WASHINGTON STATE DEPARTMENT OF
Natural Resources

U.S. FISH & WILDLIFE SERVICE
DEPARTMENT OF THE INTERIOR

Potential Impacts and Mitigation

Focus Paper #5

The purpose of this paper is to describe how possible impacts to murrelet habitat from harvesting, edge effects and disturbance activities on DNR-managed lands are assessed and mitigated across conservation alternatives.

Introduction

The analytical framework (see Focus Paper #1) identifies three sources of possible impacts to marbled murrelets that may incidentally occur on state-managed lands: harvest-related impacts, edge-influenced impacts and disturbance-related impacts. These impacts can be quantified using repeatable, objective methods based on sound science. By doing so, these impacts can be evaluated against the minimization and mitigation proposed under each alternative being developed for the long-term marbled murrelet conservation strategy.[1]

Quantifying impacts and mitigation

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

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

[2] See Focus Paper #3, "Estimating the Location and Quality of Stands of Marbled Murrelet Habitat." *Note: This paper will be available in late November 2015.*

Figure 1. Conceptual Steps in Quantifying Impacts and Mitigation

Harvest impacts and mitigation

Harvest impacts include activities such as timber harvest or road building that result in the removal of marbled murrelet habitat (acres with P-stage values). These activities primarily occur in the managed forest, outside areas of long-term forest cover (see Focus Paper #2, "Areas of Long-Term Forest Cover"). Removing habitat can result in the loss of existing nests and reduce future reproductive capability, therefore impacting the species. The analytical framework provides a methodology to assess harvest impacts to potential marbled murrelet habitat over the life of the HCP.

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

Table 1. Simplified Calculation of Harvest Impacts and Mitigation

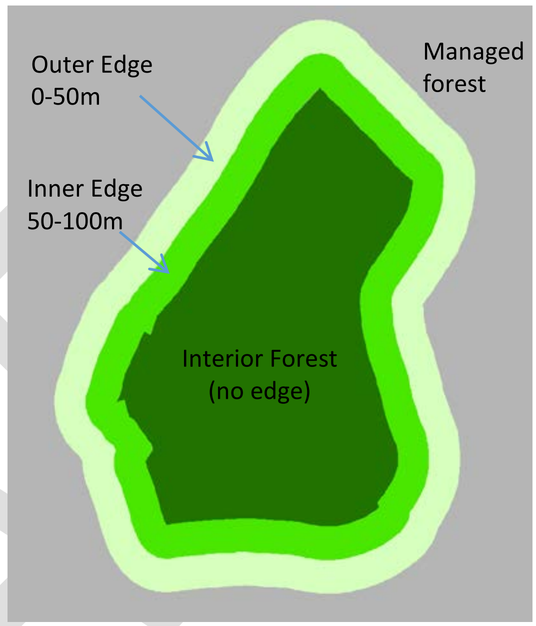
Acres Harvested		Habitat Value		Mitigation Acres Needed
500	X	.36	=	180

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

Edge impacts

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

Figure 2. Illustration of Forest Edges



How do edges impact murrelet habitat?

Timber harvest edges can influence adjacent murrelet habitat in two ways: through increased risk of nest predation and habitat degradation resulting from windthrow and microclimate changes. Edge effects resulting from timber harvest may increase the risk of marbled murrelet nest predation in habitat located close to unnatural edges (harvest edges and major road corridors). A review of known murrelet nests found average nest success was 38% within 50 meters (164 feet) of a forest edge, and 55 % at distances greater than 50 meters from an edge. Most nests failed because of predation (60%), and predation was higher within 50 meters of an edge than within the forest interior. No murrelet nests greater than 150 meters (492 feet) from an edge failed because of predation (Manley and Nelson 1999, McShane and others 2004, p. 4-89). Based on these data from actual murrelet nests, the average nesting success rate within 50 meters of an unnatural edge is 69 % of nests located greater than 50 meters from an edge.

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

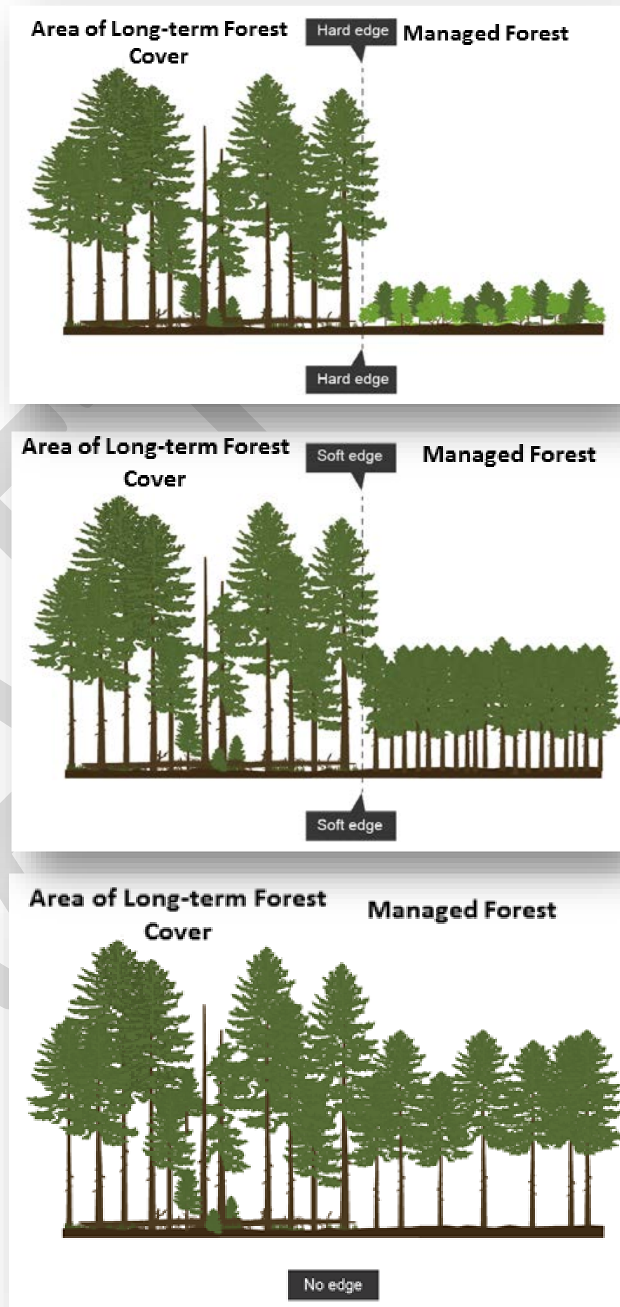
Observations at known nests are affirmed in other research studies that examined the fate of simulated murrelet nests relative to forest edges and stand structure (Raphael and others 2002, Malt and Lank 2009). Simulated murrelet nests located within 50 meters (164 feet) of high contrast edges created by recent timber harvest are 2.5 times more likely to be disturbed by predators relative to nests located in adjacent interior forest (Malt and Lank 2009, p. 1274). The increased predation risk is associated primarily with Steller's jays (*Cyanocitta stelleri*) because they are habitat generalists that respond positively to forest fragmentation and preferentially use forest edges due to the abundance of berries and insects in young regenerating forests (Malt and Lank 2009, pp. 1283-1284). Predation risk associated with harvest edges declines over time (20 to 40 years after timber harvest) as young forests regenerate and become dense, simple-structured stands with no understory (Malt and Lank 2009, p. 1282).

Edge effects also increase windthrow and alter microclimate regimes, both of which impact murrelet habitat. Van Rooyen and others (2011) analyzed platform abundance, epiphyte growth, and microclimate at forest edges to understand edge effects on murrelet habitat. In "outer edge forest," which the authors define as 0-50 meters from an edge, they found platform abundance adjacent to regenerating forest (a "hard edge," approximately 0 – 20 years old) was reduced by 75% in comparison with interior forest. Platform abundance at "soft edges" (young forest stands approximately 21 to 40 years old) was only 60% of the abundance found in interior forests.[3] Reductions in platform abundance at these various-aged edges were attributed to the loss of

[3] Table 4 in van Rooyen and others 2011; authors found a mean of 16.02 ± 5.14 platform trees at soft edges, as opposed to 26.8 ± 6.60 platform trees in interior forests (16.02 divided by 26.8 equals 60%).

platform-bearing trees from windthrow and other mortality sources, and to microclimatic effects that diminished epiphytic growth important to development of potential nesting platforms. The lesser effects at soft edges suggests that epiphyte growth is recovering from the hard edge impacts and is contributing more towards platform development.

Figure 3. Edges Change with Forest Succession



How far into the forest do the edge effects occur?

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

How does forest succession influence edge effects?

Studies have shown that forest edge effects diminish over time, as harvest areas regenerate and develop into mature forest stands (Matlack 1993, Harper and others 2005, cited in Van Rooyen 2012; see Figure 3). Early stages of stand development following harvest, referred to as *ecosystem initiation*, are characterized by actively growing young trees and other herbaceous vegetation (DNR 2007). With their rapidly growing vegetation and increasing forage base (e.g., insects, berries), ecosystem initiation stands provide a wide range of food sources and more opportunities for foraging to predators, particularly Steller's jays, a known predator of marbled murrelets (McShane and others, 2004).

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

When adjacent forests reach 80 feet in height they are assumed to ameliorate edge effects, for the purposes of this analysis (Malt and Lank 2009, Van Rooyenand others 2011). Once stands achievesthis height, the crowns begin to overlap with the those of the stand containing murrelet habitat, diminishing the impacts resulting from altered climatic regimes and windthrow.

How does the analytical framework address edge effects?

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

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

The analytical framework categorizes edge conditions into three groups: hard, soft, and no edge. Newly initiated stands adjacent to the mature forest containing murrelet habitat are considered to create "hard edge" where their height is 40 feet or less (see Figure 3 and Figure 4). Stands in competitive exclusion adjacent to a mature forest containing murrelet habitat are considered to create "soft edge" where their height is between 40 and 80 feet. Finally, stands with a height greater than 80 feet adjacent to a mature forest containing habitat are not considered to be "edge-creating;" as they have a diminished effect on the adjacent habitat compared to hard edges

Figure 4. Example of Hard Forest Edge Created by Harvest

Edge conditions are not static over time; they change as forests regenerate. The relative percentages of edge across DNR-managed lands will, however, remain generally similar throughout the life of the HCP. This is because DNR will continue to manage its forest consistent with its policies, continuing the pattern of sustainable harvest in portions of the analysis area while leaving the LTFC portion to develop mostly without direct management intervention.

How are edge effects quantified?

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

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

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

- Hard, Outer Edges: predation, microclimate, and windthrow;
- Soft, Outer Edges: microclimate only.

Table 2. Outer Edge Effect

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

[a] Percentages are presented here and in Table 3 as an example. Each alternative conservation proposal will have different percentages, due to differences in the amount and configuration of LTFC.

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

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

[d] No edge discounts are assumed.

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

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

Table 3. Inner Edge Effect

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

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

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

[c] No edge discounts are assumed.

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

Disturbance impacts

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

What are disturbance impacts?

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

What activities can disturb murrelets?

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

How are disturbance events evaluated?

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

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

How far from murrelet habitat can activities disturb murrelets?

In a review of best available information on avian ecology, disturbance, and acoustics, USFWS determined that significant disturbances to murrelets can occur within a distance of 100 meters of suitable habitat throughout the murrelet nesting season (USFWS 2012a). Exceptions include blasting, (0.25 mile-radius disturbance distance), and large aircraft (e.g., military jets) where the disturbance distance is defined by where the sound exposure level (SEL) from the aircraft meets or exceeds 92 dBA (A-weighted decibels).

What time of year can murrelets be disturbed?

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

How do murrelets respond to these disturbances?

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

How does the analytical framework evaluate the significance of each activity?

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

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

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

In order to quantify the potential impacts that result from these activities, the analytical framework assigns values for the following qualities that are used to measure the significance of the disturbance activities: stressors, duration, and response. Disturbance is quantified by determining the birds' likely response given the duration and intensity of a stressor and converting that information into acres of habitat exposed.

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

- Ground-based noise (examples: chainsaws that are harvesting trees, removing hazard trees from campgrounds, or heavy equipment maintaining roads);
- Visual disturbance (example: human presence around nest trees, such as someone hiking around or near a nest tree);
- Human activity that attracts predators (example: campgrounds close to murrelet habitat, because the human activity draws the predators to the habitat);

- Impulsive noise (example: blasting in rock pits to generate crushed rock for forest roads)
- Aircraft noise (example: sounds generated by helicopters and small planes).

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

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

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

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

How does the analytical framework evaluate disturbance?

Once each activity is assigned stressor, duration and response the activities are allocated into six groups based on similar combinations of these three categories (see Table 5). For each group, the analytical framework estimates the total habitat area within the appropriate distance bands of each activity (100 meters of each ground-based and small aircraft activity and ¼ mile for blasting) and then adjusts the acreage for habitat quality, time of year that the activity occurs, and then by the total years remaining in the HCP.

Table 5. Activity Groups by Stressor, Distance, Duration, and Response

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

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

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

When estimating possible responses of the marbled murrelet to human activity, it is important to note that empirical data are lacking for the range of activities represented in Table 5. Studies evaluating the effects of noise on various animals frequently use different metrics, and often fail to report which metrics they use, making comparisions and interpretation difficult. For the pursposes of this analysis, we do not expect that short-term exposures to low intensity stimuli that last less than 1 day will adversely effect marbled murrelets. However, any reduction in feedings has the potential to physiologically effect a murrelet chick, depending on how many feedings are received in one day, and presumably, the energy content of the food that is delivered. Further, aborted or delayed feedings have the potential to increase energy demands and predation risk on adult murrelets. Conversely, when weighing these risks, we must also consider that many of these short duration activities are intermittent and low intensity (e.g. mushroom pickers walking through a stand of suitable habitat) and pose little risk. After considering these factors, we expect that exposure of juvenile and adult murrelets to these low-intensity activites, when lasting <1 day are not expected to result in measureable effects, and are therefore insignificant.

Adjusting disturbance impacts for habitat area, quality and time

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

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

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

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

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

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

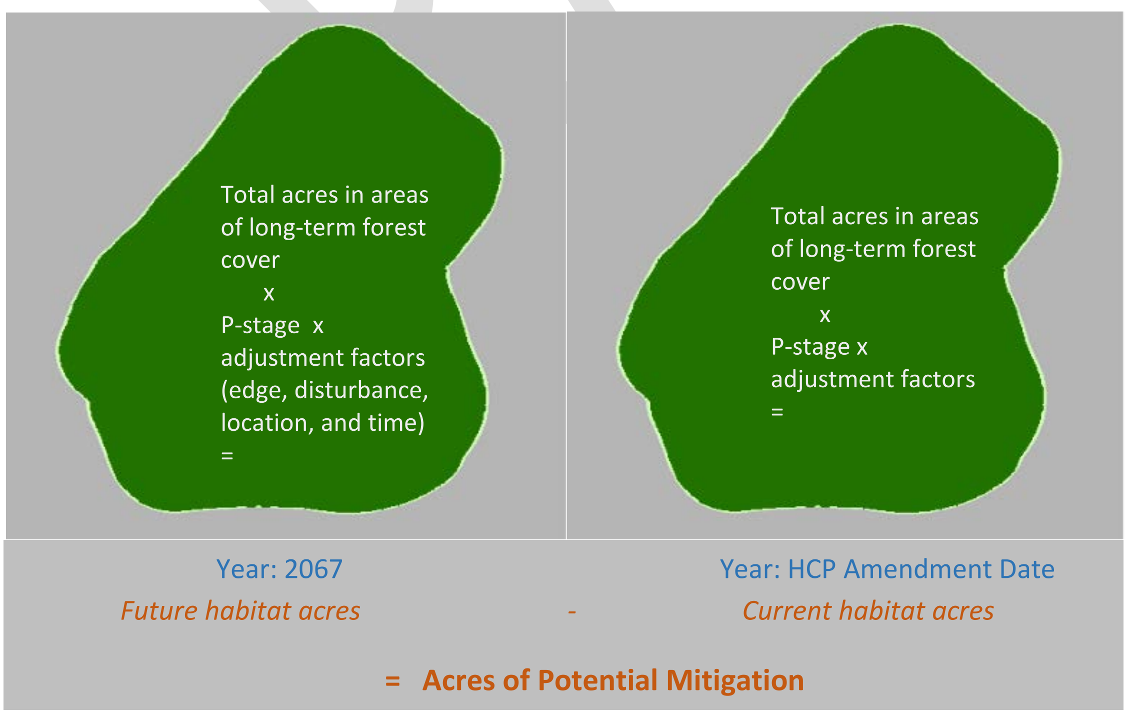
Some of these habitat acres will be disturbed repeatedly over the life of the HCP. To account for this, the framework takes the time-adjusted weighted habitat acres and multiplies them by the years remaining in the HCP (52 years), for a final amount of statewide time-adjusted acres of P-stage habitat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

Where will mitigation occur?

DNR's conservation strategy uses areas of *long-term forest cover* to provide both minimization and mitigation for the types of impacts described above.[4] Areas of long-term forest are established to meet a variety of conservation objectives but within the murrelet conservation strategy they serve three major purposes:

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

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



[4] See Focus Paper #2, "Areas of Long-Term Forest Cover."

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

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

Not all habitat is considered for mitigation

An *interim strategy* for marbled murrelet conservation has been operating since the HCP was adopted in 1997. This strategy included protections for occupied sites and reclassified habitat (see focus paper #3, "Occupied Sites"for a brief description of the interim strategy)[5]. USFWS issued an incidental take permit for impacts to the murrelet occurring on DNR's managed forest lands over this time period, and DNR has complied with that permit. Habitat has also been growing and developing for the murrelet during this time. However, no mitigation credit will be given for that interim habitat development because this analysis starts with current conditions. The analytical framework is forward-looking. It begins in "Decade 0" (current year until 2025) and focuses on potential impacts and mitigation occurring out to 2067 ("Decade 5"). Habitat is expected to increase within areas of long-term forest cover through that time period.

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

Adjusting mitigation values for time

Adjustments to the mitigation value of habitat are necessary to accommodate edge and disturbance effects, as described above. However, a different kind of adjustment is needed to address another modifier of habitat quality: time. Habitat that exists today currently provides nesting opportunities to murrelets and is therefore more valuable than habitat that will be

[5] *Note: This paper will be available in late November 2015.*

developed further into the future (as forests mature). If an impact to that habitat happens today, the offsetting mitigation (the same value of habitat becoming available to the murrelet) may not happen for several years. The analytical framework takes this into account by adjusting the value of mitigation through time, which is expressed by decade to the end of the HCP.

The decadal adjustment factor is based on how much habitat develops in a particular decade, as well as which decade that habitat is realized. For example, the total habitat that develops in long-term forest cover from the present into the first decade receives full mitigation credit to offset harvest in the managed forest within that first decade; all of the acres are counted. However, the total habitat that develops between the first and second decades receive only 80% of the total credit. This is because the habitat that grows during this decade will contribute to murrelet conservation for less time, four out of the five total decades (4/5 = 80%). Growth occurring between the second and third decades receives 60% credit (three out of five decades of growth), and so forth through to the end of the HCP. (See Table 2, below.)

Table 2. Adjusting Future Habitat in Mitigation Value. Numbers are for illustration purposes only. They are not a representation of DNR-managed lands.

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

Adjusting mitigation values based on location

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

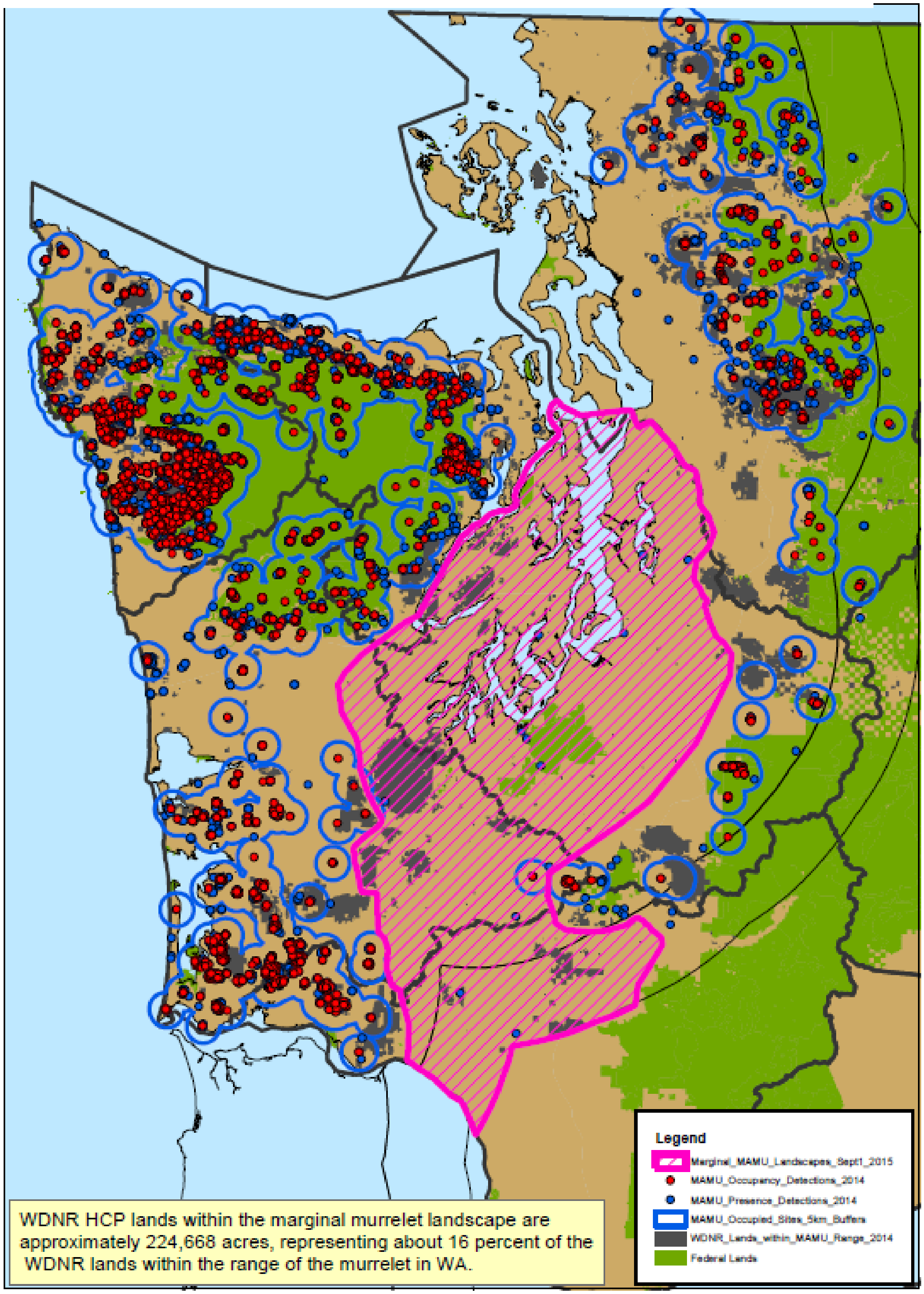
To define marginal murrelet landscapes we considered multiple factors:

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

Our delineation of marginal murrelet landscapes includes more than 224,000 acres of DNR-managed lands located primarily in the Puget Trough lowlands from the Kitsap Peninsula south to the Columbia River (see Figure 7). These landscapes currently contain low amounts of murrelet habitat (about two percent) in small scattered patches, are located further than 5 km from any known occupied murrelet sites, and have a relatively low capacity for developing future habitat within the life of the HCP.

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

Figure 7. Map of Marginal Landscapes for Murrelet Conservation



Calculating take and mitigation in marginal landscapes

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

Putting it all together: take and mitigation

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

Attachment 1: Calculating the Mitigation for Disturbance

Example: Campground operations

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

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

Identify impacted habitat acres

Acres of P-stage habitat in campgrounds, plus 100m buffer	X Average P-stage value across DNR lands	= Acres impacted (weighted)
305	**.34**	**104**

Determine proportion of impacted acres in LTFC

104 acres	X .51 (51% of DNR lands in LTFC)	= **53 acres**

Adjust for time

Number of impacted acres	X Nesting season/ number of camp days	X Number of activity days out of a week	= Impacted acres during nesting season
53	**176/176**	**7/7**	**53**

Calculate over the life of the HCP

53 impacted campground acres during annual nesting season	X **52** years	= **2,756** time-adjusted acres of P-stage habitat disturbed by campground activities

Attachment 2: Roads as Edges

How do forest roads impact murrelet habitat?

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

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

How is the road edge effect calculated?

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

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

Percent of habitat in interior, or inner-edge LTFC assumed to be within 50 m of a road (4.8%)	x	**Acres of habitat in each edge condition, adjusted by other edge factors (varies depending on the conservation alternative)**	x	**Road edge factor (15.5%)**	=	**Acres of habitat impacted by roads**

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

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