions where topographic breaks (e.g., ridge) may result in barriers to sound propagation, or slightly higher where topographic openings (e.g., intervening canyon) promote sound transmission.

[3] The Visual Disturbance Distance is the distance at which murrelets can detect humans and their activities from the species' nest site or flight approach path, up to a maximum of 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by murrelets on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area.

[4] Report appropriate results from low or moderate natural background sound level depending on normally encountered background sound conditions at the site. Habitat near areas with a Natural Background Sound Level significantly greater than 50 dB may need site-specific analysis.

Scenario 10: Very high action-generated sounds in species habitat subject to high human sound-generating activity.		
Sound Source	**Maximum Decibels [1]**	**Typical Sound Sources**
Natural Background Sound	35 - 45	Typical natural background sound level in species habitat for isolated sites on "average" day.
Existing Point Source Sound	76-95	Moderate to high existing point source ambient at the site.
Existing Line Source Sound	88-95	High level of existing line source ambient at the site.
Action-Generated Sound	95-108	The largest construction equipment, large trucks at high speeds on rough roads, railroads, large helicopters, impact pile driver, rock drills, vibratory pile driver, pneumatic tools in combination with other equipment.
Description of Existing Ambient Sound Conditions: The existing environment is characterized by high levels of existing ambient sound associated with human activities, and is typified by gas-powered tools, very large chain saws, medium to heavy vehicular traffic moving at moderate to high speeds on improved or rough roads, backhoes, generators, ground compactors, small jackhammers, and many urban and rural commercial activities, and includes sound sources similar to very large construction equipment such as dump trucks, dozers, cranes, front end loaders, and large drill rigs. Includes large trucks, large RVs, buses and similar sources when moving at high speed and jake braking on long downhill road segments. These sound levels are typical of commercial zones where manufacturing occurs, or along high speed roadways where traffic includes a broad range of vehicle types that may be subject to steep or excessive grades. **Typical Action-Generated Sound Sources and Projects**: Action-generated sound sources are typically very high, somewhat above existing ambient and natural background sound levels. Typical sources of sounds in this situation are very large construction equipment, railroads, impact and vibratory pile drivers, tractor mounted jackhammers, helicopters, rock drills, and pneumatic tools in combination with other large equipment. May also covered greatly amplified rock music, truck horns and other loud signals. Typical projects covered by this scenario include the use of very large construction equipment, pile drivers and jackhammers in the construction of new roads, stream restoration projects, or mining activities near areas where high levels of human-generated ambient sound levels exist, such as major freeways and roads subject to heavy traffic, large trucks (and jake brakes) and similar regular high sound levels already at the upper limits of regularly generated sounds.		
Reported Disturbance Distances for:	**Auditory Disturbance Distance [2]**	**Visual Disturbance Distance [3]**
Low Natural Background Sound Level (~35 dB)[4]	500 m	*Maximum estimated detection distance or 100 m, whichever is lesser.*
Moderate Natural Background Sound Level (~45 dB)[4]	500 m	

[1] Maximum Decibels reports the maximum sound level attributable to these sources that are likely to be encountered in the habitat under most typical conditions for this scenario. Sound levels might exceed these maximum values only infrequently, and by a few decibels at most.
[2] The values reported here for Auditory Disturbance Distance are maximum distances. These values may be less under conditions where topographic breaks (e.g., ridge) may result in barriers to sound propagation, or slightly higher where topographic openings (e.g., intervening canyon) promote sound transmission.
[3] The Visual Disturbance Distance is the distance at which murrelets can detect humans and their activities from the species' nest site or flight approach path, up to a maximum of 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by murrelets on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area.
[4] Report appropriate results from low or moderate natural background sound level depending on normally encountered background sound conditions at the site. Habitat near areas with a Natural Background Sound Level significantly greater than 50 dB may need site-specific analysis.

Sound Attenuation Model for Estimating Disturbance Distance

We developed the Sound Model for Estimating Disturbance Distance and associated spreadsheet to model the attenuation of sound generated by user-identified sources across a model landscape, using published formulae for predicting sound levels at particular distances from those sources. As with many models, certain assumptions are made regarding factors for which precise data are unavailable, or for conditions that cannot be controlled by the analyst. For reference purposes, these assumptions, along with data entry and other instructions, are displayed in pop-up comments at each data entry point (as identified by the small, red triangles in the spreadsheet). The associated model spreadsheet can found here.

This list is not necessarily exhaustive as other behaviors, such as nest abandonment, premature fledging or habitat avoidance, may also indicate harm.

Users are cautioned to ensure that all assumptions and instructions of this model are followed when applying project- or site-specific data. Otherwise, outcomes predicted by the model may be incorrect or misleading.

The Fish and Wildlife Service developed the Sound Model for Estimating Disturbance Distance to quantitatively and objectively estimate the extent and distance to which actions resulting in human activity or elevated sound levels near marbled murrelet nest sites are likely to take (i.e. harm) the species. This model is designed to accomplish two tasks.

1. The model calculates attenuation rates of sound away from typical line and point sources across a virtual landscape that *approximates* typical wildlife habitat. These attenuation rates are based on published formulae, and account for some of the principle physical factors that affect sound attenuation: initial volume, distance from source, source type (line or point), relative elevation of source or receiver, ground surface condition, and intervening vegetation. However, the model does not account for other important factors, such as topography and weather conditions that vary spatially or temporally under site-specific conditions. These site- and time-specific conditions should be addressed by the analyst in the interpretation of model outputs, as discussed below.

2. The model compares the projected sound attenuation to standards recommended in Region 1 of the USFWS to estimate distances at which marbled murrelets are likely to be harmed due to elevated sound levels or visual proximity to human activities (USFWS 2003). The model presents a simple method whereby site-specific conditions can be analyzed against a somewhat flexible recommendation to determine whether a likelihood of harm to the species exists.

The distance values calculated by this model are intended to provide the analyst with an objective means of estimating distance to auditory or visual disturbance.

1. The model estimates the distance from proposed activities wherein murrelets are disturbed (i.e., have a likelihood of harm), thereby triggering appropriate project modifications, such as seasonal and/or daily timing restrictions, if feasible, to reduce or

avoid take due to harm.

2. These distance estimates can be used to approximate the number of nest sites (if specific locations of nest trees are known) or the area of habitat (if protocol surveys are not completed) subject to take should it not be possible to avoid take through implementation of avoidance measures.

The model assumes a relatively uniform, flat landscape across which sound travels and diminishes. For site-specific circumstances where topographic barriers create a significant impediment to sound transmission, persons who have some understanding of the influences of these factors on sound attenuation should interpret the results of the model. Some basic guidance on this matter is provided later in this document.

The model performs calculations based on accepted formulae and supportable assumptions, derived from available literature and data, yielding results the analyst may apply to action- and site-specific circumstances. These results help the analyst estimate the area around a proposed action within which elevated sound levels or visual proximity of an action create harm. Future review of the model may lead to additional consideration of the biological assumptions, newly available literature, and species-specific data the model uses to estimate the reported distances.

It is unlikely that the formulae used in the calculations will change in any significant manner, as they are derived from established physical principles. In contrast, the biological information supporting the model is likely to continue to grow, providing significant sources of data to improve model assumptions, and standards incorporated into the model. As this information becomes available, the model itself should be updated, and modifications should be documented for future users.

Model User Guide

This user guide provides the reader with an understanding of how the available information on auditory and visual disturbance has been used to estimate the effects of typical projects on the murrelet, as applied in a numeric model. To help achieve that goal, the guide includes information on the characteristics of sound attenuation and visual detection in habitats typical of the marbled murrelet and other interior forest dwelling species.

The user guide provides a step-by-step set of instructions for entering data into the Excel model, should the analyst choose to analyze an action using site-specific data. Further, these instructions are intended to assist the reader in understanding the set of scenarios developed to analyze the effects of various project types on murrelets, as described in an earlier document. Each step is described in detail to ensure the analyst understands the appropriate data entry for each field, and the output of the model results.

Some background information is presented regarding sound behavior in typical wildlife habitats. This section also provides a brief discussion of the assumptions adopted at this time to estimate the distances at which sound is likely to result in take of marbled murrelets due to harm. These assumptions may change over time as additional information and data become available to assess this issue.

Characteristics and Behavior of Sound

Before delving into the use and interpretation of the model, it is important that the biologist have a fundamental understanding of the characteristics and behavior of sound and its attenuation away from sources in typical wildlife habitat. This User Guide does not discuss the physics of sound waves, or refer to specific mathematical formulae upon which sound behavior prediction is based. The reader is encouraged to consult appropriate technical texts for a thorough discussion of these aspects of sound attenuation, such as CalTrans' Technical Noise Supplement (Jones and Hendriks 1998).

In addition to this discussion, we provide a glossary to define those terms specific to sound and its attenuation, as well as terms used in the analysis of wildlife habitat.

Soft and Hard Site

The condition of the ground surface (i.e. paved versus forested), can affect the attenuation rate of sound across a landscape. Hard sites are those where the ground surface is predominantly hard soil, pavement, smooth water or a similar non-dampening surface that mostly reflects sound waves. Hard sites such as roads and water bodies do not attenuate sound pressure. Soft sites are those where ground surface vegetation, shrubs, grass, or even softened soil dampen or absorb sound waves across the site.

Because soft sites absorb sound, sound attenuates (i.e., decreases in volume) more rapidly across soft sites than hard sites. That is, equivalent sounds will sound quieter at a particular distance from the source across a soft site than the same sound at the same distance heard across a hard site. Classification of a site as soft or hard should generally consider the entire landscape where elevated sound is a concern, as opposed to the immediate vicinity of the sound source or receptor (species). In general, most terrestrial wildlife habitats are considered soft sites.

Point Sources

Point sources are those where sound emanates from a single or localized point, such as stationary motors, a loudspeaker, hand tool, or human voice. Sound emanating from a point source attenuates in a circular (spherical in 3-dimensional space) fashion. A characteristic of point source sound measurement is that the duration of the measure is relatively short in relation to the rate of movement of the source. For example, if the duration of measure of sound of a slowly moving car were of less than one second, this *single* car would be a point source. Conversely, if the duration of measure of sound of that same car were several minutes (such as $L_{eq,15\ minutes}$), this would be recorded as a line source. Finally, a speeding vehicle might be considered a line source even if the duration of sound measure is quite short (such as $L_{eq,10,\ 5\ seconds}$).

Line Sources

Line sources are those where sound emanates from a linear source, such as relatively constant highway traffic, or a flowing stream. Sound attenuates at a lesser rate from a line source than from a point source of similar volume, because it attenuates in a linear (cylindrical in 3-

dimensional space) fashion perpendicular to the line source. As with the example above, if the duration of measure of sound of the speeding car were of several seconds or more, the single car would be a line source. Multiple cars moving in close proximity will always be considered a line source. When considering sound sources such as automobiles, it is often best to consider them as line sources, except in unusual circumstances where vehicles are so intermittent as to not travel in close proximity, the sound measure is of very short duration, and the vehicle is traveling relatively slowly.

Rates of Attenuation

Sound emanating from a point source attenuates at a faster rate than sound emanating from a line source. Further, both point and line source sounds attenuate more rapidly across soft sites than across hard sites. The point source attenuation rate across a hard surface is about 6 dB per doubling of distance from the source, whereas a point source sound attenuation rate across a soft surface is about 7.5 dB per doubling of distance from the source. In the case of a hard site, line source sound attenuates at about 3 dB per doubling of distance. In the case of a soft site, line source sound attenuates at about 4.5 dB per doubling of distance.

It is especially important to note that, because sound measure is on a logarithmic scale, and its attenuation is a function of the square of distance from the source, its attenuation is in relation to doubling of distance from the source to the receptor, rather than a simple linear relationship.

Another factor to be considered in evaluating sound attenuation is the frequency of the sound being produced. Sounds of low pitch attenuate at a slightly lower rate than sounds of high pitch. For example, music heard at a distance will generally have a predominance of bass sounds and less treble sound. However, we have not incorporated any special consideration of this phenomenon in the analytical methods described here.

Effects of Elevated Source or Receiver

When either the sound source or receiver (or both) is substantially elevated above the ground, the sound path is relatively unaffected by the softness or hardness of the site. Under these conditions, where the path of sound transmission is not close to the ground over a substantial portion of the sound path, the attenuation of sound is independent of the softness or hardness of the site, and more closely approximates the rate for hard sites.

Effects of Intervening Vegetation on Sound

When sound travels through dense vegetation, its volume is reduced by as much as 5 dB for the first 30 m (100 ft) of vegetation, as measured from the sound source, and an additional 5 dB for an additional, contiguous 30 m (100-200 ft). Note: this is a different consideration than soft site vs. hard site. "Dense" is defined as being at least 30 m (100 ft) wide and 5 m (16 ft) tall, and of sufficient density as to completely block the visual pathway. This definition applies to vegetation growing along the sound path of interest. Wildlife that is nesting, denning, or perched high in the canopy will generally not benefit from this attenuation, as the sound may propagate through the upper canopy more easily than through understory and mid-canopy vegetation. This attenuation would apply if the line-of-sight path to the nest feature fully meets the criteria as stated above.

Vegetation consisting of large tree trunks, thick yet well-spaced shrubs, and similar conditions would not qualify as dense, since these situations do not completely block the visual pathway over the sound pathway. Also, this attenuation is applicable only in situations where vegetation is fairly continuous within the 30-meter bands between the dominant sound source(s) and the receptor of interest (e.g., nesting habitat or nest tree). Beyond about 60 m (200 ft), virtually no additional benefit accrues from dense vegetation, as much of the sound goes over the dense vegetation and is reflected back to the ground. This attenuation must be applied cautiously and sparingly, and must be clearly understood when entering data into Step 4 of the spreadsheet model (discussed in more detail in following sections).

Species-Specific Audio Thresholds

Sound is comprised of a range of frequencies, or octaves. Each animal species possesses a different range and weighting of frequencies that its members are capable of hearing. Owls are known to hear sounds that are higher pitched than humans, but are less capable of hearing sounds in lower frequency hearing ranges (Schwartzkopff 1955). Thus, a species detects a sound as "louder" when it is comprised of frequencies well within its hearing range, and detects a sound as "quieter" when those sounds are comprised of frequencies at the periphery of its hearing range, even though both sounds may contain the same overall sound energy.

While any method, such as this model, of measuring the effects of sound on wildlife behavior would benefit from a species-specific frequency response curve, we have relied here on the human-weighted response curve, or dBA. We have not incorporated species-specific frequency curves into this model for three primary reasons. First, hearing frequency curves are not available for most species, including the murrelet, and development of this information is beyond the model's scope at this time. Second, and perhaps more important, virtually all reported measures of sound levels from various human sources is reported in human-weighted decibels, or as unweighted. This information is not readily available to assist in the analysis. Lastly, we assume that the error introduced into the model output by the use of human-weighted response curves is within the overall error rate resulting from the variability of the other factors in the model, and that using species-weighted curves would add little to our understanding of sound effects on wildlife species at this time.

Entering Data into the Model

Data entry into this spreadsheet model is accomplished through a 12-step process that allows the analyst to specify action- and action area-specific data, or data derived from other relevant studies as reported in various literature. Each of these steps is described in detail in the following sections. Data is entered into the spreadsheet in the green boxes, in cells with red- colored text. These are the only cells where data can be entered or otherwise changed anywhere in the spreadsheet. All other cells are protected and cannot be changed, except by the administrator responsible for incorporating regionally agreed-to changes to the analytical method.

All of the data entry cells and several of the information cells in the spreadsheet contain popup comments that are activated when the cursor is moved over the cell. These cells are identified by a small red triangle in the corner of the cell. These comment boxes assist the analyst in entering appropriate data in each cell, or in the proper interpretation of the information displayed. Move the cursor off the cell to close the comment.

<u>Step 1</u>
Enter a descriptive title that provides information to the reader about the ambient conditions, existing sound sources at the action site, and equipment being analyzed. Because the title is limited to one line on the spreadsheet form, information will have to be concise yet informative. The purpose for giving each modeled scenario a title is to provide information to anyone reviewing a printed version of this form a better understanding what is being analyzed. Examples of concise, informative titles are: Small chainsaw and hand tool maintenance of existing trails in old growth forest, Prairie Creek State Park, away from roads; and, Construction of new 4-lane freeway, adjacent to Redwood National Park, using large equipment and tractors, no existing road.

<u>Step 2</u>
In this step, the analyst classifies the action area as a soft site or a hard site (refer to earlier discussion of these terms). The value entered here must be “1” for soft surfaces or “0” for hard surfaces. In cases where the site is a roughly equal mixture of soft and hard surfaces, treat it as a hard site and enter “0”.

<u>Step 3</u>
To account for the phenomenon of elevated source or receiver, the analyst is requested to enter 0 (zero) in this step whenever the source or the receiver of the sound is elevated above the ground. This value can overrule (in the sound attenuation formulae) the value previously entered to account for soft vs. hard sites. For purposes of this model, “elevated” is defined as being at least 10 m above ground, but for extended distances (beyond 50 m) between the source or receiver, the elevated source/receiver should be correspondingly higher to account for the more acute angle of the sound path from the ground. No exact formula for this estimate exists, but for purposes of consistency in this guidance, we recommend that “elevated” should apply to known sources/receivers greater than 20 m above the ground for distances between 50 and 100 meters, and 30 m for distances beyond 100 meters. In the case of unsurveyed habitat that occurs at varying distances from the sound source, enter 0 whenever the source and/or receiver is expected to be elevated more than 10 m above the ground.

<u>Step 4</u>
This step accounts for dense vegetation that grows close to the sound source (within bands of 0-30 or 30-60 m from the source). Enter “1” in the 0-30 m cell and/or 30-60 m cell of the spreadsheet if vegetation meets the definition of *dense* (refer to earlier discussion of this term), or “0” if it does not. For some situations, such as the right-of-way along a freeway, dense vegetation may not begin for some distance from the sound sources on the highway, due to vegetation management practices in the right-of-way. In these cases, do not apply the attenuation factor (i.e., enter “0” in the data form) for the 0-30 and possibly the 30-60 m cells, as appropriate. In cases where the vegetation is moderately dense across the entire 0-60 m bands (but does not fully meet the definition of dense for both bands), enter "0" for the 0-30 m cell, and “1” for the 30-60 m cell. For cases where vegetation may occur, but does not meet the definition

of dense in either band, enter “0” in both spreadsheet cells.

<u>Step 5</u>
In this step, the analyst accounts for vegetation that serves as a *visual* barrier for the species of interest, such as a nesting murrelet. This value calculates the maximum distance at which harm is likely to occur strictly as a result of the subject species visually detecting humans or human-related activities, and reacting by significantly disrupting normal behavior patterns.

The analyst enters the *maximum* distance at which murrelets are capable of detecting human activities from the nest branch, or when flying into the stand to access the nest branch, in habitat typical of the project area. Enter a value to the nearest meter, as available. This distance can be estimated by a ground observer by assuming that if the ground observer can see nest branches, murrelets nesting there can see human activities. It is reasonable and appropriate to use a measuring instrument, such as laser or infrared measuring devices, to document these measurements when available.

<u>Note:</u> This value estimates a maximum distance that the model compares against a standard value. The standard value is that distance which available data suggests is the maximum at which murrelets may be harmed by visual disturbances near their nests. If the analyst specifies a value that is less than the standard value, the final distance reported in the model outcome for visual-related harm is the analyst-specified value. If the value entered in Step 5 is greater than the standard value, the distance reported in the model outcome defaults to the standard value. That is, the determined visual harm distance can never be greater than the standard value.

<u>Step 6</u>
Natural Background sound is comprised of the existing natural sounds and those human-caused sounds extraneous to the action being considered. Generally, Natural Background would consist of habitat-associated sounds, such as breezes in the trees, birds chirping, even normal high altitude air traffic or very distant road traffic. Natural Background is distinguished by its relative uniformity across the area, and its independence from the action itself (such as the distant highway or air traffic), whereas other line and point sound source either existing sources or sources associated with the action being analyzed) attenuate away from a particular point or line somewhere within the area of interest.

Existing Line Source and Existing Point Source (entered in Steps 7 through 10) differ from Natural Background in that they are not relatively constant across the area of interest, because their sources are within the action area and attenuate away from those specific sources.

Normal values for Natural Background in forested habitats away from development range from 25 to 45+ dB, and may be somewhat higher when influenced by some uncommon sound sources, such as distant streams, waterfalls, airports, or highways. Enter an appropriate value for your site-specific conditions, but the value must be between 25 and 80 (dB), inclusive. When estimating Natural Background, take into account the normal range of conditions likely to occur in the habitat of interest.

If the project is located in habitat generally sheltered from wind and not exposed to other distant sources, values of 25 to 35 dB may be appropriate; in areas of greater exposure to wind or distant sources, values of 35 to 50 may apply. In very rare cases, such as habitat adjacent to a large airport, values in the range of 50 to 80 may be appropriate. Enter an appropriate estimate here, but do not attempt to estimate extreme conditions (such as high winds uncommonly encountered). When estimating Natural Background in areas subject to daily or seasonal wind patterns or other distant sound sources, estimate the Natural Background based on the predominant effect of wind on sound level, not extremes. For example, if a site normally experiences low wind speeds and sound levels of 35 dB, but is also subject to occasional afternoon winds elevating sound levels to 45 dB, enter 35 dB here, as this is the predominant sound level at the site. Likewise, if the site is more commonly exposed to sound levels near 45 dB such as at a windy ridgetop location, enter 45.

Note: It is important that all measures for sound level entered into this model use a similar measurement standard. For purposes of this model (to estimate the effect of near-peak sounds on wildlife), use of L_{10} measured over a period of less than 10 seconds or a similar measure such as L_{max} is recommended. Use of mixed measurements, such as mixing L_{10} and L_{max} or $L_{eq,}$ in the same model may yield unpredictable and often erroneous results. Use of measures such as L_{eq} or L_{dn} are specifically recommended against, as they provide a more general averaged sound level useful for determining noise disturbance, and may be less applicable to wildlife species. Mixed usage of L_{10} and L_{max} may be compatible when measured over very short time periods, as L_{10} measures are often with 3 dB of L_{max} under these circumstances.

Step 7

Existing Line Sound Sources represent existing sound sources at the action site that are best described as linear, such as a busy highway with relatively continuous traffic flow. Line sources can include other moving sources if the measurement metric is based on other than a very short or instantaneous measurement period (see earlier discussion). Infrequent traffic should also be modeled as a line source, when the method of sound measure uses any non- instantaneous measure of sound (such as L_{10}, L_{50}, or L_{90}) that includes a measurement period of more than a few seconds. Stationary sound sources, or single moving sources measured using a relatively instantaneous measurement metric (e.g., L_{max}), should be entered into the model as point sources, under Step 9. Enter a value here that ranges from zero (indicating no line sound source) to a maximum of 140 dB, based on actual measurements or values reported in reputable literature.

Step 8

The perpendicular distance from a line sound source is the distance from an existing line sound source to the sound recording meter and should be accurately measured, or should be based on reputable literature. Actual values used in the measurement, or reported in reference literature, can be in any measurement unit (feet, meters, miles), but must be converted to meters before entering into Step 8. Use the Distance Measure Conversion table in the model if needed. If no existing line source occurs at the site, enter zero here. Sound level data that do not include an accurate and precise measure of source-receptor distance cannot be used in this model.

Step 9

Existing Point Sound Sources represent any established, permanent point source(s) for sounds in the immediate vicinity of the action, such as a generator, transformer, parking slots, or visitor facility. Sound sources that move slowly, and whose sound level is measured using a short measurement interval relative to the rate of movement (such as L_{max} or $L_{10,\ 3\ seconds}$) may be treated as point sources. Enter a value here that ranges from zero (indicating no point sound source) to a maximum of 140 dB. Point sources that exist along a line source and are at least 5 dB less than that line source in volume may be ignored. If existing point sources are infrequently distributed along a line source, and are greater than the line source volume, it may be best to separate out those short sections of line source and prepare a separate analysis. If point sources are not less than 5 dB below existing line sources and relatively numerous along the line source, include them in the model as a line source and calculate results for the entire line source.

Several existing point sources with nearly identical sound levels may occur in close proximity to each other. For example, multiple human conversations may occur at the same time along a nature trail. To account for this, it is appropriate to add 3 decibels to the normal average human voice level of 65 decibels (at 1 meter) to account for this in the model. Should four separate and similar point sound sources exist concurrently, add 6 decibels to the normal single source value. (Note that in this example, 2 separate conversations assumes at least 4 persons, if both people in each conversation are not speaking at the same time, and that the measurement distance for human speech is only 1 m, not 50 feet, as it is for many pieces of equipment).

Step 10

As with Step 8 for line sources, the distance from the existing point sound source to sound recording meter should be accurately measured, or should be based on reputable reference sources. Actual values used in the measurement, or reported in reference literature, can be in any measurement unit (feet, meters, miles), but must be converted to meters before entering here. Use the Distance Measure Conversion table in the model if needed. If no existing point source occurs at the site, enter zero here. Data that do not include an accurate and precise measure of source-receptor distance cannot be used in this model.

Step 11

Action-Generated Sound Sources are the sound sources added during implementation of the proposed action, such as road machinery, new trail construction, chainsaw use, generator installation, parking facility, or future use on a new trail.

Values entered here should reflect only the sound being generated by the action of interest, and not include other existing sources previously accounted for in this model. Because most construction activity and use of existing roads or new or existing recreational facilities occurs as a series of points, this value is calculated into the model as a point source. The value entered here should account for the combined sound level of all sources likely to occur in close proximity (within a few feet) during the project. For example, if large chain saws (86 dB) will be used as part of project implementation, the analyst should enter 89 dB if expecting two chain saws to be working closely together (doubling equivalent sound sources results in a 3 dB increase over one source), or if four rock drills (94 dB) are working together, the proper entry is 100 dB (94+3+3). Enter a value between zero and 140 dB, based on actual measurements or tabled reference values from documented, measured sources.

Step 12

Measured Distance from Sound Source is the distance from point sound source of interest to sound recording meter. As with Step 10 for point sources, the distance should be accurately measured, or should be based on reputable reference sources. Actual values used in the measurement, or reported in reference literature, can be in any measurement unit (feet, meters, miles), but must be converted to meters before entering here. Use the conversion table in the Reference Data section of this spreadsheet if needed. Data that do not include an accurate and precise measure of source-receptor distance should not be used in this model.

Model Outputs

The model outputs are updated and displayed as data are entered into the appropriate data cells in the Excel spreadsheet. The user is encouraged to verify that each value displayed is correct for the scenario being analyzed before reporting model results. Controls in the spreadsheet should eliminate entry of inappropriate data where data are limited to a constraining range of values. The user should verify each data entry is appropriate for the action being considered.

The uppermost page of the Excel spreadsheet includes the 12-step Data Entry box, in which all data entry cells are located. As earlier described, only fields with red-colored text are valid data entry cells. All other cells are locked and cannot be changed. Cells with blue-colored text are either reference data or model default values (i.e., Reference Information), or are output values calculated from entered data (i.e., Model Output/Results). Appropriate data entry into the data entry cells is described in the preceding sections of the user guide.

The numeric outputs of the model are displayed in the last column of the Data Entry box of the spreadsheet, labeled Model Output/Results. A description of these outputs and their interpretation is provided later in this section following the description of the data calculations.

Following the Data Entry box is a table entitled Results of Calculations. This table shows the Natural Background Sound Level, the Existing Line Source Sound Levels, the Existing Point Source Sound Levels, and the Action-Generated Sound Levels, each attenuated over a distance of 500 m from the sources.

These values are calculated directly from the data input into the model by the analyst, taking in to account the effects of habitat conditions on sound attenuation. The last column in the Model Input/Reference Data section of this table shows the Above-Ambient Decibel Value, as established for the species and indicated in the Reference Information section of the spreadsheet.

The table also includes two Calculated Attenuation columns. The Net Existing Ambient Sound is the sound level of the combined existing point and line sources attenuated across an assumed uniform Natural Background Sound level, to a distance of 500 m from their sources. These values represent the level of sound at various distances from the sources *prior to implementing the proposed action*. The Cumulative Sound Attenuation includes the Net Existing Ambient Sound with the Action-Generated Sound. This number represents the likely maximum sound level *during implementation of the proposed action*, when attenuated out from the sources.

Finally, the table includes the Tolerance Threshold established for the species (as reported in cell L41 in the Data Entry block). This is the sound level above which harm could occur due solely to its excessive volume, regardless of the relative sound contribution of the proposed action. The

Above-Ambient Threshold is the value of the Above-Ambient Decibel Value added to the attenuated Net Existing Ambient Sound Level. This value establishes the level at which Action-Generated Sound may significantly exceed that sound level normally experienced by the species at its location, and result in harm of the species.

Two figures graphically display key numbers from the table to assist the analyst in understanding their relationship. Figure 1 displays the relationship between the Cumulative Sound Attenuation and the Tolerance Threshold. Disturbance of the species occurs whenever the Cumulative Sound Attenuation line exceeds the Tolerance Threshold. The vertical line indicating the Tolerance Threshold Distance is that distance within which the contribution of the Action-Generated Sound results in a cumulative sound level above which the species is harmed regardless of the ambient sound levels existing at the site. At this time, the Tolerance Threshold is estimated at 82 dB for the marbled murrelet. That is, the site may become "intolerable" to the species and harm occurs due to the total sound level the species must endure.

Figure 2 displays the relationship between the Cumulative Sound Attenuation and the Above-Ambient Threshold. This figure includes the Net Existing Ambient Sound Attenuation for reference purposes. We determined that harm of the species likely occurs whenever the Cumulative Sound Attenuation line exceeds the Above-Ambient Threshold. The vertical line labeled Above-Ambient Threshold Distance establishes the distance below which sound generated by the action is likely to exceed by a significant amount the sound level to which the species may be regularly exposed, to the point of significantly altering its essential behaviors. The "significance amount" is established by the Above-Ambient Decibel Value determined for the species (at this time, 25 dB for the murrelet). Figure 2 also displays the Visual Disturbance Distance, within which the species may be harmed due to visual detection of human activities in close proximity to the nest. This distance is established by the visual detection distance entered into the model by the analyst, but not exceeding the maximum value currently established for the species (at this time, 100 meters for the murrelet).

The Model Output/Results column of the Data Entry section reports both the Tolerance Threshold Distance and the Above-Ambient Threshold Distance. These two values calculate the distance at which the species is harmed due to elevated sound levels, based on two somewhat different sets of criteria and assumptions. The Final Auditory Disturbance Distance is the maximum of these two values. The Final Disturbance Distance is identical to that reported in Figure 2, and represents the distance at which the species is harmed due to human activities in the vicinity of the nest, to a maximum of 100 meters.

Interpretation of the Model Results in Marbled Murrelet Habitat

The output from the model allows the analyst to answer three fundamental questions regarding the likelihood that the proposed action could harm marbled murrelets due to elevated sound levels or visual detection from human activity in close proximity to the nest.

To simplify the interpretation of model output, estimated disturbance distances are displayed in the *Output/Decision Results* section on the top page of the spreadsheet. These values indicate the distances within which harm is likely to occur. The following discussion explains the derivation of these numbers in relation to the three fundamental questions above.

Question 1: Does the proposed action generate sounds, in combination with existing sound sources at the action site, which exceed a tolerance threshold (i.e., 82 dB) at known sites of the species or within unsurveyed nesting habitat during critical periods?

The numeric answer to Question 1 is displayed as the Tolerance Threshold Distance in the Output/Decision Result area of the spreadsheet.

This distance is graphically displayed in Figure 1 as the point where the Cumulative Sound Attenuation line crosses the 82-dB line (the Tolerance Threshold line for marbled murrelets). This value is best interpreted as the distance within which murrelets are likely to be harmed as a result of action implementation from the excessive volume of sound at the nest site, regardless of the existing ambient sound level at the site.

Question 2: Does the action-generated sound level exceed all existing sound levels by a significant amount within habitat? That is, do sound levels created by the proposed action exceed the existing ambient by an amount equal to or greater than a specified decibel value for the species, resulting in modifications of normal behavior?

The numeric answer to Question 2 is displayed as the Above-Ambient Threshold Distance in the Output/Decision Result area of the spreadsheet.

This distance is graphically displayed in Figure 2 at the point at which the Cumulative Sound Attenuation line crosses the Above-Ambient Threshold line. This value is best interpreted as the distance within which murrelets are harmed by sound generated by the proposed action due to a significant sound level increase above existing levels to which the individuals are habituated. The sound level within this distance of the action results in behavior indicating harm, regardless of the amount of sound generated by the proposed action.

Question 3: Does human activity occur in close proximity to known nests or unsurveyed nesting habitat such that nesting murrelets might exhibit disturbance behaviors due to this activity?

The numeric answer to Question 3 is displayed as the Visual Disturbance Distance in the Output/Decision Result area of the spreadsheet.

This distance is graphically displayed in Figure 2 as the Visual Disturbance Distance, indicated by the red triangle on the x-axis. This value is best interpreted as that distance within which murrelets are likely to be harmed by visual detection of human activities in close proximity to the nest. Beyond this distance, human activities are either not detectable by murrelets due to vegetation and/or topography blocking the visual pathway, or human activities are of sufficient distance to not cause the species to modify normal behaviors (for the murrelet, this maximum distance is estimated as 100 meters, based on available information).

What Do These Numbers Mean?

The reporting of these numbers requires careful interpretation. While these numbers might appear to provide precise distances within which murrelets are harmed during implementation of proposed actions, the analyst should understand that they only represent distances within which there is a "likelihood of harm", as supported by available data. That is, these numbers estimate the distances within which available data on murrelets or surrogate species, as available, show that at least some murrelets are likely to be injured (i.e. would be harmed) as a result of elevated sound levels or visual detection near nest sites.

Murrelets closer to the sound sources (or visual disturbance cues) may have a higher likelihood of harm than those at the outer limits of the ham distance (due to louder sound levels, or visually perceived threat to the nest). Further, in many circumstances, not all murrelets, except those at the very closest distances to the disturbance, are likely to be disturbed to the level of harm. Thus, the likelihood of harm to nesting murrelets within this distance to sound/visual sources would range from some low proportion (low, yet reasonably greater than zero) to some higher value (not necessarily equal to 1) at points closer to the sound/visual sources. It is neither reasonable nor necessary to predict that all (or even a high proportion of) murrelets within this distance are subject to harm. Conversely, it is also unreasonable to conclude that **no** murrelets beyond this distance would ever be harmed.

A more supportable interpretation is that there is currently no available information indicating that murrelets subject to these more distant sound/visual disturbances have a likelihood of harm. Further, this interpretation is consistent with meeting the Section 7 Consultation Handbook definition of "insignificant" when concluding that "a person would not… be able to meaningfully measure, detect, or evaluate insignificant effects" (page XVI) for disturbances beyond this distance.

Modifications to the Model

Because conditions and sound sources may change substantially over a project area, especially for large projects or programmatic consultations, the model is best applied by doing separate calculations for localized conditions, so as to minimize variability and potential error over a large, diverse project area. As a rule of thumb, separate analyses should be considered whenever ambient sound levels, existing point or line sources, or project-generated sound change by more than about 6 decibels within the project area(s). The analyst should also keep in mind that this model does not account for some site-specific conditions, such as topographic or human-made barriers (such as ridges, ravines, or road cut banks) that may greatly alter the attenuation of sound in local situations. The analyst should qualify the numbers reported by the model, and provide a reasoned discussion of these differences, to account for these special conditions.

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Glossary

A-Weighted Decibel (dBA): An overall frequency-weighted sound level in decibels which approximates the frequency response of the human ear.

Above-Existing Threshold (also referred to as the Aversion Threshold): A sound level that significantly exceeds existing levels in a species' environment, and is likely to significantly disrupt normal behaviors related to breeding, feeding, and sheltering. The point of significance is established as that amount by which action-generated sounds exceed the combined Natural Background plus Existing Line and Point Sources to a degree that behavioral disruptions have been noted for the subject species or appropriate surrogates. For the marbled murrelet, this threshold has been established as 25 dB.

Above-Existing Threshold Distance (or Aversion Threshold Distance): The maximum distance at which the sound level likely exceeds the Above-Existing Threshold, resulting in harm of the species.

Action-Generated Sound Source: The sound source of interest in an investigation, such as road machinery, new trail use, chainsaw use, generator installation, parking facility, etc. These are the sound sources being added as a result of implementing the action. These sound sources reflect only the sound being generated by the action of interest, and do not include other existing sources.

Attenuation (or Sound Attenuation): The gradual decline in volume of sound as the sound energy wave moves away from the source. The decline is generally a factor of the square of the distance from the source.

Decibel (dB): A unitless measure of sound on a logarithmic scale, which indicates the squared ratio of sound pressure amplitude to a reference sound pressure amplitude. The reference pressure is 20 micro-pascals.

Equivalent Sound Level (Leq): The average of sound energy occurring over a specified period. In effect, Leq is the steady-state sound level that in a stated period would contain the same acoustical energy as the time-varying sound that actually occurs during the same period.

Exceedance Sound Level (Lxx): The sound level exceeded XX percent of the time during a sound level measurement period. For example L_{90} is the sound level exceed 90 percent of the time and L_{10} is the sound level exceeded 10 percent of the time.

Existing Line Sound Sources: Represent existing sound levels emanating from linear sources, such as a busy highway with continuous traffic flow, where sound moves away from a line, rather than a single point, of sound. Note also that a single moving sound source may be described as a line source if the sound metric includes a significant period of time in relation to the speed of the source.

Harm: Actions which actually kill or injure wildlife. Such an act may include significant habitat modification or degradation where it can kill or injure wildlife by significantly impairing essential behavior patterns including breeding, feeding, or sheltering. [50 CFR §17.3]

Hard Sites: Sites where the ground surface is predominantly hard soil, pavement, water or similar non-dampening surface that mostly reflects sound waves. Sound attenuates more rapidly across a soft site than across a hard site.

Maximum Sound Levels (L_{max}): The maximum sound level measured during a measurement period, representing the peak measurement level.

Minimum Sound Levels (L_{min}): The minimum sound level measured during a measurement period, representing the lowest measured point.

Natural Background: The existing sound comprised of natural sounds and those human-caused sounds that are extraneous to the action area being considered. Generally, Natural Background would consist of habitat-associated sounds, such as mild breezes in the trees, birds chirping, even normal high altitude air traffic or very distant road traffic. Natural Background is distinguished by its relatively uniformity across the area, or its independence from the action itself (such as the distant highway or air traffic). In contrast, line and point sources attenuate away from a particular point or line somewhere in or near the area of interest, indirectly associated with the action.

Noise: See “sound”.

Soft sites: are those where ground surface vegetation, shrubs, grass, or even softened soil dampen or absorb sound waves across the site. Sound attenuates more rapidly across a soft site than across a hard site.

Sound: A vibratory disturbance created by a vibrating object, which, when transmitted by pressure waves through a medium such as air, is capable of being detected by a receiving mechanism, such as the human ear or a microphone. Sound that is loud, unpleasant, unexpected, or otherwise undesirable may be referred to as “noise”.

Tolerance Threshold: The maximum sound level, resulting from all sources, that a species may be able to tolerate without a likelihood of significantly disrupting its normal behaviors related to breeding, feeding and sheltering. For the marbled murrelet, this threshold has been established at 82 dB.

Literature Cited

Awbrey, F.T., and A.E. Bowles. 1990. The effects of aircraft noise and sonic booms on raptors: a preliminary model and a synthesis on the literature on disturbance. U.S. Air Force, Patterson Air Force Base, Ohio.

Becker, B.H., and S.R. Beissinger. 2006. Centennial decline in the trophic level of an endangered seabird after fisheries decline. Conservation Biology Vol. 20, No. 2, pp. 470- 479.

Bednarz, J.C. and T.J. Hayden. 1994. The effects of human activities on the productivity of birds of prey in the Los Medanos area, New Mexico. Journal of Raptor Research 28(1):52-53.

Bindford, L. C., B. G. Elliott, AND S. W. Singer. 1975. Discovery of a nest and the downy young of the marbled murrelet. Wilson Bull. 83:303-319.

Blickley, J. L., Word, K. R. Krakauer, A. H., and others. 2012. Experimental chronic noise is related to elevated fecal corticosteroid metabolites in lekking male greater sage-grouse. PLoS ONE 7(11).

Blethoff, J. R. and Dufty Jr. A. M. 1998. Locomotor activity levels and the dispersal of western screech-owls, *Otus kennicottii*. The Association for the Study of Animal Behaviour. Vol. 50, pp. 558-561.

Bloxton, T.D. and M.G. Raphael. 2009. Breeding ecology of the marbled murrelet in Washington State: project update 2004-2008. A report to the U.S. Fish and Wildlife Service and U.S. Forest Service. 41 pp.

Carney, K.M. and W.J. Sydeman. 1999. A Review of human disturbance effects on nesting colonial waterbirds. Waterbirds 22(1):68-79.

Carter, H.R. and Stein J. L. 1995. Molts and plumages in the annual cycle of the marbled murrelet. USDA Forest Service General Technical Report Pacific Southwest Research Station-152. Chapter 9 pp. 99- 109.

Craig, T. H., and E. H. Craig. 1984. Results of a helicopter survey of cliff nesting raptors in a deep canyon in southern Idaho. Journal of Raptor Research 18:20–25.

Crino, O., Johnson, E., Blickley, J., Patricelli, G., & Breuner, C. 2013. Effects of experimentally elevated traffic noise on nestling white-crowned sparrow stress physiology, immune function and life history. The Journal of Experimental Biology, 216, pp. 2055-2062.

Delaney, D. K., T.G. Grubb, P. Beier, L.L. Pater and M.H. Reiser. 1999. Effects of helicopter noise on Mexican spotted owls. J. Wildl. Manage. 63(1):60-76.

Delaney, D. K. and Grubb T. G. 2001. Effect of off-highway vehicle noise on northern spotted owls: sound data results. Unpublished report. Mendocino National Forest 32-91Z9-0.

DeSanto, T.L., and S.K. Nelson. 1995. Comparative reproductive ecology of the Auks (Family Alcidae) with emphasis on the marbled murrelet. Pages 33-47 in C.J. Ralph, G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds.). Ecology and conservation of the marbled murrelet. General Technical Report. PSW-GTW-152. Pacific Southwest Experimental Station, U.S. Forest Service, Albany, California. 420 pp.

Dooling, R. J. 1980. Behavior and psychophysics of hearing in birds. Comparative Studies of Hearing in Verebrates. Springer-Verlag, New York. Pp. 261-288.

Dooling, R.J., and A.N. Popper. 2007. Effects of highway noise on birds. Prepared for the California Dept. of Transportation Division of Environmental Analysis. Sacramento, California. Prepared under contract 43A0139 Jones and Stokes Associates. September 2007. 74 pp.

Federal Highway Administration. 2006. Highway construction noise handbook. Chapter 9. Construction equipment noise levels and ranges. U.S. Department of Transportation Federal Highway Administration Office of Natural and Human Environment. Washington, D.C. August 2006. http://www.fhwa.dot.gov/environment/noise/handbook/.

Francis, C.D., Paritsis, J., Ortega, C. P., and Cruz, A. 2011. Landscape patterns of avian habitat use and nest success are affected by chronic gas well compressor noise. Landscape Ecology Vol. 26, pp. 1269-1280.

Fraser, J. D., Frenzel, L.D., and Mathisen, J.E. 1984. The impact of human activities on breeding bald eagles in North-central Minnesota. Journal of Wildlife Management 49(3) pp. 585-592.

Gabrielsen, G.W., Taylor, J. R. E., Konarzewski, M., and Mehlum,F. 1991. Field and Laboratory Metabolism and Thermoregulation in Dovekies (*Alle alle*), *The Auk*, Vol. 108, Issue 1, pp. 71–78

Gutowsky S, Janssen M. H, Arcese P, Kyser TK and others. 2009. Concurrent declines in nestling diet quality and reproductive success of a threatened seabird over 150 years. Endangered Species Research. 9:247-254.

Grubb, T.G., D.K. Delaney, W.W. Bowerman and M.R. Wierda. 2010. Golden eagle indifference to heli-skiing and military helicopters in Northern Utah. Journal of Wildlife Management. 74:1275–1285

Halfwerk, W., Holleman, L.J.M., Lessells, M. C., and Slabbekoorn, H. 2010. Negative impact of traffic noise on avian reproductive success. Journal of Applied Ecology 48, pp. 210-219.

Hamer, Thomas and S. Kim Nelson. 1998. Effects of disturbance on Nesting Marbled Murrelets: Summary of Preliminary Results. Prepared for Paul Henson, US Fish and Wildlife Service, Portland, Oregon. January 1998. 24 pp.

Hamer, T. 2002. Personal communication to Lee Folliard of the U.S. Fish and Wildlife Service, Oregon Fish and Wildlife Office.

Hamernik, R. P. and Hsueh, K D. 1991. Impulse noise: some definitions, physical acoustics and other considerations. Journal of the Acoustical Society of America 90:189-196.

Hayden, T.J. and J.C. Bednarz. 1991. Los Medanos Cooperative Raptor Research and Management Program – Final Report 1988-1990. Department of Biol. University of New Mexico, Albuquerque. 96 pp.

Hébert, P. N. and R. T. Golightly. 2006. Movements, nesting, and response to anthropogenic disturbance of Marbled Murrelets (*Brachyramphus marmoratus*) in Redwood National and State Parks, California. Unpublished report, Department of Wildlife, Humboldt State University, Arcata, California and California Department of Fish and Game Report 2006- 02, Sacramento, California.

Henson, P. and T.A. Grant. 1991. The effects of human disturbance on trumpeter swan breeding behavior. Wildlife Society Bull. 19(3):248-257.

Hodum, P.J., W.J. Sydeman, G.H. Visser, W.W. Weathers. 1998. Energy expenditure and food requirement of Cassin's Auklets provisioning nestlings. Condor 100:546-550.

Hull, C.L., G.W. Kaiser, C. Lougheed, L. Lougheed, S. Boyd and F. Cooke. 2001. Intraspecific variation in commuting distance of Marbled Murrelets (*Brachyramphus marmoratus*): Ecological and energetic consequences of nesting further inland. Auk 118(4):1036-1046.

Janssen, M. H., Arcese, P., Kyser, T. K., Bertram, D. F., and Norris, D. R. 2011. Stable isotopes reveal strategic allocation of resources during juvenile development in a cryptic and threated seabird, the marbled murrelet. Canadian Journal of Zoology. 89: 859-868.

Jones, Keith and Rudy Hendriks. 1998. Traffic noise analysis protocol. PDF. Online. https://dot.ca.gov/-/media/dot-media/programs/environmental-analysis/documents/f0008617-traffic-noise-protocol-oct1998-a11y.pdf

Kitaysky, A.S. 1999. Metabolic and developmental responses of alcid chicks to experimental variation in food intake. Physiology and Biochemical Zoology, Vol. 72, No. 4 pp. 462-473.

Kitaysky, A.S., J.C. Wingfield and J.F. Piatt. 2001. Corticosterone facilitates begging and affects resource allocation in the black-legged kittiwake. Behavioral Ecology 12(5): 619-625.

Knight, R.L. and S.K. Knight. 1984. Responses of wintering bald eagles to boating activity. Journal of Wildlife Management 48:999-1004.

Kuletz, K.J. 2005. Foraging behavior and productivity of a non-colonial seabird, the marbled murrelet (Brachyramphus marmoratus), relative to prey and habitat. Dissertation, University of Victoria. 195 pp.

Long, L.L. and C.J. Ralph. 1998. Regulation and observations of human disturbance near nesting Marbled Murrelets. Arcata, CA: Pacific Southwest Research Station, Redwood Sciences Laboratory, Forest Service, U.S. Department of Agriculture.

Malt, J. M. and Lank, D.B. 2009. Marbled murrelet nest predation risk in managed forest landscaped: dynamic fragmentation effects at multiple scales. Ecological Society of America 19(5), pp/ 1274-1287.

Marra, P. and R.L. Holberton. 1998. Corticosterone levels as indicators of habitat quality: effects of habitat segregation in a migratory bird during the non-breeding season. Oecologia 116:284-292.

Marzluff, J. M. and Neatherlin, E. 2006. Corvid response to human settlements and campgrounds: causes, consequences, and challenges for conservation. Biological Conservation, 130(2), pp. 301-314.

McFadden, Edith A. and Saunders, James C. 1989. Recovery of auditory function following intense sound exposure in the neonatal chick. Hearing Research. 41(12-3) pp. 205-215.

McGarigal, K., R.G. Anthony, and F.B. Isaacs. 1991. Interactions of humans and Bald Eagles on the Columbia River estuary. Wildlife Monographs 115. 47 pp

McShane, C., Hamer, T., Carter, H. and others. 2004. Evaluation report for the 5-year status review of the marbled murrelet in Washington, Oregon, and California. Unpublished Report. EDAW, Inc. Seattle, Washington. Prepare for U.S. Fish and Wildlife Service, Region 1. Portland Oregon.

Mehlum, F.G., W. Gabrielsen and K.A. Nagy. 1993. Energy expenditure by Black-Guillemots (Cepphus grylle) during chick-rearing. Colonial Waterbirds 16:45-52.

Michael Minor and Associates (MM&A). 2008. Blasting and helicopter noise analysis and mitigation plan. Unpublished report prepared for the Pacific Connector Gas Pipeline, L.P., by Michael Minor & Associates, Portland, Oregon. 27 pp.

Moberg, G. P. 1985. Biological Response to stress: Key to assessment of animal well-being? Animal Stress. Spring, New York, NY.

Montevecchi, W.A., R.E. Ricklefs, I.R. Kirkham and D. Gabaldon. 1984. Growth energetics of nestling Northern Gannets (Sula bassanus). Auk 101:334-341.

Munck, A., Guyre, P.M., Holbrook, N.J., and others. 1984. Physiological Functions of Glucocorticoids in Stress and Their Relation to Pharmacological Actions. Endocrine Reviews, 5(1) pp. 25-44.

Nelson, S.K. 1997. Marbled murrelet. The Birds of North America, No. 276. The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

Nelson, S.K. and T.E. Hamer. 1995a. Nesting biology and behavior of the Marbled Murrelet. Pages 57-68 in, Ralph, C.R., G.L. Hunt Jr., M.G. Raphael and J.F. Piatt eds., Ecology and conservation of the Marbled Murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: Pacific Southwest Research Station, Forest Service. U.S. Department of Agriculture.

Nelson, S.K. and T.E. Hamer. 1995b. Nest success and the effects of predation on Marbled Murrelets. Pages 89-98 in, Ralph, C.R., G.L. Hunt Jr., M.G. Raphael and J.F. Piatt eds., Ecology and conservation of the Marbled Murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: Pacific Southwest Research Station, Forest Service. U.S. Department of Agriculture.

Nelson, S.K. and R.W. Peck. 1995. Behavior of marbled murrelets at nine nest sites in Oregon. Northwestern Naturalist 76(1): 43-53.

Nelson, S.K. 1997. Marbled murrelet. The Birds of North America, No. 276. The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

Obst, B.S., R.W. Russell, G.L. Hunt, Z.A. Eppley and N.M. Harrison. 1995. Foraging radii and energetic of Least Auklets (Aethia pusilla) breeding on three Bering Sea islands. Physiological Zoology 68(4):647-672.

Øyan, H. S. and Anker-Nilssen, T. 1996. Allocation of growth in food-stressed Atlantic puffin chicks. The Auk 113(4) pp. 830-841.

Peery, M. Z., and Henry, R. W. 2010. Recovering marbled murrelets via corvid management: a population viability analysis approach. Biological Conservation 143(11) pp. 2414-2424.

Ralph, C.J, G.L. Hunt Jr., M.G. Raphael and J.F. Piatt. 1995. Ecology and conservation of the Marbled Murrelet in North America: An overview. Pages 3-22 in, Ralph, C.R., G.L. Hunt Jr., M.G. Raphael and J.F. Piatt eds., Ecology and conservation of the Marbled Murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture.

Raphael, M. G., Mack, D. E., Cooper, B. A. 2002. Landscape-scale relationships between abundance of marbled murrelets and distribution of nesting habitat. The Cooper Ornithological Society. The Condor 104 pp. 331-342.

Ricklefs, R.E. 1983. Avian postnatal development. Pages 2-72 in, D. Farner, J. King and K. Parkes eds., Avian Biology Volume II. Academic Press: New York, New York.

Ricklefs, R.E., D.D. Roby and J.B. Williams. 1986. Daily energy expenditure by adult Leach's Storm-petrels during the nesting cycle. Physiological Zoology 59(6):649-660.

Rodgers, Jr., J.A., and H.T. Smith. 1995. Set-back distances to protect nesting bird colonies from human disturbance in Florida. Conservation Biology 9(1):89-99.

Schroeder, J., Nakagawa, S., Cleasby, I. R., Burke, T. 2012. Passerine birds breeding under chronic noise experience reduced fitness. PLoS ONE 7(7): e39200.

Scarpignato, A. L. and George, T. L. 2013. Space use by common ravens in marbled murrelet nesting habitat in Northern California. Journal of Field Ornithology, 84(2):147-159.

Schwartzkopff, Johann. 1955. On the Hearing of Birds. The Auk. 72(4) pp. 340-347.

Simons, T. R. 1980. Discovery of a ground-nesting marbled murrelet. The Condor. 82(1) pp. 1-9

Sims, C.G. and R.L. Holberton. 2000. Development of the corticosterone stress response in young northern mockingbirds (*Mimus polyglottos*). General and Comparative Endocrinology 119:193-201.

Singer, S. W., N. L., Naslund, Singer, S. A., Ralph, C. J. 1991. Discovery and observation of two tree nests of the marbled murrelet. The Conor. 93(2) pp. 330-339.

Stalmaster, M.V. and J.L. Kaiser. 1997. Flushing responses of wintering Bald Eagles to military activity. Journal of Wildlife Management 61(4):1307-1313.

Thiessen, G.J. and Shaw E.A.G. 1957. Acoustic Irritation Threshold of Ringbilled Gulls. The Journal of the Acoustical Society of America. 29(12) 1307.

Washington State Department of Transportation. 2011. Biological assessment preparation for transportation projects – advanced training manual. Washington State Department of Transportation. Olympia, Washington. Available online at: http://www.wsdot.wa.gov/Environment/Biology/BA/BAguidance.htm

U.S. Fish and Wildlife Service [USFWS] 2003. Biological Opinion and letter of concurrence for effects to bald eagles, marbled murrelets, northern spotted owls, bull trout, and designated critical habitat for marbled murrelets and northern spotted owls from Olympic National Forest program of activities for August 5, 2003 to December 18, 2008. USFWS Reference 1-3-03-F-0833. U.S. Fish and Wildlife Service, Lacey, Washington.

U.S. Fish and Wildlife Service [USFWS]. 2006. Transmittal of Guidance: Estimating the Effects of Auditory and Visual Disturbance to Northern Spotted Owls and Marbled Murrelets in Northwestern California. Arcata Fish and Wildlife Office, July 31, 2006.

U.S. Fish and Wildlife Service. 2012a. Marbled Murrelet Nesting Season and Analytical Framework for Section 7 Consultation in Washington. Washington Fish and Wildlife Office, Lacey, WA. June 20, 2012.

U.S. Fish and Wildlife Service. 2012b. Revised in-air disturbance analysis for marbled murrelets. Unpublished agency document prepared by E. Teachout. U.S. Fish and Wildlife Service, Washington Fish and Wildlife Office, Lacey, Washington. 12 pp.

Wasser, S.K., K. Bevis, G. King and E. Hanson. 1997. Noninvasive physiological measures of disturbance in the northern spotted owl. Conservation Biology 11:1019-1022.

Wingfield, J. C. & Ramenofsky, M**.** 1985. Testosterone and aggressive behaviour during the reproductive cycle of male birds. In: Neurobiology: Current Comparative Approaches (Ed. by R. Giles & J. Balthazart), pp. 92–104.

Appendix B
Northern Spotted Owl
(*Strix occidentalis caurina*)
Auditory and Visual Disturbance Decision Support Tool

User Guide
Version 2
U.S. Fish and Wildlife Service, Arcata, CA
October 1, 2020

Table of Contents

Overview

To facilitate use and understanding of these materials:

- This is an updated guidance from the 2006 Appendix B.
- We have placed instructions and scenarios within the beginning of this document and placed the explanatory and supportive materials within the appendices.
- We have embedded hyperlinks to allow the user quick access and navigation to sections and key terms.
- We have explained the assumptions underlying this decision support tool.

These materials will help users determine the distance within which an auditory or visual disturbance tolerance may rise to the level of take (i.e. harm), as defined in the implementing regulations of the Endangered Species Act of 1973, as amended and related to northern spotted owls (hereafter referred to as spotted owls). The information is intended to be used by an analyst using our decision support tools in conjunction with project-specific information to make an effects determination.

Northern Spotted Owl Auditory and Visual Disturbance

We developed a summary of behaviors that indicate a reasonable likelihood that a spotted owl has been harmed from sound or visual stimuli disturbances.

The Use of Scenarios

We have created a set of scenarios that combines a range of possible activities with common existing environmental conditions. The user selects the scenario(s) that best fits their situation and then selects the distances that are associated with the related activity.

Sound Attenuation Model for Estimating Harm Take Distance

We developed a Sound Attenuation Model and then incorporated it into an Excel spreadsheet to quantitatively and objectively estimate the extent and distance to which actions resulting in human activity or elevated sound levels near spotted owl nest sites are likely to harm the species.

Auditory Disturbance Threshold Analysis

We conclude spotted owls may be harmed from project-generated sound under one or both of two conditions:

1. *Tolerance Threshold*: the species may be harmed at or above an absolute limit of sound in its habitat. This upper sound limit was set as 82 decibels (92 for aircraft), which includes the action-generated and all existing sound sources;

2. *Above-Existing Threshold*: the species may react to elevated sounds in relation to all existing sound sources. We determined this elevated decibel difference to be a 25 decibel difference between all existing noise (i.e., natural background ambient, line and point sound sources) and only the action-generated sound (e.g., a chainsaw).

Visual Disturbance Threshold Analysis

We conclude spotted owls may be harmed from project-generated visual disturbances if the project is within 100 meters of the base of nest tree or habitat.

Northern Spotted Owl Auditory and Visual Disturbance

Flushing an adult and/or juvenile spotted owl during the breeding season by sound and visual stimuli is a behavior considered to potentially indicate disturbance of an owl.

Behaviors may reach to the level of take (i.e. harm) of owls due to:

- Increased risk of predation
- Increase risk of exposure to heat stress
- Risk of decreased reproduction
- Risk of decreased feedings
- Risk of decreased fledgling success
- Risk of reduced adult and juvenile fitness
- Increase risk of mortality of chicks

Given the limited spotted owl-specific auditory and visual disturbance data, information from other species was incorporated in this analysis, though we have attempted to be discretionary about which surrogate species and data we use. Additionally, the available evidence, although minimal, suggest that responses of owls to noise are not very different from those of hawks, eagles, and falcons (Awbrey and Bowles 1990). While different avian species react differently to auditory and visual disturbances, most birds have "very similar frequency ranges and thresholds," due to the relatively simple construction of the avian ear (Awbrey and Bowles 1990). All birds, except pigeons, are less sensitive to low frequencies than humans, which should make them less sensitive to aircraft noise (Awbrey and Bowles 1990). Further, bird hearing can be damaged by continuous noise, e.g., high-amplitude pure-tone noise for long periods, such as 86-115 dB for several days.

The spotted owl is a secretive, solitary species with cryptic plumage (Forsman et al. 1984). Spotted owls have co-evolved with their old-growth forest habitats and thus are behaviorally and physiologically adapted to these forests (Carey 1985). The passive defense behaviors and physical characteristics tend to decrease the visibility of a nesting or roosting owl. Adult spotted owls maintain a constant diurnal presence at nest sites during the breeding season. Adults primarily roost during the day and remain inactive; occasionally they move in place or may fly to retrieve cached food, to drink, bathe, or change roost trees (Forsman et al. 1984). Spotted owls have remarkably low metabolic rates and require seemingly little food. The spotted owl also has a large repertoire of calls. Two particular calls, the contact and warning call, are very quiet and commonly given during the day.

Disruption of Normal Behavior

Northern spotted owls are typically non-aggressive and utilize their cryptic markings, secretive behaviors, and warning vocalizations to avoid predators. These owls use their passive defense behaviors and physical characteristics to decrease their detectability. Northern spotted owls utilize cavity and platform nests and roosts during the day when they are relatively inactive.

Adult owls maintain a constant diurnal presence at nest sites during the breeding season. The general breeding season for northern spotted owl is February 1 to July 31. Females rarely leave the nest during the incubation and brooding periods for longer than 10 to 20 minutes, especially during the hottest portion of the day. During the incubation and brooding periods the embryos and chicks are highly susceptibility to the elements and to predators. Thus, these owls are highly heat intolerant and actively seek roost sites with favorable microclimate conditions. Therefore, flushing responses during the hottest portion of the day can increase the risk of heat stress to spotted owls and to predators.

High levels of short-duration recreational hiking reduced female Mexican spotted owl (*S. o. lucida*) daytime maintenance behaviors by 30% (Swarthout and Steidl 2003). Daytime maintenance includes self-preening, preening nestlings, allopreening, and maintaining their nest (Swarthout 1999). Preening cleans and improves the flexibility and insulating properties of feathers and reduces ectoparasite loads; adults often assume this duty for nestlings too young to preen themselves. Decreased time allotted to these activities could decrease the health of owls and possibly alter social interactions among birds (Swarthout and Steidl 2003).

Female spotted owls may be more directly affected by human disturbance than males since females attend nests almost exclusively, and because egg and nestling survival depend largely on their behavior (Swarthout and Steidl 2003). Any reduction in nestling vigor either through reduced energy intake, reduced parental care, or a combination of both may make fledged juveniles more susceptible to these sources of mortality." (Swarthout and Steidl 2003).

A reasonable worse-case scenario indicates that, in an occupied nest site, we would expect that one adult female per nest will be present any time during the day. Therefore there is a likelihood that the types of audio and visual activities addressed herein would disrupt essential nesting behavior at some point during each day during the breeding season. Hence, any stimulus that significantly disrupt essential behaviors may lead to the likelihood of harm.

Likelihood of Harm to Northern Spotted Owl

Increased Risk of Predation

We presume that any disturbances that cause exposure of adult or juvenile spotted owls increases predation risks. A flushing response may create the likelihood of harm by increasing the likelihood of predation, e.g., through the advertisement of the nest's location, advertisement of

the adult and juvenile, or premature departure of a nestling from a platform nest.
Predation is presumed the single largest cause of spotted owl mortality, particularly of juveniles, due to diurnal raptors, great horned owls, and corvids (e.g., jays, crows, ravens) (Forsman et al. 1984; Verner et al. 1992). Although direct predation on spotted owls has been rarely observed, Forsman et al. (1984) reported that 10 of 29 owlets (35%) in their study disappeared and were presumed dead. Predation was the suspected cause because owlets appeared healthy shortly before they disappeared. Forsman et al. (1984) also provide a firsthand account of predation on a spotted owl nest caused by exposure of the adult: "In one encounter, a female spotted owl dived repeatedly at two ravens that were hopping around on limbs just outside her nest cavity. This incident was instigated when we called the female out of her nest during the day."

Physiological Stress Effects

Northern spotted owls may respond physiologically to a disturbance without exhibiting a behavioral response. Extended periods with elevated stress hormone levels may have negative effects on reproductive function, disease resistance, or physical condition (Carsia and Harvey 2000; Sapolsky et al. 2000). In avian species, the secretion of corticosterone is the primary non-specific stress response (Carsia and Harvey 2000). The quantity of this hormone in feces can be used as a measure of physiological stress (Wasser et al. 1997). Fecal glucocorticoid metabolites (fGCs), which reflect disturbance and the number of offspring fledged within a season.

Glucocorticoids (GCs) are the hormones most often measured in studies of disturbance and the number of offspring fledged within a season. Corticosterone is released by the hypothalamo-pituitary-adrenal gland to help animals respond to environmental stress. Frequently used as index of the ''stress'' perceived by an organism, fGCs show good potential as a diagnostic tool for conservationists (Busch and Hayward 2009). In all vertebrates studied to date, GCs increase as part of a generalized physiological stress response to challenge (Romero 2004). Similarly, relatively high baseline fGC levels tend to be associated with disturbance. For example, increased predation pressure (Boonstra et al. 1998), decreased food availability (Clinchy et al. 2004), traffic exposure (Creel et al. 2002), tourism (Walker et al. 2006) and habitat fragmentation (Suorsa et al. 2003; Busch and Hayward 2009).

Elevated GCs tend to be associated with decreased fitness either due to reduced survival (Pride 2005) or reduced reproductive success (Bonier et al. 2007). However, the relationship between fGCs and fitness is not always significant or consistent (Busch and Hayward 2009). "Chronic high levels of GCs may have negative consequences on reproduction or physical condition" (Marra and Holberton 1998). The exact corticosterone levels that relate to a level of harm is unknown. However, the strong association of physiological stress with impaired health and reproductive performance among vertebrates warrants that this biological factor be considered (Moberg 1985; Munck et al. 1984; Wingfield and Farner 1993). Kitaysky et al. (2001) reported that corticosterone implanted black-legged kittiwake adults (a colonially-nesting *Charadriiformes*, *Laridae* species) spent more time (nearly 20x) away from nest and less time brooding/guarding than sham-implanted adults. The proportion of corticosterone-implanted parents that failed to return to the breeding colony was significantly larger than its sham-implanted parents. Kitaysky et al. (2001) conclude, though, their results do not demonstrate an effect of high corticosterone levels on the breeding success of adults. Nestling mockingbirds

(*Mimus polyglottos*) less than 10 days old showed little or no secretion of corticosterone, but late-stage nestlings showed elevated levels when they were about to fledge, indicating that young-stage nestlings may not be susceptible to corticosterone effects due to disturbance (Sims and Holberton 2000); it could also be that corticosterone is naturally produced to help in the fledging process. Blethoff and Duffy (1998) reported a correlation between an increase in serum corticosterone levels in young screech owls and an increase in motor activities (jumping and wing flapping) in preparation for dispersal.

Some studies of fecal corticosterone levels of spotted owls indicate that low intensity noise of short duration and minimal repetition does not elicit a physiological stress response (Tempel and Gutiérrez 2004). However, prolonged activities, such as those associated with timber harvest, may increase fGC metabolites levels depending on their proximity to spotted owl core use areas (Tempel and Gutiérrez 2004; Wasser et al. 1997). Male spotted owls whose home range centers were within 0.41 km of a major logging road or recent (within 10 years) timber activity showed higher levels of corticosterone than those with home range centers farther from logging roads or recent timber activity. Females showed no such increase physiological effect of proximity to road or logging activity (Wasser et al. 1997). This result is consistent with the literature for other avian species that showed fecal corticosterone levels were significantly higher in adult male versus female in the wild (Wingfield and Farner 1993). Disturbance impacts tied to home range were largely confined to adult males, perhaps reflecting the predominantly male role in territorial defense (Wasser et. al 1997). Higher corticosterone levels in males whose home ranges were in proximity to clear-cut versus selectively logged areas suggest that impacts of different timber harvesting methods on spotted owl survivorship may additionally become discernible with these fecal stress hormone measures. (Wasset et al. 1997.) Based on the findings by Wasser et al. (1997) for elevated corticosterone levels of spotted owls, it appears that spotted owl physiology is similar to these other bird species; therefore it is likely that adults and late-stage nestlings could produce elevated levels of corticosterone in response to disturbances. At the same time Wasser et al. (1997) found that owls baseline fGCs vary by sex and season, increasing in females through the course of the breeding season but decreasing in males (Wasser and Hunt 2005).

Hayward et al. 2011 did a study examining the effects of off-highway vehicle use on the spotted owl by measuring fGCs, which reflect disturbance and the number of offspring fledged within a season. Hayward et al. 2011 applied one hour of motorcycle exposure (less than 96 dB) to spotted owls during periods of incubation (May) and fledging (July), comparing fGC levels of treated spotted owls with those of non-exposed controls. Acute vehicle exposure generally increased fGCs in the short term. Males showed the highest glucocorticoid response to vehicle disturbance in May when they were typically solely responsible for feeding themselves, their mates and their nestlings. Levels of fGCs were highest post treatment among females that lacked young and had high fT3 (good nutrition); fGC levels were lower in treated females compared to controls among females with two young and low fT3 (compromised nutrition), possibly reflecting allostatic overload. Surprisingly, fGC levels were unrelated to proximity of roads, irrespective of noise. Presumably, the tendency for traffic exposure to increase fGCs over the long-term was offset by nutritional gains (i.e., reduced fGCs and high fT3) associated with proximity to roads.

Multiple stressors (e.g., psychological disturbance or reduced food availability) can also elevate GCs, complicating its interpretation. Baseline GCs can predict the relative fitness of individuals and populations, but the relationship is not always consistent or present (Bonier et al. 2009). Whether such elevated levels of corticosterone would result in adverse effects of spotted owls to a level of harm is unknown. Therefore, we decided not to include the possible effects of elevated corticosterone in this analysis given the lack of data for any avian species showing a clear correlation between elevated corticosterone levels and effects to feeding, breeding or sheltering.

Decrease in Reproduction

Northern spotted owls close to noisy roads fledged significantly fewer young than owls near quiet roads, indicating that routine traffic exposure may decrease reproductive success over time (Hayward et al. 2011). In an American kestrel reproduction and human disturbance study (traffic conditions and land development) 36% of kestrels nesting attempts failed and 88% of failures occurred during incubation. Kestrels nesting in higher disturbance areas were 9.9 times more likely to fail than kestrels nesting in lower disturbance areas (Strasser and Health 2013).

Likelihood of Harm to Juvenile Owls

Effects of Reduced Feedings

Noise disturbance can cause significant changes to owl behaviors. Delaney et al. (1999) report a high correlation between noise stimulus distance (helicopter over-flights) and reductions of prey deliveries by Mexican spotted owls. The authors report that the estimated potential threshold distance for negative effect on prey deliveries was 96 meters. Senaski et al. 2016 estimate that effects of traffic noise on owls' ability to detect prey reach greater than 120 meters from a road. The ability of short-eared owls (*Asio fammeus*) and long-eared owls (*Asio otis*) to detect prey was impacted at a low sound level (40 dB) and was approximately 17% lower than detections in ambient sound conditions (Senaski et al. 2016). For each decibel increase in noise, the odds of hunting success in northern saw-whet owls (*Aegolius acadius*) also decreased by 8% (Mason et al. 2016). In northern saw-whet owls, the odds of prey detection and strike behavior also decreased with increasing noise falling 11% and 5%, respectively (Mason et al. 2016).

Food consumption by both nestling and adult raptors during nesting is positively correlated with brood size (Korpimäki and Norrdahl 1989), growth rate and mass of nestlings (Lacombe 1994), and nestling survival (Wiehn and Korpimäki 1997) and is negatively correlated with rates of nestling and fledgling predation in many bird species (Yom-Tov 1974; Arcese and Smith 1988; Ward and Kennedy 1996). When exposed to visual disturbance, several species of raptors are known to display reductions in essential nesting behaviors. Some examples include: Mexican spotted owls reduced prey handling by 57% (Swarthout and Stiedl 2003); marsh harriers decreased nest attendance and prey delivery rates (Fernández and Azkona 1993, Knight and Cole 1991); and bald eagles decreased amount of prey delivered to nests (Steidl and Anthony 2000). Mexican spotted owls have also shown reduced prey delivery rates in response to experimental helicopter over-flights of nest sites (Delaney et al. 1999).

Auditory Disturbance Threshold Analysis

Data from Thiessen and Shaw (1957), Awbrey and Bowles (1990), Brown (1990), and Delaney et al. (1999) were used to estimate disturbance thresholds. The proximity of a noise is a major factor in the response of an individual of a species to the disturbance. Platt (1977) reported that the probability of gyrfalcons flying away from nests increases with decreasing distance of an approaching helicopter; Delaney et al. (1999) reported that owl flushing was negatively related to stimulus distance and positively related to noise level. Similar findings have been reported for numerous raptor species (i.e., bald eagle, prairie falcon, and red-tail hawk) (Awbrey and Bowles 1990).

Spotted owls are likely to be disturbed by sound levels that exceed a certain level at nest sites because there is a sound level above which spotted owls are likely to be intolerant, and respond with behavior that characterizes disturbance. This value represents the sound level wherein the cumulative sound generated by the proposed action combined with existing line and point sound sources is likely to result in disturbance of the species due to the overall volume of noise at the location. A potential cause of sound-related harm is project-generated sound levels exceeding the existing sound level (i.e., the existing line and point sources, and background ambient sound levels) currently experienced by individuals of the species near the project site by 25 dB.

Published Auditory Disturbance to Raptors

Awbrey and Bowles (1990) stated that "what little published literature [on raptors] is available suggests that noise begins to disturb most birds at around 80-85 dB sound levels and that the threshold for the flight response is around 95 dB." Thiessen and Shaw (1957) found that caged ring-billed gulls (*Larus delawarensis*) subjected to varying sound levels and frequencies, cringed at 83-91 dB at 150 cps (cycles per second = Hertz) and had elevated heart rates at 92 dB; it is unknown at what dB level these birds would have flushed. Delaney et al. (1999) provide excellent descriptions of Mexican spotted owls flushing to helicopter over-flights and chainsaws at 92 dB(A) and 46 dB(A), respectively. Swarthout and Steidl (2003), provide descriptions of Mexican spotted owls flushing and vocalizing to hikers walking by nest sites. Swarthout and Steidl (2003) also provide examples of Mexican spotted owls vocalizing to hikers walking by nest sites. Forsman et al. (1984) provide a description of observers flushing a female northern spotted owl from a nest. There are also other studies of raptors flushing from nests due to human presence and aircraft over-flights (Awbrey and Bowles 1990, Knight and Knight 1984, McGarigal et al. 1991, Stalmaster and Kaiser 1997, Bednarz and Hayden 1994). Additionally, the available evidence, although minimal, suggest that responses of owls to noise are not very different from those of hawks, eagles, and falcons (Awbrey and Bowles 1990).

The frequency range of the noise created by power-equipment appears to be a major factor in flush response of the Mexican spotted owl. Mexican spotted owls were flushed by chainsaw noise (≤46 dBA) that was considerably lower than helicopter noise levels that flushed owls (≥92 dBA) (Delaney et al. 1999). It appears that more of the total chain saw noise energy was in the mid-frequency range where estimated spotted owl hearing sensitivity is greatest. Helicopter sound energy level peaked at the lower end of the spectrum below the estimated spotted owl hearing sensitivity range. This difference partially explains the higher response rates of Mexican spotted owls to chainsaws at lower noise levels than for helicopters (Delaney et al. 1999).

Industrial noise has been shown to negatively affect owl hunting success and reduce foraging efficiency by affecting their ability to detect prey. (Shonfield and Bayne 2017). In a study done by Shonfield and Bayne (2017) it was determined that barred owls (*Strix varia*), great horned owls (*bubo virginiaus*), and boreal owls (*Aegolius funereus*) were likely to occupy both types of noisy sites compared to sites with no noise. No barred owls were detected at sites with a noise level more than 93 dB (Shonfield and Bayne 2017). Boreal owl detection probability decreased with increasing noise levels (Shonfield and Bayne 2017). Shonfield and Bayne (2017) found that barred owl use declines with increased human disturbance resulting in the loss of forest cover.

Johnson and Reynolds (2002) report that Mexican spotted owl behavior during military fixed-wing aircraft training in which maximum noise levels measured at the owl site were 78, 92, and 95 dB for the three fly-bys, ranged from no response to a sudden turning of the head. Delaney et al. (1999) found that Mexican spotted owls, during both the nesting season and the non-nesting season, did not flush from helicopter noise unless the noise was at least 92 dB(A).

Spotted owls may also perceive aircraft "as less threatening…because of their shorter duration, gradual crescendo in noise levels, minimal visibility, and lack of association with human activity. Additionally, raptors may be less disturbed by aircraft because of their use of that medium (Gilmer and Stewart 1983). Further, in the helicopter manipulations conducted by Delaney et al. (1999), the authors state: "Helicopters would have elicited greater spotted owl response if exposure times were increased through slower maneuvers such as hovering."

The greater response of test owls to chain saws versus helicopters in the study by Delaney et al (1999) are in line with the analysis by Awbrey and Bowles (1990) that aircraft overflights were less detrimental than common ground-based activities such as hiking; and, visual detection may also interact synergistically with auditory detection of humans and their activities. Delaney et al (1999) report that "Although chainsaws were ...operated out of sight of reference spotted owls, field crews had to set up recording equipment beneath the spotted owls for both types of manipulations". Subsequent owl flushes may have been associated with the synergistic combination of ground-based human activity and chainsaw noise.

For aircraft related projects we estimate the sound-only harm threshold to be 92-95 dB (rounded down to 92 dB). For ground-based activities, sound-only harm threshold for chainsaw and motorcycle noise are estimated at 46 dB(A). For other ground-based machinery and equipment associated with forest management, it was decided to lower the sound-only harm threshold 10 dB to 82 dB. The recommended 82 dB was based on (1) a sound that is measured at 10 dB louder than another sound transmits ten-times as much energy, but is perceived by human hearing as having about twice the volume; (2) the rapid onset that is more likely for noise from ground-based activities; (3) the synergistic effects of noise and ground-based human activity; (4) the fact that projects other than aircraft can remain in an area for much longer time than typical aircraft overflights; and (5) noise reaching nesting and roosting owls may be higher than estimated due to elevated nest location and the resonating characteristics of cavity nests (see next section).

Hayward et al. (2011) conducted a study on the effects of acute long-term vehicle exposure to northern spotted owls. The 60 dBA value was eventually selected because it was in the middle of the range tested and was exceeded by only a few percent of the 2-second samples at most sites in the absence of vehicle noise (less than 1% at 22 of 23 sites in 2006 and 13 of 19 sites in 2007). Average ambient levels were generally between 25 dBA and 50 dBA (ambient L_{Aeq} for the observation period). Average ambient levels were generally between 25 dBA and 50 dBA (ambient L_{Aeq} for the observation period). The range of distances between road and spotted owl was 5–800 m. Simulations involved between one and six riders on two-stroke or four-stroke bikes that met the legal criteria for noise production (less than 96 decibels). The results of the Hayward et al. (2011) concluded there was no evidence that GC response diminished with exposure to routine road noise in May or among spotted owls within 50 m of a road in July. Traffic appeared always to be associated with high GC response in these spotted owls. The fact that male spotted owls 50–800 m from loud roads showed lower GC response to acute motorcycle exposure than males 50–800 m from quiet roads in July suggests that partial habituation to traffic may occur in this species among males a sufficient distance (50 m) from the road. Distance to closest road and its interaction with road noise on that road were strongly and significantly associated with number of young fledged by mid-July. When noise levels on the road were low, spotted owls close to roads fledged more young; when noise levels on the road were high, the opposite pattern held.

Auditory Disturbance Determination

We expect Spotted owls to have significant behavioral responses when project-generated sound exceed ambient nesting conditions by 20-25 dB based on differences between the recorded minimum ambient decibel levels in the Delaney et al. (1999), Hayward et al. (2011), Awbrey and Bowles (1990), Brown (1990). There were 25 dB and 37 dB difference between the recorded minimum ambient decibel levels in the Mexican spotted owl study by Delaney et al. (1999) and the red-cockaded woodpecker study by Delaney et al. (2000), respectively; and 55 dB for crest-tern study by Brown (1990). Further, the lowest decibel level at which these studies witnessed one of the behaviors we identified as indicating harassment are 46 dB for Delaney et al. (1999), 75 dB for Delaney et al. (2000), and 90 dB for Brown (1990). The difference between the lowest ambient-level and the noise level at which harassment-indicating behavior was observed for the three studies are 21 dB, 38 dB, and 35 dB, respectively, which average to 31 dB. Due to the usually slow onset and only transit over a spotted owl site for aircrafts, we expect spotted owls may flush the nest in response to exposure to aircraft at sound levels exceeding 92 dB SEL based on observed response of Mexican spotted owls to helicopters (Delaney 1999).

Visual Disturbance Threshold Analysis

Published Raptor Response to Visual Disturbance

Altered owl activity budgets were selected to represent visual harassment to spotted owls for several reasons: (1) hikers reduced Mexican spotted owl prey handling by 57% (Swarthout and Stiedl 2003); (2) recreation activities (visual disturbance) have caused altered activity budgets for breeding bald eagles (Steidl and Anthony 2000), decreased reproductive success for ferruginous hawks (White and Thurow 1985), decreased nest attendance and prey delivery rates by marsh harriers (Fernandez and Azkona 1993) and nest site selection by kestrels (van der Zande and Verstrael 1984); (3) reported the amount of prey delivered and consumed at bald eagle nests decreased in response to human campers near nests (Steidl and Anthony 2000); (3) Mexican spotted owls reduced prey delivery rates in response to experimental helicopter over-flights of nest sites (Delaney et al. 1999); and (4) Food consumption by adult and nestling raptors is positively correlated with brood size (Korpimäki and Norrdahl 1989), growth rate and mass of nestlings (Lacombe 1994), and nestling survival (Wiehn and Korpimäki 1997), and is negatively correlated with rates of nestling and fledgling predation in many bird species (Yom-Tov 1974; Arcese and Smith 1988; Ward and Kennedy 1996).

Animals may respond to a stimulus either passively or actively (Steen et al. 1988; Gabrielsen and Smith 1995; Gabrielsen and Smith 1985). A passive response is when an animal remains motionless when sensing danger and stays in this position until the stimulus disappears or until a critical distance is reached between the prey and predator forcing the animal to flee (Gabrielsen and Smith. 1985; Gabrielsen and Smith 1995). In the case of birds, it generally involves remaining motionless on a nest when sensing danger until a critical distance is reached when the bird takes flight (Gabrielsen et al. 1977, Gabrielsen and Smith 1985; Steen et al. 1988). A passive response produces dramatic physiological changes in the animal and is exhibited in all animals (Gabrielsen and Smith 1995).

Raptors are reported to be more sensitive to visual disturbances than auditory disturbances. Awbrey and Bowles (1990) report that aircraft overflights were less detrimental than common ground-based activities such as hiking. Visual detection may also interact synergistically with auditory detection of humans and their activities (Awbrey and Bowles 1990). Delaney et al (1999) describe the greater response by Mexican spotted owls to ground-based than to aerial disturbances: "Although chainsaws were ...operated out of sight of reference spotted owls, ... field crews had to set up recording equipment beneath the spotted owls for both types of manipulations. Subsequent spotted owl flushes may have been associated with the synergistic combination of ground-based human activity and chainsaw noise."

Numerous studies on visual disturbance of bald eagles (Knight and Knight 1984, McGarigal et al. 1991, Stalmaster and Kaiser 1997), for example, recommend limiting activities beyond 250 m to reduce threats from visual disturbances. Bednarz and Hayden (1994) state that approaches by humans flushed 100 percent of great horned owls at a mean distance of 111.3 m, with a range of 5-700 m, and those owls did not return to the initial site as long as humans were visible. Spotted owls have a greater threshold to human approach than other raptor species (Delaney et al. 1999). Spotted owls become accustomed to observers sitting quietly 25-50 m away in only 10-15 minutes (Sovern et al. 1994). Swarthout and Steidl (2003) report that 95% of both adult and juvenile Mexican spotted owls that responded (flushed) to a hiker became alert within 55 m and 95% of adult and juvenile flushes occurred within 24 m and 12 m, and adults having been flushed previously, increased the odds 7-fold of being flushed on subsequent approaches.

Spotted owls vocalize to human presence at nest sites. Spotted owl adults and juveniles vocalized in response to first being approached by a hiker, with 20% of flushed adults and 36% of flushed juveniles vocalizing (Swarthout and Steidl 2003). A study of Mexican spotted owls demonstrated that hikers caused both females and males to increase the frequency of contact vocalizations by 58% and 534% respectively (Swarthout and Steidl 2003).

Although spotted owls appear very tolerant of close non-threatening human approach, there may be significant changes to spotted owl behaviors when repeated human approaches occur at nest sites. Swarthout and Steidl (2003), in experimental tests of the effects of hikers on breeding Mexican spotted owls, found that female owls "decreased the amount of time they handled prey by 57% and decreased the amount of time they performed daytime maintenance behaviors by 30%." Hikers also caused increased vocalizations by female (58%) and male (53%) Mexican spotted owls Swarthout and Steidl (2003). Vocalizations can attract predators to nest sites. The authors reported that female owls responded more to hikers than did males. Female spotted owls attend nests almost exclusively, thus egg and nestling survival depend largely on their behavior (Swarthout and Steidl 2003). Because of carry-over effects of the treatments, the authors state that their findings should be interpreted as the minimum response of owls to hikers. The authors concluded that "the cumulative effects of high levels of short-duration recreational hiking near nests may be detrimental to Mexican spotted owls. Recreation activities also have been shown to cause altered activity budget for breeding bald eagles (Steidl and Anthony 2000), decreased reproductive success for ferruginous hawks (White and Thurow 1985), decreased nest attendance and prey delivery rates by marsh harriers (Fernandez and Azkona 1993) and nest site selection by kestrels (van der Zande and Verstrael 1984).

Human disturbance near nest sites decrease the quantity of prey delivered and consumed at raptor nests. Steidl and Anthony (2000) reported the amount of prey delivered and consumed at bald eagle nests decreased in response to human campers near nests. Similarly, Delaney et al. (1999) reported decreased prey delivery rates due to experimental helicopter over-flights of Mexican spotted owl nest sites. Net differences in prey deliveries were highly correlated with stimulus distance and 96 m was estimated for helicopter noise as the potential threshold distance for a negative effect on prey deliveries (Delaney et al. 1999). Food consumption by adult and nestling raptors is positively correlated with brood size (Korpimäki, and Norrdahl 1989), growth rate and mass of nestlings (Lacombe 1994), and nestling survival (Wiehn and Korpimäki, 1997), and is negatively correlated with rates of nestling and fledgling predation in many bird species (Yom-Tov 1974; Arcese and Smith 1988; Ward and Kennedy 1996).

Based on the above discussion, we estimate the sight-only disturbance distance for spotted owls at nest sites at 100 meters. A spotted owl will not be disturbed by sight-only activities, such as hikers, that are equal to or further than 100 meters distance from a spotted owl nest or roost tree. This is a conservative estimate aiming to prevent disturbance to nesting owls, particularly females on the nest. This sight-only disturbance distance will: prevent flushing; minimize alert behaviors; minimize altering owl activity budgets; and prevent vocalizations due to human presence near nest sites. The 100 meters distance aims to provide complete visual obstruction of humans in typical habitat from the high vantage-point of elevated owl nests, which appear to influence owl response to hikers (Swarthout 1999); establish a sight-only threshold distance that is adequate for most low- to moderate-levels of human presence near spotted owl nest sites. It is appropriate that site-specific conditions may warrant changes to the 100 meters sight-only disturbance distance, while still meeting the goals of this action. Differences at individual sites associated with vegetation density, landform, or the level of recreation activity, may warrant decreasing or increasing the 100 meters distance. For example, the sight-only distance can be shortened at an owl nest site where a low-use hiking trail is mostly screened by dense vegetation. Conversely, in situations of heavy-levels of recreational hiking, i.e., >50 hikers/day, adjacent to nest or roost sites, application of longer sight-disturbance distances can be considered.

Visual Disturbance Distance Determination

Numerous studies on visual disturbance of bald eagles (Knight and Knight 1984, McGarigal et al. 1991, Stalmaster and Kaiser 1997) recommend limiting activities beyond 250 m to reduce threats from visual disturbances. Bednarz and Hayden (1994) state that approaches by humans flushed 100 percent of great horned owls at a mean distance of 111.3 meters, with a range of 5-700 meters, and those owls did not return to the initial site as long as humans were visible. Another study demonstrated that 97% of raptors (kestrels, merins, rough-legged hawks, ferruginous hawks, golden eagles) approached by humans on foot flushed with a mean flush distance of 118 meters, whereas 38% of raptors approached by car flushed with a mean flush distance of 75 meters. (Holmes et al. 1993).

Spotted owls have a greater threshold to human approach than other raptor species (Delaney et al. 1999). Spotted owls become accustomed to observers sitting quietly 25-50 m away in only 10-15 minutes (Sovern et al. 1994). Swarthout and Steidl (2003) report that 95% of both adult and juvenile Mexican spotted owls that responded (flushed) to a hiker became alert within 55 meters and 95% of adult and juvenile flushes occurred within 24 meters and 12 meters, respectively. Further, for adults, having been flushed previously increased the odds 7-fold of being flushed on subsequent approaches.

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The Use of Scenarios

Determining whether human activities may harm nesting owls due to elevated sound levels and/or close visual proximity of human activities to an active nest includes a daunting array of factors. To simplify this task and facilitate a consistent application of available information, we have incorporated a range of scenarios into a decision support tool.

These scenarios cover a range of conditions likely to be encountered during actions in or near owl nesting habitat. They provide a reasonable approximation of the effects of sound and visual detection from human activity on owls under specified conditions. Whereas the physical formulae applied to sound attenuation are quite precise in theory, their application under field conditions may be subject to substantial error of estimation. Further, the available data on actual sound levels that might disturb wildlife species, especially the owl, are limited.

Scenarios includes two levels of natural background sound. The use of 35 dBA is appropriate for those project sites where the sound sources are predominantly quite low and are only occasionally elevated due to wind events and other similar natural sources. The use of 45 dBA is appropriate where natural background sound levels are slightly elevated due to commonly encountered sound sources that may be present at the site, such as afternoon winds, or distant human-generated sounds (e.g., airport, highway). In deciding on the appropriate scenario to use (described in greater detail in Step 6), choose 35 dBA or 45 dBA to reflect the predominant conditions encountered by owls at the project site, not the rare or exceptional condition.

Derivation of Disturbance Distances

The values for auditory and visual disturbance were calculated from an Excel spreadsheet model described in detail in this Appendix. For circumstances where more precise and credible data may become available, and for which the analyst may wish to "do the math", we have provided the model as part of this decision support tool. We encourage additional testing and refinement of the model, but discourage its use by those who are unwilling to devote the time to understanding its limitations, or who cannot meet the conditions for quality control of data collection as described in this appendix.

Table 1 provides a summary of auditory disturbance distances estimated for various levels of sound generated by human activities, when considered in a range of existing conditions. The reader must refer to the following pages for detailed information pertinent to each scenario and its appropriate interpretation.

Table 2 displays a summary of values for typical sound sources that we have used in the model to develop the scenarios. These values represent the most valid data we could find on sound sources, collected under reasonably controlled conditions, and for which source-receptor distances are recorded. Other data may be available. The analyst is encouraged to use additional data provided the data have been collected using standardized and accepted methods, including a precise measure of the source-receptor distance, and indicate the metric used.

How to Use the Scenarios to Calculate Disturbance Distances

1. Review the list of provided scenarios and choose from the following pages which best matches the equipment used, the likely sound levels generated by the project, and the background sound levels expected in the affected habitat, i.e., the existing point and line sound sources.

2. Once a scenario is selected, the analyst uses the values to calculate the overall habitat area within which owls are disturbed by elevated sound levels or visual detection by spotted owls of human activities near nests or potential nests. These distances are used to calculate the total area

within which take due to harm is likely to occur due to the project.

As an example, we need to estimate the area of owl nesting habitat subject to auditory and visual disturbance from proposed maintenance of 2 miles of hiking trail through spotted owl nesting habitat. No surveys have been done in this area, but this habitat is similar to nearby known occupied habitat, justifying our assumption that this habitat is also occupied. The maintenance involves the use of a chainsaw to clear windfalls. All other tools used in the maintenance are hand tools that produce lower sound levels. The natural background sound level along this trail is low, about 35 decibels, and there are no other existing point or line sources of sound. The only existing sound on the trail is from human speech and the sounds of hikers.

Scenario 1 estimates an Auditory Disturbance Distance of 30 m and a Visual Disturbance Distance of no more than 100 meters. Therefore, the area of habitat subject to auditory disturbance is (30 m x 2 (both sides of the trail) x 3220 m)/10,000= 19.3 ha (47.6 acres). Calculate the area of visual disturbance as follows: (100 m x 2 x 3220 m)/10,000 = 64.4 ha (159.1 acres). One hectare is 10,000 square meters or 2.47 acres.

Now, let us suppose site-specific information suggests the visual detection distance is only 60 m (rather than the maximum default of 100 meters) due to vegetation density along the trail. Our visual disturbance distance is now (60 m x 2 x 3220 m)/10,000 = 38.6 ha (95.4 acres). Finally, suppose topographic barriers (a sharp ridge, for instance) along one side of the trail preclude sound from being transmitted more than 15 m along that side of the trail. In this case, calculate the two sides of the trail independently to reflect this site- specific information—((30 m x 3220 m) + (15 m x 3220 m))/10,000 = 14.5 ha, or 35.8 acres. Based on this output, it may be appropriate to explore ways of reducing disturbance of owls by applying seasonal timing restrictions, or requiring use of hand saws, if feasible.

Determine the effects of the action and use this analysis to help quantify take due to harm. If more information is desired or if the offered scenarios are insufficient, look to the appendices for information on the assumptions and use of further decision- making tools.

3. For some projects, it may be appropriate to apply different scenarios to different parts of the action area, when conditions vary across the action area. For example, a road construction project that includes work in both isolated areas and areas subject to existing sound sources might apply two different scenarios to account for these two different situations. Then, the total area affected is the sum of the two calculations.

4. The analyst should choose the scenario that *most closely approximates* the conditions encountered at the action site. If the analyst finds that conditions encountered in the proposed action seem to fall intermediate between two scenarios, it is appropriate to select the scenario that provides the greater protection to the species. That is, select the scenario that provides the wider zone of presumed harm, and report the area affected based on that distance. If avoidance of take is not possible, the distance values should be used to calculate the area within which take due to harm is likely to occur.

Scenarios for which harm is unlikely have not been included in this list. Examples would include those situations for which action-generated sound levels are below or barely exceed the ambient sound levels on or near the work area. Under these circumstances, action-generated sound levels would not result in harm of owls. Please also note, however, that visual disturbance of spotted owls may occur under these circumstances, and the analyst should discuss the likelihood of visual disturbance in the absence of excessive noise.

Some scenarios involve action-generated sounds so extreme as to not be applicable to the methods described in this document. These extreme cases cannot be analyzed using these scenarios and the model underlying these scenario outcomes. Those circumstances will need separate, action-specific analyses to determine their potential impacts to owls.

Table 1. Table of Scenarios

Action Scenario	Natural Background (dB)	Existing point sound sources [1]	Existing line sound sources [1]	Action-generated sound [1]	Disturbance Distance for Marbled Owl (m) (35 dBA/45 dBA)
Scenario 1	35/45	zero	zero	very low	30/10
Scenario 2	35/45	zero to very low	zero to very low	low	75/30
Scenario 3	35/45	zero	zero	medium	300/100
Scenario 4	35/45	very low to low	very low to low	medium	30/30
Scenario 5	35/45	zero to very low	zero	high	500/250
Scenario 6	35/45	low to moderate	very low to low	high	75/75
Scenario 7	35/45	low to moderate	moderate	high	100/100
Scenario 8	35/45	zero to low	zero to very low	very high	500/500
Scenario 9	35/45	moderate to high	low to moderate	very high	300/300
Scenario 10	35/45	moderate to high	high	very high	500/500

[1] The follow sound levels are used for the categories presented in this summary table: Zero: < 45 dBA.

- Very low: 46-65 dBA
- Low: 66-76 dBA
- Medium: 77-87 dBA
- High: 88-95 dBA
- Very High: 96-108 dBA
- Extreme: >108 dBA

Table 2. Some Common Sound Levels for Equipment/Activities[1]

	Range of Reported dB Values @ Distance Measure *Distance Measure assumed to be 50 ft unless otherwise indicated.*	
Project Sound Sources	**Reported Decibel Level @ 50 ft.**	**Relative Noise Level [2]**
Library (ambient sound level)	30	Ambient
Conversation	34	Ambient
Speech (normal)	41	Ambient
Milling Machine	61	Low
Motorcycle on Trail (620 cc street legal, meter at ground level)	62	Low
Power Lawn Mower	68	Low
Yelling	70	Low
Generator (25 KVA or less)	70	Low
Gas Lawn Mower	72	Moderate
Chainsaw (Stihl 025)	73	Moderate
Welder	74[3]	Moderate
Pickup Truck (driving)	75[3]	Moderate
Flatbed Pickup Truck	77	Moderate
BPA Powerline	78	Moderate
Cat-skidder	80	Moderate
Compressor (air)	80[3]	Moderate
Backhoe	80[3]	Moderate
Concrete Mixer (Vibratory)	80[3]	Moderate
Pumps	81[3]	High
Horizontal Boring Hydraulic Jack	82[3]	High
Slurry Machine	82[3]	High
Vacuum Street Sweeper	82[3]	High
Concrete Pump	82	High
Log Loader	83	High
Ground Compactor	83[3]	High
Concrete Batch Plant	83	High
Dump Truck	84	High
Flat Bed Truck	84	High
Roller	85[3]	High
Mowers, leaf blowers	85	High
Passenger Cars/Light Trucks (65 mph)	85	High

Project Sound Sources	**Reported Decibel Level @ 50 ft.**	**Relative Noise Level** [2]
Auger Drill Rig	85	High
Truck Horn (Warning)	85[3]	High
Equipment > 5 horsepower	85	High
Impact Wrench	85	High
Concrete Truck	85	High
Road Grader	85	High
Chain saws	85[3]	High
Highway-Traffic	85	High
Dozer	85[3]	High
Rock Drill	85[3]	High
Crane	85[3]	High
Gradall	85[3]	High
Paver	85[3]	High
Scraper	85[3]	High
Pneumatic tools	85[3]	High
Large Diesel Engine	86	High
Generator	87	High
Front-end Loader	87	High
Front-end loader	87	High
Drill Rig	88	High
Medium Trucks & Sport Vehicles (65 mph)	89	High
General construction	89	High
Large Truck	89	High
Jackhammer	89[3]	High
Concrete Saw	90	High
Hydra Break Ram	90	High
Mounted Impact Hammer Hoe-Ram	90	High
Large Tree Falling	92	Very High
Clam Shovel	93	Very High
Jake Brake on Truck	94	Very High
Hydromulcher	94	Very High
Boat motors	95	Very High
RVs (large)	95	Very High
Pneumatic Chipper	95	Very High
Heavy Trucks and Buses	95	Very High
Heavy Construction	96	Very High
Logging Truck	97	Very High
Railroad	98	Very High

Project Sound Sources	**Reported Decibel Level @ 50 ft.**	**Relative Noise Level** [2]
Vibratory (Sonic) Pile Driver	101[3]	Extreme
Impact Pile Driver	101	Extreme
Guardrail Installation and Pile Driving	105	Extreme
23 ft Detonation Cord, on surface	106	Extreme
Track Hoe	106	Extreme
Helicopter S-61 (large, single rotor, loaded)	112	Extreme
Rock Blast	112	Extreme
12 ft Detonation Cord, buried	112	Extreme
Exterior Cone Blast w/ sand bags	120	Extreme
Jet Overflight	136	Extreme
Exterior Cone Blast (obstructed)	127	Extreme
Treetop Blast	137	Extreme

[1] Most values in this table are derived from U.S. Department of Transportation. FHA. 2017. Construction Noise Handbook. Table 9.1 RCNM Default Noise Emission Reference Levels and Usage Factors.
[2] Relative Noise Level: a general, subjective ranking of relative noise levels created by the sources considered here, when used for analysis of relative noise effects on species.
[3] Equipment decibel level has been revised from the 2003 guidance with data provided from U.S. Department of Transportation (2017).

Scenario 1: Very low action-generated sounds in species habitat otherwise unaffected by human sound-generating activity.		
Sound Source	**Maximum Decibels [1]**	**Typical Sound Sources**
Natural Background Sound	35 - 45	Typical natural background sound level in species habitat for isolated sites on "average" day.
Existing Point Source Sound	0 - 45	No existing point sound sources at the site, or sounds equivalent to natural background.
Existing Line Source Sound	0 - 45	No existing line sound sources at the site, or sounds equivalent to natural background.
Action-Generated Sound	46 - 65	Very low action-generated sounds. Typical of activities limited to small hand tools, human speech, and other fairly inconsequential sounds only slightly higher than natural background.

Description of Existing Ambient Sound Conditions: The existing environment is characterized by the near absence of ambient sounds associated with human activities, and is typified by natural background sounds found in the species habitat (e.g., bird calls, light breezes through vegetation, distant stream flow). Human-generated sound is non-existent, extremely low, or very distant and makes no measurable contribution to ambient sound level at the site. These actions occur in habitats that are either isolated from human activities, or receive minimal human use, and only by the least obtrusive sound sources. Typical sites include isolated habitats, or may occur near hiking trails with relatively infrequent use. No existing sources of significant human-generated sound exists at the site.

Typical Action-Generated Sound Sources and Projects: Action-generated sound sources are typically very low, only slightly above existing ambient and natural background sound levels. Typical sources of sounds in this situation are hand tools and small electric tools, cordless drills, normal to somewhat loud human speech, non-amplified music, small appliances. A typical project covered by this scenario might be the use of hand tools during the maintenance of an infrequently used and isolated hiking trail.

Reported Disturbance Distances for:	**Auditory Disturbance Distance [2]**	**Visual Disturbance Distance [3]**
Low Natural Background Sound Level (~35 dB)[4]	30 m	*Maximum estimated detection distance or 100 m, whichever is lesser.*
Moderate Natural Background Sound Level (~45 dB)[4]	10 m	

[1] Maximum Decibels reports the maximum sound level attributable to these sources that are likely to be encountered in the habitat under most typical conditions for this scenario. Sound levels might exceed these maximum values only infrequently, and by a few decibels at most.

[2] The values reported here for Auditory Disturbance Distance are maximum distances. These values may be less under conditions where topographic breaks (e.g., ridge) may result in barriers to sound propagation, or slightly higher where topographic openings (e.g., intervening canyon) promote sound transmission.

[3] The Visual Disturbance Distance is the distance at which spotted owls can detect humans and their activities from the species' nest site or flight approach path, up to a maximum of 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by spotted owls on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area.

[4] Report appropriate results from low or moderate natural background sound level depending on normally encountered background sound conditions at the site. Habitat near areas with a Natural Background Sound Level significantly greater than 50 dB may need site-specific analysis.

Scenario 2: Low action-generated sounds in species habitat subject to very low to near zero human sound-generating activity.		
Sound Source	**Maximum Decibels [1]**	**Typical Sound Sources**
Natural Background Sound	35 - 45	Typical natural background sound level in species habitat for isolated sites on "average" day.
Existing Point Source Sound	0 - 65	Very low to non-existent line sound sources at the site
Existing Line Source Sound	0 - 65	Very low to non-existent line sound sources at the site
Action-Generated Sound	66 - 75	Low sound sources typical of milling machine, motorcycle on trail (620 cc), power lawn mower, generator (25 KVA or less), gas lawn mower, chainsaw (Stihl 025), welder.

Description of Existing Ambient Sound Conditions: The existing environment is characterized by very low to zero sources of existing ambient sounds associated with human activities, and is typified by natural background sounds found in the species habitat (e.g., bird calls, light breezes through vegetation, distant stream flow). Human-generated sound is non-existent or very low, and makes only a minor contribution to existing sound level at the site. These actions occur in habitats that are either isolated from human activities, or receive low human use with no sound amplifying tools or devices, and only by the least obtrusive sound sources. Typical sites include isolated habitats, or may occur near hiking trails with infrequent to moderate use levels, but do not include motorized use or motorized maintenance. No existing sources of significant human-generated sound exist at the site.

Typical Action-Generated Sound Sources and Projects: Action-generated sound sources are typically low, somewhat above existing ambient and natural background sound levels. Typical sources of sounds in this situation are hand tools, electric tools, small gas-powered engines with near-new mufflers (such as gas lawn mowers at typical mowing speed), generators (25 KVA or less), loud human speech, moderately-amplified music. A typical project covered by this scenario might be the use of small power tools during the maintenance of a more frequently used hiking trail with existing sources of sound of a low level.

Reported Disturbance Distances for:	**Auditory Disturbance Distance [2]**	**Visual Disturbance Distance [3]**
Low Natural Background Sound Level (~35 dB)[4]	75 m	*Maximum estimated detection distance or 100 m, whichever is lesser.*
Moderate Natural Background Sound Level (~45 dB)[4]	30 m	

[1] Maximum Decibels reports the maximum sound level attributable to these sources that are likely to be encountered in the habitat under most typical conditions for this scenario. Sound levels might exceed these maximum values only infrequently, and by a few decibels at most.
[2] The values reported here for Auditory Disturbance Distance are maximum distances. These values may be less under conditions where topographic breaks (e.g., ridge) may result in barriers to sound propagation, or slightly higher where topographic openings (e.g., intervening canyon) promote sound transmission.
[3] The Visual Disturbance Distance is the distance at which spotted owls can detect humans and their activities from the species' nest site or flight approach path, up to a maximum of 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by spotted owls on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area.
[4] Report appropriate results from low or moderate natural background sound level depending on normally encountered background sound conditions at the site. Habitat near areas with a Natural Background Sound Level significantly greater than 50 dB may need site-specific analysis.

Scenario 3: Moderate action-generated sounds in species habitat otherwise unaffected by human sound-generating activity.		
Sound Source	**Maximum Decibels [1]**	**Typical Sound Sources**
Natural Background Sound	35 - 45	Typical natural background sound level in species habitat for isolated sites on "average" day.
Existing Point Source Sound	0 - 45	No existing point sound sources at the site, or sounds equivalent to natural background.
Existing Line Source Sound	0 - 45	No existing line sound sources at the site, or sounds equivalent to natural background.
Action-Generated Sound	76 - 87	Most flatbed pick up trucks, cat-skidder, air compressor, backhoe, concrete mixer, pumps, horizontal boring hydraulic jack, concrete pumps, log loader, ground compactor

Description of Existing Ambient Sound Conditions: The existing environment is characterized by the near absence of sounds associated with human activities, and is typified by natural background sounds found in the species habitat (e.g., bird calls, light breezes through vegetation, distant stream flow). Human-generated sound is non-existent or very distant and makes no measurable contribution to ambient sound level at the site. These actions occur in habitats that are either isolated from human activities, or receive minimal human use, and only by the least obtrusive sound sources. Typical sites include isolated habitats, or may occur near hiking trails with relatively infrequent use. No existing sources of significant human-generated sound exist at the site.

Typical Action-Generated Sound Sources and Projects: Action-generated sound sources are typically moderate, noticeably above existing ambient and natural background sound levels. Typical sources of sounds in this situation are flatbed pickup trucks, cat-skidder, air compressor, backhoe, concrete mixer, pumps, horizontal boring hydraulic jack, concrete pumps, log loader, ground compactor, dump truck, roller, mowers and lead blowers and improvement activities using small to moderate-sized chain saws and similar power tools, but would not include use of aircraft or felling of large trees.

Reported Disturbance Distances for:	**Auditory Disturbance Distance [2]**	**Visual Disturbance Distance [3]**
Low Natural Background Sound Level (~35 dB)[4]	300 m	*Maximum estimated detection distance or 100 m, whichever is lesser.*
Moderate Natural Background Sound Level (~45 dB)[4]	100 m	

[1] Maximum Decibels reports the maximum sound level attributable to these sources that are likely to be encountered in the habitat under most typical conditions for this scenario. Sound levels might exceed these maximum values only infrequently, and by a few decibels at most.
[2] The values reported here for Auditory Disturbance Distance are maximum distances. These values may be less under conditions where topographic breaks (e.g., ridge) may result in barriers to sound propagation, or slightly higher where topographic openings (e.g., intervening canyon) promote sound transmission.
[3] The Visual Disturbance Distance is the distance at which spotted owls can detect humans and their activities from the species' nest site or flight approach path, up to a maximum of 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by spotted owls on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area.
[4] Report appropriate results from low or moderate natural background sound level depending on normally encountered background sound conditions at the site. Habitat near areas with a Natural Background Sound Level significantly greater than 50 dB may need site-specific analysis.

Scenario 4: Moderate action-generated sounds in species habitat subject to very low to low human sound-generating activity.		
Sound Source	**Maximum Decibels [1]**	**Typical Sound Sources**
Natural Background Sound	35 - 45	Typical natural background sound level in species habitat for isolated sites on “average” day.
Existing Point Source Sound	46 - 75	Very low to low level of existing ambient sound at the site, slightly above natural background.
Existing Line Source Sound	46 - 75	Very low to low level of existing ambient sound at the site, slightly above natural background.
Action-Generated Sound	76 - 87	Most flatbed pick up trucks, cat-skidder, air compressor, backhoe, concrete mixer, pumps, horizontal boring hydraulic jack, concrete pumps, log loader, ground compactor

Description of Existing Ambient Sound Conditions: The existing environment is characterized by the low to very low levels of sound associated with human activities, and is typified by small power tools, light vehicular traffic moving at slow speeds, recreational activities, and many urban and rural residential activities. In more isolated areas, sounds include those associated with small parks, visitor centers, bike paths, tour roads and residences.

Typical Action-Generated Sound Sources and Projects: Action-generated sound sources are typically moderate, noticeably above existing ambient and natural background sound levels. Typical sources of sounds in this situation are flatbed pickup trucks, cat-skidder, air compressor, backhoe, concrete mixer, pumps, horizontal boring hydraulic jack, concrete pumps, log loader, ground compactor, dump truck, roller, mowers and lead blowers and improvement activities using small to moderate-sized chain saws and similar power tools, but would not include use of aircraft or felling of large trees.

Reported Disturbance Distances for:	Auditory Disturbance Distance [2]	Visual Disturbance Distance [3]
Low Natural Background Sound Level (~35 dB)[4]	30 m	*Maximum estimated detection distance or 100 m, whichever is lesser.*
Moderate Natural Background Sound Level (~45 dB)[4]	30 m	

[1] Maximum Decibels reports the maximum sound level attributable to these sources that are likely to be encountered in the habitat under most typical conditions for this scenario. Sound levels might exceed these maximum values only infrequently, and by a few decibels at most.
[2] The values reported here for Auditory Disturbance Distance are maximum distances. These values may be less under conditions where topographic breaks (e.g., ridge) may result in barriers to sound propagation, or slightly higher where topographic openings (e.g., intervening canyon) promote sound transmission.
[3] The Visual Disturbance Distance is the distance at which spotted owls can detect humans and their activities from the species’ nest site or flight approach path, up to a maximum of 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by spotted owls on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area.
[4] Report appropriate results from low or moderate natural background sound level depending on normally encountered background sound conditions at the site. Habitat near areas with a Natural Background Sound Level significantly greater than 50 dB may need site-specific analysis.

Scenario 5: High action-generated sounds in species habitat otherwise subject to very low human sound-generating activity.

Sound Source	Maximum Decibels [1]	Typical Sound Sources
Natural Background Sound	35 - 45	Typical natural background sound level in species habitat for isolated sites on "average" day.
Existing Point Source Sound	0 - 65	Very low to non-existent point sound sources at the site.
Existing Line Source Sound	0 - 45	No existing line sound sources at the site, or sounds equivalent to natural background.
Action-Generated Sound	88 - 95	Most large trucks, jackhammer, large falling trees, clam shovel, jake brake on truck, boat motors, large RVs, pneumatic chippers

Description of Existing Ambient Sound Conditions: The existing environment is characterized by very low to zero sources of sounds associated with human activities, and is typified by natural background sounds found in the species habitat (e.g., bird calls, light breezes through vegetation, distant stream flow). Human-generated sound is non-existent or very low, and makes only a minor contribution to existing sound level at the site. These actions occur in habitats that are either isolated from human activities, or receive low human use with no sound amplifying tools or devices, and only by the least obtrusive sound sources. Typical sites include isolated habitats, or may occur near hiking trails with infrequent to moderate use levels, but do not include motorized use or motorized maintenance. No existing sources of significant human-generated sound exist at the site.

Typical Action-Generated Sound Sources and Projects: Action-generated sound sources are typically high, much above existing ambient and natural background sound levels. Typical sources of sounds in this situation are large trucks, jackhammer, large falling trees, clam shovel, jake brake on truck, boat motors, large RVs, pneumatic chippers

Reported Disturbance Distances for:	Auditory Disturbance Distance [2]	Visual Disturbance Distance [3]
Low Natural Background Sound Level (~35 dB)[4]	500 m	*Maximum estimated detection distance or 100 m, whichever is lesser.*
Moderate Natural Background Sound Level (~45 dB)[4]	200 m	

[1] Maximum Decibels reports the maximum sound level attributable to these sources that are likely to be encountered in the habitat under most typical conditions for this scenario. Sound levels might exceed these maximum values only infrequently, and by a few decibels at most.
[2] The values reported here for Auditory Disturbance Distance are maximum distances. These values may be less under conditions where topographic breaks (e.g., ridge) may result in barriers to sound propagation, or slightly higher where topographic openings (e.g., intervening canyon) promote sound transmission.
[3] The Visual Disturbance Distance is the distance at which spotted owls can detect humans and their activities from the species' nest site or flight approach path, up to a maximum of 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by spotted owls on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area.
[4] Report appropriate results from low or moderate natural background sound level depending on normally encountered background sound conditions at the site. Habitat near areas with a Natural Background Sound Level significantly greater than 50 dB may need site-specific analysis.

Scenario 6: High action-generated sounds in species habitat subject to very low to moderate human sound-generating activity.		
Sound Source	**Maximum Decibels [1]**	**Typical Sound Sources**
Natural Background Sound	35 - 45	Typical natural background sound level in species habitat for isolated sites on "average" day.
Existing Point Source Sound	66 - 87	Low to moderate level of existing ambient sound at the site.
Existing Line Source Sound	46 - 75	Very low to low level of existing ambient sound at the site, slightly above natural background.
Action-Generated Sound	88 - 95	Most large trucks, jackhammer, large falling trees, clam shovel, jake brake on truck, boat motors, large RVs, pneumatic chippers

Description of Existing Ambient Sound Conditions: The existing environment is characterized by the medium to very low levels of existing ambient sound associated with human activities, and is typified by small power tools, light vehicular traffic moving at slow speeds, recreational activities, and many urban and rural residential and commercial activities. Where existing ambient sound levels approach medium levels, typical point sources include backhoes, ground compactors, road graders, generators, electric power tools, chain saws, and other similar stationary or slow moving, moderate sized equipment. In more isolated areas, sounds include those associated with larger parks, visitor centers, motorized recreational facilities (except loud sources, such as ATVs), businesses, small manufacturing sites, drill rigs, etc. This scenario would not include existing heavy equipment, high speed road traffic, or medium to heavy trucks except at fairly slow speeds and on paved roads (but no jake brakes).

Typical Action-Generated Sound Sources and Projects: Action-generated sound sources are typically high, somewhat above existing ambient and natural background sound levels. Typical sources of sounds in this situation are large trucks, jackhammer, large falling trees, clam shovel, jake brake on truck, boat motors, large RVs, pneumatic chippers

Reported Disturbance Distances for:	Auditory Disturbance Distance [2]	Visual Disturbance Distance [3]
Low Natural Background Sound Level (~35 dB)[4]	75 m	*Maximum estimated detection distance or 100 m, whichever is lesser.*
Moderate Natural Background Sound Level (~45 dB)[4]	75 m	

[1] Maximum Decibels reports the maximum sound level attributable to these sources that are likely to be encountered in the habitat under most typical conditions for this scenario. Sound levels might exceed these maximum values only infrequently, and by a few decibels at most.
[2] The values reported here for Auditory Disturbance Distance are maximum distances. These values may be less under conditions where topographic breaks (e.g., ridge) may result in barriers to sound propagation, or slightly higher where topographic openings (e.g., intervening canyon) promote sound transmission.
[3] The Visual Disturbance Distance is the distance at which spotted owls can detect humans and their activities from the species' nest site or flight approach path, up to a maximum of 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by spotted owls on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area.
[4] Report appropriate results from low or moderate natural background sound level depending on normally encountered background sound conditions at the site. Habitat near areas with a Natural Background Sound Level significantly greater than 50 dB may need site-specific analysis.

Scenario 7: High action-generated sounds in species habitat subject to moderate human sound-generating activity.		
Sound Source	**Maximum Decibels [1]**	**Typical Sound Sources**
Natural Background Sound	35 - 45	Typical natural background sound level in species habitat for isolated sites on "average" day.
Existing Point Source Sound	66 - 87	Low to moderate level of existing ambient sound at the site.
Existing Line Source Sound	76 - 87	Moderate level of existing ambient sound at the site.
Action-Generated Sound	88 - 95	Drill rig, medium trucks (65 mph), general construction, jackhammer, concrete saw, clam shovel

Description of Existing Ambient Sound Conditions: The existing environment is characterized by medium to very low levels of existing ambient sound associated with human activities, and is typified by small power tools, light to heavy vehicular traffic moving at slow to moderate speeds on improved roads, recreational activities, and many urban and rural residential and commercial activities. Where existing ambient sound levels approach medium levels, typical point sources include backhoes, ground compactors, road graders, generators, electric power tools, chain saws, and other similar stationary or moving equipment, and may include large street-legal trucks and buses but at low speeds. In more isolated areas, sounds include those associated with larger parks, visitor centers, motorized recreational facilities (except loud sources, such as unmuffled ATVs), businesses, small manufacturing sites, small generators, etc. This scenario would not include heavy equipment, high speed road traffic, or medium to heavy trucks except at slow to moderate speeds and on paved roads (but no jake brakes). The primary difference in existing ambient sound between this scenario and Scenario 6 is the slightly higher existing line source ambient sound, as demonstrated by the somewhat higher speeds of vehicular traffic.

Typical Action-Generated Sound Sources and Projects: Action-generated sound sources are typically high, above existing ambient and natural background sound levels. Typical sources of sounds in this situation are large to very large construction equipment, large gas-powered engines, and ATVs and small trucks at high speed or on rough surfaces. Would also include larger construction equipment such as the largest backhoes, large dozers, hoe-rams, large trucks using jake brakes or at moderate to high speeds, clam shovels, pavers, front-end loaders, and impact wrenches. A typical project covered by this scenario is similar to Scenario 6, but this scenario includes a higher level of existing ambient sound levels. These project would typically occur near sources of sound that are of higher level, such as along rural highways and other transportation facilities with moderate traffic and speeds, but not including peak sound sources such as the use of jake brakes.

Reported Disturbance Distances for:	**Auditory Disturbance Distance [2]**	**Visual Disturbance Distance [3]**
Low Natural Background Sound Level (~35 dB)[4]	100 m	*Maximum estimated detection distance or 100 m, whichever is lesser.*
Moderate Natural Background Sound Level (~45 dB)[4]	100 m	

[1] Maximum Decibels reports the maximum sound level attributable to these sources that are likely to be encountered in the habitat under most typical conditions for this scenario. Sound levels might exceed these maximum values only infrequently, and by a few decibels at most.

[2] The values reported here for Auditory Disturbance Distance are maximum distances. These values may be less under conditions where topographic breaks (e.g., ridge) may result in barriers to sound propagation, or slightly higher where topographic openings (e.g., intervening canyon) promote sound transmission.

[3] The Visual Disturbance Distance is the distance at which spotted owls can detect humans and their activities from the species' nest site or flight approach path, up to a maximum of 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by spotted owls on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area.

[4] Report appropriate results from low or moderate natural background sound level depending on normally encountered background sound conditions at the site. Habitat near areas with a Natural Background Sound Level significantly greater than 50 dB may need site-specific analysis.

Scenario 10: Very high action-generated sounds in species habitat subject to high human sound-generating activity.		
Sound Source	**Maximum Decibels [1]**	**Typical Sound Sources**
Natural Background Sound	35 - 45	Typical natural background sound level in species habitat for isolated sites on "average" day.
Existing Point Source Sound	76-95	Moderate to high existing point source ambient at the site.
Existing Line Source Sound	88-95	High level of existing line source ambient at the site.
Action-Generated Sound	95-108	The largest construction equipment, large trucks at high speeds on rough roads, railroads, large helicopters, impact pile driver, rock drills, vibratory pile driver, pneumatic tools in combination with other equipment.

Description of Existing Ambient Sound Conditions: The existing environment is characterized by high levels of existing ambient sound associated with human activities, and is typified by gas-powered tools, very large chain saws, medium to heavy vehicular traffic moving at moderate to high speeds on improved or rough roads, backhoes, generators, ground compactors, small jackhammers, and many urban and rural commercial activities, and includes sound sources similar to very large construction equipment such as dump trucks, dozers, cranes, front end loaders, and large drill rigs. Includes large trucks, large RVs, buses and similar sources when moving at high speed and jake braking on long downhill road segments. These sound levels are typical of commercial zones where manufacturing occurs, or along high speed roadways where traffic includes a broad range of vehicle types that may be subject to steep or excessive grades.

Typical Action-Generated Sound Sources and Projects: Action-generated sound sources are typically very high, somewhat above existing ambient and natural background sound levels. Typical sources of sounds in this situation are very large construction equipment, railroads, impact and vibratory pile drivers, tractor mounted jackhammers, helicopters, rock drills, and pneumatic tools in combination with other large equipment. May also covered greatly amplified rock music, truck horns and other loud signals. Typical projects covered by this scenario include the use of very large construction equipment, pile drivers and jackhammers in the construction of new roads, stream restoration projects, or mining activities near areas where high levels of human-generated ambient sound levels exist, such as major freeways and roads subject to heavy traffic, large trucks (and jake brakes) and similar regular high sound levels already at the upper limits of regularly generated sounds.

Reported Disturbance Distances for:	Auditory Disturbance Distance [2]	Visual Disturbance Distance [3]
Low Natural Background Sound Level (~35 dB)[4]	500 m	*Maximum estimated detection distance or 100 m, whichever is lesser.*
Moderate Natural Background Sound Level (~45 dB)[4]	500 m	

[1] Maximum Decibels reports the maximum sound level attributable to these sources that are likely to be encountered in the habitat under most typical conditions for this scenario. Sound levels might exceed these maximum values only infrequently, and by a few decibels at most.

[2] The values reported here for Auditory Disturbance Distance are maximum distances. These values may be less under conditions where topographic breaks (e.g., ridge) may result in barriers to sound propagation, or slightly higher where topographic openings (e.g., intervening canyon) promote sound transmission.

[3] The Visual Disturbance Distance is the distance at which spotted owls can detect humans and their activities from the species' nest site or flight approach path, up to a maximum of 100 meters. This distance may be limited to less than 100 meters by dense vegetation that is capable of concealing human activities from detection by spotted owls on the nest or adults approaching the nest along the flight approach path. The analyst may specify a distance less than 100 meters if information is available on actual vegetation density on the action area.

[4] Report appropriate results from low or moderate natural background sound level depending on normally encountered background sound conditions at the site. Habitat near areas with a Natural Background Sound Level significantly greater than 50 dB may need site-specific analysis.

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Sound Attenuation Model for Estimating Disturbance Distance

We developed the associated spreadsheet to model the attenuation of sound generated by user-identified sources across a model landscape, using published formulae for predicting sound levels at particular distances from those sources. As with many models, certain assumptions are made regarding factors for which precise data are unavailable, or for conditions that cannot be controlled by the analyst. For reference purposes, these assumptions, along with data entry and other instructions, are displayed in pop-up comments at each data entry point (as identified by the small, red triangles in the spreadsheet). The excel spreadsheet can found here.

This list is not necessarily exhaustive as other behaviors, such as nest abandonment, premature fledging or habitat avoidance, may also indicate harm.

Users are cautioned to ensure that all assumptions and instructions of this model are followed when applying project- or site-specific data. Otherwise, outcomes predicted by the model may be incorrect or misleading.

The Fish and Wildlife Service developed the Owl Disturbance Model, incorporated into an Excel spreadsheet, to quantitatively and objectively estimate the extent and distance to which actions resulting in human activity or elevated sound levels near owl nest sites are likely to take (i.e. harm) the species. This model is designed to accomplish two tasks.

> 1. The model calculates attenuation rates of sound away from typical line and point sources across a virtual landscape that *approximates* typical wildlife habitat. These attenuation rates are based on published formulae, and account for some of the principle physical factors that affect sound attenuation: initial volume, distance from source, source type (line or point), relative elevation of source or receiver, ground surface condition, and intervening vegetation. However, the model does not account for other important factors, such as topography and weather conditions that vary spatially or temporally under site-specific conditions. These site- and time-specific conditions should be addressed by the analyst in the interpretation of model outputs, as discussed below.
>
> 2. The model compares the projected sound attenuation to standards recommended in Region 1 of the USFWS to estimate distances at which owls are likely to be injured (are harmed) due to elevated sound levels or visual proximity to human activities. The model presents a simple method whereby site-specific conditions can be analyzed against a somewhat flexible recommendation to determine whether a likelihood of harm to the species exists.

The distance values calculated by this model are intended to provide the analyst with an objective means of estimating the number of individuals or amount of nesting habitat subject to auditory or visual disturbance.

> 1. The model estimates the distance from proposed activities wherein owls are disturbed (i.e., have a likelihood of harm), thereby triggering appropriate project modifications, such as seasonal and/or daily timing restrictions, to reduce or avoid take due to harm.

2. These distance estimates can be used to approximate the number of nest sites (if specific locations of nest trees are known) or the area of habitat (if protocol surveys are not completed) subject to take should it not be possible to avoid take through implementation of avoidance measures.

The model assumes a relatively uniform, flat landscape across which sound travels and diminishes. For site-specific circumstances where topographic barriers create a significant impediment to sound transmission, persons who have some understanding of the influences of these factors on sound attenuation should interpret the results of the model. Some basic guidance on this matter is provided later in this document.

The model performs calculations based on accepted formulae and supportable assumptions, derived from available literature and data, yielding results the analyst may apply to action- and site-specific circumstances. These results help estimate the area around a proposed action within which elevated sound levels or visual proximity of an action create disturbance. Future review of the model may lead to additional consideration of the biological assumptions, newly available literature, and species-specific data the model uses to estimate the reported distances.

It is unlikely that the formulae used in the calculations will change in any significant manner, as they are derived from established physical principles. The biological information supporting the model is likely to continue to grow, providing significant sources of data to improve assumptions, and standards incorporated into the model. As information becomes available, the model itself should be updated, and modifications should be documented for future users.

Model User Guide

This user guide provides the reader with an understanding of how the available information on auditory and visual disturbance has been used to estimate the effects of typical projects on the species considered here, as applied in a numeric model. To help achieve that goal, the guide includes information on the characteristics of sound attenuation and visual detection in habitats typical of the spotted owl and other interior forest dwelling species.

The user guide provides a step-by-step set of instructions for entering data into the model, should the analyst choose to analyze an action using site-specific data. Further, these instructions are intended to assist the reader in understanding the set of scenarios developed to analyze the effects of various project types on owls, as described in an earlier document. Each step is described in detail to ensure the analyst understands the appropriate data entry for each field, and the output of the model results.

Some background information is presented regarding sound behavior in typical wildlife habitats. This section also provides a brief discussion of the assumptions adopted at this time to estimate the distances at which sound is likely to result in take of owls due to harm.

Characteristics and Behavior of Sound

Before delving into the use and interpretation of the model, it is important that the biologist have a fundamental understanding of the characteristics and behavior of sound and its attenuation away from sources in typical wildlife habitat. This User Guide does not discuss the physics of sound waves, or refer to specific mathematical formulae upon which sound behavior prediction is based. The reader is encouraged to consult appropriate technical texts for a thorough discussion of these aspects of sound attenuation, such as CalTrans' Technical Noise Supplement (Hendriks, 1998).

In addition to this discussion, we provide a glossary to define those terms specific to sound and its attenuation, as well as terms used in the analysis of wildlife habitat.

Soft and Hard Site

The condition of the ground surface (i.e. paved versus forested), can affect the attenuation rate of sound across a landscape. Hard sites are those where the ground surface is predominantly hard soil, pavement, smooth water or a similar non-dampening surface that mostly reflects sound waves. Hard sites such as roads and water bodies do not attenuate sound pressure. Soft sites are those where ground surface vegetation, shrubs, grass, or even softened soil dampen or absorb sound waves across the site.

Because soft sites absorb sound, sound attenuates (i.e., decreases in volume) more rapidly across soft sites than hard sites. That is, equivalent sounds will sound quieter at a particular distance from the source across a soft site than the same sound at the same distance heard across a hard site. Classification of a site as soft or hard should generally consider the entire landscape where elevated sound is a concern, as opposed to the immediate vicinity of the sound source or receptor (species). In general, most terrestrial wildlife habitats are considered soft sites.

Point Sources

Point sources are those where sound emanates from a single or localized point, such as stationary motors, a loudspeaker, hand tool, or human voice. Sound emanating from a point source attenuates in a circular (spherical in 3-dimensional space) fashion. A characteristic of point source sound measurement is that the duration of the measure is relatively short in relation to the rate of movement of the source. For example, if the duration of measure of sound of a slowly moving car were of less than one second, this *single* car would be a point source. Conversely, if the duration of measure of sound of that same car were several minutes (such as $L_{eq,15\ minutes}$), this would be recorded as a line source. Finally, a speeding vehicle might be considered a line source even if the duration of sound measure is quite short (such as $L_{eq,10,\ 5\ seconds}$).

Line Sources

Line sources are those where sound emanates from a linear source, such as relatively constant highway traffic, or a flowing stream. Sound attenuates at a lesser rate from a line source than from a point source of similar volume, because it attenuates in a linear (cylindrical in 3-dimensional space) fashion perpendicular to the line source. As with the example above, if the duration of measure of sound of the speeding car were of several seconds or more, the single car would be a line source. Multiple cars moving in close proximity will always be considered a line source. When considering sound sources such as automobiles, it is often best to consider them as line sources, except in unusual circumstances where vehicles are so intermittent as to not travel in close proximity, the sound measure is of very short duration, and the vehicle is traveling relatively slowly.

Rates of Attenuation

Sound emanating from a point source attenuates at a faster rate than sound emanating from a line source. Further, both point and line source sounds attenuate more rapidly across soft sites than across hard sites. The point source attenuation rate across a hard surface is about 6 dB per doubling of distance from the source, whereas a point source sound attenuation rate across a soft surface is about 7.5 dB per doubling of distance from the source. In the case of a hard site, line source sound attenuates at about 3 dB per doubling of distance. In the case of a soft site, line source sound attenuates at about 4.5 dB per doubling of distance.

It is especially important to note that, because sound measure is on a logarithmic scale, and its attenuation is a function of the square of distance from the source, its attenuation is in relation to doubling of distance from the source to the receptor, rather than a simple linear relationship.

Another factor to be considered in evaluating sound attenuation is the frequency of the sound being produced. Sounds of low pitch attenuate at a slightly lower rate than sounds of high pitch. For example, music heard at a distance will generally have a predominance of bass sounds and less treble sound. However, we have not incorporated any special consideration of this phenomenon in the analytical methods described here.

Effects of Elevated Source or Receiver

When either the sound source or receiver (or both) is substantially elevated above the ground, the sound path is relatively unaffected by the softness or hardness of the site. Under these conditions, where the path of sound transmission is not close to the ground over a substantial portion of the sound path, the attenuation of sound is independent of the softness or hardness of the site, and more closely approximates the rate for hard sites.

Effects of Intervening Vegetation on Sound

When sound travels through dense vegetation, its volume is reduced by as much as 5 dB for the first 30 m (100 ft) of vegetation, as measured from the sound source, and an additional 5 dB for an additional, contiguous 30 m (100-200 ft). Note: this is a different consideration than soft site vs. hard site. "Dense" is defined as being at least 30 m (100 ft) wide and 5 m (16 ft) tall, and of sufficient density as to completely block the visual pathway. This definition applies to vegetation growing along the sound path of interest. Wildlife that is nesting, denning, or perched high in the canopy will generally not benefit from this attenuation, as the sound may propagate through the upper canopy more easily than through understory and mid-canopy vegetation. This attenuation would apply if the line-of-sight path to the nest feature fully meets the criteria as stated above.

Vegetation consisting of large tree trunks, thick yet well-spaced shrubs, and similar conditions would not qualify as dense, since these situations do not completely block the visual pathway over the sound pathway. Also, this attenuation is applicable only in situations where vegetation is fairly continuous within the 30-meter bands between the dominant sound source(s) and the receptor of interest (e.g., nesting habitat or nest tree). Beyond about 60 m (200 ft), virtually no additional benefit accrues from dense vegetation, as much of the sound goes over the dense vegetation and is reflected back to the ground. This attenuation must be applied cautiously and sparingly, and must be clearly understood when entering data into Step 4 of the spreadsheet model (discussed in more detail in following sections).

Species-Specific Audio Thresholds

Sound is comprised of a range of frequencies, or octaves. Each animal species possesses a different range and weighting of frequencies that its members are capable of hearing. Owls are known to hear sounds that are higher pitched than humans, but are less capable of hearing sounds in lower frequency hearing ranges. Thus, a species detects a sound as "louder" when it is comprised of frequencies well within its hearing range, and detects a sound as "quieter" when those sounds are comprised of frequencies at the periphery of its hearing range, even though both sounds may contain the same overall sound energy.

While any method, such as this model, of measuring the effects of sound on wildlife behavior would benefit from a species-specific frequency response curve, we have relied here on the human-weighted response curve, or dBA. We have not incorporated species-specific frequency curves into this model for three primary reasons. First, hearing frequency curves are not available for most species, including the spotted owl, and development of this information is beyond the model's scope at this time. Second, and perhaps more important, virtually all reported measures of sound levels from various human sources is reported in human-weighted decibels, or as unweighted. This information is not readily available to assist in the analysis. Lastly, we assume that the error introduced into the model output by the use of human-weighted response curves is within the overall error rate resulting from the variability of the other factors in the model, and that using species-weighted curves would add little to our understanding of sound effects on wildlife species at this time.

Entering Data into the Model

Data entry into this spreadsheet model is accomplished through a 12-step process that allows the analyst to specify action- and action area-specific data, or data derived from other relevant studies as reported in various literature. Each of these steps is described in detail in the following sections. Data is entered into the spreadsheet in the green boxes, in cells with red- colored text. These are the only cells where data can be entered or otherwise changed anywhere in the spreadsheet. All other cells are protected and cannot be changed, except by the administrator responsible for incorporating regionally agreed-to changes to the analytical method.

All of the data entry cells and several of the information cells in the spreadsheet contain popup comments that are activated when the cursor is moved over the cell. These cells are identified by a small red triangle in the corner of the cell. These comment boxes assist the analyst in entering appropriate data in each cell, or in the proper interpretation of the information displayed. Move the cursor off the cell to close the comment.

Step 1

Enter a descriptive title that provides information to the reader about the ambient conditions, existing sound sources at the action site, and equipment being analyzed. The title information should be concise yet informative. The purpose for giving each modeled scenario a title is to provide information to anyone reviewing a printed version of this form a better understanding what is being analyzed. Examples of concise, informative titles are: Small chainsaw and hand tool maintenance of existing trails in old growth forest, Prairie Creek State Park, away from roads; and, Construction of new 4-lane freeway, adjacent to Redwood National Park, using large equipment and tractors, no existing road.

Step 2

In this step, the analyst classifies the action area as a soft site or a hard site (refer to earlier discussion of these terms). The value entered here must be “1” for soft surfaces or “0” for hard surfaces. In cases where the site is a roughly equal mixture of soft and hard surfaces, treat it as a hard site and enter “0”.

Step 3

To account for the phenomenon of elevated source or receiver, the analyst is requested to enter 0 (zero) in this step whenever the source or the receiver of the sound is elevated above the ground. This value can overrule (in the sound attenuation formulae) the value previously entered to account for soft vs. hard sites. For purposes of this model, “elevated” is defined as being at least 10 m above ground, but for extended distances (beyond 50 m) between the source or receiver, the elevated source/receiver should be correspondingly higher to account for the more acute angle of the sound path from the ground. No exact formula for this estimate exists, but for purposes of consistency in this guidance, we recommend that “elevated” should apply to known sources/receivers greater than 20 m above the ground for distances between 50 and 100 m, and 30 m for distances beyond 100 meters. In the case of unsurveyed habitat that occurs at varying distances from the sound source, enter 0 whenever the source and/or receiver is expected to be elevated more than 10 m above the ground.

Step 4

This step accounts for dense vegetation that grows close to the sound source (within bands of 0-30 or 30-60 m from the source). Enter “1” in the 0-30 m cell and/or 30-60 m cell of the spreadsheet if vegetation meets the definition of *dense* (refer to earlier discussion of this term), or “0” if it does not. For some situations, such as the right-of-way along a freeway, dense vegetation may not begin for some distance from the sound sources on the highway, due to vegetation management practices in the right-of-way. In these cases, do not apply the attenuation factor (i.e., enter “0” in the data form) for the 0-30 and possibly the 30-60 m cells, as appropriate. In cases where the vegetation is moderately dense across the entire 0-60 m bands (but does not fully meet the definition of dense for both bands), enter "0" for the 0-30 m cell, and “1” for the 30-60 m cell. For cases where vegetation may occur, but does not meet the definition of dense in either band, enter “0” in both spreadsheet cells.

Step 5

In this step, the analyst accounts for vegetation that serves as a *visual* barrier for the species of interest, such as a nesting owl. This value calculates the maximum distance at which harm is likely to occur strictly as a result of the subject species visually detecting humans or human-related activities, and reacting by significantly disrupting normal behavior patterns.

The analyst enters the *maximum* distance at which owls are capable of detecting human activities from the nest branch, or when flying into the stand to access the nest branch, in habitat typical of the project area. Enter a value to the nearest meter, as available. This distance can be estimated by a ground observer by assuming that if the ground observer can see nest branches, owls nesting there can see human activities. It is reasonable and appropriate to use a measuring instrument, such as laser or infrared measuring devices, to document these measurements when available.

Note: This value estimates a maximum distance that the model compares against a standard value. The standard value is that distance which available data suggests is the maximum at which owls may be harmed by visual disturbances near their nests. If the analyst specifies a value that is less than the standard value, the final distance reported in the model outcome for visual-related harm is the analyst-specified value. If the value entered in Step 5 is greater than the standard value, the distance reported in the model outcome defaults to the standard value. That is, the determined visual harm distance can never be greater than the standard value.

Step 6

Natural Background sound is comprised of the existing natural sounds and those human-caused sounds extraneous to the action being considered. Generally, Natural Background would consist of habitat-associated sounds, such as breezes in the trees, birds chirping, even normal high altitude air traffic or very distant road traffic. Natural Background is distinguished by its relative uniformity across the area, and its independence from the action itself (such as the distant highway or air traffic), whereas other line and point sound source either existing sources or sources associated with the action being analyzed) attenuate away from a particular point or line somewhere within the area of interest. Existing Line Source and Existing Point Source (entered in Steps 7 through 10) differ from Natural Background in that they are not relatively constant across the area of interest, because their sources are within the action area and attenuate away from those specific sources.

Normal values for Natural Background in forested habitats away from development range from 25 to 45+ dB, and may be somewhat higher when influenced by some uncommon sound sources, such as distant streams, waterfalls, airports, or highways. Enter an appropriate value for your site-specific conditions, but the value must be between 25 and 80 (dB), inclusive. When estimating Natural Background, take into account the normal range of conditions likely to occur in the habitat of interest.

If the project is located in habitat generally sheltered from wind and not exposed to other distant sources, values of 25 to 35 dB may be appropriate; in areas of greater exposure to wind or distant sources, values of 35 to 50 may apply. In very rare cases, such as habitat adjacent to a large airport, values in the range of 50 to 80 may be appropriate. Enter an appropriate estimate here, but do not attempt to estimate extreme conditions (such as high winds uncommonly encountered). When estimating Natural Background in areas subject to daily or seasonal wind patterns or other distant sound sources, estimate the Natural Background based on the predominant effect of wind on sound level, not extremes. For example, if a site normally experiences low wind speeds and sound levels of 35 dB, but is also subject to occasional afternoon winds elevating sound levels to 45 dB, enter 35 dB here, as this is the predominant sound level at the site, or if the site is more commonly exposed to sound levels near 45 dB such as at a windy ridgetop location, enter 45.

Note: It is especially important that all measures for sound level entered into this model use a similar measurement standard. For purposes of this model (to estimate the effect of near-peak sounds on wildlife), use of L_{10} measured over a period of less than 10 seconds or a similar measure such as L_{max} is recommended. Use of mixed measurements, such as mixing L_{10} and L_{max} or L_{eq}, in the same model may yield unpredictable and often erroneous results. Use of measures such as L_{eq} or L_{dn} are specifically recommended against, as they provide a more general averaged sound level useful for determining noise disturbance, and may be less applicable to wildlife species. Mixed usage of L_{10} and L_{max} may be compatible when measured over very short time periods, as L_{10} measures are often with 3 dB of L_{max} under these circumstances.

Step 7

Existing Line Sound Sources represent existing sound sources at the action site that are best described as linear, such as a busy highway with relatively continuous traffic flow. Line sources can include other moving sources if the measurement metric is based on other than a very short or instantaneous measurement period (see earlier discussion). Infrequent traffic should also be modeled as a line source, when the method of sound measure uses any non- instantaneous measure of sound (such as L_{10}, L_{50}, or L_{90}) that includes a measurement period of more than a few seconds. Stationary sound sources, or single moving sources measured using a relatively instantaneous measurement metric (e.g., L_{max}), should be entered into the model as point sources, under Step 9. Enter a value here that ranges from zero (indicating no line sound source) to a maximum of 140 dB, based on actual measurements or values reported in reputable literature.

Step 8

The perpendicular distance from a line sound source is the distance from an existing line sound source to the sound recording meter and should be accurately measured, or should be based on reputable literature. Actual values used in the measurement, or reported in reference literature, can be in any measurement unit (feet, meters, miles), but must be converted to meters before entering into Step 8. Use the Distance Measure Conversion table in the model if needed. If no existing line source occurs at the site, enter zero here. Sound level data that do not include an accurate and precise measure of source-receptor distance cannot be used in this model.

Step 9

Existing Point Sound Sources represent any established, permanent point source(s) for sounds in the immediate vicinity of the action, such as a generator, transformer, parking slots, or visitor facility. Sound sources that move slowly, and whose sound level is measured using a short measurement interval relative to the rate of movement (such as L_{max} or $L_{10,\ 3\ seconds}$) may be treated as point sources. Enter a value here that ranges from zero (indicating no point sound source) to a maximum of 140 dB. Point sources that exist along a line source and are at least 5 dB less than that line source in volume may be ignored. If existing point sources are infrequently distributed along a line source, and are greater than the line source volume, it may be best to separate out those short sections of line source and prepare a separate analysis. If point sources are not less than 5 dB below existing line sources and relatively numerous along the line source, include them in the model as a line source and calculate results for the entire line source.

In some situations, several existing point sources with nearly identical sound levels may occur in close proximity to each other. For example, multiple human conversations may occur at the same time along a nature trail. To account for this, it is appropriate to add 3 decibels to the normal average human voice level of 65 decibels (at 1 meter) to account for this in the model. Should four separate and similar point sound sources exist concurrently, add 6 decibels to the normal single source value. (Note that in this example, 2 separate conversations assumes at least 4 persons, if both people in each conversation are not speaking at the same time. Also note that the measurement distance for human speech is only 1 m, not 50 feet, as it is for some equipment.

<u>Step 10</u>
As with Step 8 for line sources, the distance from the existing point sound source to sound recording meter should be accurately measured, or should be based on reputable reference sources. Actual values used in the measurement, or reported in reference literature, can be in any measurement unit (feet, meters, miles), but must be converted to meters before entering here. Use the Distance Measure Conversion table in the model if needed. If no existing point source occurs at the site, enter zero here. Data that do not include an accurate and precise measure of source-receptor distance cannot be used in this model.

<u>Step 11</u>
Action-Generated Sound Sources are the sound sources added during implementation of the proposed action, such as road machinery, new trail construction, chainsaw use, generator installation, parking facility, or future use on a new trail. Values entered here should reflect only the sound being generated by the action of interest, and not include other existing sources previously accounted for in this model.

Because most construction activity and use of existing roads or new or existing recreational facilities occurs as a series of points, this value is calculated into the model as a point source. The value entered here should account for the combined sound level of all sources likely to occur in close proximity (within a few feet) during the project. For example, if large chain saws (86 dB) will be used as part of project implementation, the analyst should enter 89 dB here if expecting two chain saws to be working closely together (doubling equivalent sound sources results in a 3 dB increase over one source). As another example, if four rock drills (94 dB) are working together, the proper entry is 100 dB (94+3+3). Enter a value between zero and 140 dB, based on actual measurements or tabled reference values from documented, measured sources.

<u>Step 12</u>
Measured Distance from Sound Source is the distance from point sound source of interest to sound recording meter. As with Step 10 for point sources, the distance should be accurately measured, or should be based on reputable reference sources. Actual values used in the measurement, or reported in reference literature, can be in any measurement unit (feet, meters, miles), but must be converted to meters before entering here. Use the conversion table in the Reference Data section of this spreadsheet if needed. Data that do not include an accurate and precise measure of source-receptor distance should not be used in this model.

Model Outputs

The model outputs are updated and displayed as data are entered into the appropriate data cells in the Excel spreadsheet. The user is encouraged to verify that each value displayed is correct for the scenario being analyzed before reporting model results. Controls in the spreadsheet should eliminate entry of inappropriate data where data are limited to a constraining range of values. The user should verify each data entry is appropriate for the action being considered.

The uppermost page of the Excel spreadsheet includes the 12-step Data Entry box, in which all data entry cells are located. As earlier described, only fields with red-colored text are valid data entry cells. All other cells are locked and cannot be changed. Cells with blue-colored text are either reference data or model default values (i.e., Reference Information), or are output values calculated from entered data (i.e., Model Output/Results). Appropriate data entry into the data entry cells is described in the preceding sections of the user guide.

The numeric outputs of the model are displayed in the last column of the Data Entry box of the spreadsheet, labeled Model Output/Results. A description of these outputs and their interpretation is provided later in this section following the description of the data calculations.

Following the Data Entry box is a table entitled Results of Calculations. This table shows the Natural Background Sound Level, the Existing Line Source Sound Levels, the Existing Point Source Sound Levels, and the Action-Generated Sound Levels, each attenuated over a distance of 500 m from the sources. These values are calculated directly from the data input into the model by the analyst, taking in to account the effects of habitat conditions on sound attenuation. The last column in the Model Input/Reference Data section of this table shows the Above-Ambient Decibel Value, as established for the species and indicated in the Reference Information section of the spreadsheet.

The table includes two Calculated Attenuation columns. The Net Existing Ambient Sound is the sound level of the combined existing point and line sources attenuated across an assumed uniform Natural Background Sound level, to a distance of 500 m from their sources. These values represent the level of sound at various distances from the sources *prior to implementing the proposed action*. The Cumulative Sound Attenuation includes the Net Existing Ambient Sound with the Action-Generated Sound. This number represents the likely maximum sound level *during implementation of the proposed action*, when attenuated out from the sources.

Finally, the table includes the Tolerance Threshold established for the species (as reported in cell L41 in the Data Entry block). This is the sound level above which harm could occur due solely to its excessive volume, regardless of the relative sound contribution of the proposed action. The Above-Ambient Threshold is the value of the Above-Ambient Decibel Value added to the attenuated Net Existing Ambient Sound Level. This value establishes the level at which Action-Generated Sound may significantly exceed that sound level normally experienced by the species at its location, and result in harm of the species.

Two figures graphically display key numbers from the table to assist the analyst in understanding their relationship. Figure 1 displays the relationship between the Cumulative Sound Attenuation and the Tolerance Threshold. Disturbance of the species occurs whenever the Cumulative Sound Attenuation line exceeds the Tolerance Threshold. The vertical line indicating the Tolerance Threshold Distance is that distance within which the contribution of the Action-Generated Sound results in a cumulative sound level above which the species is harmed regardless of the ambient sound levels existing at the site. At this time, the Tolerance Threshold is estimated at 82 dB for the owl. That is, the site may become "intolerable" to the species and harm occurs due to the total sound level the species must endure.

Figure 2 displays the relationship between the Cumulative Sound Attenuation and the Above-Ambient Threshold. This figure also includes the Net Existing Ambient Sound Attenuation for reference purposes. We determined that harm of the species likely occurs whenever the Cumulative Sound Attenuation line exceeds the Above-Ambient Threshold. The vertical line labeled Above-Ambient Threshold Distance establishes the distance below which sound generated by the action is likely to exceed by a significant amount the sound level to which the species may be regularly exposed, to the point of significantly altering its essential behaviors. The "significance amount" is established by the Above-Ambient Decibel Value determined for the species (at this time, 25 dB for the owl). Figure 2 also displays the Visual Disturbance Distance, within which the species may be harmed due to the visual detection of human activities in close proximity to the nest. This distance is established by the visual detection distance entered into the model by the analyst, but not exceeding the maximum value currently established for the species (at this time, 100 meters for the owl).

The Model Output/Results column of the Data Entry section reports both the Tolerance Threshold Distance and the Above-Ambient Threshold Distance. These two values calculate the distance at which the species is harmed due to elevated sound levels, based on two somewhat different sets of criteria and assumptions. The Final Auditory Disturbance Distance is the maximum of these two values. The Final Disturbance Distance is identical to that reported in Figure 2, and represents the distance at which the species is harmed due to human activities in the vicinity of the nest, to a maximum of 100 meters.

Interpretation of the Model Results in Northern Spotted Owl Habitat

The output from the model allows the analyst to answer three fundamental questions regarding the likelihood that the proposed action could harm owls due to elevated sound levels or visual detection from human activity in close proximity to the nest.

To simplify the interpretation of model output, estimated disturbance distances are displayed in the *Output/Decision Results* section on the top page of the spreadsheet. These values indicate the distances within which harm is likely to occur. The following discussion explains the derivation of these numbers in relation to the three fundamental questions above.

Question 1: Does the proposed action generate sounds, in combination with existing sound sources at the action site, which exceed a tolerance threshold (i.e., 82 dB) at known sites of the species or within unsurveyed nesting habitat during critical periods?

The numeric answer to Question 1 is displayed as the Tolerance Threshold Distance in the

Output/Decision Result area of the spreadsheet.

This distance is graphically displayed in Figure 1 as the point where the Cumulative Sound Attenuation line crosses the 82-dB line (the Tolerance Threshold line for owls). This value is best interpreted as the distance within which owls are likely to be harmed as a result of action implementation from the excessive volume of sound at the nest site, regardless of the existing ambient sound level at the site.

Question 2: Does the action-generated sound level exceed all existing sound levels by a significant amount within habitat? That is, do sound levels created by the proposed action exceed the existing ambient by an amount equal to or greater than a specified decibel value for the species, resulting in modifications of normal behavior?

The numeric answer to Question 2 is displayed as the Above-Ambient Threshold Distance in the Output/Decision Result area of the spreadsheet.

This distance is graphically displayed in Figure 2 at the point at which the Cumulative Sound Attenuation line crosses the Above-Ambient Threshold line. This value is best interpreted as the distance within which owls are harmed by sound generated by the proposed action due to a significant sound level increase above existing levels to which the individuals are habituated. The sound level within this distance of the action results in behavior indicating harm, regardless of the amount of sound generated by the proposed action.

Question 3: Does human activity occur in close proximity to known nests or unsurveyed nesting habitat such that nesting owls might exhibit disturbance behaviors due to this activity?

The numeric answer to Question 3 is displayed as the Visual Disturbance Distance in the Output/Decision Result area of the spreadsheet.

This distance is graphically displayed in Figure 2 as the Visual Disturbance Distance, indicated by the red triangle on the x-axis. This value is best interpreted as that distance within which owls are likely to be harmed by visual detection of human activities in close proximity to the nest. Beyond this distance, human activities are either not detectable by owls due to vegetation and/or topography blocking the visual pathway, or human activities are of sufficient distance to not cause the species to modify normal behaviors (for the owl, this maximum distance is estimated as 100 meters, based on available information).

What Do These Numbers Mean?

The reporting of these numbers requires careful interpretation. While these numbers might appear to provide precise distances within which owls are harmed during implementation of proposed actions, the analyst should understand that they only represent distances within which there is a "likelihood of harm", as supported by available data. That is, these numbers estimate the distances within which available data on owls or surrogate species, as available, show that at least some owls are likely to be injured (i.e., would be harmed) as a result of elevated sound levels or visual detection near nest sites.

Spotted owls closer to the sound sources (or visual disturbance cues) may have a higher likelihood of harm than those at the outer limits of the ham distance (due to louder sound levels, or visually perceived threat to the nest). Further, in many circumstances, not all owls, except those at the very closest distances to the disturbance, are likely to be disturbed to the level of harm. Thus, the likelihood of harm to nesting owls within this distance to sound/visual sources would range from some low proportion (low, yet reasonably greater than zero) to some higher value (not necessarily equal to 1) at points closer to the sound/visual sources. It is neither reasonable nor necessary to predict that all (or even a high proportion of) owls within this distance are subject to harm.

A more supportable interpretation is that there is currently no available information indicating that spotted owls subject to these more distant sound/visual disturbances have a likelihood of harm. Further, this interpretation is consistent with meeting the Section 7 Consultation Handbook definition of "insignificant" when concluding that "a person would not… be able to meaningfully measure, detect, or evaluate insignificant effects" (page XVI) for disturbances beyond this distance.

Modifications to the Model

Because conditions and sound sources may change substantially over a project area, especially for large projects or programmatic consultations, the model is best applied by doing separate calculations for localized conditions, so as to minimize variability and potential error over a large, diverse project area. As a rule of thumb, separate analyses should be considered whenever ambient sound levels, existing point or line sources, or project-generated sound change by more than about 6 decibels within the project area(s). The analyst should also keep in mind that this model does not account for some site-specific conditions, such as topographic or human-made barriers (such as ridges, ravines, or road cut banks) that may greatly alter the attenuation of sound in local situations. When appropriate, the analyst should qualify the numbers reported by the model, and provide a reasoned discussion of these differences, to account for these special conditions.

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Glossary

A-Weighted Decibel (dBA): An overall frequency-weighted sound level in decibels which approximates the frequency response of the human ear.

Above-Existing Threshold (also referred to as the Aversion Threshold): A sound level that significantly exceeds existing levels in a species' environment, and is likely to significantly disrupt normal behaviors related to breeding, feeding, and sheltering. The point of significance is established as that amount by which action-generated sounds exceed the combined Natural Background plus Existing Line and Point Sources to a degree that behavioral disruptions have been noted for the subject species or appropriate surrogates. For the owl, this threshold has been established as 25 dB.

Above-Existing Threshold Distance (or Aversion Threshold Distance): The maximum distance at which the sound level likely exceeds the Above-Existing Threshold, resulting in harm of the species.

Action-Generated Sound Source: The sound source of interest in an investigation, such as road machinery, new trail use, chainsaw use, generator installation, parking facility, etc. These are the sound sources being added as a result of implementing the action. These sound sources reflect only the sound being generated by the action of interest, and do not include other existing sources.

Attenuation (or Sound Attenuation): The gradual decline in volume of sound as the sound energy wave moves away from the source. The decline is generally a factor of the square of the distance from the source.

Decibel (dB): A unitless measure of sound on a logarithmic scale, which indicates the squared ratio of sound pressure amplitude to a reference sound pressure amplitude. The reference pressure is 20 micro-pascals.

Equivalent Sound Level (Leq): The average of sound energy occurring over a specified period. In effect, Leq is the steady-state sound level that in a stated period would contain the same acoustical energy as the time-varying sound that actually occurs during the same period.

Exceedance Sound Level (Lxx): The sound level exceeded XX percent of the time during a sound level measurement period. For example L_{90} is the sound level exceed 90 percent of the time and L_{10} is the sound level exceeded 10 percent of the time.

Existing Line Sound Sources: Represent existing sound levels emanating from linear sources, such as a busy highway with continuous traffic flow, where sound moves away from a line, rather than a single point, of sound. Note also that a single moving sound source may be described as a line source if the sound metric includes a significant period of time in relation to the speed of the source.

Harm: Actions which actually kill or injure wildlife. Such an act may include significant habitat modification or degradation that may kill or injure wildlife by significantly impairing essential behavior patterns including breeding, feeding, or sheltering. [50 CFR §17.3]

Hard Sites: Sites where the ground surface is predominantly hard soil, pavement, water or similar non-dampening surface that mostly reflects sound waves. Sound attenuates more rapidly across a soft site than across a hard site.

Maximum Sound Levels (L_{max}): The maximum sound level measured during a measurement period, representing the peak measurement level.

Minimum Sound Levels (L_{min}): The minimum sound level measured during a measurement period, representing the lowest measured point.

Natural Background: The existing sound comprised of natural sounds and those human-caused sounds that are extraneous to the action area being considered. Generally, Natural Background would consist of habitat-associated sounds, such as mild breezes in the trees, birds chirping, even normal high altitude air traffic or very distant road traffic. Natural Background is distinguished by its relatively uniformity across the area, or its independence from the action itself (such as the distant highway or air traffic). In contrast, line and point sources attenuate away from a particular point or line somewhere in or near the area of interest, indirectly associated with the action.

Noise: See “sound”.

Soft sites: are those where ground surface vegetation, shrubs, grass, or even softened soil dampen or absorb sound waves across the site. Sound attenuates more rapidly across a soft site than across a hard site.

Sound: A vibratory disturbance created by a vibrating object, which, when transmitted by pressure waves through a medium such as air, is capable of being detected by a receiving mechanism, such as the human ear or a microphone. Sound that is loud, unpleasant, unexpected, or otherwise undesirable may be referred to as “noise”.

Tolerance Threshold: The maximum sound level, resulting from all sources, that a species may be able to tolerate without a likelihood of significantly disrupting its normal behaviors related to breeding, feeding and sheltering. For the owl, this threshold has been established at 82 dB.

Literature Cited

Andersen, D.E. O.J. Rongstad and W.R. Mytton. 1989. Response of nesting red-tailed hawks to helicopter overflights. Condor 91(2):296-299.

Arcese, P. and Smith, J. N. M. 1988. Effects of population destiny and supplemental food on reproduction in song sparrows. Journal of Animal Ecology, Vol. 57, pp. 119-136.

Awbrey, F.T. and A.E. Bowles. 1990. The effects of aircraft noise and sonic booms on raptors: a preliminary model and a synthesis of the literature on disturbance. Noise and Sonic Boom Impact Technology Technical Operating Report 12. Wright-Patterson Air Force Base, Ohio, USA.

Bednarz, J.C. and Hayden, T.J. 1994. The effects of human activities on the productivity of birds of prey in the Los Medanos area, New Mexico. Journal of Raptor Research.

Blethoff, J. R. and Dufty Jr. A. M. 1998. Locomotor activity levels and the dispersal of western screech-owls, *Otus kennicottii*. The Association for the Study of Animal Behaviour. Vol. 50, pp. 558-561.

Bonier, F., Martin, P. R., Moore, I. T., Windfield, J. C. 2009. Do baseline glucocorticoids predict fitness? Trends in Ecology and Evolution, Vol. 24(11), pp. 634-642.

Bonier, F., Martin, P. R., and Wingfield, J. C. 2007. Maternal corticosteroids influence primary offspring sex ratio in a free-ranging passerine bird. Behavioral Ecology, Vol. 8(6) pp. 1045-1050.

Boonstra, R., Hik, D., Singleton, G. R., Tinnikov, A. 1998. The impact of predator-induced stress on the snowshoe hare cycle. Ecological Society of America, Vol. 68(3), pp. 371-394.

Bortolotti, G. R. 1989. Factors influencing the growth of bald eagles in north central Saskatchewan. Vol. 67(3) pp. 606-611.

Brown, A. L. 1990. Measuring the effect of aircraft noise on sea birds. Environment International. Vol. 16(4-6), pp. 587-592.

Busch, D.S. and Hayward, L. S. 2009. Stress in a conservation context: a discussion of glucocorticoid actions and how levels change with conservation-relevant variables. Biological Conservation, Vol. 142(12) pp. 2844-2853.

Carey, A. B. 1985. A summary of the scientific basis for spotted owl management. Ecology and management of the spotted owl in the Pacific Northwest. United States Department of Agriculture Forest Service General Technical Report PNW, pp. 100–114.

Carsia, R. V. and Harvey, S. 2000. Adrenals. Sturkie's Avian Physiology. 5th ed. Academic Press, San Diego, U.S. pp. 489-537.

Clinchy, M., Zanette, L., Boonstra, R. and others. 2004. Balancing food and predator pressure induces chronic stress in songbirds. The Royal Society, Vol. 274, pp. 2473-2479.

Creel, S., Fox, J. E., Hardy, A. and others. 2002. Snowmobile activity and glucocorticoid stress responses in wolves and elk. Society for Conservation Biologist, Vol. 16(3) pp. 809-814.

Delaney, D.K., Grubb, T.G., Beier, P. and others. 1999. Effects of helicopter noise on Mexican spotted owls. Journal of Wildlife Management, 63(1), pp. 60-76.

Fernández, C. and Azkona, P. 1993. Human disturbance affects parental care of marsh harriers and nutritional status of nestlings. Journal of Wildlife Management, 57(3) pp. 602-608.

Forsman, E. D., Meslow, E. C., Wright, H. M. 1984. Distribution and biology of the spotted owl in Oregon. Wildlife Monographs, No. 87, pp. 3-64.

Gabrielsen, G.W. and Smith, E.N. 1985. Physiological responses associated with feigned death in the American opossum. Acta Physiologica Scandinavica. 123(4), pp. 393-398.

Gabrielsen, G.W. and Smith, E.N. 1995. Physiological responses of wildlife to disturbance. Wildlife and Recreationists: coexistence through management and research. Chapter 7, pp. 95-115.

Gabrielsen, G.W., Mehlum, F., Nagy K. A. 1977. Daily energy expenditure and energy utilization of free-ranging black-legged kittwakes. The Condor, 89(1), pp. 126-132.

Ganey, J. L., Block, W. M., Dwyer, J.K. and others. 1998. Dispersal movements and survival rates of juvenile Mexican spotted owls in northern Arizona. Wilson Bulletin, 110(2), pp. 206-217.

Gilmer, D. S. and Stewart R.E. 1983. Ferruginous hawk populations and habitat use in North Dakota. The Journal of Wildlife Management, Vol. 47(1), pp. 146-157.

Hayward, L. S., Bowles, A. E., Ha, J. C., Wasser, S.K. 2011. Impacts of acute and long-term vehicle exposure on physiology and reproductive success of the northern spotted owl. Ecosphere, Vol. 2(6) Article 65.

Holmes, T. L., Knight, R. L., Stregall, L., Craig, G. R. 1993. Response of wintering grassland raptor to human disturbance. Wildlife Society Bulletin, Vol. 21, pp. 461-468.

Johnson, C.L. and Reynolds, R. T. 2002. Responses of Mexican spotted owls to low-flying military jet aircraft. USDA Forest Service Research. Rocky Mountain Research Station. Note RMRS-RN-12.

Kitaysky, A.S., J.C. Wingfield and J.F. Piatt. 2001. Corticosterone facilitates begging and affects resource allocation in the black-legged kittiwake. Behavioral Ecology 12(5): 619-625.

Knight, R. L. and Cole, D. N. 1991. Effects of recreational activity on wildlife in wildlands. Trans. North American Wildlands and Natural Resource Conference. Vol. 56, pp. 238-247.

Knight, R.L. and Knight, S.K. 1984. Responses of wintering bald eagles to boating activity. The Journal of Wildlife Management. Vol. 48(3), pp. 999-1004.

Korpimäki, E. and Norrdahl, K. 1989. Predation of Tengmalm's Owls: numerical responses, functional responses and dampening impact on population fluctuations of microtines. Nordic Society Oikos, Vol. 54, pp. 154-164.

Lacombe, D. 1994. Influence of reduced food availability on growth of captive American kestrels. Canadian Journal of Zoology, Vol. 72(12) pp. 2084

Marra, P. and R.L. Holberton. 1998. Corticosterone levels as indicators of habitat quality: effects of habitat segregation in a migratory bird during the non-breeding season. Oecologia 116:284-292.

Mason, J.T., McClure, C.J.W., and Barber, J.R. 2016. Anthropogenic noise impairs owl hunting behavior. Biological Conservation. 199, pp.29-32.

McGarigal, K., R.G. Anthony, and F.B. Isaacs. 1991. Interactions of humans and Bald Eagles on the Columbia River estuary. Wildlife Monographs 115, pp. 1-47.

Moberg, G. P. 1985. Biological Response to stress: Key to assessment of animal well-being? Animal Stress. Spring, New York, NY.

Munck, A., Guyre, P.M., Holbrook, N.J., and others. 1984. Physiological Functions of Glucocorticoids in Stress and Their Relation to Pharmacological Actions. *Endocrine Reviews,* 5(1) pp. 25-44.

Platt, J.B. 1977. The breeding behavior of wild and captive gyrofalcons in relation to their environment and human disturbance. Ph.D. Cornell University.

Pride, R. E. 2005. High faecal glucocorticoid levels predict mortality in ring-tailed lemurs. Biology Letters, 1 pp. 60-63.

Romero, L. M. 2004. Physiological stress in ecology: lessons from biomedical research. Trends in Ecology and Evolution. Vol. 19(5) pp. 249-255.

Sapolsky, R. M., Romero, L. M., Munck, A. U. 2000. How do glucocorticoids influence stress response? Integrating permissive, suppressive, stimulatory, and preparative actions. Endocrine Reviews, Vol. 21(1), pp. 55-89.

Sensaki, M., Yamaura, Y., Francis, C. D., and Nakamura, F. 2016. Traffic noise reduces foraging efficiency in wild owls. Scientific Reports, 6(30602).

Shonfield J., and Bayne, E.M. 2017. The effect of industrial noise on owl occupancy in the boreal forest at multiple spatial scales. Avian Conservation and Ecology. Vol. 12(2):13.

Sims, C. G. and Holberton, R. L. 2000. Development of the corticosterone stress response in young northern mockingbirds. General and Comparative Endocrinology Vol. 119 pp. 193-201.

Sovern, S. G., Forsman, E.D., Biswell, B.L. and others. 1994. Diurnal behavior of the spotted owl in WA. The Condor, 96(1), pp. 200-202.

Stalmaster, M.V. and J.L. Kaiser. 1997. Flushing responses of wintering Bald Eagles to military activity. Journal of Wildlife Management 61(4):1307-1313.

Strasser, E.H. and Health, J.A. 2013. Reproductive failure of human-tolerant species, the American kestrel, is associated with stress and human disturbance. Journal of Applied Ecology Vol. 50, pp. 912-919.

Steen, J.B., Gabrielsen, G.W., and Kanwisher, J.W. 1988. Physiological aspects of freezing behavior in willow ptarmigan hens. Acta Physical Scan, 134, pp. 299-304.

Steidl, R.J. and Anthony, R.G. 2000. Experimental effects of human activity on breeding bald eagles. Ecological Applications, 10(1), pp. 258-268.

Suorsa, P., Huhta, E., Nikula, A. and others. 2003. Forest Management is associated with physiological stress in an old-growth forest passerine. The Royal Society Publishing. Vol. 270(1518).

Swarthout, E.C.H. 1999. Effects of backcountry recreation on Mexican spotted owls. M.S. Thesis University of Arizona.

Swarthout, E.C.H., and R.J. Steidl. 2003. Experimental effects of hiking on breeding Mexican spotted owls. Conservation Biology 17(1):307-315.

Tempel, D. J. and Gutiérrez, R. J. 2004. Factors related to fecal corticosterone levels in California spotted owls: implications for assessing chronic stress. Conservation Biology, 18(2), pp. 538-547.

Thiessen, G.J. and Shaw, A.G. 1957. Acoustic irritation threshold of ring billed gulls. Journal of Acoustical Society of America, Vol. 29.

Van der Zande, A.N. and Verstrael, T.J. 1984. Impacts of outdoor recreation upon nest-site choice and breeding success of the kestrel. Ardea, 73, pp. 90-99

Verner, J., McKelvey, K.S., Noon, B.R. and others. 1992. The California Spotted Owl: A technical assessment of its current status. USDA Forest Service Gen. Tech. Rep. PSW-GTR-133.

Walker, B. G., Boersma, P.D., and Wingfield, J.C. 2006. Habituation of adult magellanic penguins to human visitation as expressed through behavior and corticosterone secretion. Conservation Biology Vol. 20(1) pp. 146-154.

Ward, J. M. and Kennedy, P.L. 1996. Effects of supplemental food on size and survival of juvenile northern goshawks. The Auk. 113(1), pp. 200-208.

Wasser, S. K. and Hunt, K. E. 2005. Noninvasive measures of reproductive function and disturbance in the barred owl, great horned owl, and northern spotted owl. Center for Conservation Biology, 1046 pp. 1-29.

Wasser, S.K., K. Bevis, G. King and E. Hanson. 1997. Noninvasive physiological measures of disturbance in the northern spotted owl. Conservation Biology 11:1019-1022.

White, C.M. and Thurow, T.L. 1985. Reproduction of ferruginous hawks exposed to controlled disturbance. The Condor (87)1 pp. 14-22.

Wiehn, J. and Korpimaki, E. 1997. Food limitation on brood size: experimental evidence in the Eurasian kestrel. Ecological society of America (78)7 pp. 2043-2050.

Wikelski, M., Wong, V., Chevalier, B. and others. 2002. Marine iguanas die from tace oil pollution. Nature 417, pp.. 607-608.

Wingfield, J.C. and Farner, D. S. 1993. Endocrinology of reproduction in wild species. Avian Biology. Vol. 9, pp. 164-327.

Yom-Tov, Y. 1974. The effect of food and predation on breeding density and success, clutch size, and laying date of the crow. The Journal of Animal Ecology, 43(2), pp. 479-498.