MONITORING SELECTED WILDLIFE SPECIES RESPONSES TO FOREST TREATMENTS ASSOCIATED WITH THE SOUTHWEST CROWN OF THE CONTINENT COLLABORATIVE FOREST LANDSCAPE RESTORATION PROJECT INTERIM REPORT JULY 2012 REPORT PREPARED BY JONATHAN HAUFLER AND SCOTT YEATS ECOSYSTEM MANAGEMENT RESEARCH INSTITUTE SEELEY LAKE, MONTANA
INTRODUCTION

The Southwest Crown of the Continent (SWCC) Collaborative Forest Landscape Restoration Project (CFLRP) is a planned 10-year project designed to find collaborative opportunities for addressing fuel mitigation, forest restoration, watershed improvements, and economic development through improvements to U.S. Forest Service lands within the 1.5 million acre project area. Treatments to be conducted over the duration of the project will collectively address these project goals. One specific objective of the project is to improve fish and wildlife habitat, including for endangered, threatened, and sensitive species. Monitoring of accomplishments including both implementation and effectiveness monitoring are an important component of the overall project.

Threatened, endangered and sensitive species could potentially be affected by any of the planned terrestrial treatments. Monitoring the effects of treatments on these species was identified as a desirable component of monitoring. This wildlife monitoring project was initiated by the SWCC Wildlife Monitoring Committee to monitor the effects of treatments on selected species that fit the above criteria in the SWCC: fisher (Martes pennanti), American marten (Martes americana), northern goshawk (Accipiter gentilis), flammulated owl (Otus flammeolus), hairy woodpecker (Picoides villosus), and pileated woodpecker (Dryocopus pileatus).

Most of the threatened, endangered and sensitive species in the SWCC occur in relatively low densities, have large home ranges, and have complex habitat requirements. Because of this, monitoring population responses of these species at the scale of specific projects is not meaningful in terms of gathering statistically relevant information. Consequently, we chose to monitor the effects of planned treatments on the habitat quality of the selected species through habitat modeling and collection of site specific vegetation parameters.

The SWCC Wildlife Monitoring Committee selected habitat suitability modeling as the underlying framework to monitor the response of the identified species to treatments. These models evaluate habitat suitability for each species at appropriate scales and compare habitat suitability before and after treatment. Vegetation variables at treatment sites will be sampled pre-treatment to establish baseline conditions, and these same variables will be sampled post-treatment to provide inputs to the models to determine the effects of the treatment on habitat quality for each species.

Efforts will be made to validate the habitat models when feasible to assure their effectiveness and accuracy in evaluating habitat in the SWCC landscape. However, the difficulty in generating accurate vegetation parameters from remotely sensed sources for most habitat attributes of the selected species makes model validation challenging. Consequently this initial wildlife monitoring project focuses on development of the models and identification of the vegetation variables to be collected at selected treatment sites. A follow-up wildlife monitoring project will evaluate the variability in vegetation parameters, the influence of this variability on the ability to predict habitat quality for the selected species, and the influence of vegetation classifications used in remotely-sensed information on the variance associated with vegetation parameters.
METHODS

The primary question to be addressed in this overall wildlife monitoring project is: how do selected treatments (e.g., mechanical thinning, prescribed burning, combination of thinning and burning) influence the habitat suitability of selected threatened, endangered, sensitive, and management indicator species (fisher, American marten, northern goshawk, flammulated owl, hairy woodpecker, pileated woodpecker)? This monitoring will be coordinated with the integrated monitoring efforts that are addressing other effectiveness components of treatments. Thus, the statistical design of the treatment monitoring is that developed for the overall integrated terrestrial monitoring effort of the SWCC Monitoring Committee.

Changes in habitat suitability will be quantified using the habitat models developed for the six selected species. As indicated, treatment effects at the project level will be determined through pre- and post-treatment sampling of specific vegetation variables from replicated plots. Changes in the contribution of each treatment site to the habitat of each species will be quantified as changes to the habitat suitability of the species based on habitat model analyses.

Vegetation variables required to run the habitat suitability models were identified, and provided to the Vegetation Monitoring Committee to be included in the integrated vegetation sampling design. Specific variables for wildlife modeling included:

1. Overstory tree canopy cover
2. Ecological site (Groupings of habitat types)
3. Total trees per acre (>1 in.) by size class
4. Snags per acre by size/decay class
5. Percent ground covered by coarse woody debris by size class (diameter)
6. Profile board measurement of horizontal cover
7. Shrub canopy cover by species (for shrubs >1m)
8. Average shrub height
9. Basal area
10. Understory canopy cover
11. Defective trees per acre by size class (DBH) and species (broken tops, butt-rot, heart-rot, presence of conks)
12. Log decay classes (Maser et al. 1979)

As indicated, the sampling design will follow that developed for the integrated vegetation monitoring for the overall SWCC project. Sampling sites will be selected based on their ecological site (habitat type grouping), existing vegetation condition (large trees present or absent, other criteria), treatment goals (restoration of native ecosystem, fuel mitigation), and treatment applied (e.g., mechanical thinning, prescribed burning, or a combination of thinning and burning). For each combination of site, vegetation, goal, and treatment, replicated project sites will be selected. Within each project site, specific treatment stands will be sampled using replicated randomly placed plots. In addition, comparable control areas will be located within the surrounding landscape and similarly sampled. Vegetation sampling will occur for at least 1 year pre-treatment and at appropriate times post-treatment (e.g., Year 1, 2, 3, 5, 10 and 15).
Post-treatment sampling may correspond with follow-up treatments such as prescribed burning or weed spraying.

Wildlife models will be run pre- and post-treatment (multiple runs over the duration of the CFLRP monitoring) at various scales of interest. Scales of analyses may be for the surrounding 6th code HUC, Forest Service Ranger District, larger watershed, or entire SWCC area.

Wildlife models have been developed using a habitat suitability framework. Habitat suitability models identify the known habitat characteristics of each species, and the relationship between identified variables to the habitat suitability of the species. An example is shown in Figure 1.

![Tree Canopy Cover - Nesting](HSI_Value.png)

**Figure 1.** Example of the relationship between a vegetation parameter and habitat suitability of a modeled wildlife species.

Wildlife models evaluate the contributions of each stand of vegetation in a treatment area towards the habitat needs of a species. Each stand will receive a rating for each vegetation parameter, and the overall contribution of each stand to the habitat needs of the species quantified. If multiple treatment stands are treated, then the contribution of each stand towards the habitat needs of each species is determined. By conducting pre and post treatment sampling, the effects of the treatment on the habitat needs of each species can be measures. However, because treatment areas are typically much smaller than the home range size for most species selected for analysis, the changes in habitat quality produced by each treatment must be evaluated at a larger spatial scale. To accomplish this, either a larger area must be mapped and sampled for stand characteristics (desirable but logistically not feasible), or habitat values must be assigned to areas based on remotely-sensed mapping criteria. In the latter, each pixel in the selected landscape must be assigned a value for each habitat variable. Because remotely-sensed information often does not track the vegetation parameters required by a species, the assignment of a habitat value for a pixel may contain considerable variance or even errors.
For treatment areas, the actual sampled data will be used to assign the value of each variable to the pixels in the treatment area. These values will change with pre- and post-treatment vegetation conditions based on the vegetation sampling results. To determine the effect of the treatment on habitat suitability for species assessed at a larger scale, values will be assigned to the remotely sensed mapped forest classification type/ecological site type conditions in the surrounding landscape. Control plots occurring within these mapping categories will provide some estimates of the variance of each variable within that mapping category. The accuracy of assigning a value for each variable to each pixel will vary with the specific variable, with some major limitations in the ability to remotely define conditions for many variables noted. However, these potential inaccuracies will at least be held constant relative to the treatment effects that will be based on accurate field-sampled vegetation changes. Thus, while the accuracy of the remotely-sensed analysis of habitat quality for a species may be a problem, the changes produced by the treatments can be accurately evaluated using the sampled data, and the influence of these changes on the species evaluated at landscape scales is at least consistently evaluated so that the overall effects of the treatments can be assessed in an unbiased manner.

Each wildlife model combines the various specific variables used to characterize the habitat of the species into an overall habitat suitability rating for each pixel or stand of vegetation. These habitat suitability maps reveal (for the treatment areas and to the extent that remotely-sensed information can assess habitat quality of a species) where high quality habitat occurs, and where lower quality conditions occur. However, this does not indicate how this available habitat may be able to be used by the species (i.e., is enough habitat present to provide for a high quality home range). The habitat suitability information can be furthered analyzed to determine the effects of treatments on number and suitability of home ranges for each species (Roloff and Haufler 1997, 2002). Examples of this were run for two of the six species.
WILDLIFE HABITAT SUITABILITY MODELS

Fisher (*Martes pennanti*) model

The fisher is a medium sized forest carnivore that was nearly extirpated from the intermountain west, but was reintroduced in the mid 1960’s (Powell 1993). The current range of fisher is shown in Figure 2. In general, fisher habitat is ideal in late-successional conifer stands (USFWS 2004). Specifically, fishers select for stands with canopy cover >50% (preferably 80-100%), large diameter trees (>18.5 in.), multi-story stands, and high levels of coarse woody debris (Jones 1991, Powell 1993, Powell and Zielinski 1994). There is also preferential selection for riparian areas interspersed within a forest stand due to the associated gentle slopes, moderate temperatures, and increased prey densities (Jones 1991, Powell and Zielinski 1994, Lewis and Stinson 1998). In north-central Idaho, stands dominated by grand fir (*Abies grandis*) and Engelmann spruce (*Picea engelmannii*) were preferentially selected (Jones 1991). Fishers avoid nonforested areas (USFWS 2004).

The fisher model was primarily based on the framework set forth in Allen (1983). It was modified by adding a shrub canopy cover variable and spruce/fir canopy variable found in Olsen et al. (1999). Winter habitat is generally considered the limiting factor for fishers. Optimum winter habitat is found in mature stands with high tree canopy cover, a diverse understory, and a mix of deciduous and evergreen overstory trees. The HSI model for fisher was built based on these optimal conditions.

The first variable is tree canopy cover (Figure 3). Fishers have been found to avoid open areas and their prevalence increases with decreasing amounts of open areas in the landscape (Weir and Corbould 2010). They have also been found to prefer areas with a minimum of 30% tree canopy cover with use increasing with amounts of canopy cover (Jones and Garton 1994, Thomasma et al. 1994). Proulx (2006) found radio collared fisher in British Columbia to use stands with 30-60% canopy cover.

The second habitat variable for fisher is mean DBH of overstory trees (Figure 4). This variable helps address stand age and successional state as fisher occurring in heavy snow regions have...
been shown to prefer older, mid- to late-successional stands (Powell and Zielinski 1994). Fisher prefer stands with mean tree diameter >8 in. and suitability increases with tree diameter (Jones 1991, Jones and Garton 1994, Thomasma et al. 1994, Proulx 2006).

The third variable is canopy cover of shrubs ≥3 ft. in height (Figure 5). In the Pacific states and Rocky Mountains fisher have been shown to prefer multi-layer stands and areas with high canopy cover (Powell and Zielinski 1994, Weir and Harestad 2003). Higher levels of horizontal cover created by shrubs and/or small trees are also important habitat for snowshoe hares (Litvaitis et al. 1985). Snowshoe hares have been shown to be the primary food source for fisher in Idaho and Montana (Jones 1991, Roy 1991). During the winter months in western Montana snowshoe hares are most abundant in early successional stands and late successional heterogeneous stands with high levels of horizontal cover (Koehler and Aubry 1994, Thomas et al. 1997, Griffin 2004, Griffin and Mills 2007, Griffin and Mills 2009). Hare use reaches the highest levels when horizontal cover of above snow vegetation is ≥50% (Carreker 1985). Dense cover provides the hares with critical food, cover, and thermal protection (Litvaitis et al. 1985, Hodges 2000). When horizontal cover drops below 10% the habitat is considered unsuitable (Thomas et al. 1997). Horizontal cover has not been included as a variable in the fisher model at this time, but it may be desirable to add this variable to the model to better assess the potential abundance of snowshoe hare in an area.

Deciduous trees in the overstory (based on relative cover) could have an influence on fisher habitat use. In the intermountain west deciduous species are often associated with riparian areas which have been shown to be preferred by fisher due to decreased snow depths, prevalence of spruce, and gentle topography (Jones 1991, Powell and Zielinski 1994, Lewis and Stinson 1998). However, this variable was not included in the model for the SWCC landscape, as deciduous cover is limited in this area, and it is uncertain if it would be selected by fisher. Additional research on this question is needed.

The final model variable is the absolute canopy cover of spruce and true fir (Figure 6). Ecotypes that contain spruce and true fir have been shown to be highly preferred by fisher for foraging and resting (Powell 1991, Powell and Zielinski 1994, Proulx 2006). These types of stands have also been shown to provide good habitat for snowshoe hares (Griffin 2004).

The final HSI grid for fisher was calculated with the following formula:

\[ Fisher\ HSI = Deciduous\ HSI \times \left[(Tree\ Canopy\ HSI \times DBH\ HSI \times (Min\ (1, [2+0.55\times Shrub\ HSI+0.85\times Spruce/Fir\ HSI])))^{0.333} \right] \]
Figure 3. Relationship between tree canopy cover and HSI values for fisher. The equation between 20 and 40 is $y=0.005x-0.1$ and the equation between 40% and 80% is $y=0.022x-0.827$.

Figure 4. Relationship between mean diameter at breast height of overstory trees and HSI values for fisher. The equation between 2.5 and 15 in. is $y=0.08x-0.2$. 

Figure 5. Relationship between canopy cover of shrubs and HSI values for fisher. The equation between 5% and 15% is $y=0.1x-0.5$.

Figure 6. Relationship between the absolute canopy cover of spruce and true fir and HSI values for fisher. The equation between 0% and 50% is $y=0.02x$. 
Flammulated Owl (*Otus flammeolus*)

Flammulated owls are a small owl found throughout the lower elevation valleys of western Montana (Figure 7), but typically are limited to dry, conifer dominated stands (Groves et al. 1997). These low elevation stands are dominated by mature to old-growth ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) with multiple canopies, low stocking rates, open canopies, and moderate shrub cover (McCallum 1994, Groves et al. 1997). Flammulated owls have also been documented nesting successfully in stands dominated by Douglas-fir and lacking ponderosa pine (Howie and Ritcey 1987, Powers et al. 1996). The mature trees are important for nesting while the younger trees and shrubs in the understory provide roosting areas and the openings facilitate foraging (Goggans 1986, Reynolds and Linkhart 1987). For example, tree densities in stands where males responded to callback surveys (typically roosting areas) averaged 202 trees per acre with a mean diameter at breast height from 11.1-15 inches (Groves et al. 1997). Due to their preference for dry conditions and intolerance of high humidity, riparian areas are considered non-habitat (McCallum 1994).

The flammulated owl model is based on optimum conditions for nesting, roosting, and foraging, however nesting habitat is considered the primary determinant of flammulated owl habitat. Flammulated owls prefer xeric, open, old growth ponderosa pine and Douglas-fir with scattered clumps of dense younger trees (roosting areas) and a component of large snags (Christie and van Woudenberg 1997, Linkhart 2001). The habitat variables selected for this model characterize stands based on these optimum conditions.

The first habitat variable is ponderosa pine, western larch, and Douglas fir snags >20 in. DBH per acre (Figure 8). As secondary cavity nesters it is critically important that flammulated owls have access to suitable nesting trees (McCallum 1994). Bull et al. (1990) found 88% of nest trees in Oregon (n=33) to be >20 in. DBH and 97% of nest trees to be either ponderosa pine or western larch. Occupied nest trees in south-central Idaho were found in either Douglas fir or aspen with a mean diameter of 19.6 in. (Powers et al. 1996). Douglas fir or ponderosa pine were the preferred nesting trees in both south-central British Columbia (Christie and van Woudenberg 1997) and Colorado (Linkhart et al. 1998). The purpose of this variable is to
insure enough snags are present in a stand to keep the lack of nest sites from being a limiting factor.

The second variable is total canopy cover of the tree overstory (Figure 9). Flammulated owls prefer open to semi-open stands for both nesting and foraging (McCallum 1994). Stands surrounding nest sites in Oregon had a mean canopy cover of 55% (n=33) (Bull et al. 1990). In British Columbia canopy cover surrounding nest sites ranged from 30-50% (n=35) (Christie and van Woudenberg 1997). In the Blue Mountains of Oregon stands used by nesting owls all had canopy cover <50% (n=20) (Goggans 1986). Callback surveys in Idaho found male owls occupying stands with canopy cover ranging from 52-64% (Groves et al. 1997), which was likely to represent roosting habitat. The canopy cover variable gives stands an optimum suitability rating when cover is between 30% and 50%.

The third variable used in the flammulated owl model was percent of maximum stand density index (SDI) (Figure 10). The percent of maximum SDI is a variable that provides more detail about stand conditions than trees per acre or basal area (Woodall and Miles 2006). SDI is a function of stand density based on the average specific gravity of trees in the stand. Each stand has a maximum density. The percent of maximum of the stand’s current condition provides an accurate measure of stand characteristics and stand potential (Long and Daniel 1990). This variable allows the model to assign higher suitability to stands that are characterized by both large trees and open canopies. It also avoids assigning high suitability to stands that meet one criteria, such as basal area, while not meeting another, such as trees per acre.

The final habitat variable is ecological site (Figure 11). This variable identifies ecological sites and disturbance regimes that are used by flammulated owl. They are consistently found in low elevation stands dominated by ponderosa pine and Douglas fir with open canopies and large trees (McCallum 1994, Christie and van Woudenberg 1997, Linkhart 2001). Sites can be further characterized by the lack of moist site indicator species such as Salix and Vaccinium (Wright et al. 1997). The habitat type HSI was based on the relative moisture of a site as indicated by the presence of understory species such as Salix and Vaccinium. In stands where these species are present the value for this variable is always zero.

The final HSI grid was calculated by multiplying the geometric mean of the snag HSI, canopy cover HSI, and SDI HSI by the habitat type HSI.

Samson (2006) developed a regional wildlife habitat relationship model for flammulated owls designed to assign habitat values to mapped classes of vegetation. The model used dominance group, canopy cover, aspect, structure class, snag density, and a relationship between basal area and tree diameter as variables. These variables are roughly equivalent to the variables described in this habitat suitability model.
Figure 8. Relationship between ponderosa pine, Douglas fir, and western larch snags per acre > 20 in. DBH and HSI values for flammulated owl. The equation between 0 and 1.5 is \( y=0.6667x \).

Figure 9. Relationship between overstory tree canopy cover and HSI values for flammulated owl. The equation between 0 and 30 is \( y=0.0267x+0.2 \) and the equation between 50 and 100 is \( y=-0.02x+2 \).
Figure 10. Relationship between relative stand density index (for trees >6 in. DBH) and HSI values for flammulated owl. The equation between 0 and 33.33 is \( y = 0.03x \) and the equation between 40 and 73.33 is \( y = -0.03x + 2.2 \).

Figure 11. Relationship between ecological site and HSI values for flammulated owl. Ecosystems not listed received a rating of zero.
Northern Goshawk (*Accipiter gentilis*)

Northern goshawks are a large accipiter found in forested areas throughout the Rocky Mountains (figure 12) (Squires and Reynolds 1997). Northern goshawks have long been considered sympatric with mature or old-growth conifer stands and the bulk of available literature supports this (Greenwald et al. 2005). Nest sites in particular require mature stands with high canopy cover (>75%), large trees, and multiple canopies (Crocker-Bedford and Chaney 1988, Hayward and Escano 1989, Squires and Reynolds 1997). However, the nest stand can be fairly small (down to 25 ac.) (USFWS 1998). In northern Idaho, the mean nest height was 41 feet, in trees with a mean height of 85.3 feet and a mean diameter at breast height of 19.7 inches (Hayward and Escano 1989). Also, the canopy cover around the nest was higher than the mean cover for the stand.

Ideal conditions for foraging are stands with a closed canopy, but an open understory that provides clear flight corridors (Reynolds et al. 1982, Hayward and Escano 1989). Goshawks have been found to avoid open areas, such as meadows, shrublands, and logged early seral stands (<30 years in age) (Austin 1993, Bloxton 2002). Avoidance of mature and old-growth stands with <40% canopy cover has also been documented (Austin 1993, Bright-Smith and Mannan 1994, Beier and Drennan 1997).

Separate nesting and foraging models were developed for goshawks. They were based on the framework described by Shaffer et al. (1999). Goshawk prefer mature stands with complex canopies, high canopy cover, a mix of deciduous and conifer species, and minimal human disturbance.

The first variable used in the nesting model is mean overstory tree height (Figure 13). The purpose of this variable is to help predict the availability of large trees in the stand that are suitable for nesting. It also provides a measure of stand maturity. Goshawks in western Montana and Idaho nested in trees ranging from 39.4-157.5 feet (n=17) in height (Hayward and Escano 1989). Further work in the interior Pacific Northwest found a similar range of heights for nest trees (40.4-157.5 ft; n=82) (McGrath et al. 2003). A study in the Yellowstone region of
Wyoming measured the heights of 49 nest trees and found a range from 39.4-124.7 feet with a mean height of 82 feet (Patla 1997).

The second nesting variable is overstory tree canopy cover (Figure 4). Goshawks have been found to nest in stands with closed canopies (Crocker-Bedford and Chaney 1988, Hayward and Escano 1989, Squires and Reynolds 1997). Dense canopies provide protection both from predation (Reynolds et al. 1992) and weather extremes during the early portion of the nesting season (Moore and Henry 1983). Hayward and Escano (1989) looked at 17 nest sites in Montana and Idaho that had mean canopy cover of 80% and a range from 65-90%. At 82 nest sites in Oregon and Idaho the mean canopy cover was 53.1% (McGrath et al. 2003). In south-central Wyoming on higher elevation sites characterized by subalpine pine, Engelmann spruce, and lodgepole pine the mean cover at 39 nest sites was 66.7% (Squires and Ruggiero 1996). Also in Wyoming, Patla (1997) measured canopy cover at 44 nest sites and found average canopy cover to be 73%.

The third variable in the nesting model is basal area (Figure 15). In eastern Oregon and Washington basal area was found to be a strong factor in the selection of nest sites, and was found to be more predictive of nest locations than stand structure (McGrath et al. 2003). Samson (2006) created a regional goshawk nesting model that used basal area as one variable. This study identified a range of basal areas from 104.5-257 ft²/ac. A subsequent study (unpublished) on the Helena, Lewis and Clark, and Custer National Forests found that goshawks rest in stands with both higher and lower amounts of basal area. For this model the range of 104.5-257 ft²/ac will be considered optimal habitat while recognizing that values on either side of this range can still support successful nest sites.

The final nesting HSI grid was calculated by using the geometric mean of the three preceding habitat variables. The second component of the goshawk model is the foraging HSI grid. The variables used for the foraging grid are discussed below.

The first variable is overstory tree canopy cover (Figure 16). Northern goshawk physiology requires them to have somewhat open forest conditions to forage effectively (Reynolds et al. 1992). As the bulk of most goshawk diets in North America consist of mammals (86-94%) an open understory promotes foraging efficiency (Shaffer et al. 1999).

The second variable in the foraging model is mean overstory tree height (Figure 17). The variable is also used to target older, more mature stands that will have optimal habitat for goshawk foraging. The final foraging HSI grid was calculated by taking the geometric mean of these two variables.
Samson (2006) developed a regional nesting and foraging wildlife habitat relationship model and the Helena National Forest tested the model for areas east of the continental divide. The Samson model identified dominance type, canopy cover, basal area, structure class, and a relationship between tree diameter and basal area as model variables. The Helena National Forest model used existing nest data to test the Samson model. They discovered that the attributes and the range of values used by Samson did not correspond to nest site attributes on the Helena National Forest. They found goshawks to be less selective than the Samson model indicated. However, the Samson values still fell within the range of values found by the Helena team. The third nesting variable included in the model presented here is stand basal area. The values used in Figure 15 were those indicated by Samson (2006) as optimal habitat conditions, and the range of basal areas reflects the findings of the Helena National Forest.

Figure 13. Relationship between mean overstory tree height and HSI values for northern goshawk nesting. The equation between 40 and 65 ft. is $y=0.04x-1.6$. 
Figure 14. Relationship between overstory tree canopy cover and HSI values for northern goshawk nesting. The equation between 30 and 50 is $y=0.05x-1.5$.

Figure 15. Relationship between basal area and HSI values for northern goshawk nesting. The equation between 0 and 104.5 is $y=0.0096x$ and the equation between 257 and 350 is $y=-0.0108x+3.7636$. 
Figure 16. Relationship between tree canopy cover and HSI values for northern goshawk foraging. The equation between 10 and 40 is $y=0.0333x-0.333$.

Figure 17. Relationship between mean overstory tree height and HSI values for northern goshawk foraging. The equation between 25 and 55 ft. is $y=0.0333x-0.833$. 
Pileated Woodpecker (*Dryocopus pileatus*)

Pileated woodpeckers are a primary cavity nester found throughout the United States (Figure 18) in forested vegetation types (Bull and Jackson 1995). They generally occur in mature forests with partially closed to closed canopies and large diameter trees (Bull 1987, Aney and McClelland 1990). For nesting, tree size seems to be the most important variable with a variety of tree species used (Bull 1987, Aney and McClelland 1990, McClelland and McClelland 1999, Bonar 2001, Aubrey and Raley 2002).

Pileated woodpeckers primarily feed on ants (*Camponatus* and *Formica* spp.) (Beckwith and Bull 1985, Bull et al. 1992a, Bonar 2001). Thus, habitat that provides high suitability for ants should be suitable for woodpecker foraging, especially if it also provides overhead cover for protection from aerial predators. Avian predators are one of the leading causes of mortality for adult pileated woodpeckers (Bull et al. 1992b). Ideal ant habitat, and thus foraging habitat, consists of a mix of standing snags, stumps, and downed logs (Aney and McClelland 1990, Torgerson and Bull 1995).

The other important habitat characteristic for pileated woodpeckers is roost trees (Bull et al. 1992b, Aubrey and Raley 2002). Roost trees provide year round protection for mature birds and are important both for thermoregulation in the winter and protection from predation (Bull et al. 1992b). Roost trees differ from nest trees in that they can be completely hollow and have multiple entrances; however sizes are similar to nest trees (Bull et al. 1992b).

Roloff (2004) updated the pileated model developed by Aney and McClelland (1990) in order to account for new research and better integrate the requirements for roosting trees into a habitat model. The model presented here follows the framework of Roloff (2004). The first variable for the nesting component of the model is overstory tree canopy cover of preferred nesting species (Figure 19). For the purpose of this model overstory trees are defined as trees ≥ 65 feet tall. Pileated woodpeckers require large trees for nesting and these are generally found in stands with low to moderate canopy closure (Bull 1987, Aney and McClelland 1990, McClelland and McClelland 1999). Moderate amounts of canopy closure provide better protection from avian predators (Bull et al. 1992b). The preferred tree species for nesting are...
western larch and ponderosa pine, likely due to the fact they quickly lose their bark and lower branches (Bull 1987). Other tree species used for nesting include cottonwood, aspen, Douglas fir, western white pine, and grand fir (McClelland and McClelland 1999, Bonar 2001, Aubrey and Raley 2002).

The second and third nesting variables are the densities of small snags (Figure 20) and large snags (Figure 21). Pileated woodpeckers nest in snags and decadent trees with a range of diameters and seem to prefer a mix of available size classes (McClelland and McClelland 1999, Bonar 2001, Aubrey and Raley 2002). Having two size class variables insures there is a good diversity of size classes present in the landscape.

The fourth variable for the nesting portion of the model is the average size of suitable nesting trees (Figure 22). This variable supports the snag density variable by insuring that the majority of dead and decadent trees are suitably sized for nesting. Pileated woodpecker nest tree selection has been positively correlated to increasing tree diameter (Bull 1987). A minimum size of 15 in has been used in other models (Samson 2006).

The nesting HSI value is calculated with the following formula:

\[ \text{Nesting HSI} = \left( \frac{(\text{Snag Density}_{\text{small}} \times \text{HSI} + \text{Snag Density}_{\text{large}} \times \text{HSI} + \text{Snag DBH HSI})}{3} \right) \times \text{Canopy Cover HSI} \right)^{0.5} \]

The second component of the pileated woodpecker model is foraging habitat. Ants have been shown to be the primary food source for pileated woodpeckers during the breeding season (Beckwith and Bull 1985, Bull et al. 1992a, Bonar 2001) thus ideal foraging habitat provides optimal conditions for ants while also providing some overhead cover to protect woodpeckers from aerial predation (Bull et al. 1992b). The foraging component is composed of four habitat variables. The first variable is tree canopy cover (Figure 23). Moderate amounts of canopy cover provide cover from predation while allowing open flight lines to facilitate foraging. This variable also helps insure the site being rated has forest cover.

The second variable in the foraging model is the density of preferred foraging sites (Figure 24). As the amount of standing snags and downed debris increases so does the population of ants (Torgerson and Bull 1995). Downed wood has been found to be as important for foraging as standing dead wood (Bull 1987, Aney and McClelland 1990).

The third variable is average tree size (Figure 25). Pileated woodpeckers have shown a preference for foraging or large standing trees, with preference increasing with tree diameter.
Woodpeckers in Alberta also selected large trees for foraging (Bonar 2001).

The final variable for the foraging component is the diversity of log decay classes (Figure 26). This variable is based on the log decay classes identified by Maser (1979). A diversity of decay classes has been shown to provide habitat for multiple ant species (Torgerson and Bull 1995), and thus increase foraging quality.

The final foraging HSI score is calculated by taking the arithmetic mean of the four foraging habitat variables.

Roost trees are the final component of the pileated woodpecker model. Bull (1992b) first addressed the importance of nest trees and determined that a density of >0.5/ac was necessary for high suitability. More recent work has further emphasized the role of roost trees in pileated woodpecker ecology (McClelland and McClelland 1999, Aubry and Raley 2002). Table 1 shows how values are assigned for the roosting variable.

The final pileated HSI is calculated with the following formula:

$$Final\ HSI = \frac{(((2 \times Nest\_HSI) \times Forage\_HSI)^{0.33} + Roost\_HSI)/3}{3}$$

Samson (2006) developed a regional wildlife habitat relationship model for pileated woodpecker nesting and winter foraging. The model used dominance group, tree size (for nesting), and snag, log, and stump size (for winter foraging) as variables. The variables used in the habitat suitability model presented here are finer scale than those described for a Samson model, which was designed as a regional wildlife habitat relationship model.
Figure 19. HSI values for pileated woodpecker nesting based on overstory canopy cover of preferred tree species. The equation between 30 and 67 is $y=0.0267x - 0.8$.

Figure 20. HSI values for pileated woodpecker nesting based on density of dead and defective western larch, grand fir, ponderosa pine, and quaking aspen >20 in. DBH and >60 ft. tall. The equation between 3 and 45.6 is $y=0.0235x - 0.0706$. 
Figure 21. HSI values for pileated woodpecker nesting based on density of dead and defective western larch, grand fir, ponderosa pine, and quaking aspen >30 in. DBH and >60 ft. tall. The equation between 0 and 20 is \( y = 0.05x \).

Figure 22. HSI values for pileated woodpecker nesting based on average DBH (cm) of live and dead western larch, grand fir, ponderosa pine, and quaking aspen >20 in. DBH and >60 ft. tall. The equation between 15 and 30 in. is \( y = 0.07x - 1.1 \).
Figure 23. HSI values for pileated woodpecker foraging based on overstory canopy cover. The equation between 16.67 and 50 is $y=0.03x-0.5$ and the equation between 80 and 100 is $y=-0.02x+2.5$.

Figure 24. HSI values for pileated woodpecker foraging based on density of butt-rot and dead trees >20 in. DBH plus stumps >3 ft. tall and >12 in. diameter plus logs >10 in. diameter and >6 ft. long. The equation between 60 and 316 is $y=0.0093x-0.2333$. 
Figure 25. HSI values for pileated woodpecker foraging based on the average DBH (in.) of overstory trees. The equation between 10 and 20 in. is $y=0.00394x-0.2333$.

Figure 26. HSI values for pileated woodpecker foraging based on diversity of log decay classes present within a stand.
Table 1. Calculation of HSI values for pileated woodpecker roosting.

A: Number of trees/ac with pileated cavities
B: Number of true of Douglas fir >20 in. dbh, >50 ft. tall, with fungal conks and old injury above 30 ft.
C: Number of true or Douglas fir >20 in. dbh, >50 ft. tall, with fungal conks but no injury
D: Number of ponderosa pine or western larch that are hollow

If $A + 0.25B + 0.05C + 0.2D$ is:
- 0/ha then $\text{HSI(roost)} = 0.00$
- $>0$ and $<0.5$/ac then $\text{HSI(roost)} = 0.50$
- $>0.5$/ac then $\text{HSI(roost)} = 1.00$
**American Marten (Martes americana)**

The American marten is a medium-sized forest carnivore found throughout the coniferous forest region of northern and western North America (Hall 1981) (Figure 27). Martens are strongly associated with conifers and intolerant of areas lacking overhead cover (Buskirk and Ruggerio 1994). Marten are generally considered to rely on late-successional, mesic forests with large amounts of standing and downed woody material that create complex cover near ground level (Buskirk and Powell 1994). Physical structure near ground level appears to be the most important habitat characteristic as it provides protection from predators, access to subnivean spaces for winter foraging, and thermal cover (Buskirk and Powell 1994). In locations with sufficient overhead cover marten can be found in young stands (<40 years old) and deciduous dominated stands (Poole et al. 2004). Primary prey species for marten include red-backed voles (*Clethrionomys* spp.), pine squirrels (*Tamiasciurus* spp.), and meadow voles (*Microtus* spp.) (Buskirk and Ruggerio 1994). Deer mice (*Peromyscus* spp.) are taken at a lower proportion than their availability and winter habitat with high numbers of deer mice generally have low habitat quality for martens (Buskirk and Ruggerio 1994).

The American marten model is based on the framework described by Allen (1982) with changes based on more recent literature. The first habitat variable in the model is tree canopy cover (Figure 28). Marten in the Intermountain West have been shown to preferentially select areas with high overhead canopy cover and avoid areas with less than 30% canopy cover (Koehler and Hornocker 1977). The odds of detecting marten in southern British Columbia increased with canopy cover (Mowat 2006).

The second variable is relative percent cover of fir and spruce in the overstory tree canopy (Figure 29). Marten most commonly associated with mesic sites characterized by spruce and true fir cover types (Buskirk and Powell 1994, Fecske et al. 2002, Baldwin and Bender 2008). The majority of resting sites used by marten in Oregon were in true fir or spruce (Bull and Heater 2000). Red-backed voles, a primary prey species, are also most common in mesic, spruce/fir dominated stands (Raphael 1989). Ruggiero et al. (1998) found high densities of Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) to be significant for the selection of marten natal den sites.
The third habitat variable is the percent of ground covered by coarse woody debris (CWD) that has a diameter >6 inches (Figure 30). CWD is particularly important in the winter because it creates access points to the subnivean spaces which are important for both foraging and resting sites (Buskirk and Powell 1994). Marten have been shown to have higher foraging success rates on red-backed voles in uncut forests with high amounts of CWD compared to regenerating stands with lower amounts of CWD, but similar population levels of voles (Andruskiw et al. 2008). Sherburne and Bissonette (1994) found both prey densities and marten occurrence increased with increasing percent cover of CWD. CWD is also important for providing natal and maternal den sites (Ruggiero et al. 1998, Bull and Heater 2000).

The fourth model variable is the average diameter of coarse woody debris (CWD) (Figure 31). Larger diameter logs have been linked to increased foraging success for marten (Payer and Harrison 2003). Larger diameter logs also provide greater security for denning females (Patton and Escano 1990, Ruggiero et al. 1998).

The final variable is ecological site and disturbance regime (Figure 32). The ecological site provides a measure of moisture at the site (Patton and Escano 1990) which is important because marten are associated with mesic sites and avoid xeric sites (Buskirk and Powell 1994). Red-backed voles are also most common in mesic, spruce/fir dominated stands (Raphael 1989).

The final HSI for American marten is calculated with the following formula:

\[
\text{Marten HSI} = \left( \left( \text{Canopy Cover HSI} \times \text{Spruce/Fir HSI} \times CWD \text{ Cover HSI} \times CWD \text{ Diameter} \right)^{1/2} \right) \times \text{Ecosite HSI}
\]
Figure 28. HSI values for American marten based on the percent canopy cover of overstory trees. The equation between 25 and 50 is \( y = 0.04x - 1 \).

Figure 29. HSI values for American marten based on the relative percent cover of true fir and spruce that comprise the overstory tree canopy. The equation between 0 and 40 is \( y = 0.0225x + 0.1 \).
Figure 30. HSI values for American marten based on the percent of ground covered by coarse woody debris >6 in. diameter. The equation between 0 and 20 is $y=0.025x+0.5$. The equation between 50 and 100 is $y=0.01x+1.5$.

Figure 31. HSI values for American marten based on the average diameter (in.) of coarse woody debris. The equation between 0 and 8 is $y=0.125x$ and the equation between 30 and 40 is $y=-0.0833x+2.5$. 
Figure 32. HSI values for American marten based on the ecological site of the stand. Ecological sites not listed in the graph received an HSI score of zero.
Hairy Woodpecker (*Picoides villosus*)

The hairy woodpecker is a year-round resident throughout most of North America (Figure 33) and is a primary cavity nester in both coniferous and deciduous forests (AOU 1983). As a cavity nester hairy woodpeckers utilize both living and dead trees for potential nest sites (Thomas et al. 1979, Mannan et al. 1980, Zarnowitz and Manuwal 1985). Both hardwood and softwood snags provide important foraging habitat for breeding and overwintering woodpeckers (Mannan et al. 1980, Weikel and Hayes 1999, Ripper et al. 2007). Hairy woodpeckers have been associated with what were termed old-growth forests (Mannan 1980) and both nesting and foraging use is higher in stands with larger, older trees (Thomas et al. 1979, Zarnowitz and Manuwal 1985, Ripper et al. 2007).

The model for hairy woodpecker is based on initial work done by Sousa (1987) and modified by O’Neil et al. (1988). The model has both a nesting and foraging component. The first variable used in the nesting portion of the model is snag density (Figure 34). Thomas et al. (1979) suggested that a density of 2 snags per acre >10 inches was necessary to provide for maximum occupancy by hairy woodpeckers for nesting.

The second variable for nesting is the mean diameter of overstory trees (Figure 35). A minimum tree size of 10 inches has been suggested for nesting trees (Thomas et al. 1979). However, suitability for nesting has been shown to increase with the average diameter of snags (Mannan et al. 1980, Zarnowitz and Manuwal 1985). Older stands with larger diameter trees also tend to have larger diameter snags and hairy woodpeckers have been shown to select older stands for nesting (Ripper et al. 2007). In Washington the average nest tree had a diameter of 22.8 inches (n=16) (Zarnowitz and Manuwal 1985). Nest trees in Oregon had an average diameter of 36.2 inches (n=7) (Mannan et al. 1980).

The third variable is the canopy cover of the tree overstory (Figure 36). Hairy woodpeckers forage in open areas with snags, but predominately nest in stands with tree cover (Mannan et al. 1980, Zarnowitz and Manuwal 1985). However, they have been shown to avoid nesting in stands that are extremely dense or have complete canopy closure (Verner 1980).
The HSI value for the nesting component was calculated with the following formula:

\[ \text{Nesting HSI} = \text{Snag Density HSI} \times \text{Canopy Cover HSI} + (0.75 \times \text{DBH HSI}) \] - maximum value is 1.0

The foraging component of the hairy woodpecker model uses two habitat variables. The first variable is the mean diameter of overstory trees (Figure 37). Hairy woodpeckers have been shown to selectively forage on larger diameter trees (Weikel and Hayes 1999, Ripper et al. 2007). In Oregon, the mean diameter of tree used for foraging was >23.6 inches (Mannan et al. 1980).

The second variable in the foraging component is the density of foraging sites (Figure 38). Hairy woodpeckers forage on live trees, standing snags, and downed wood (Thomas et al. 1979, Sousa 1987, Weikel and Hayes 1999). Large diameter, heavily decayed logs were the primary selected foraging sites in Oregon (Weikel and Hayes 1999). High densities of foraging sites provide year round food supply and increase the suitability of a site.

The foraging HSI value was calculated by taking the geometric mean of the two foraging variables.

Figure 34. HSI values for hairy woodpecker nesting based on the density of snags ≥ 10 in. dbh per acre. The equation between 0 and 2 is y=0.5x. For snag densities >2/ac the HSI value is 1.0.
Figure 35. HSI values for hairy woodpecker nesting based on the average DBH (in.) of overstory trees. The equation between 8 and 15 is $y=0.1429x-1.1429$.

Figure 36. HSI values for hairy woodpecker nesting based on the canopy cover of overstory trees. The equation between 15 and 85 is $y=0.0143x-0.2143$. The equation between 90 and 100 is $y=-0.02x+2.8$. 
Figure 37. HSI values for hairy woodpecker foraging based on the average DBH (in.) of overstory trees. The equation between 6 and 10 is $y=0.125x-0.25$.

Figure 38. HSI values for hairy woodpecker foraging based on the density of snags >10 in., stumps >1.5 ft. tall and >10 in. diameter and logs >10 in. diameter and >6 ft. long. The equation between 60 and 330 is $y=0.0037x-0.2211$.

MODEL OUTPUTS
Habitat suitability maps were generated for each of the 6 selected wildlife species as examples of the types of output that these models will produce. Habitat values for each variable were assigned to each VMAP classification. The assigned values were selected to be in the general range of what might be expected to occur within that VMAP classification, but were not considered to be an actual value to use in future modeling, rather, they were selected as place holders to demonstrate the types of outputs the models will produce. Actual values to use in the models will be generated from the sampled data on treatment sites and on the follow up wildlife monitoring project that will analyze actual plot data collected within VMAP classification categories. In addition, home range quality maps were generated using the methods of Roloff and Haufler (1997, 2002) for northern goshawks and pileated woodpeckers to demonstrate how the application of habitat-based species viability analysis can be conducted.

The habitat suitability index (HSI) map for fisher is displayed in Figure 39, flammulated owl in Figure 40, northern goshawk foraging (Figure 41) and nesting (Figure 42), American marten (Figure 43), pileated woodpecker foraging (Figure 44), pileated woodpecker nesting (Figure 45), hairy woodpecker foraging (Figure 46), and hairy woodpecker nesting (Figure 47).

![Fisher HSI Values](image)

Figure 39. Example habitat suitability map for fisher habitat in the SWCC project area.
Figure 40. Example habitat suitability map for flammulated owls in the SWCC project area.

Figure 41. Example habitat suitability map for northern goshawk foraging habitat in the SWCC project area.
Figure 42. Example habitat suitability map for northern goshawk nesting habitat in the SWCC project area.

Figure 43. Example habitat suitability map for American marten in the SWCC project area
Figure 44. Example habitat suitability map for pileated woodpecker foraging habitat in the SWCC project area.

Figure 45. Example habitat suitability map for pileated woodpecker nesting habitat in the SWCC project area.
Figure 46. Example habitat suitability map for hairy woodpecker foraging habitat in the SWCC project area.

Figure 47. Example habitat suitability map for hairy woodpecker nesting habitat in the SWCC project area.
Figure 48 displays the example home range quality map generated for northern goshawks in the SWCC project area. This map displays that an estimate (example only) of 99 potential high quality home ranges, 476 potential medium quality home ranges, and 44 potential low quality home ranges occur across the SWCC project area. This methodology when applied using actual sampled data would produce an estimate of how project treatments influence the number and quality of home ranges for this species in the SWCC project area or any other selected landscape of interest. For the pileated woodpecker, the example habitat-based species viability output is displayed in Figure 49. This figure indicates 5 high quality, 95 medium quality, and 220 low quality home ranges within the SWCC project area for this species.

Figure 48. Example of an output map for potential home ranges for northern goshawk within the SWCC project area.
Figure 49. Example of an output map for potential home ranges for pileated woodpeckers in the SWCC project area.
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