Wildlife and Diversity Analyses in Support of the Kaibab National Forest Land Management Plan Revision

Prepared for the U.S. Forest Service by The Nature Conservancy

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Introduction

The Nature Conservancy was approached by the Kaibab National Forest with an interest in further understanding several analyses undertaken for the White Mountains Stewardship Project's 5-Year Report. Over the course of a number of discussions with the Kaibab National Forest, a project emerged that focused on assisting the Forest with targeted spatial analyses that would support their forest's Land Management Plan revision. These analyses fall into three main topics: 1) Comparing current aggregation of tree arrangement (post-treatment) to historic spatial aggregation that existed on the forest prior to Euro-American settlement; 2) Comparing current wildlife habitat connectivity under the existing forest LMP to the proposed treatments identified under the proposed draft LMP; 3) Evaluating avian habitat association models to determine factors driving the occurrence of potential management indicator species. These analyses were completed in cooperation with Forest Service personnel and expert review of connectivity models.

Evaluating Historic Spatial Structure

Over the past decade, forest treatments have shifted focus from purely fire and fuels objectives to restoring forest structure, function and processes that existed during presettlement times. With the increased implementation of forest treatments across the landscape, there has been a growing interest in emphasizing the creation of horizontal and vertical heterogeneity in forest structure. The concept of a patchy structure made up of small clumps of trees that form larger groups in a matrix of forest gaps or openings has been gaining momentum as a management strategy in ponderosa pine vegetation types. Given the inherent difficulty in measuring this type of forest structure, there has been little examination of how to quantify and statistically test differences in forest structure among ponderosa pine stands.

In order to understand the spatial arrangement and degree of aggregation in presettlement trees (e.g., trees > 120 years old), a total of eight 20-acre plots were surveyed to determine the range of natural variability that occurred across the forest. Previous research has shown that the degree of aggregation varies among soil types and moisture regimes (Abella and Denton 2009). Limestone soils were sampled on the North Kaibab Ranger District, and basalt soils on the Williams Ranger District. These areas were chosen because these soil types represent the majority of area on the Forest. It is also likely that the majority of treatments proposed over the coming decade will occur in these areas as well. By understanding the spatial arrangement of pre-settlement trees, we can better design projects to reflect the presettlement conditions, and evaluate progress towards the desired conditions. This survey and analysis will help inform future forest restoration treatments based on our improved understanding about the degree of aggregation in tree structure that existed historically.

Methods

To gain a site specific understanding of the relationship between size (diameter at breast height; dbh) and age, more than 80 trees on each District (a minimum of 20 trees at each grid) were cored. Trees were cored at a downward angle near the base of the tree to provide the best opportunity to reach the oldest part of the tree. Tree age was assessed in the field and cores were retained for additional analysis. These data were collected to help the survey crew "calibrate" their selection of pre-settlement evidences/trees during the mapping data collection.

Sampling grids were located in a GIS environment, and using the X-Y coordinates of the North-West corner, the sampling grids were established in the field. Surveyors used a rangefinder and compass to lay out each sampling grid. Each point within the grid was then recorded using a Trimble GPS unit and differentially corrected for improved accuracy. Four grids were established on the Williams Ranger District (~20 acres each) and an additional four grids were established on the North Kaibab Ranger District. All sampling grids were located in the ponderosa pine forest type, where minimal logging and other management activities that would disturb the pre-settlement evidence were minimal. Within each sampling grid, surveyors mapped the location of all remnant evidences found, which included live trees, standing dead trees or snags, logs and stumps. In addition, the total tree height, crown base height, vigor class and/or decay class were also recorded. These additional variables were collected for any future analyses that the Kaibab National Forest may want to pursue in assessment of fire behavior in pre-settlement stands, or other data gaps not yet identified.

Field collected mapping data was then used to capture variation in spatial structure across the landscape. Each subsample was 9 hectares (300 m x 300 m; 22.2 acres) in size. Once areas were mapped and data entered, the X-Y coordinates of each evidences identified were then computed to identify the aggregation patterns. The Ripley's K function was run using program R v.2.8.0 (www.r-project.org). A 2 m (6.5 ft) lag distance with a maximum distance of 150 m, half the length of the sample plot, was used for this analysis.

Results and Discussion

As has been determined previously by other authors (Abella et al 2006), tree size was a weaker predictor of age on the Williams Ranger District, probably due to high density of trees and its suppressive effect on tree height and incremental growth. However, physical characteristics of old growth trees (yellow, platy bark; flat tops) were observed in the field, and, while slightly subjective, were verified for all trees determined to be of pre-settlement age (i.e., greater than 120 years old) by coring.

Size was determined to be a moderate predictor of age on the North Kaibab Ranger District. Given the management implemented at each district and the more intact fire regime on the North Kaibab, these results are as would be expected. Similar to the Williams Ranger District, trees sampled on the North Kaibab of pre-settlement age also exhibited old growth characteristics.

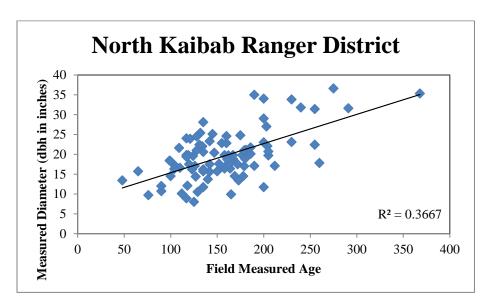


Figure 1 Scatter plot of field-measured diameter and age of trees sampled on the North Kaibab Ranger District

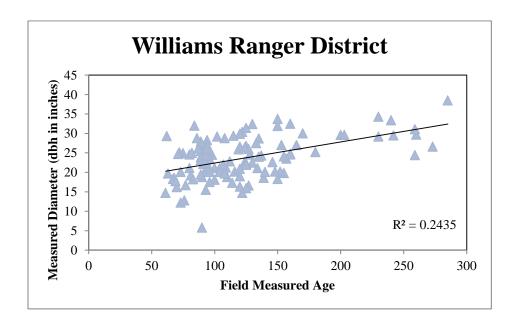
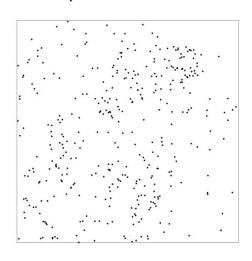


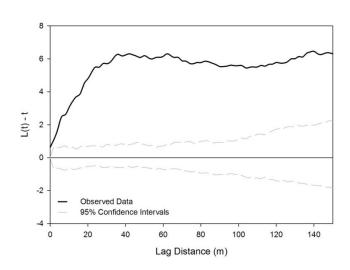
Figure 2 Scatter plot of field-measured diameter and age of trees sampled on the Williams Ranger District

The above figures (Figure 1 and Figure 2) show subsampled plots of trees evaluated on the Williams and the North Kaibab Ranger Districts. The figures below (Figure 3 and Figure 4) include a stem map created from the field mapping data, and spatial test results for the evaluated areas. The first panel shows the stem map created in the GIS environment from field data collected. The second panel is the statistical results of the Ripley's K function for that sample. To interpret this output, the solid line illustrates the observed spatial arrangement of trees within that subsample. The dotted lines show the 95% confidence interval for the observed function. When the observed data line is above the 95% confidence interval, it shows that forest structure is clustered at that lag distance. When the observed data line is in between both 95% confidence intervals, the trees are randomly distributed. When the observed data line is below the 95% confidence interval, it shows that the trees are evenly spaced.

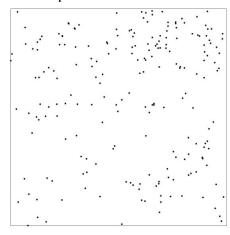
North Kaibab Spatial Structure (Limestone soils)

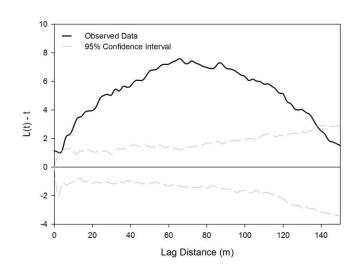
Subsample A





Subsample B





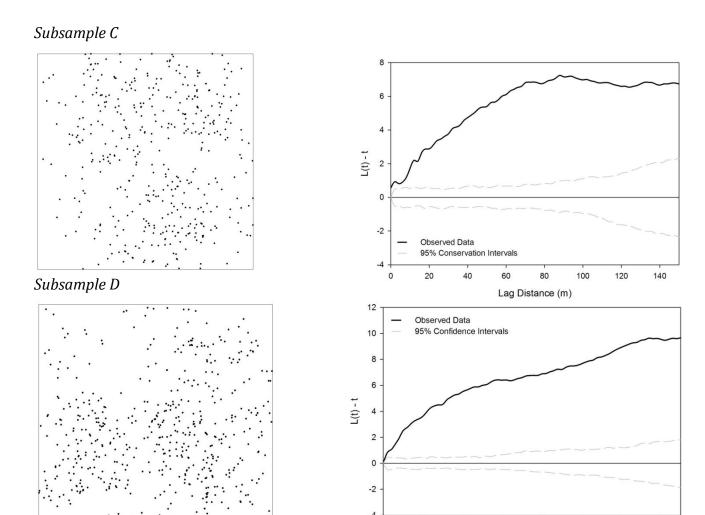


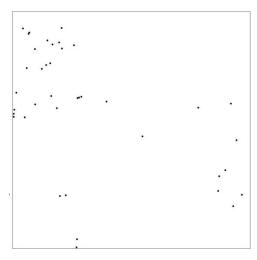
Figure 3 Tree stem maps and Ripley's K function for plots found on limestone soils on the North Kaibab Ranger District. For interpretation, please see text above.

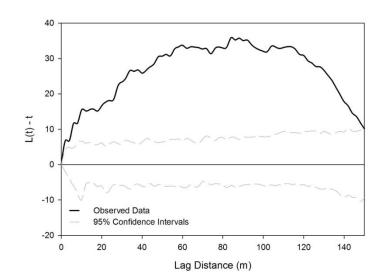
0

20

Williams Ranger District Spatial Structure (Basalt soils)

Subsample A





100

Lag Distance (m)

140

Subsample B

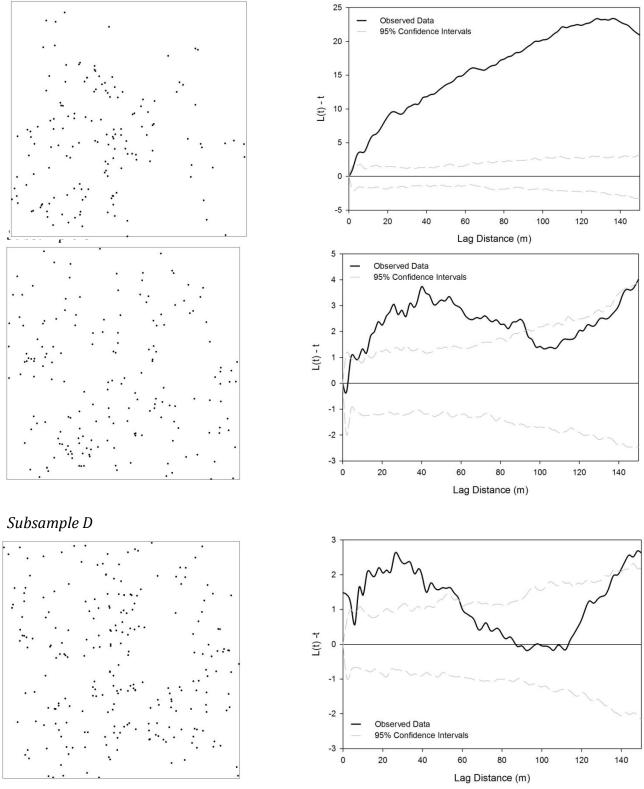


Figure 4 Tree stem maps and Ripley's K function for plots found on basalt soils on the Williams Ranger District. For interpretation, please see text above.

The results of the spatial aggregation statistical test show considerable variation in spatial patterns across the areas sampled. The areas sampled on the North Kaibab Ranger District tend to have a slightly higher moister regime compared to the Williams Ranger District. This increased level of precipitation tends to increase productivity on this portion of the Forest. Overall, the North Kaibab Ranger District samples had on average more than twice as many trees per plot than the Williams Ranger District. The North Kaibab samples also exhibit a strong pattern of clustering at nearly all lag distances. The stem maps from the North Kaibab illustrate small clumps of trees that aggregate into larger groups. There are also several natural openings present in the forest structure at these sites that would create a variety of habitats for native plants and animals.

On the Williams Ranger District, there was a high degree of variability among the replicate plots. While all plots on this district exhibit some degree of aggregation, two plots transition to a random distribution after 60-100m lag distance. The other sampling areas show strong aggregation at all lag distances. These patterns illustrate the degree of variation that existed in historic stands on the Kaibab National Forest, not only between soil types, but also within soil types. After further investigation into the placement of subplot A on the Williams District, it was determined that this area was historically a pine savanna rather than a pine forest, and bordered historic grassland. This sample area illustrates a single forest structure likely to be replicated under future restoration treatments. The other sampling areas on this district more accurately represent historic pine forest spatial structure.

To further understand the spatial patterns in historic stand structure found on this study's field sampling sites, several descriptive statistics were calculated to quantify the existing patterns. The minimum, maximum, and average distance to the nearest neighbor tree within 30 meters were calculated. A distance of 30 meters was used as a cut-off point to illustrate the stand structure within a group-level. The minimum distance and average distance to the nearest neighbor tree was determined to be greater on the Williams subplots when compared to the North Kaibab subplots. However, the maximum distance (up to 30 m) to the nearest neighbor tree was higher on the North Kaibab. This provides additional evidence that there were different spatial structures among the sampling areas.

Subsample	Min. Distance to Nearest Tree (m)	Max. Distance to Nearest Tree (m)	Avg. Distance to Nearest Tree (m; ± SD)	Number of Trees in subsample	
North Kaibab Ranger District					
Subsample A	0	29.50	6.54 ± 4.83	377	
Subsample B	0	29.75	8.82 ± 5.70	209	
Subsample C	0.47	25.33	6.81 ± 4.42	426	
Subsample D	0.12	26.27	5.55 ± 3.70	392	
Williams Ranger District					
Subsample A	1.8	21.70	9.11 ± 7.08	39	
Subsample B	0.29	28.67	8.56 ± 5.78	152	
Subsample C	0.43	28.13	10.67 ± 6.14	178	
Subsample D	0	24.69	8.50 ± 5.43	243	

Table 1 Descriptive statistics for distances between trees on subsampled plots within the North Kaibab and Williams Ranger Districts

Quantifiable metrics such as these descriptive statistics could be used in the development of future restoration projects in the thinning prescription. For example, if managers wanted to restore an area that historically was a pine savanna, the thinning prescription might provide a range of distances for leave trees.

Name of Treatment: Full Restoration to Savanna

<u>Treatment Objectives</u>: 1) Maintain and enhance pine savannah conditions; 2) Create antelope access corridors; 3) Improve distribution and production of wildlife forage and browse.

<u>Marking Guide</u>: Leave 1 to 2 ponderosa pine replacement trees for each pre-settlement evidence found (live trees, standing dead, logs or stumps). Retain all yellow pine.

Generally, select the largest, oldest, fullest crowned pine for retention but leave some younger vigorous ponderosa pine to represent a younger age class. Distances between trees can range from 2 to 22 meters with an average distance to the nearest tree of 10 meters. An average of 2 trees per acre left in small clumps or groups. Interlocking canopies is encouraged for small clumps.

Do not remove all mistletoe infected blackjack ponderosa pines. Dwarf mistletoe infected pine can be selected for retention over non-infected pine if the infected tree is clearly the most dominant tree available.

Evaluating Current Spatial Structure

Forest treatments have been implemented across the forest for many years. The objectives and goals of these forest treatments has shifted focus from timber production to fire and fuels management, and now to restoration of ecological function. Because of these shifting objectives, the types of treatments and resulting stand structure has varied over the years. To better understand how contemporary conditions contrast with past spatial patterns and how recent management has changed the trajectory of forest growth, the resulting spatial patterns of recently implemented forest treatments were compared to the historic pattern. This comparison could inform what changes need to be made in future forest treatments to better meet desired conditions and restore historic forest structure on the Kaibab National Forest.

Methods

To examine tree aggregation patterns, a quantitative assessment of the resulting structure following thinning treatments and controls was compared to the historic range of variability using the Ripley's K function. This function statistically analyzes spatial patterns between pairs of points within *t* radial lag distance. It tests the degree of spatial aggregation of the remaining trees on the sample plots, to determine whether the treatments resulted in an evenly-spaced, random, or aggregated (clumpy) forest structure.

Cutting units or task orders within two project areas, Frenchy and Spring Valley, representing various treatment prescriptions and soil types were selected for examination of tree aggregation patterns. A minimum of three subsamples were located within each cutting unit analyzed. Each subsample was 4 hectares (200 m x 200 m; 9.88 acres) in size. Individual trees were identified by their spectral reflectance signature from high-resolution aerial

photographs using a supervised training algorithm in the Feature Analyst tool in a GIS environment. Each subsample was then visually inspected to verify that all trees were identified properly. Post-processing of the polygon boundaries, smoothing of features and conversion to centroid point locations were completed for each subsample. The X-Y coordinates of each stem were then computed to identify the aggregation patterns. The Ripley's K function was run using program R v.2.8.0 (www.r-project.org). A 2 m (6.5 ft) lag distance with a maximum distance of 100 m (328 ft), half the length of the sample plot, was used for this analysis.

Results and Discussion

The Ripley's K spatial test is a tool that can be used to quantify the spatial arrangement of trees across the landscape. As treatments include more structural heterogeneity at various scales, this statistical test will help the Kaibab NF achieve its desired conditions. This test allows the Forest to verify the degree to which the forest structure described in the thinning prescription was achieved on-the-ground, and to also evaluate heterogeneity of an untreated area.

The following figures (5-7) show subsamples evaluated at a control/untreated site (Burnt Saddle), and two treated project areas (Spring Valley and Frenchy) on the Kaibab National Forest. These figures include an aerial photograph, stem map, and spatial test results for the evaluated control and treatment areas. The first panel shows the aerial photograph of the sample plot. The center panel depicts the stem map created in the GIS environment from that aerial photograph. The third panel is the statistical results of the Ripley's K function for that sample. To interpret this output, the solid line illustrates the observed spatial arrangement of trees within that subsample. The dotted lines show the 95% confidence interval for the observed function. When the observed line is above the 95% confidence interval, it shows that forest structure is clustered at that lag distance. When the observed line is in between both 95% confidence intervals, the trees are randomly distributed. When the observation line is below the 95% confidence interval, it shows that the trees are evenly spaced.

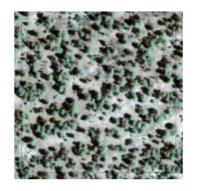
For the Burnt Saddle control (Figure 5), aggregation patterns were evaluated at five subsamples in unit 5. There was a high degree of variation among subsamples within a single untreated stand, demonstrating the importance of scale on heterogeneity. In three of the five subsamples the spatial pattern shows evenly distributed trees within the stand. In subsample A there was an evenly spaced pattern at small distances (0-15m) and large distances (75-100m). Conversely, a high degree of spatial aggregation exists in subsample D, which indicates a continuous canopy layer in this portion of the stand as is apparent from Figure 5 subsample D.

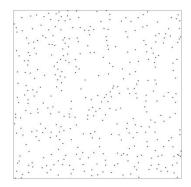
The areas sampled within the Spring Valley project also illustrate a high degree of variation in the resulting spatial patterns (Figure 6). In subsample A, B and D there is a strong aggregation of trees, leaving moderate openings. Subsample C shows some clustering of trees between 20 and 60 meters and then transitions into a randomly distributed pattern. Similarly, subsample E also shows a random pattern over the majority of distances measured.

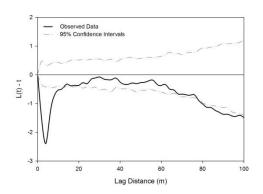
Similar patterns were found within the Frenchy project area (Figure 7). Subsamples A-D all show an aggregated spatial pattern that transition into random distribution of trees across the sample area. Subsample E shows a random pattern over the majority of distances measured.

Burnt Saddle Untreated/Control Units

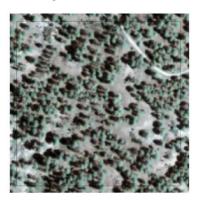
Subsample A

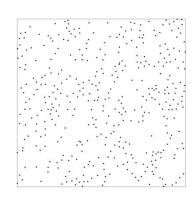


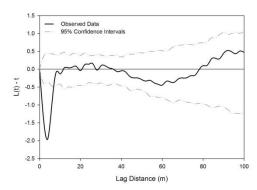




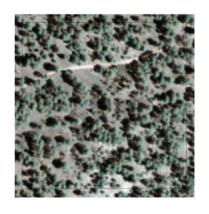
Subsample B

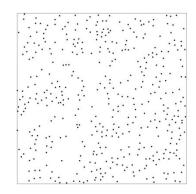


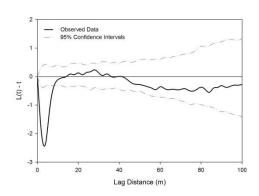




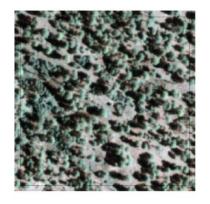
Subsample C

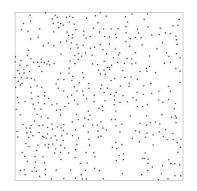


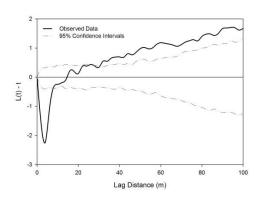




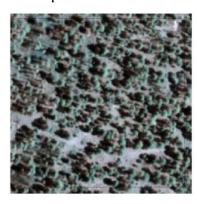
Subsample D

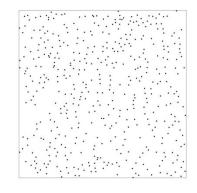






Subsample E





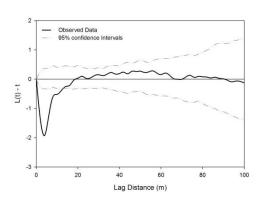
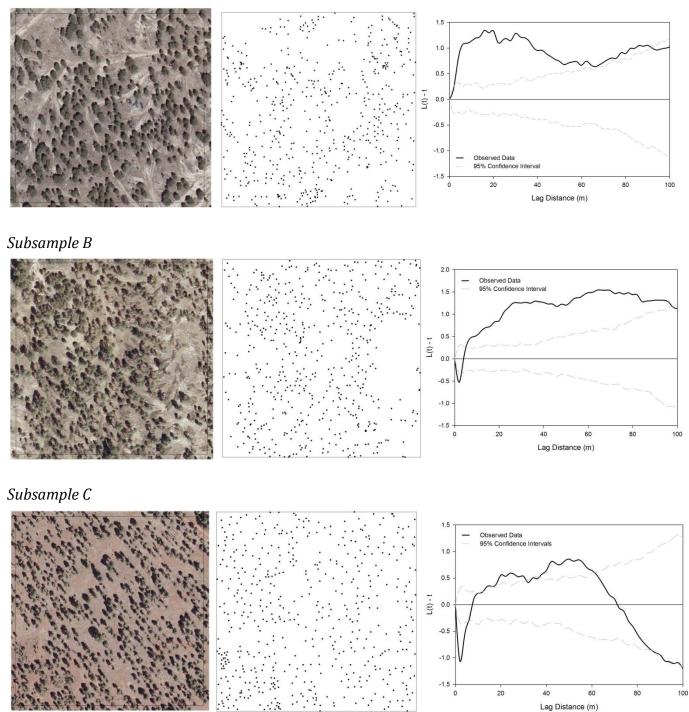


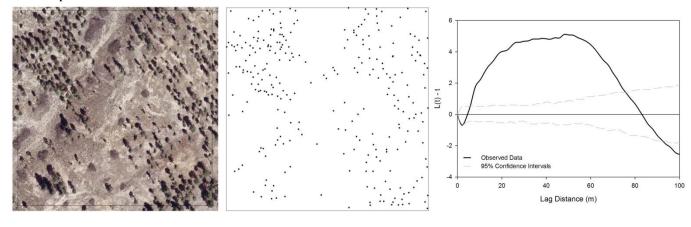
Figure 5 Spatial patterning and statistics for Burnt Saddle Untreated/Control Unit

Spring Valley Treatment Units

Subsample A



Subsample D



Subsample E

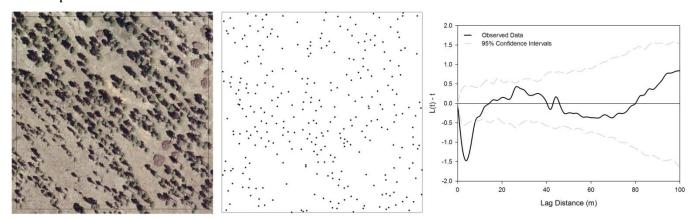
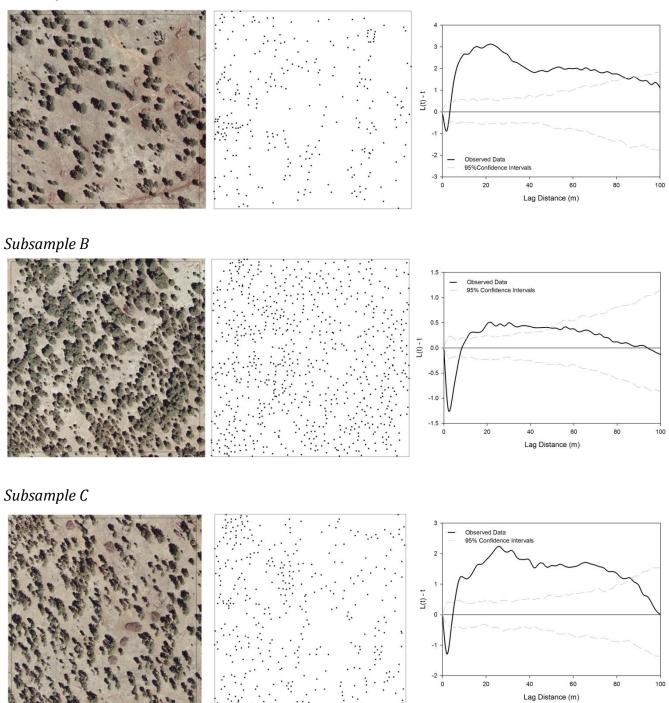


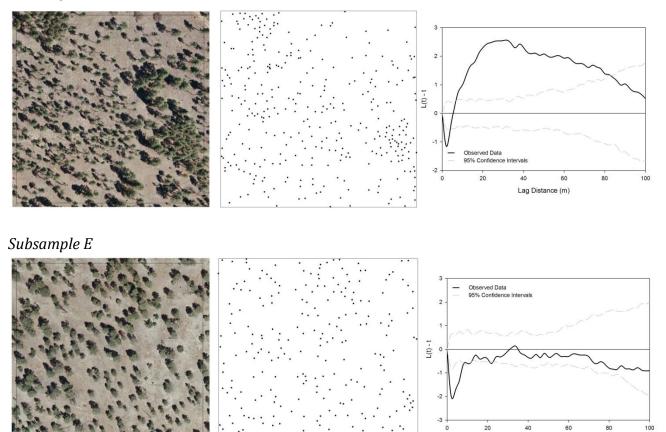
Figure 6 Spatial patterning and statistics for Spring Valley Treatment Unit

Frenchy Treatment Units

Subsample A



Subsample D



Lag Distance (m)

Figure 7 Spatial patterning and statistics for Frenchy Treatment Unit

Summary

While clustering does occur on the control (e.g. Burnt Saddle) and the sites most recently treated (e.g. Spring Valley and Frenchy), comparing the stem maps to the historic distribution (Figures 3 and 4), there are still improvements that can be made in the resulting forest structure. Looking at the stem maps and aerial photographs of the evaluated areas shows that there is some degree of evenly spaced trees occurring between the clumps and groups. When looking at the stem maps of the historic structure there is less even distribution across the sample area. Additional investigation into sizes of openings and distance among clumps and groups will provide supplementary quantitative parameters to include into thinning prescriptions that will help recreate the forest structure that existed prior to Euro-American settlement.

Evaluating Wildlife Habitat Connectivity

Vegetation structural characteristics and composition are frequently used to define wildlife habitat needs. A few of the metrics used to examine wildlife habitat include spatial heterogeneity, structural diversity, and vegetation temporal dynamics (Zenner and Hibbs 2000). Variation in these metrics across the landscape, in patches of optimal, sub-optimal, and deficient habitat, are what allows species to co-exist and be sustainable over time (Rosenzweig 1981). Wildlife population dynamics are likely to be modified by restoration treatments that influence wildlife habitat (Block et al. 2001). Given that restoration treatment implementation rates are expected to increase over the life of the Kaibab National Forest Land Management Plan (LMP), it is important to understand how these treatments would influence species of management interest and their habitat. The scale at which these changes occur relative to the species of interest is also important in assessing the potential impacts. Previous research has shown that the concepts of ecological scaling, fragmentation, patch sizes, and the ability to move between optimal habitats are important in assessing potential species' responses to potential disturbances (Wiens 1989; Kotliar and Wiens 1990; Battin and Sisk 2003). Therefore, it is important to evaluate habitat connectivity at a scale appropriate to the species of interest.

This study utilized a patch delineation algorithm called PatchMorph (Evan Girvetz; http://arcscripts.esri.com) to characterize functionally connected habitat for two focal species. The PatchMorph algorithm allows for the use of natural history characteristics specific to the focal species to inform the threshold values for habitat suitability, habitat gaps, and habitat spurs on the landscape. In this algorithm, a gap is defined as an area of non-suitable habitat that is included in the patch when it is less than the threshold thickness (Girvetz and Greco 2007; Girvetz and Greco 2009). The gap distance is a measure of the distance across unsuitable habitat that an organism would normally move through to access another area of suitable habitat. A spur then is an area of suitable habitat that is excluded from the patch when it is narrower than the specified threshold thickness (Girvetz and Greco 2007). The spur threshold can be thought of as a measure of the minimum thickness of a "core area" of suitable habitat. By using a range of gap and spur distances, PatchMorph creates a configuration of suitable habitat across a range of spatial scales through an iterative process (Girvetz and Greco 2007). By overlaying the range of gap and spur distances, PatchMorph creates a connectivity surface that can be used to evaluate and visually display the functionally connected habitat for a given species (Girvetz and Greco 2007). This algorithm was chosen to evaluate the potential impacts of restoration treatments on the Kaibab National Forest because it has been successful in identifying habitat patches for restoration of other wildlife species (Girvetz and Greco 2009).

Focal Species

Two focal species were selected by the Kaibab National Forests (KNF) with consideration of comments provided by The Nature Conservancy (TNC) and other environmental organizations. The focal species are the Abert's squirrel (*Sciurus aberti*) and the American pronghorn (*Antilocapra americana americana*). A literature review was completed for each species to determine gap and spur thresholds based on the natural history of the species and to inform the habitat suitability characteristics for a variety of forest and grassland restoration treatments

that are proposed under the draft LMP. Draft models were developed based on information and attributes gleaned from the literature. All models were reviewed by species experts, and model parameters were modified based on comments received.

The analysis extent for each species was determined by the target areas identified in the Kaibab National Forests "need for change" section of the proposed LMP. All proposed grassland restoration projects are on the Williams Ranger District, therefore the District boundary was used as the analysis extent for pronghorn. Additionally, because this species is wide-ranging, a broader spatial scale was appropriate to address connectivity concerns. Forest restoration in the ponderosa pine type is focused on areas identified as priority for treatment by the community-based Kaibab Forest Health Focus (KFHF) process (weblinks here: USFS and NAU). These priority areas served as the analysis extent to evaluate habitat connectivity for Abert's squirrels. The Sycamore Rim area was identified as the fourth-level priority in the KFHF on the Williams Ranger District. This area was excluded from the Abert's squirrel analysis area because it is predominantly a pine-oak vegetation type, which is not as frequently utilized by this species.

Pronghorn Habitat Needs

The American pronghorn (*Antilocapra americana americana*) is a large ungulate that was once common throughout the West. Known as the fastest land mammal in North America, the pronghorn is built for speed which is used to escape predators. Though frequently referred to as an antelope, it is not related to true antelope found in the Old World and is the only surviving member of the family Antilocapridea. While the populations of this species were once abundant in the state of Arizona, pronghorn have been identified as a species of concern by the Arizona Game and Fish Department (AGFD) because they no longer inhabit all of their former range (Ockenfels et al. 1996). Habitat loss, fragmentation, and the reduction of habitat quality are all factors thought to influence abundance, distribution and recruitment in pronghorn populations (McKinney et al. 2008).

Pronghorn are most frequently found in grassland and shrub-steppe habitats, with some populations utilizing open woodlands, forests and desert habitats (Ockenfels et al. 2002). Previous research has found that pronghorn will utilize relatively small openings in forests and woodlands but spend the majority of their time in areas with low visual obstructions (Ockenfels et al. 2002). Pronghorn most frequently use gentle terrain with slopes less than 5% and generally avoid habitats with slopes greater than 40% (Waddell et al. 2005). While they don't frequently occupy areas with high tree densities, pronghorn will move through other vegetation types such as pinyon-juniper woodland and ponderosa pine forests (Ockenfels et al. 2002). These movement corridors between preferred habitat types (i.e., open grasslands) become particularly important during winter months when pronghorn move to lower elevation rangelands. The connectivity of this elevational gradient is critical to their survival during this period (Ockenfels et al. 2002).

Restoration of grasslands has been targeted by the Kaibab National Forest to improve habitats for grassland obligate species like the pronghorn. Populations of pronghorn have been particularly impacted from grassland encroachment by woodland and forest tree species,

habitat fragmentation through the creation of barriers such as fences and roadways, and changes in grassland species composition (Ockenfels et al. 1996). Pronghorn are notoriously nervous animals that commonly won't cross fences or roadways. Radio telemetry data frequently identifies this problem by showing a distinct line of occurrences that match up with an existing highway, or pasture fence. Pronghorn will not jump fences like other native ungulates; they may crawl under the bottom wire if enough clearance is available. These human-created barriers impede migration and seasonal movements, further fragmenting their available habitat. Restoration efforts have been focused on removing tree encroachment to grasslands, shrublands and savannas and retrofitting fence lines to create "pronghorn friendly fences" (e.g., a non-barbed bottom wire, 18 inches above the ground) to restore habitat connectivity for this species of concern.

Pronghorn Model Parameters

The Williams Ranger District will serve as the analysis extent to evaluate the current and proposed habitat connectivity for pronghorn. Current vegetation was based on stand-level data provided by the Kaibab National Forest. Slope data was downloaded from LANDFIRE (30 m pixels) and classified into categories pertinent to pronghorn based on information gleaned from the scientific literature. Pronghorn movement locations (GIS point layers) were obtained from the Arizona Game and Fish Department, which were used to identify frequent movement corridors between commonly used grassland habitats. The Kaibab National Forest has proposed approximately 50,000 acres of grassland restoration over the life of the proposed LMP. The areas established for grassland restoration were identified based on the AGFD pronghorn movement data and the potential natural vegetation type. More specifically, if there was an area that was historically grassland or savanna (<10% canopy cover) that is now classified as forest or woodland, and pronghorn movement data showed that the species moves through the area, it was identified as a restoration priority. In total, 54,998 acres were identified for grassland restoration and are shown on the proposed vegetation type map as grasslands.

The Williams Ranger District includes a variety of vegetation types ranging from grasslands to mixed conifer and spruce-fir forests. Each vegetation type was assigned a suitability value based on the preferred habitat characteristics determined by previous research. Slope is another factor identified in previous research as an important habitat characteristic that pronghorn key into. Classified slope categories are also included as a factor in the connectivity model. Additionally, large highways such as Interstate 40, State Route 64, and State Highway 89, were selected as barriers to movement for this species, as identified as such in the connectivity model.

Table 2 (below) outlines what habitat suitability values were assigned to each variation of the factors outlined above. Gap and spur distances ranged from 3 km to 5 km and were evaluated in 1 km increments with an output cell size of 500m.

Vegetation type	Slope category	Suitability value assigned
Grassland	< 10%	100
Grassland	10 – 20%	75
Grassland	> 20%	50
Shrublands	< 10%	100
Shrublands	10 – 20%	75
Shrublands	> 20%	50
Pinyon-Juniper	< 20%	25
Pinyon-Juniper	> 20%	0
All other vegetation types	Any	0
Any	> 40%	0

Table 2 Vegetation type, slope category, and suitability value for pronghorn habitat modeling

Pronghorn Modeling Results and Discussion

The model based on vegetation type and slope accurately predicted commonly used grasslands by pronghorn (Figure 8). When the AGFD movement locations were overlaid on top of the connectivity surface, the two layers were in alignment (Figure 9). The current suitability model suggests a lack of connectivity across all major highways and between Government Prairie and the farthest north portion of the district. As one moves north on the district the elevation drops, and this northern area is currently not sufficiently connected to the southern part of the district for this species.

When the proposed grassland restoration priority areas are included in the model, there was a dramatic increase in functionally connected habitat across the district (Figures 10 and 11). Highways continue to be an issue as they are still a substantial barrier to pronghorn movement. However, this model may provide additional information for the Kaibab National Forest to collaborate on future road improvement projects. Additionally, this model suggests a vast improvement in habitat connectivity between Garland Prairie and primary grassland habitat farther to the east, and between Government Prairie and grassland habitat at the north end of the district. Implementing these grassland restoration treatments in the identified priority areas would likely re-establish important movement corridors.

One aspect of pronghorn habitat that was not included in these models, but should be further considered is habitat quality. Previous research has shown that grassland species composition play an important role in pronghorn health, reproduction, and survival (Ockenfels

et al. 2002). Unfortunately, data for habitat quality were not available at the scale that was undertaken by this analysis. As broad scale spatial information that characterizes grassland quality become available, this model could be reevaluated to include this information. Furthermore, it was suggested by one of the expert reviewers that habitat connectivity for this species should be represented as it could exist without barriers to movement. For the purpose of full exploration of the data available, the results have been included with (Figures 12-13) and without (Figures 8-11) physical barriers to pronghorn movement.

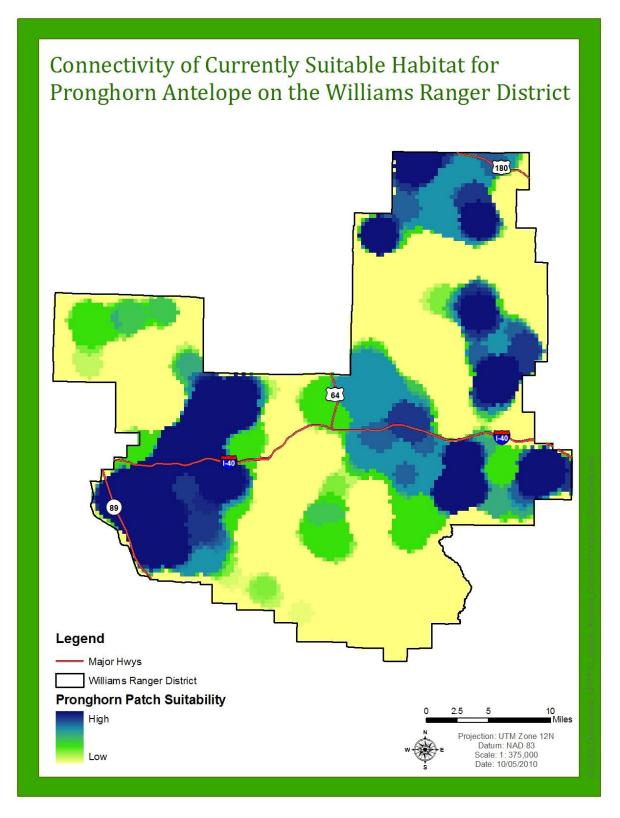


Figure 8 Map of Pronghorn patch current suitability for American pronghorn on the Williams Ranger District

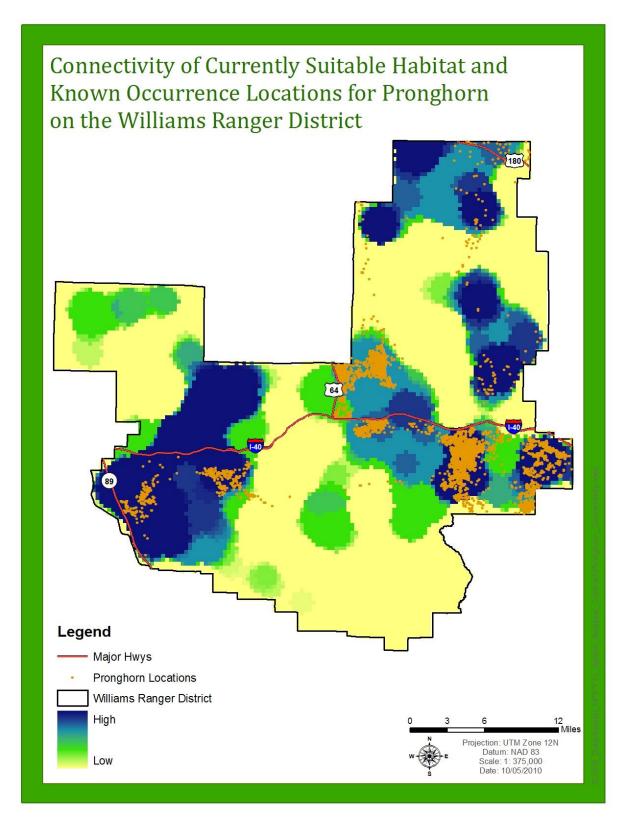


Figure 9 Connectivity of currently suitable habitat and known occurrence locations for pronghorn on the Williams Ranger District

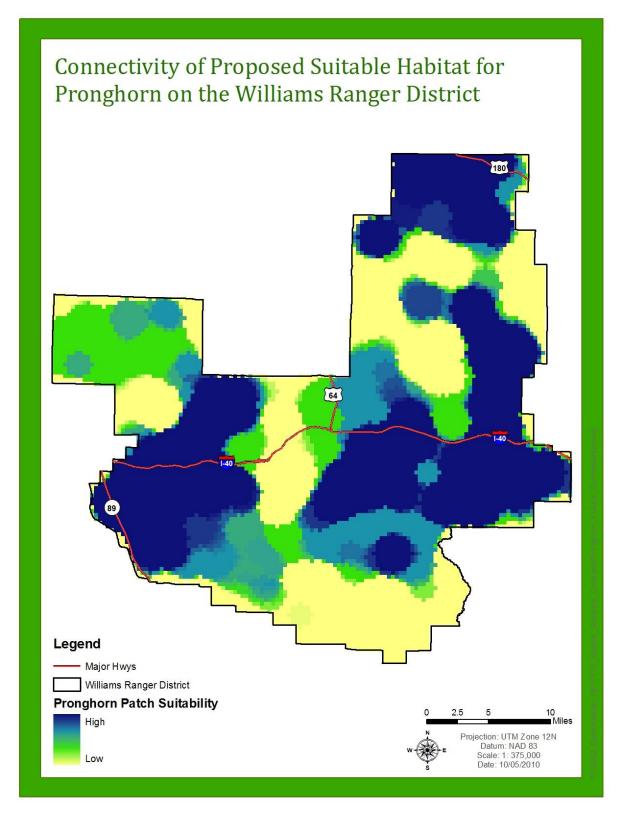


Figure 10 Connectivity of proposed suitable habitat for American pronghorn on the Williams Ranger District

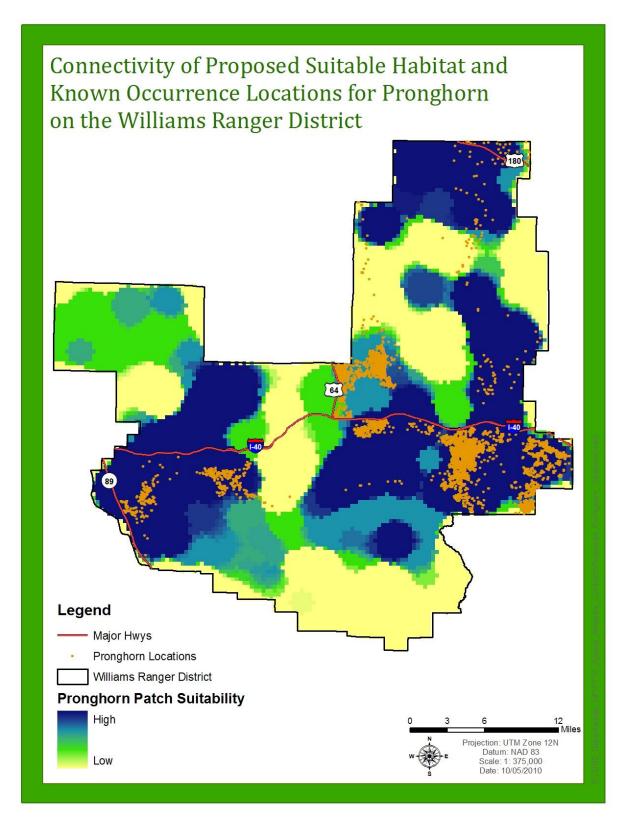


Figure 11 Connectivity of proposed suitable habitat and known occurrence locations for American pronghorn on the Williams Ranger District

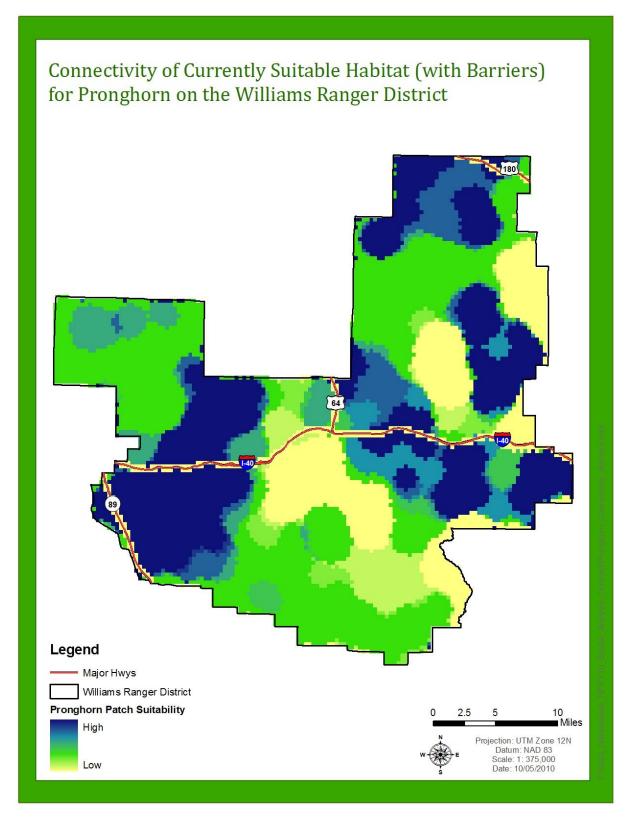


Figure 12 Connectivity of proposed suitable habitat with barriers for American pronghorn on the Williams Ranger District

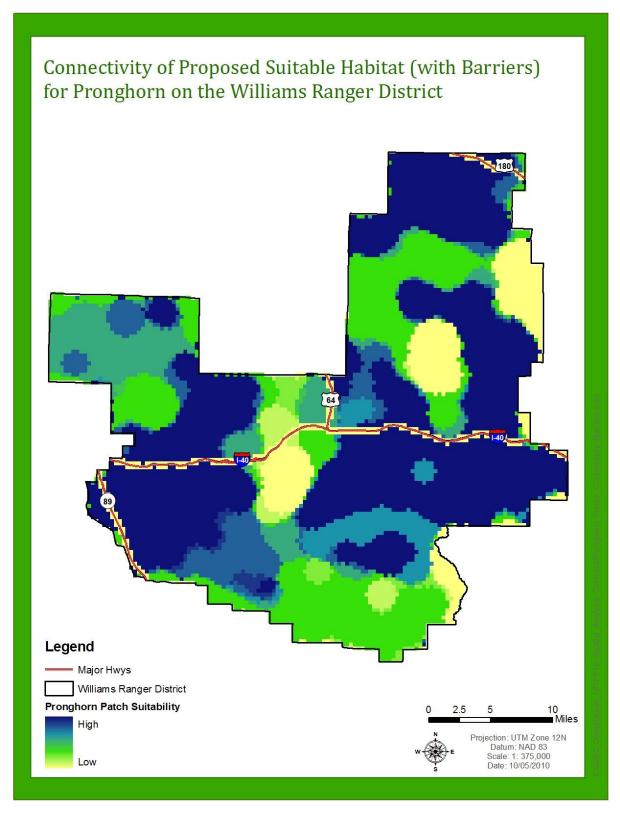


Figure 13 Connectivity of proposed suitable habitat with barriers for American pronghorn on the Williams Ranger District

Abert's Squirrel Habitat Needs

The Abert's Squirrel (*Sciurus aberti*), also known as the tassel-eared squirrel, inhabits ponderosa pine (*Pinus ponderosa*) and mixed-conifer forests in the southwestern U.S. and Mexico. They are distributed across the Colorado Plateau and the southern Rockies of Colorado, Utah, Arizona and New Mexico (Keith 1965). Populations are also known to exist in the Sierra Madre Occidental of Chihuahua and Durango, Mexico (Keith 1965). The Abert's squirrel is a ponderosa pine obligate species, meaning that it is dependent on this species of pine for its foraging and nesting requirements (Patton 1984; Dodd et al. 2003; 2006; Prather et al 2006).

The Abert's squirrel is a large (weighing ~ 680-900 grams) diurnal species that requires foraging resources associated with ponderosa pine trees, which include the inner bark of twigs, pollen, seed and hypogeous fungi associated with the roots (Burt and Grossenheider 1976; Patton 1984). Like many small mammals, there is an important symbiotic relationship between squirrels and the conifer species that make-up their habitat. Squirrels and other small mammals consume the underground fruiting bodies of mycorrhizal fungi (i.e., truffles), which are an important seasonal food resource that then passes through their digestive system unharmed, and fungal spores are dispersed by the squirrel (States and Gaud 1997; Dodd et al. 2003; 2006; Prather et al. 2006). Previous research has shown that mycorrhizal associations are beneficial to ponderosa pine seedling establishment and survival (States and Gaud 1997). The Abert's squirrel is unique in that it does not store food over winter, so high quality habitat that provides foraging resources during the winter is important to their survival (Patton 1984). These squirrels are also dependent on ponderosa pine trees for nest building sites, cover, rest and protection from weather and predators (Patton 1984). The Abert's squirrel is also an important prey resource for the northern goshawk (Accipiter gentilis; Dodd et al. 2003; 2006; Prather et al. 2006), a species of great management interest and one that is also thought to be affected by forest management activities.

Abert's Squirrel Model Parameters

Abert's squirrels are highly dependent on forest structural characteristics. This species prefers habitat with areas of high basal area, canopy cover and interlocking branches. Research has shown that Abert's squirrels prefer habitat with a high density of mature trees at the fine scale (Dodd et al. 2006) and patches greater than 160 ha with more than 40% canopy cover (Prather et al. 2006). Dodd et al. (2003) also found that clumps of trees need to have a minimum of 3 trees with interlocking canopy. These areas that retain interlocking canopy in an aggregated clump create the necessary microclimate that promotes the production of fungi, a valuable seasonal food resource (States and Gaud 1997; Dodd et al. 2003). High quality habitat for Abert's squirrels can be summed up as a multi-aged stand with a well defined large tree component (50+ trees/ha; > 45cm dbh), a basal area of > 35 m²/ha and canopy cover of 50% or more (Dodd et al. 2006). Low quality habitat can be described as even-aged stands with few large trees (< 20 trees/ha) with a basal areas of < 18m²/ha and canopy cover of less than 30% (Dodd et al. 2006). These forest structural characteristics are likely to be impacted by forest treatments, which may reduce the quantity of high quality habitat available to squirrels (Dodd et al. 2006).

While forest restoration treatments may seem to directly contradict the habitat needs of Abert's squirrels, it is not necessarily so as there is a difference in scale. Dodd and his coauthors (2003) have suggested that squirrels may take advantage of open areas that receive thinning treatments that promote cone production when these areas are adjacent to higher-quality habitats. Squirrels may benefit from a mosaic of structural characteristics and patch sizes, such that intermediate proportions of high quality habitat (40 - 50%) are intermixed with other forest structural characteristics (Dodd et al. 2003; 2006). Group or single-tree selection harvest will maintain or even improve uneven-aged forest structure that is preferred by squirrels (Patton 1984). However, it is when forest treatments severely reduce basal area and areas of interlocking canopy negatively impact squirrel habitat and have been shown to reduce recruitment (Dodd et al. 2003). Other treatments that maintain an even-aged forest structure such as shelterwood cuts should be minimized to limit impact of treatments on squirrel habitat (Patton 1984). Thus at the fine scale, it is important to maintain both closed and open patches for squirrel habitat, and at the mid- and coarse-scale, heterogeneity of open and closed patches should benefit Abert's squirrels while meeting other objectives.

Given that Abert's squirrels are not territorial like some other species of tree squirrels (Farentinos 1979; Halloran and Bekoff 2000; Edelman and Koprowski 2006), habitat use and home range size is a little more difficult to ascertain. Previous research has found 0.42 ± 0.02 squirrels/ha in high quality habitat, with 2.5 times fewer squirrels in lower quality habitat (Patton 1984; Dodd et al. 2006). Juveniles have also been recorded frequently moving distances up to 1.5 km (Farentinos 1972). The home range of this species has been estimated at 7.8 to 14.2 ha (Dodd et al. 2006). Research completed by Loberger in 2009 found that the mean core area used by squirrels in winter was three times smaller than non-winter core areas $(1.1 \text{ ha} \pm 0.16 \text{ SD}, 3.48 \text{ ha} \pm 0.82 \text{ SD respectively})$. Similarly, the home range for winter areas was more than 60% smaller than non-winter home ranges (Loberger 2009). The Abert's squirrel home range size has also been shown to increase in harvested areas, indicating a reduction in habitat quality (Patton 1984). This information provided by the literature was used to inform the PatchMorph models. The home range size was used to inform the minimum spur distance of 400 m and the maximum spur distance of 2000 m. The frequent travel distance was also used as an approximation of the maximum gap distance and 0 to 1600 m was used for the range in the model.

Vegetation type	Treatment Status	Suitability value assigned
Aspen	Any	0
Grassland	Any	0
Lakes/Ponds/Tanks	Any	0
Oak Woodlands	Any	0
Mixed Conifer	Untreated	0
Mixed Conifer	Treated	25
Shrublands	Any	0
Spruce/Fir	Any	0
All other types	Any	0
Pinyon-Juniper	Treatment edge (up to 60 m)	25
Pinyon-Juniper	Core (treated or untreated)	0
Ponderosa Pine	Meadow Restoration	0
Ponderosa Pine	Treated with even spacing; BA <100 ft²/ac	25
Ponderosa Pine	Treated with variable spacing; BA >80ft²/ac	50
Ponderosa Pine	Untreated	75
Ponderosa Pine	Treated clumpy/ groupy; BA >80 ft²/ac	100
Ponderosa Pine	Pre-commercial thin	100
Ponderosa Pine	Wildfire edge (up to 120 m)	25
Ponderosa Pine	Treatment edge (up to 120 m)	50

Table 3 Vegetation type, treatment status, and assigned suitability value for the Abert's squirrel habitat suitability model

Abert's Squirrel Modeling Results and Discussion

It was determined that forest treatments that retain an aggregated structure provide suitable habitat for Abert's squirrels. The majority of previous treatments implemented on the Kaibab National Forest were early timber harvesting projects, but have now transitioned into ecologically-based treatments with irregular spacing that maintain some level of interlocking canopies. On the Williams Ranger District within the KFHF priority area, connectivity of the current habitat structure seems modest (Figure 14) There were no large patches of highly suitable habitat present within the areas examined. Several natural grasslands account for some of the patchiness of the forested habitat potentially available for squirrels. However, there was a general level of functionally connected habitat across the areas that are currently forested. Under the proposed LMP, a concern on the Williams Ranger District was the restoration of grassland and savanna habitat. Areas that were identified for grassland restoration for the pronghorn habitat connectivity model were also included in the proposed vegetation and included in the assessment of future connectivity for squirrels. The increase in connectedness of grasslands directly impacts the connectivity of the Abert's squirrel within the

analysis area (Figure 15). A patch of suitable habitat north and west of Government Prairie becomes completely isolated due to the targeted grassland restoration. However, the model also suggests that areas of pine habitat that were previously untreated have an increased suitability value and functional connectivity around the intersection of Highway 64 and Interstate 40. Through an iterative process of adjusting the layout and selection of grassland restoration projects, the Forest could balance the needs of both species. By changing the alignment of a few grassland restoration projects, the isolated island of squirrel habitat could maintain connectivity with the larger patches of suitable squirrel habitat.

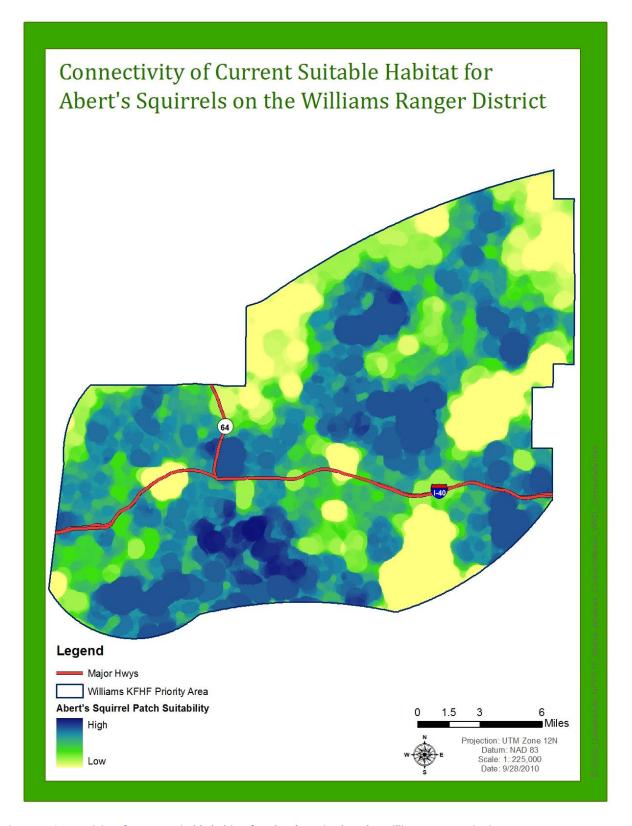


Figure 14 Connectivity of current suitable habitat for Abert's squirrel on the Williams Ranger District

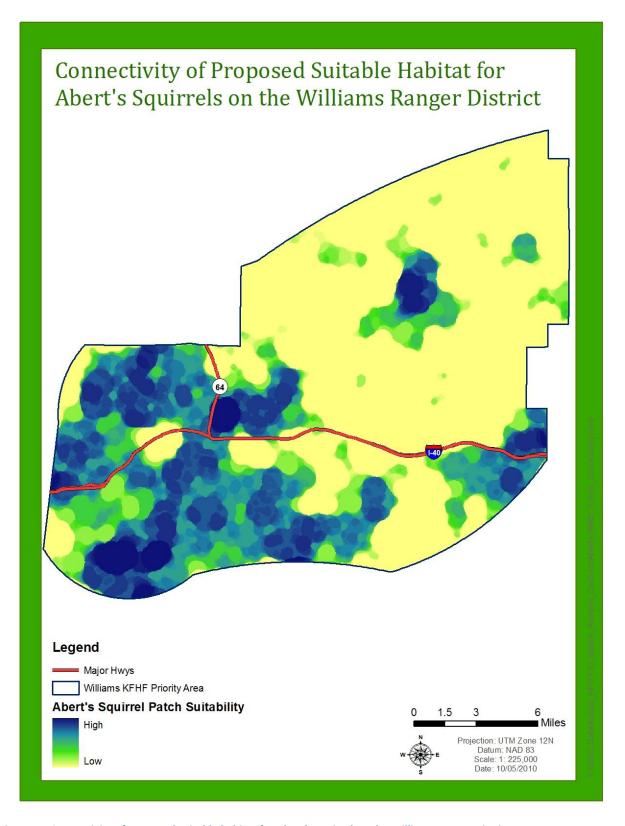


Figure 15 Connectivity of proposed suitable habitat for Abert's squirrel on the Williams Ranger District

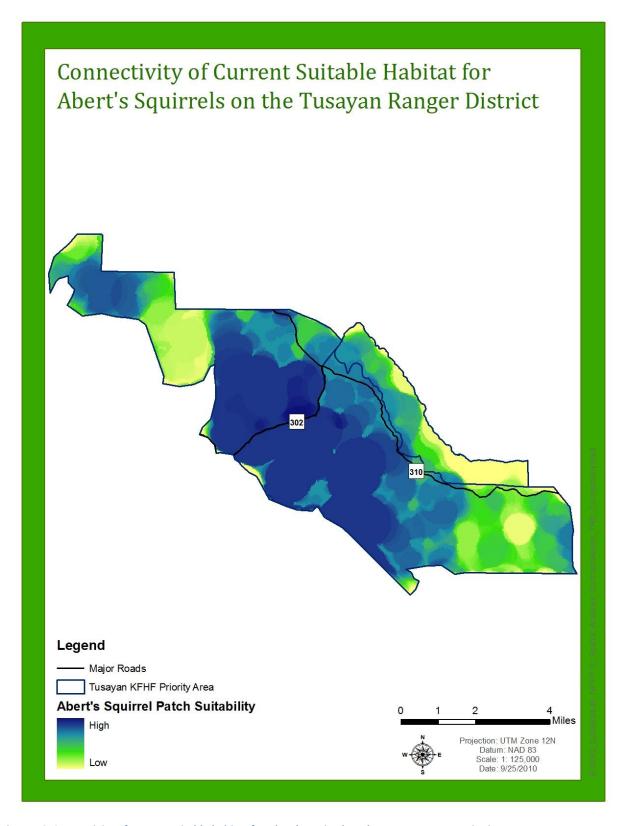


Figure 16 Connectivity of current suitable habitat for Abert's squirrel on the Tusayan Ranger District

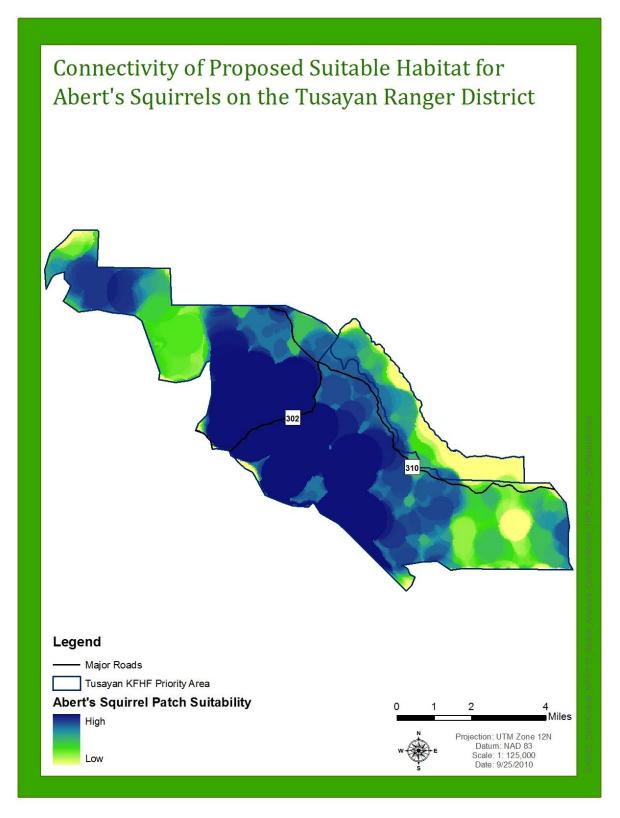


Figure 17 Connectivity of proposed suitable habitat for Abert's squirrel on the Tusayan Ranger District

Tusayan District Analysis

The pine forests on the Tusayan Ranger District have had a different management history than pine forests on the other districts. Because of the remote nature of this district, there was much less commercial timber harvesting pressure. Similarly, the structure has been maintained mostly through prescribed fire treatments or wildfire use for resource benefit given that there are few communities and infrastructure that could be damaged by fire. The current conditions connectivity model (Figure 16) suggests that squirrel habitat was well connected across the area analyzed. The exception to this is where the pine forest transitions to pinyon-juniper woodlands. These areas are not suitable habitat for Abert's squirrels and are represented in the yellow tones on the model output. The proposed LMP includes additional thinning and prescribed fire treatments in the ponderosa pine vegetation type in the areas identified during the KFHF as a priority. No significant vegetation type-shift is expected to occur as a result of the proposed treatment (unlike the currently forested areas being converted back to historic grasslands on the Williams Ranger District). Given no major changes in vegetation types within the analysis area, the model of the proposed condition (Figure 17) suggested improvement in habitat suitability and a slight increase in functional connectivity. The patch of suitable habitat in the north-west corner of the analysis area show some level of isolation in the current conditions model and in the future conditions model due to a wildfire that burned through the area several years ago. While this patch of suitable habitat appears to be isolated, there are additional areas of pine forest on either side of the analysis area that my help to connect this seemingly isolated patch. Further analysis and layout design of pine forest restoration treatments could benefit from expanding the analysis area to include all ponderosa pine stands on the District.

Evaluating Avian Habitat Association Models

National forests are required to manage for wildlife habitat and viable populations of native species. This in-turn necessitates the Forest Service to monitor and maintain these populations in light of their management actions. Many wildlife species are difficult to monitor, and assessments of population trends can be problematic. Songbirds however, are relatively easy to detect during the breeding season. The Kaibab National Forest has been monitoring its avian community populations for years through survey efforts stratified by vegetation communities. Previous research established a strong association between the occurrence of songbird species and the habitat that they most frequently utilize (Buehler et al. 2005). In developing a spatially explicit avian-habitat model, these researchers were able to predict the population viability of a fairly long list of songbirds across several national forest units. The analyses presented by Buehler and colleagues were developed as part of their LMP revision process and were the bases for the analyses completed for the Kaibab National Forest.

Methods

Songbird surveys were completed by the Rocky Mountain Bird Observatory on behalf of the Kaibab National Forest. Surveys were completed under standardized point-count protocols using distance sampling methods. Our goal was to develop a spatially-explicit habitat model that predicted the changes in population trends due to various management actions (e.g., forest treatments). Originally, five species were chosen for this analysis. One mixed conifer species, the ruby-crowned kinglet; three ponderosa pine species, the Grace's warbler, hairy woodpecker and the western bluebird; and one grassland species, the vesper sparrow. These species were chosen based on their relative abundance and ties to a specific habitat/vegetation type and their sensitivity to proposed management actions, as documented by the literature.

Habitat variables and topographic features were derived from a variety of sources (Table 4). Forest stand conditions were grown to present using FVS by Forest Service personnel. Several topographic features were included as variables, which were either downloaded from LANDFIRE or derived from LANDFIRE data (i.e., topographic roughness). Forest habitat and topographic features included were assigned to individual songbird survey points. Survey locations that did not have associated stand structure data were excluded from analysis. Occurrence data for the focal suit of species was from 2009 only.

Many habitat features are known to be correlated and therefore affect model performance. A correlation matrix was calculated to identify variables that may need to be removed. We found that several of the variables were in fact correlated with a correlation coefficient > 0.60. After discussions with biologists at the Kaibab National Forest, two factors were removed from the analysis (latitude and stand density index). Several variables that were identified as correlated were retained in the model because from an avian habitat perspective they might represent differences in resulting habitat features or could be utilized differently by different species (canopy cover, basal area, and trees per acre). A stepwise (mixed forward and backward) logistic regression was used with a P < 0.250 to enter the model and P < 0.10 to stay

in the model. These habitat models were built to predict the likelihood of a species specific occurrence based on 28 explanatory variables (Table 1).

Variable Description	Source
Elevation (m)	LANDFIRE
Slope (%)	LANDFIRE
Aspect	LANDFIRE
Topographic Roughness	Derived from LANDFIRE elevation data
Latitude	Derived from RMBO survey points
Distance to nearest water body	Derived from USFS data
Distance to nearest wildfire (2000-2009)	Derived from USFS data
Potential Natural Vegetation Type – Mixed Conifer	USFS Data
Potential Natural Vegetation Type – Pine/Oak	USFS Data
Potential Natural Vegetation Type – Grasslands	USFS Data
Potential Natural Vegetation Type – Ponderosa Pine	USFS Data
Potential Natural Vegetation Type – Spruce/Fir	USFS Data
Quadratic Mean Diameter – FVS Stand Data	Provided by the Kaibab National Forest
Average trees per acre – FVS Stand Data	Provided by the Kaibab National Forest
Trees per acre > 24 in. – FVS Stand Data	Provided by the Kaibab National Forest
Trees per acre 16 – 24 in. – FVS Stand Data	Provided by the Kaibab National Forest
Trees per acre 8 – 16 in. – FVS Stand Data	Provided by the Kaibab National Forest
Trees per acre < 8 in. – FVS Stand Data	Provided by the Kaibab National Forest
Average Canopy Cover – FVS Stand Data	Provided by the Kaibab National Forest
Canopy cover > 24 in. – FVS Stand Data	Provided by the Kaibab National Forest
Canopy cover 16 – 24 in. – FVS Stand Data	Provided by the Kaibab National Forest
Canopy cover 8 – 16 in. – FVS Stand Data	Provided by the Kaibab National Forest
Canopy cover < 8 in. – FVS Stand Data	Provided by the Kaibab National Forest
Average Basal Area – FVS Stand Data	Provided by the Kaibab National Forest
Basal Area > 24 in. – FVS Stand Data	Provided by the Kaibab National Forest
Basal Area 16 – 24 in. – FVS Stand Data	Provided by the Kaibab National Forest
Basal Area 8 – 16 in. – FVS Stand Data	Provided by the Kaibab National Forest
Basal Area < 8 in. – FVS Stand Data	Provided by the Kaibab National Forest

Table 4 Topographic and habitat variables used to construct avian habitat association models for the Kaibab National Forest

Results and Discussion

The habitat association model for ruby-crowned kinglets in the mixed conifer vegetation type was a weak predictor of occurrence. The stepwise regression identified elevation, topographic roughness, average trees per acre, canopy cover of trees < 8 in., and aspect as the variables that best predicted the occurrence of this species. However the overall regression

model only explained 17% of the variation in the data ($R^2 = 0.17$; P < 0.001). These results suggest that a more thorough review of this species habitat needs is necessary to include better predictor variable in future analyses. However, topographic features appear to be important, indicating that these features may create a microclimate necessary or preferred by this species.

The habitat association model for Grace's warbler in the ponderosa pine vegetation type was also a weak predictor of occurrence. The stepwise regression identified elevation, distance to nearest wildfire, trees per acre in the largest size class and a negative correlation with trees per acre in the smallest size class, and a negative correlation in the mixed conifer potential natural vegetation type as the variables that best predicted the occurrence of this species. The model also included basal area at the largest and smallest size classes. While still not a strong occurrence predictor, the warbler model performed better than the mixed conifer species model. The overall regression model explained 23% of the variation in the data ($R^2 = 0.23$; P < 0.001). Several of these predictor variables align nicely with habitat characteristics know to be used by Grace's warblers. For example, Grace's warblers are a foliage gleaner, therefore would benefit from large, mature trees that often have a variety of foraging options. In addition, this species is commonly found in recently burned areas that experienced low-intensity fire effects. While this model provided some information as to the habitat characteristics that may predict warbler occurrence, future modeling efforts completed by the Kaibab National forest may want to include more species specific predictor variables to improve model power.

The regression model produced for hairy woodpeckers in ponderosa pine forest has strong predictive value. The stepwise regression model selected distance to fire and basal area of 16-24 in trees. These results are perfectly explained by the preferred foraging and nesting habitat characteristics required by this species. The overall regression model explained 53% of the variation in the data ($R^2 = 0.53$; P < 0.001). Another variable that may improve this model would likely be fire severity. When District wide stand characteristic data become available, we suggest including this model in future spatially-explicit predictive analyses.

The regression model produced to predict western bluebird occurrence showed moderate success. The stepwise regression model selected distance to fire and distance to water as the primary drivers of occurrence in this species. While both habitat features align with known requirements for this species, the overall regression model only explained 33% of the variation data ($R^2 = 0.33$; P < 0.001). Other habitat features that may improve this model include proximity to opening in canopy, snag density or understory diversity. This suggests that if these types of habitat characteristics data become available then the model should include these features for increased predictive value.

In 2011, these analyses were repeated and refined using spatially-explicit occupancy models in an information theoretic approach context (i.e. AIC). These methods provide more robust results and a tighter association between on the ground vegetation structural covariates likely to be manipulated through forest management activities, and the species of interest. There was concurrence between the most significant predictor variables (e.g. canopy cover, basal area, TPA) between both modeling efforts; however, occupancy estimates are often less variable than those estimates of abundance or density providing increased power for detecting

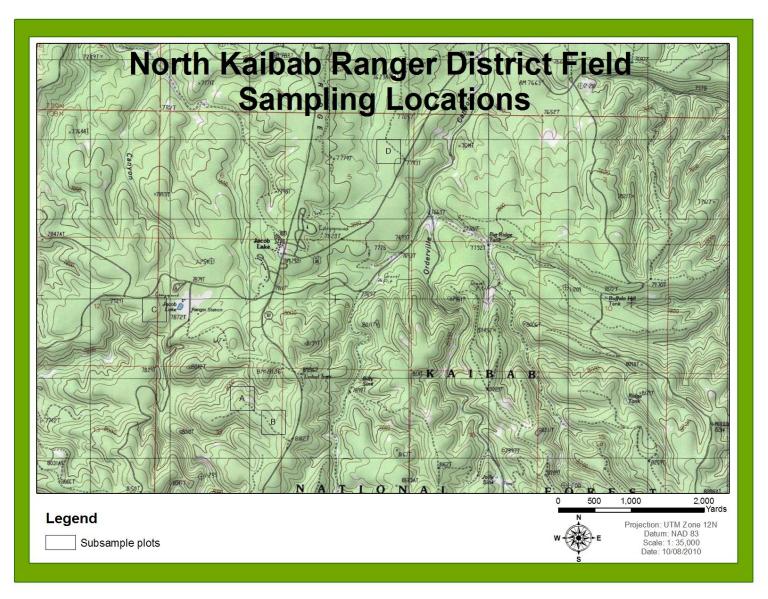
relationships between species and forest structural attributes. Further, the (generally) increased precision of occupancy estimates allows for more efficient detection of trends as monitoring is conducted in the future (see Williamson and Dickson 2011, and Dickson et al. 2011). Lastly, the spatially explicit nature of the occupancy approach used here provides site specific information on the current status of these species on the Kaibab National Forest.

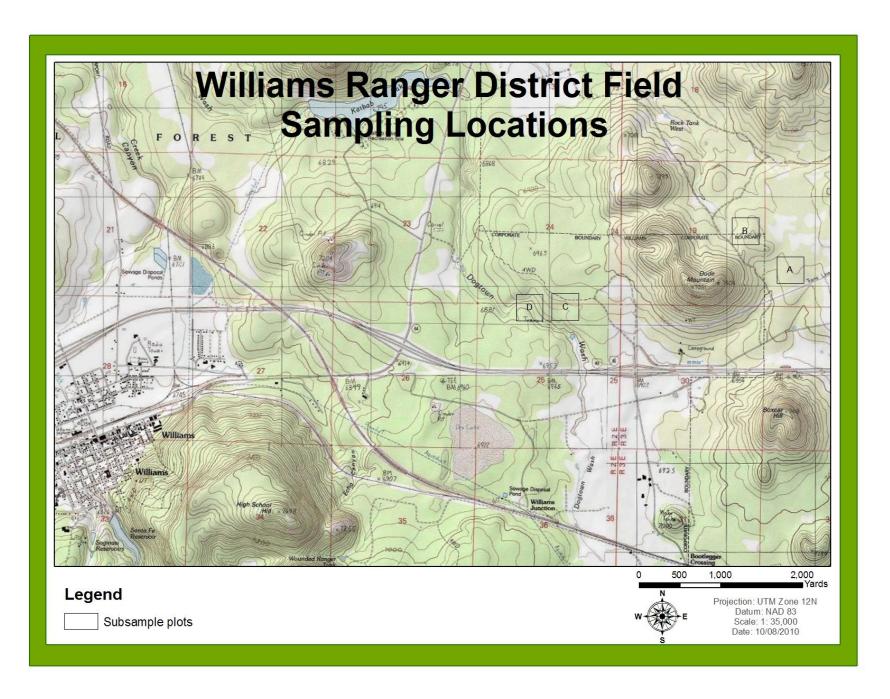
Literature Cited

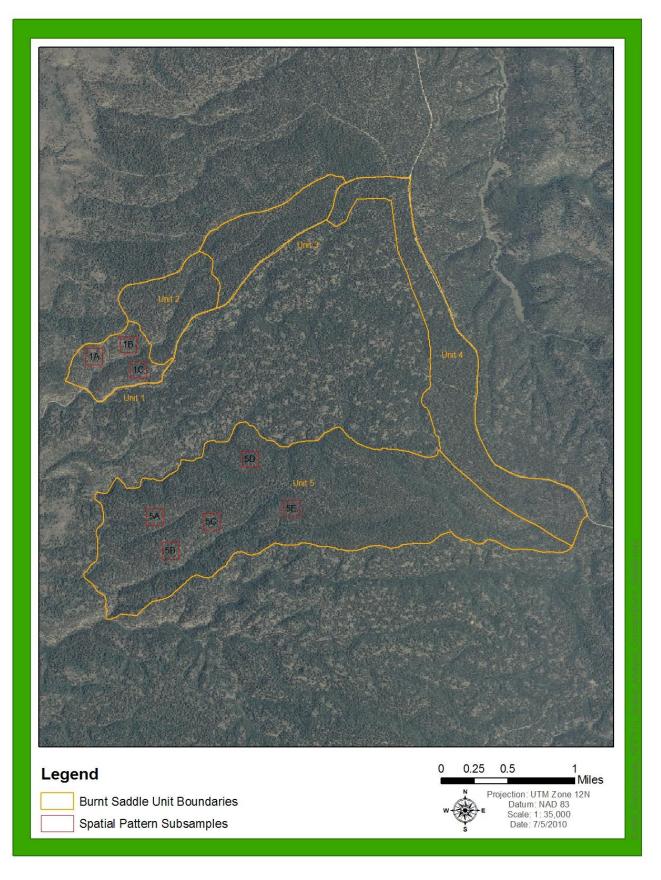
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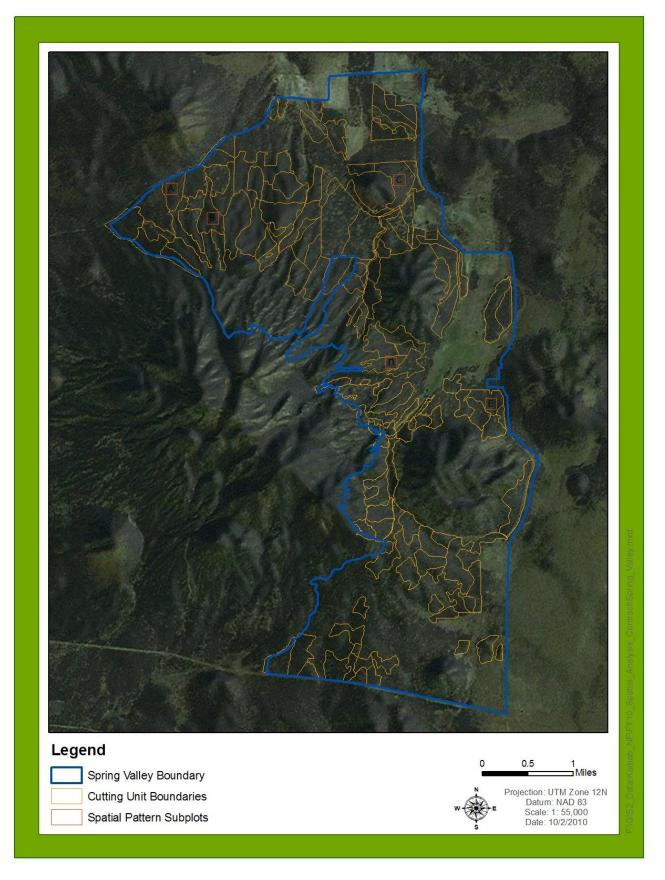
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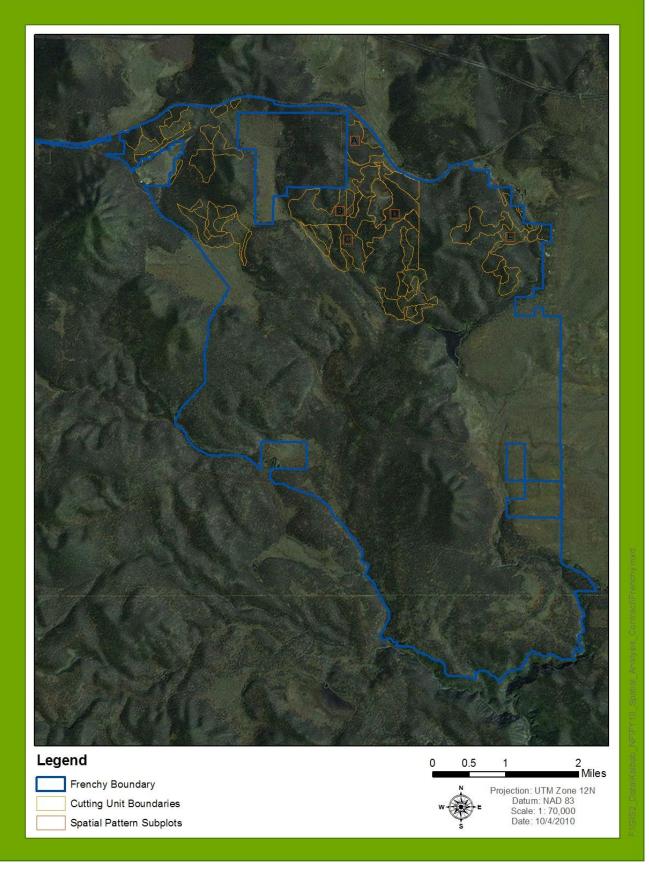
Appendix 1: Spatial Pattern Subsample Locations





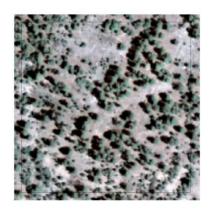


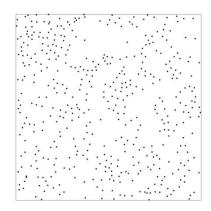


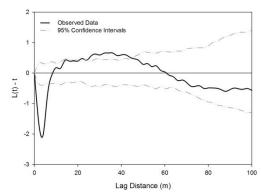


Additional Sites Tested: Burnt Saddle Control Unit 1

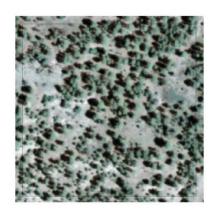
Subsample A

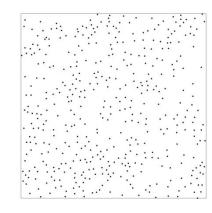


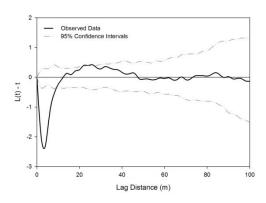




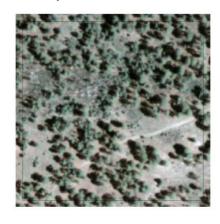
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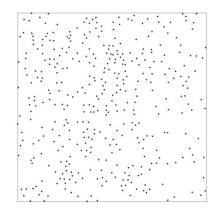


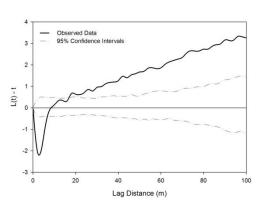




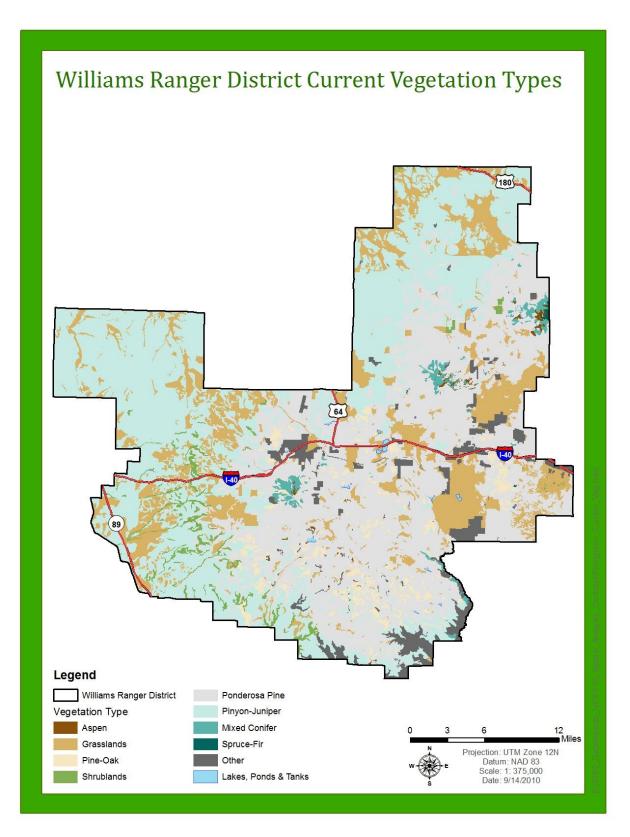
Subsample C

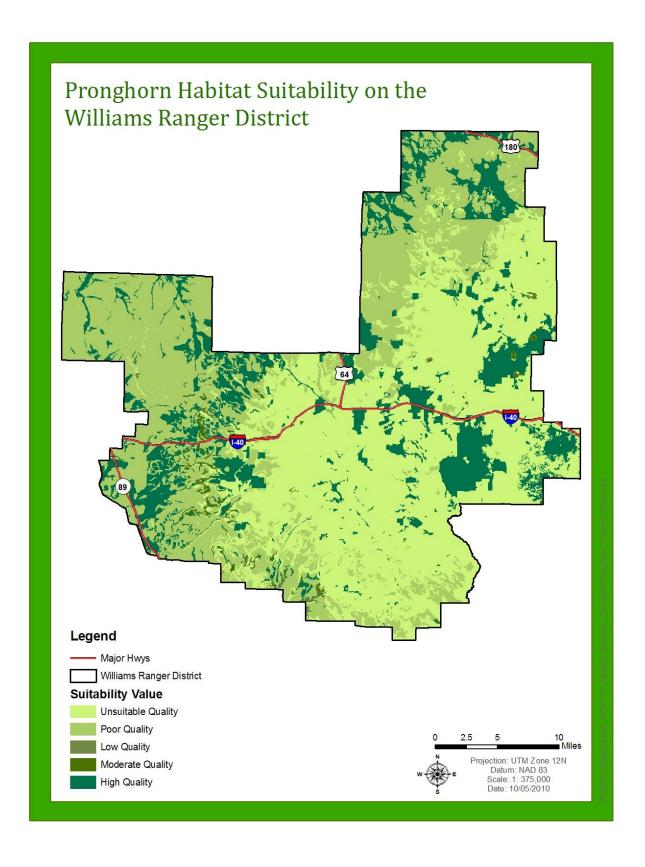


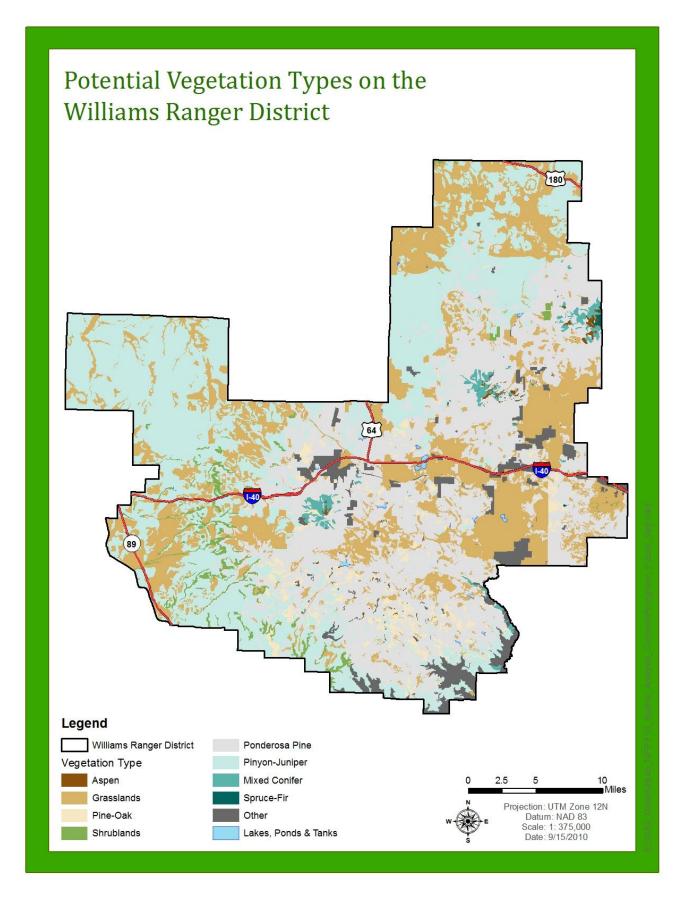


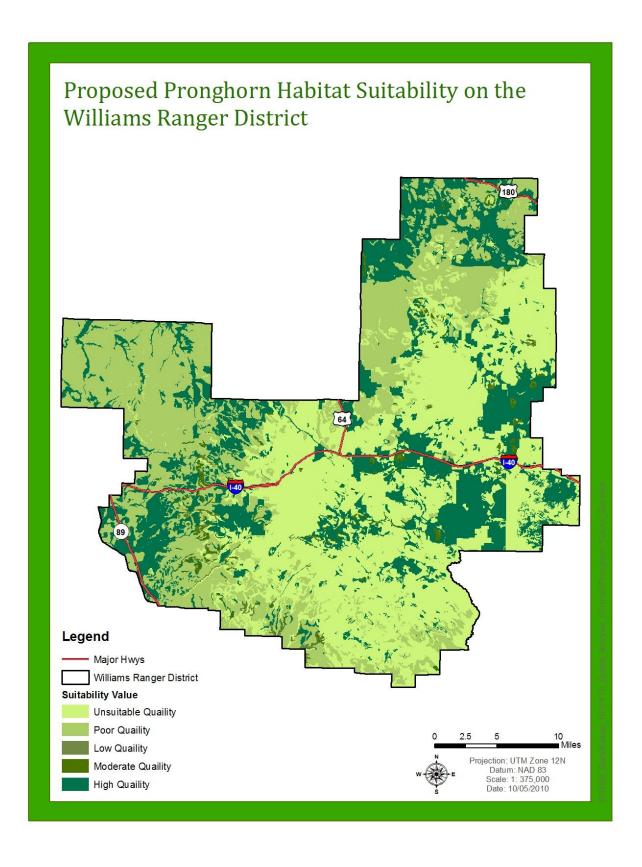


Appendix 2: Pronghorn Model Base Layer Maps

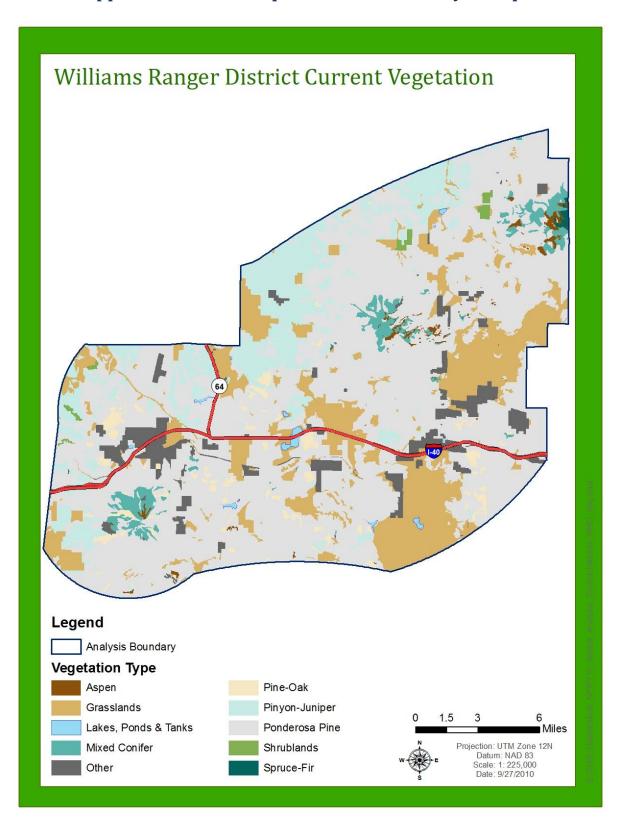


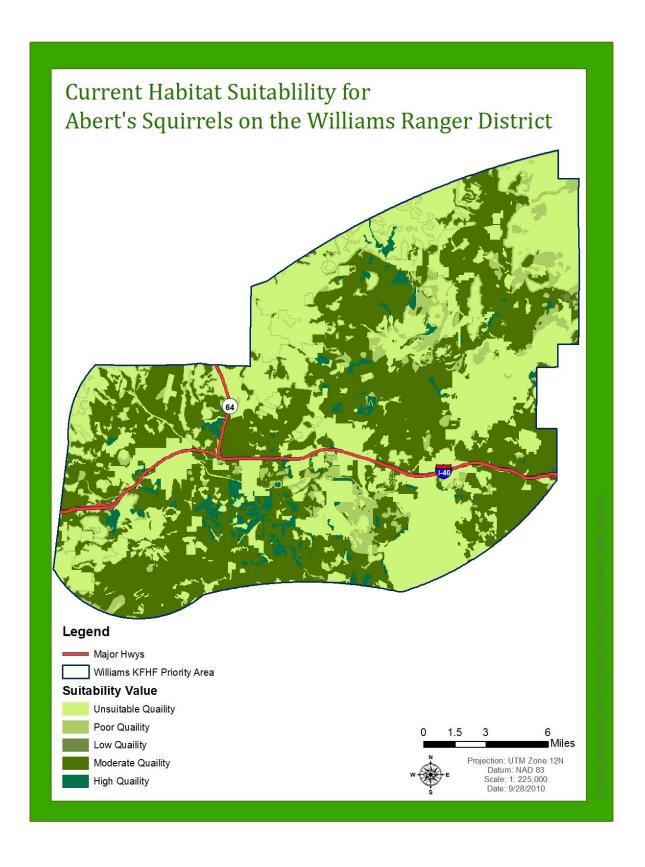


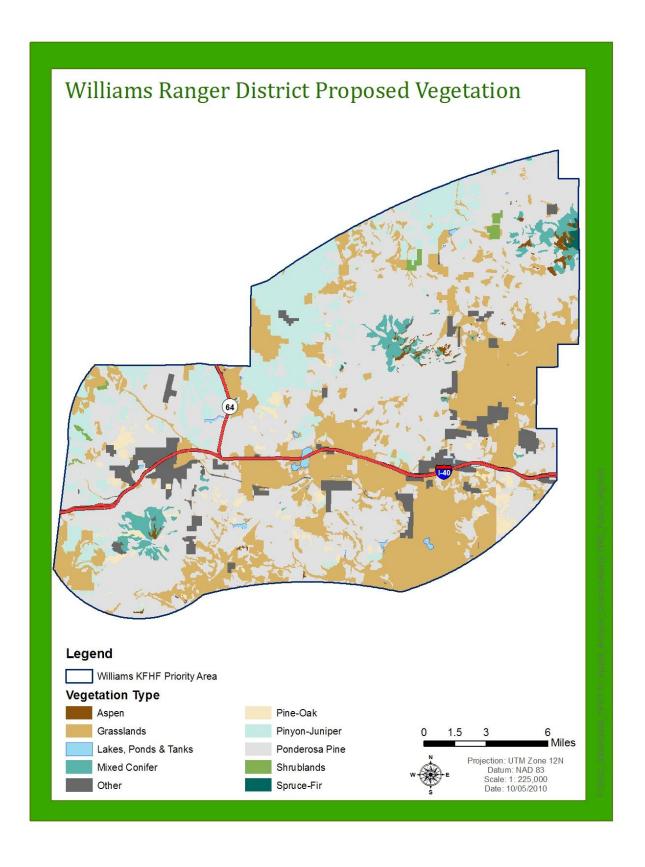


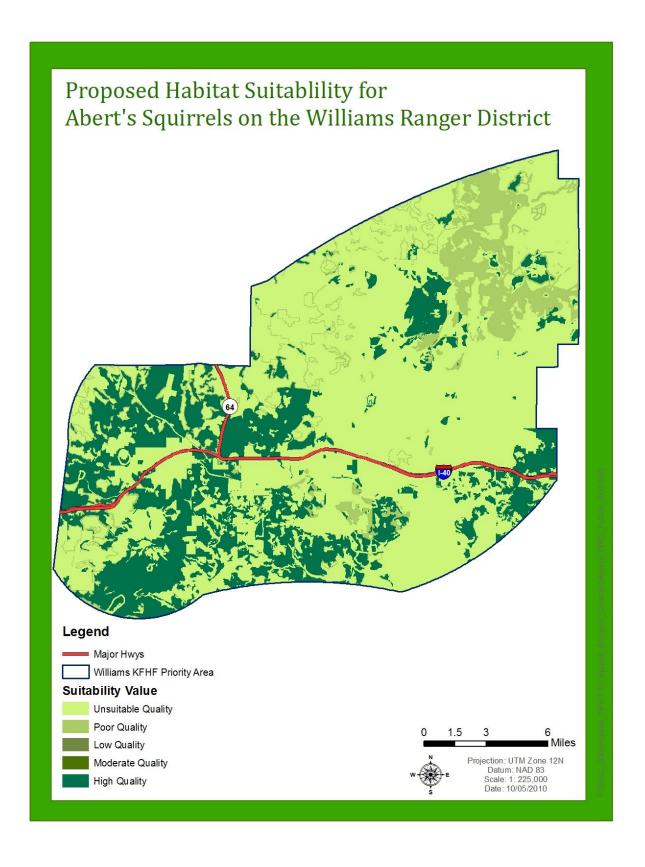


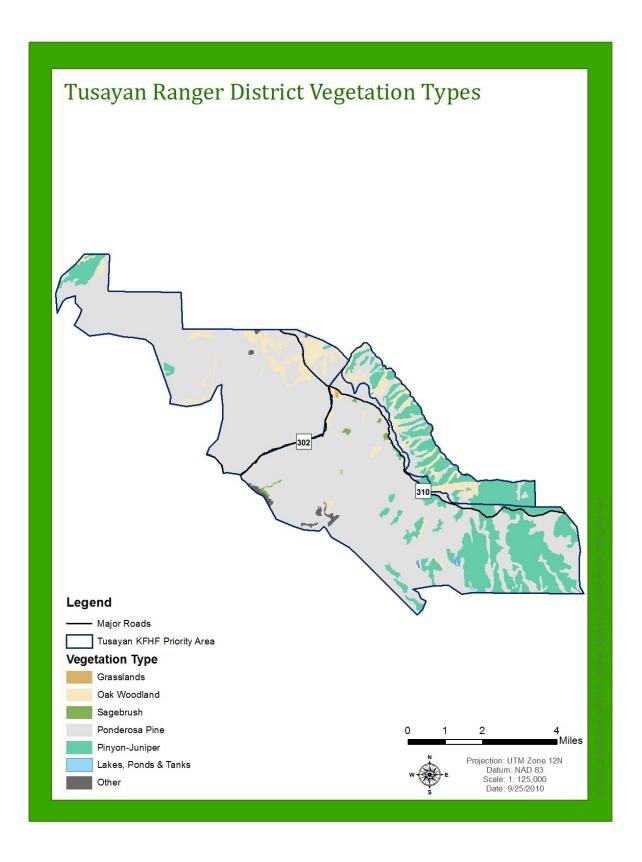
Appendix 3: Abert's Squirrel Model Base Layer Maps

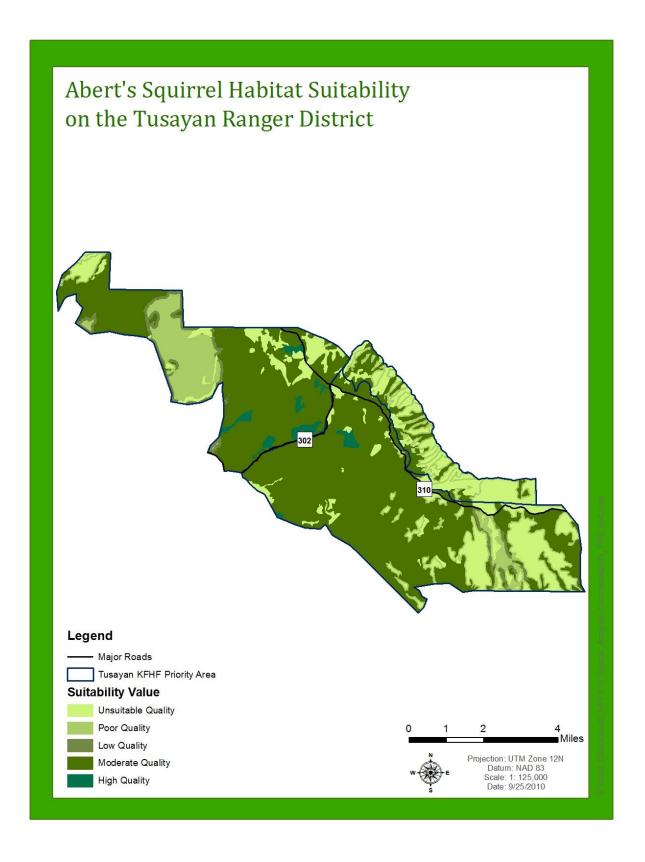


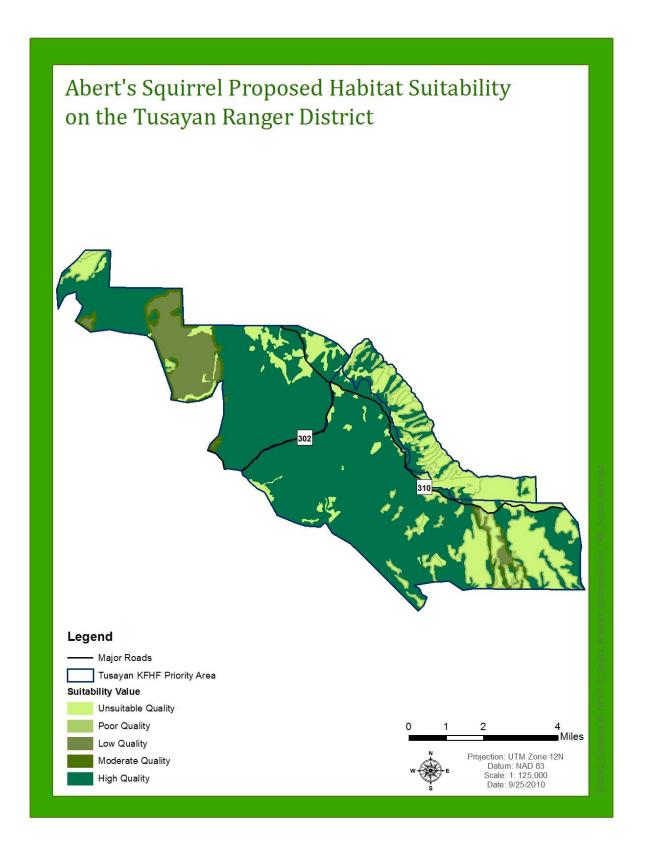


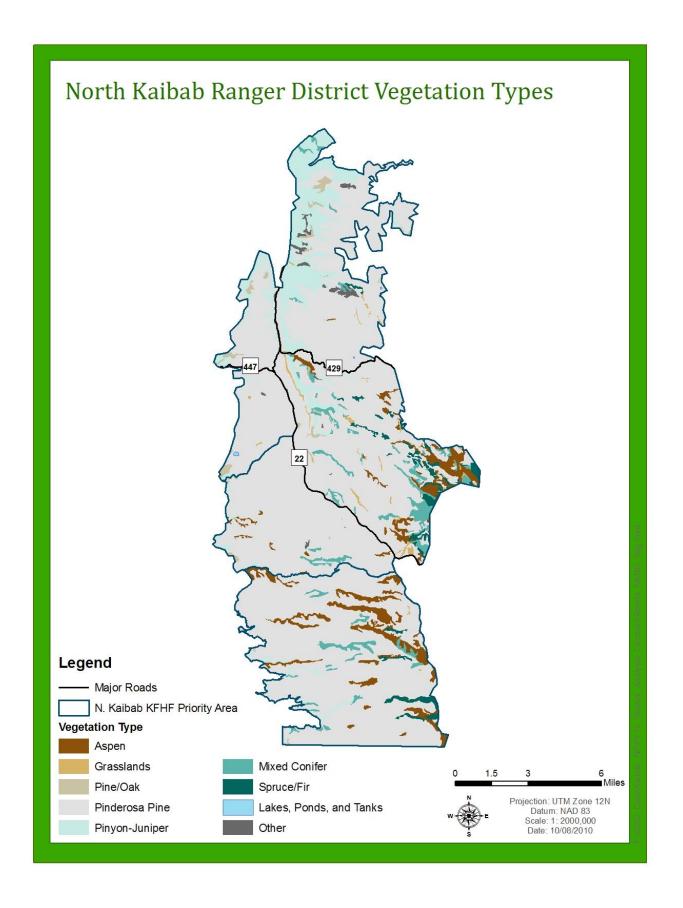












Appendix 4: Wildlife Connectivity Model Expert Reviewer Comments

Pronghorn Model Reviews

The draft pronghorn models were sent to nine species expert reviewers. These reviewers included Brian Wakeling, Rick Langley, Dave Cagle, Bob Waddell, Bob Birkeland, Carl Lutch, Scott Spragne, Jeff Gagnon, and Kirby Bristow, all of the Arizona Game and Fish Department. Below is the email sent by The Nature Conservancy asking for expert review of the draft models.

Greetings Pronghorn Experts,

I am working with the Kaibab National Forest on a pronghorn habitat connectivity analysis across the Williams Ranger District for their Land Management Plan revision process. You have been included in this email because you were suggested as a potential review for the habitat model. I have completed the first draft of the pronghorn model for the Williams Ranger District. Attached is a word document outlining the modeling process, program (PatchMorph) and model parameters along with a species literature review. I have also included a table that provides information on how I assigned the suitability values to all polygons used in connectivity analysis. I have also included preliminary maps of the current vegetation structure, and pronghorn suitability values based on my preliminary assessment from the literature. In addition, there is a map of the slope categories I included in the model and the connectivity draft output. Please be advised that I do plan on using the highways as an impassable barrier – but there is a bug in the software currently being fixed by the programmer.

Please do not circulate this information yet, as it is in draft form. Feel free to contact me if you have any questions or concerns.

Please provide any comments on the literature review, model parameters, gap and spur distance, or suitability values assigned by COB Monday Sept 27, 2010.

Thanks for your comments!

Sarah

We received comments back from four of the nine biologists asked to review the model. Below are the comments received from each reviewer and the action taken given the comments received.

Comments Received from Kirby Bristow:

Sarah,

Sorry I took so long to get back to you. I've looked this over and think overall this will be a useful tool. I've only a few comments.

Within the model description the text that discusses pronghorn migration may put too
much emphasis on seasonal migration. Few pronghorn populations in Arizona migrate
seasonally, but long range movements in response to severe weather events do
occur. This is a small distinction and may not warrant changing but could be contested
by future editors.

- 2. I think the model could be improved if there was a way to classify vegetation according to density or canopy. Flat, relatively open shrublands may be more attractive to pronghorn than grasslands, especially in Winter when pronghorn often feed on shrubby plant species. That said, I realize the difficulty in finding GIS layers that accurately depict vegetation density.
- 3. I think your Gap and Spur distances could be increased relative to pronghorn movement, however it's difficult to argue that the model needs to be created at a more coarse scale
- 4. Leaving the highways out may better display connectivity that should exist. I know that as we've gotten more GPS collars out on pronghorn collecting locations at a greater rate we have seen some road crossings, although they are still quite rare. I think Scott Sprague found populations were not genetically isolated by roads. Jeff Gagnon may have some insights relative to the highway barrier issue.

My greatest concern is the veg density issue, we are struggling with this issue with our pronghorn modeling efforts in the Big Chino Valley. This model should be perfectly suited for its purpose of identifying where connectivity should exist and directing veg treatments and fence alteration. It would be interesting to overlay actual pronghorn locations to see how well the model predicts use. Of course I'm always interested in putting out collars.

Kirby

Response to Comment: In response to Kirby's comments, suitability values for shrublands were changed to reflect the use of this vegetation type in the winter. The values are now equal in suitability to grasslands. Gap and spur distance remained the same to reflect as fine a scale of movement as possible across the District. Additionally, accurate fine scale canopy cover data were not available across the district, and therefore was not included in this modeling effort. As future data become available, this factor may be added into the model to assess changes in forest and grassland structure due to growth and restoration projects over the life of the LMP.

Comments Received from Carl Lutch:

Sarah:

Thanks for including me in the discussion. The Arizona Game and Fish Dept. is in the process of developing a similar model to predict pronghorn habitat based on a Big Chino pronghorn study. The researcher assigned to this project is Kirby Bristow. I have forwarded this to him for his review. Hopefully, Jeff Gagnon had forwarded it to him earlier. I just haven't been able to get to this as I've been on leave and away at meeting over the last 2 weeks.

The model you have here is interesting to me and the basic components look good. One thing I didn't see was a predictive criteria based on forage quality and quantity. That would be a good secondary predictor of pronghorn suitability. By this I mean, just because the area may be open and no barriers doesn't mean pronghorn will be there. If the forage base is not there or it is unavailable by fencing the pronghorn won't be there either.

I think this is a good thing to be worked on for pronghorn. I will defer to Jeff and Kirby for their expertise with pronghorn, pronghorn habitat and modeling though. They are the two within game and fish with the most expertise in this field. Sorry, I can't be of more help. Good luck with this and I'm certainly interested in the outcome!

Carl

Response to Comment: In response to Carl's comments, we spoke with him on the phone to clarify his recommendation regarding the forage quality issue. We found in our discussion that the type of data he was suggesting to include in the model did not exist at the extent we were assessing. We have included additional text in the results and discussion section identifying this factor and a key component of habitat use by this species. Future fine scale assessment of habitat use would need to include some measure of habitat and forage quantity and quality to predict fine scale movements and better assess restoration projects in these areas.

Comments Received from Scott Sprangue:

Sarah,

I've been busy so I didn't get a chance to go over this in detail, but I skimmed though it pretty quickly. The pronghorn lit review looks good and your parameters/suitability values make sense to me. Gap & spur distance, I'm not sure I understand without looking at it closer.

I hope this helps. Sorry I couldn't get more in depth.

Scott

Response to Comment: No revisions made based on Scott's comments.

Comments Received from Bob Birkeland:

Morning Sarah,

I sure appreciate the pronghorn habitat focus Williams Ranger District has placed on their planning revision; very refreshing to see (rare for districts to do this, in my experience). In no way would I consider myself a "pronghorn expert" but after 18 years in the field as a Wildlife Manager, maybe I feel comfortable providing some comments.

I like your approach and fundamentals placed into the model. The connectivity map paints a nice picture of important areas as a whole, but seems to miss the isolated areas within the ponderosa pine areas. I see two important things going on: one – identifying "traditional" pronghorn habitat for treatments and connectivity and two – identifying isolated areas away from "traditional" habitat that pronghorn, for whatever reasons, use. Important for many reasons including: how to approach treatments, what prescriptions to apply, size, etc. Even after having that information, secondarily - it would be important to have pronghorn movement information to affirm what or where these corridors are when applying to isolated areas within Pipo sites. I got off track a bit, sorry. I think you did a great job analyzing

important information, slope & veg. (diversity & densities), and using the map colors to identify connectedness of habitat. The dynamics and importance of pronghorn movements from grasslands to isolated areas within other habitats can be fascinating (e.g. some radio-collared pronghorn from Unit 9 north of Hwy 180 travelled south and spent their summers near I-40 - Bellmont). For practical uses, treating traditional pronghorn habitat can be fairly straight forward at times, but perhaps more important and beneficial is applying this to treatment prescriptions for areas within ponderosa pine types that will be beneficial to pronghorn movements.

I know that is more than you asked for, sorry again. If I had a question, it would be on the designation of spur and gap use and particularly how it could be applied to identify and link isolated use areas. Does that make sense? I think it looks great and appreciate your work on this. Good luck.

Bob

Response to Comment: No revisions made based on Bob's comments.

Abert's Squirrel Model Reviews

Abert's Squirrel models were extensively reviewed by species experts during the initial model development for the White Mountains Stewardship Project's Five Year Report. Models were reviewed up to 4 times by Norris Dodd, retired Arizona Game and Fish Research Branch Biologist, Bob Vahle, retired Biologist for the Forest Service (also retired Arizona Game and Fish Biologist), John Koprowski, Professor of Wildlife and Fisheries Science at University of Arizona, Vince Ordonez, Springerville District Biologist for the Apache-Sitgreaves National Forests, Beth Humphreys, Forest Biologist for the Apache-Sitgreaves National Forests.

Once models were developed for the Kaibab National Forest, these models were then sent out for additional review by Norris Dodd, retired Arizona Game and Fish Research Branch Biologist, Bob Vahle, retired Biologist for the Forest Service (also retired Arizona Game and Fish Biologist), John Koprowski, Professor of Wildlife and Fisheries Science at University of Arizona, Fenner Yarborough, Arizona Game and Fish Department Research Branch Biologist, and Andi Rogers, Arizona Game and Fish Department Habitat Specialist. We received comments back from two of the five biologists asked to review the model. Below are the comments received from each reviewer and the action taken given the comments received.

Comments Received from Norris Dodd:

Sarah:

I got a chance to look some of this over. The background squirrel habitat description is excellent. The only thing I'd recommend changing is the table for "Pre-commercial thin" which gets a 100 suitability score; this should be reworded to be "Pre-commercial thin in understory, overstory lightly treated".

Thanks,

Norris

Response to Comment: Text revised to reflect Norris's comment.

Comments Received from Fenner Yarborough:

Hi Sarah,

Looks good to me....really interesting stuff. One thought I had was from Chad's thesis, adds another citation to your home range numbers and adds some info relating to winter home range sizes.

"The mean 50% fixed kernel core area for winter (1.1 ha, SD = 0.16) was three times smaller than non-winter (3.48 ha, SD = 0.82; t = 2.85, df = 10, p = 0.009). Likewise, the mean 85% fixed kernel home range for winter (5.1-ha, SD = 0.80) was more than 60% smaller than non-winter (13.81 ha, SD = 2.12; t = 3.83, df = 12, p = 0.001)."

Loberger, Chad. 2009. Tassel-eared squirrel home range and habitat selection within a restoration-treated ponderosa pine forest. Northern Arizona University Thesis.

Fenner

<u>Response to Comment:</u> Text revised to reflect Fenner's comment.

Appendix 5: Habitat Association Statistical Program Outputs

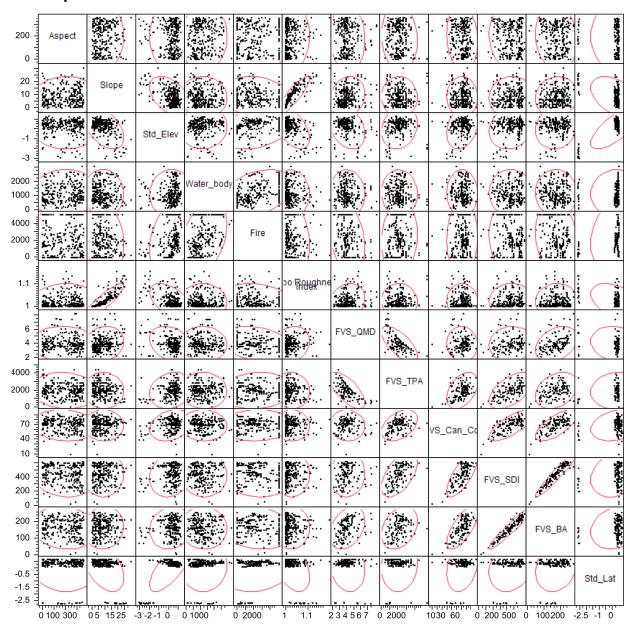
Mixed Conifer Correlation Matrix Results

Multivariate Correlations

Oution	•											
	Aspect	Slope	Std_Elev	Water_bo dy	Fire	Topo Roughnes s Index	FVS_QMD	FVS_TPA	FVS_Can_ Cov	FVS_SDI	FVS_BA	Std_Lat
Aspect	1.0000	0.0637	-0.0437	0.0465	0.0461	0.0700	-0.0548	-0.0841	-0.1108	-0.1213	-0.1158	-0.0523
Slope	0.0637	1.0000	-0.4847	-0.0423	-0.1904	0.8820	0.1689	-0.0286	-0.0209	0.0485	0.0797	-0.4556
Std_Elev	-0.0437	-0.4847	1.0000	0.0524	0.3367	-0.5160	-0.2908	0.1882	0.2579	0.1774	0.1131	0.7320
Water_body	0.0465	-0.0423	0.0524	1.0000	0.3662	-0.0450	-0.0585	-0.0417	-0.0166	-0.0296	-0.0321	0.0357
Fire	0.0461	-0.1904	0.3367	0.3662	1.0000	-0.1792	-0.2970	0.1077	0.0620	-0.1051	-0.1596	0.1458
Topo	0.0700	0.8820	-0.5160	-0.0450	-0.1792	1.0000	0.1604	-0.0318	-0.0203	0.0161	0.0437	-0.4179
Roughness Index												
FVS_QMD	-0.0548	0.1689	-0.2908	-0.0585	-0.2970	0.1604	1.0000	-0.6706	-0.0498	0.0675	0.3396	-0.1628
FVS_TPA	-0.0841	-0.0286	0.1882	-0.0417	0.1077	-0.0318	-0.6706	1.0000	0.4203	0.5683	0.3214	0.0992
FVS_Can_Cov	-0.1108	-0.0209	0.2579	-0.0166	0.0620	-0.0203	-0.0498	0.4203	1.0000	0.7417	0.6933	0.2680
FVS_SDI	-0.1213	0.0485	0.1774	-0.0296	-0.1051	0.0161	0.0675	0.5683	0.7417	1.0000	0.9574	0.2311
FVS_BA	-0.1158	0.0797	0.1131	-0.0321	-0.1596	0.0437	0.3396	0.3214	0.6933	0.9574	1.0000	0.2032
Std_Lat	-0.0523	-0.4556	0.7320	0.0357	0.1458	-0.4179	-0.1628	0.0992	0.2680	0.2311	0.2032	1.0000

The correlations are estimated by REML method.

Scatterplot Matrix



Mixed Conifer (RCKI) Habitat Association Model Results

Stepwise Fit Response: Presence

Stepwise Regression Control

Prob to Enter 0.250 Prob to Leave 0.100

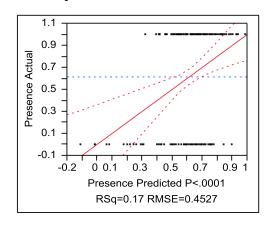
Direction: Mixed

Current Estimates

	SSE 35.652561	DFE 174	MSE 0.2048998	RSquare 0.1666	RSqu	u are Adj 0.1426	Cp 1.2798979	AICc 234.0246	
			0.20 .0000						
Lock	Entered	Parameter		Estimate	nDF	SS	"F Ratio"	"Prob>F"	
Χ	X	Intercept		-1.8699051	1	0	0.000	1	
	X	Aspect		-0.0005375	1	0.674673	3.293	0.07131	
		Slope		0	1	0.001053	0.005	0.9431	
	X	Std_Elev		0.20903537	1	4.538258	22.149	5.13e-6	
		Water_body		0	1	0.059535	0.289	0.59132	
		Fire		0	1	0.306881	1.502	0.22202	
		PNVT - MC		0	1	0.301141	1.474	0.22642	
		PNVT - Oak		0	1	0.477029	2.346	0.12742	
		PNVT - Grassland		0	1	0.099869	0.486	0.48667	
		PNVT _ PIPO		0	1	0.001731	0.008	0.92708	
		PNVT - Spruce /Fir		0	1	0.168917	0.824	0.36541	
	Χ	Topo Roughness In	dex	2.54866755	1	0.954484	4.658	0.03227	
		FVS_QMD		0	1	0.079109	0.385	0.5359	
	Χ	FVS_TPA		0.00009368	1	1.041608	5.083	0.0254	
		FVS_TPA 24		0	1	0.022294	0.108	0.74255	
		FVS_TPA 16		0	1	0.102505	0.499	0.48097	
		FVS_TPA 8		0	1	0.014942	0.073	0.788	
		FVS_TPA 0		0	1	0.000555	0.003	0.95867	
		FVS_Can_Cov		0	1	0.023426	0.114	0.73632	
		FVS_Can_Cov 24		0	1	0.002065	0.010	0.92038	
		FVS_Can_Cov 16		0	1	0.03596	0.175	0.67652	
		FVS_Can_Cov 8		0	1	0.002024	0.010	0.92117	
	Χ	FVS_Can_Cov 0		-0.0053554	1	1.078712	5.265	0.02296	
		FVS_BA		0	1	0.012757	0.062	0.80378	
		FVS_BA 24		0	1	0.005162	0.025	0.87443	
		FVS_BA 16		0	1	0.083198	0.405	0.52554	
		FVS_BA 8		0	1	3.723e-6	0.000	0.99661	
		FVS_BA 0		0	1	0.069221	0.337	0.56259	
Sten	History								

Step	Parameter	Action	"Sig Prob"	Seq SS	RSquare	Ср	р
1	Std_Elev	Entered	0.0000	3.899158	0.0911	8.5974	2
2	Topo Roughness Index	Entered	0.0385	0.931861	0.1129	6.1729	3
3	FVS_TPA	Entered	0.0688	0.709206	0.1295	4.8055	4
4	FVS_Can_Cov 0	Entered	0.0377	0.910319	0.1508	2.4833	5
5	Aspect	Entered	0.0713	0.674673	0.1666	1.2799	6
6	PNVT - Oak	Entered	0.1274	0.477029	0.1777	1.0149	7
7	PNVT - Oak	Removed	0.1274	0.477029	0.1666	1.2799	6

Response Presence Whole Model Actual by Predicted Plot



Summary of Fit

RSquare	0.166564
RSquare Adj	0.142614
Root Mean Square Error	0.452659
Mean of Response	0.611111
Observations (or Sum Wgts)	180

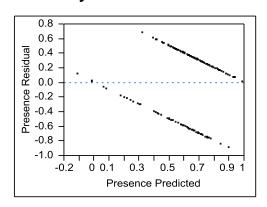
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	7.125217	1.42504	6.9548
Error	174	35.652561	0.20490	Prob > F
C. Total	179	42 777778		< 0001*

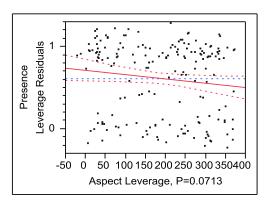
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	-1.869905	1.209844	-1.55	0.1240
Aspect	-0.000538	0.000296	-1.81	0.0713
Std_Elev	0.2090354	0.044417	4.71	<.0001*
Topo Roughness Index	2.5486675	1.180863	2.16	0.0323*
FVS_TPA	9.3681e-5	4.155e-5	2.25	0.0254*
FVS_Can_Cov 0	-0.005355	0.002334	-2.29	0.0230*

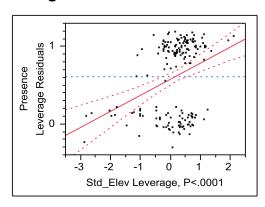
Residual by Predicted Plot



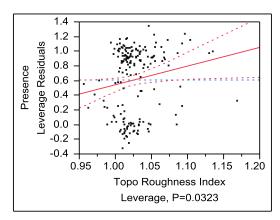
Aspect Leverage Plot



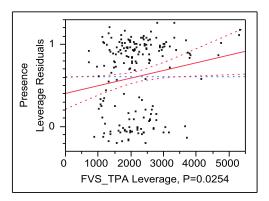
Std_Elev Leverage Plot



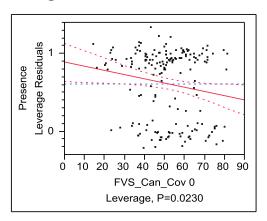
Topo Roughness Index Leverage Plot



FVS_TPA Leverage Plot



FVS_Can_Cov 0 Leverage Plot



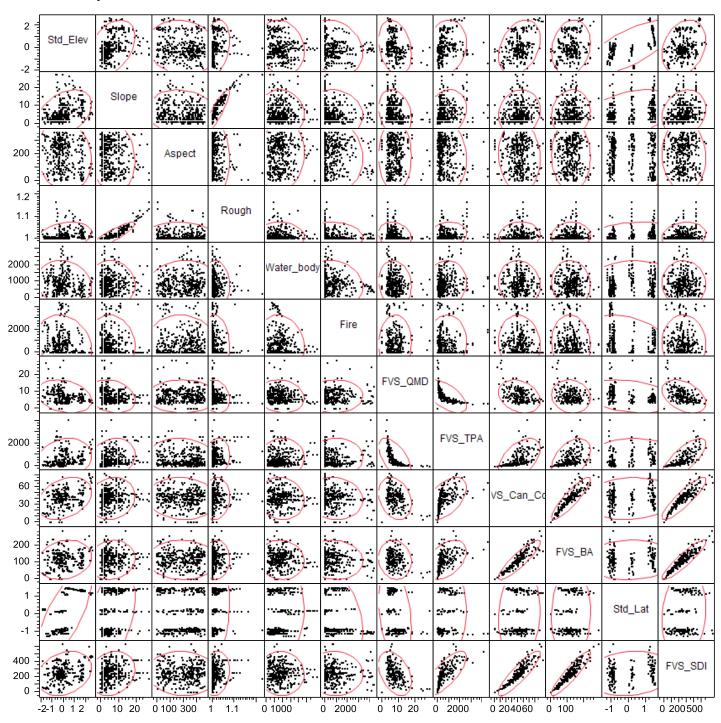
Ponderosa Pine Correlation Matrix Results

Multivariate Correlations

/II3											
Std_Elev	Slope	Aspect	Rough	Water_body	Fire	FVS_QMD	FVS_TPA	FVS_Can_ Cov	FVS_BA	Std_Lat	FVS_SDI
1.0000	0.3833	-0.1137	0.2619	-0.1510	-0.2149	-0.2573	0.1689	0.3264	0.1750	0.7270	0.2459
0.3833	1.0000	-0.1444	0.8929	-0.0598	-0.1102	-0.2293	0.2158	0.1214	0.0962	0.3707	0.1781
-0.1137	-0.1444	1.0000	-0.1214	0.0958	-0.0645	-0.0030	-0.0976	-0.0800	-0.0334	-0.0282	-0.0526
0.2619	0.8929	-0.1214	1.0000	-0.0776	-0.1122	-0.2028	0.2043	0.0827	0.0557	0.2720	0.1360
-0.1510	-0.0598	0.0958	-0.0776	1.0000	-0.1615	-0.1271	0.0651	-0.0831	-0.0723	0.1217	-0.0289
-0.2149	-0.1102	-0.0645	-0.1122	-0.1615	1.0000	0.0285	0.0681	-0.0804	-0.0686	-0.3677	-0.0319
-0.2573	-0.2293	-0.0030	-0.2028	-0.1271	0.0285	1.0000	-0.5937	-0.2692	-0.1087	-0.3075	-0.4043
0.1689	0.2158	-0.0976	0.2043	0.0651	0.0681	-0.5937	1.0000	0.5081	0.4335	0.1256	0.7454
0.3264	0.1214	-0.0800	0.0827	-0.0831	-0.0804	-0.2692	0.5081	1.0000	0.8907	0.1103	0.8834
0.1750	0.0962	-0.0334	0.0557	-0.0723	-0.0686	-0.1087	0.4335	0.8907	1.0000	0.0406	0.9102
0.7270	0.3707	-0.0282	0.2720	0.1217	-0.3677	-0.3075	0.1256	0.1103	0.0406	1.0000	0.1364
0.2459	0.1781	-0.0526	0.1360	-0.0289	-0.0319	-0.4043	0.7454	0.8834	0.9102	0.1364	1.0000
	1.0000 0.3833 -0.1137 0.2619 -0.1510 -0.2149 -0.2573 0.1689 0.3264 0.1750 0.7270	Std_Elev Slope 1.0000 0.3833 0.3833 1.0000 -0.1137 -0.1444 0.2619 0.8929 -0.1510 -0.0598 -0.2149 -0.1102 -0.2573 -0.2293 0.1689 0.2158 0.3264 0.1214 0.1750 0.0962 0.7270 0.3707	Std_Elev Slope Aspect 1.0000 0.3833 -0.1137 0.3833 1.0000 -0.1444 -0.1137 -0.1444 1.0000 0.2619 0.8929 -0.1214 -0.1510 -0.0598 0.0958 -0.2149 -0.1102 -0.0645 -0.2573 -0.2293 -0.0030 0.1689 0.2158 -0.0976 0.3264 0.1214 -0.0800 0.1750 0.0962 -0.0334 0.7270 0.3707 -0.0282	Std_Elev Slope Aspect Rough 1.0000 0.3833 -0.1137 0.2619 0.3833 1.0000 -0.1444 0.8929 -0.1137 -0.1444 1.0000 -0.1214 0.2619 0.8929 -0.1214 1.0000 -0.1510 -0.0598 0.0958 -0.0776 -0.2149 -0.1102 -0.0645 -0.1122 -0.2573 -0.2293 -0.0030 -0.2028 0.1689 0.2158 -0.0976 0.2043 0.3264 0.1214 -0.0800 0.0827 0.1750 0.0962 -0.0334 0.0557 0.7270 0.3707 -0.0282 0.2720	Std_Elev Slope Aspect Rough Water_body 1.0000 0.3833 -0.1137 0.2619 -0.1510 0.3833 1.0000 -0.1444 0.8929 -0.0598 -0.1137 -0.1444 1.0000 -0.1214 0.0958 0.2619 0.8929 -0.1214 1.0000 -0.0776 -0.1510 -0.0598 0.0958 -0.0776 1.0000 -0.2149 -0.1102 -0.0645 -0.1122 -0.1615 -0.2573 -0.2293 -0.0030 -0.2028 -0.1271 0.1689 0.2158 -0.0976 0.2043 0.0651 0.3264 0.1214 -0.0800 0.0827 -0.0831 0.1750 0.0962 -0.0334 0.0557 -0.0723 0.7270 0.3707 -0.0282 0.2720 0.1217	Std_Elev Slope Aspect Rough Water_body Fire 1.0000 0.3833 -0.1137 0.2619 -0.1510 -0.2149 0.3833 1.0000 -0.1444 0.8929 -0.0598 -0.1102 -0.1137 -0.1444 1.0000 -0.1214 0.0958 -0.0645 0.2619 0.8929 -0.1214 1.0000 -0.0776 -0.1122 -0.1510 -0.0598 0.0958 -0.0776 1.0000 -0.1615 -0.2149 -0.1102 -0.0645 -0.1122 -0.1615 1.0000 -0.2573 -0.2293 -0.0030 -0.2028 -0.1271 0.0285 0.1689 0.2158 -0.0976 0.2043 0.0651 0.0681 0.3264 0.1214 -0.0800 0.0827 -0.0831 -0.0804 0.1750 0.0962 -0.0334 0.0557 -0.0723 -0.0686 0.7270 0.3707 -0.0282 0.2720 0.1217 -0.3677	Std_Elev Slope Aspect Rough Water_body Fire FVS_QMD 1.0000 0.3833 -0.1137 0.2619 -0.1510 -0.2149 -0.2573 0.3833 1.0000 -0.1444 0.8929 -0.0598 -0.1102 -0.2293 -0.1137 -0.1444 1.0000 -0.1214 0.0958 -0.0645 -0.0030 0.2619 0.8929 -0.1214 1.0000 -0.0776 -0.1122 -0.2028 -0.1510 -0.0598 0.0958 -0.0776 1.0000 -0.1615 -0.1271 -0.2149 -0.1102 -0.0645 -0.1122 -0.1615 1.0000 0.0285 -0.2573 -0.2293 -0.0030 -0.2028 -0.1271 0.0285 1.0000 0.1689 0.2158 -0.0976 0.2043 0.0651 0.0681 -0.5937 0.3264 0.1214 -0.0800 0.0827 -0.0831 -0.0804 -0.2692 0.1750 0.0962 -0.0334 0.0557 -0.0723	Std_Elev Slope Aspect Rough Water_body Fire FVS_QMD_FVS_TPA 1.0000 0.3833 -0.1137 0.2619 -0.1510 -0.2149 -0.2573 0.1689 0.3833 1.0000 -0.1444 0.8929 -0.0598 -0.1102 -0.2293 0.2158 -0.1137 -0.1444 1.0000 -0.076 -0.0645 -0.0030 -0.0976 0.2619 0.8929 -0.1214 1.0000 -0.0776 -0.1122 -0.2028 0.2043 -0.1510 -0.0598 0.0958 -0.0776 1.0000 -0.1615 -0.1271 0.0651 -0.2149 -0.1102 -0.0645 -0.1122 -0.1615 1.0000 0.0285 0.0681 -0.2573 -0.2293 -0.0030 -0.2028 -0.1271 0.0285 1.0000 -0.5937 0.1689 0.2158 -0.0976 0.2043 0.0651 0.0681 -0.5937 1.0000 0.3264 0.1214 -0.0800 0.0827 -0.0831 -0.0	Std_Elev Slope Aspect Rough Water_body Fire FVS_QMD FVS_TPA FVS_Can_Cov 1.0000 0.3833 -0.1137 0.2619 -0.1510 -0.2149 -0.2573 0.1689 0.3264 0.3833 1.0000 -0.1444 0.8929 -0.0598 -0.1102 -0.2293 0.2158 0.1214 -0.1137 -0.1444 1.0000 -0.0776 -0.0645 -0.0030 -0.0976 -0.0800 0.2619 0.8929 -0.1214 1.0000 -0.0776 -0.1122 -0.2028 0.2043 0.0827 -0.1510 -0.0598 0.0958 -0.0776 1.0000 -0.1615 -0.1271 0.0651 -0.0831 -0.2149 -0.1102 -0.0645 -0.1122 -0.1615 1.0000 0.0285 0.0681 -0.0804 -0.2573 -0.2293 -0.0030 -0.2028 -0.1271 0.0285 1.0000 -0.5937 -0.2692 0.1689 0.2158 -0.0976 0.2043 0.0651 <td< td=""><td>Std_Elev Slope Aspect Rough Water_body Fire FVS_QMD FVS_TPA FVS_Can_Cov FVS_BA 1.0000 0.3833 -0.1137 0.2619 -0.1510 -0.2149 -0.2573 0.1689 0.3264 0.1750 0.3833 1.0000 -0.1444 0.8929 -0.0598 -0.1102 -0.2293 0.2158 0.1214 0.0962 -0.1137 -0.1444 1.0000 -0.0598 -0.0645 -0.0030 -0.0976 -0.0800 -0.0334 0.2619 0.8929 -0.1214 1.0000 -0.0776 -0.1122 -0.2028 0.2043 0.0827 0.0557 -0.1510 -0.0598 0.0958 -0.0776 1.0000 -0.1615 -0.1271 0.0651 -0.0831 -0.0723 -0.2149 -0.1102 -0.0645 -0.1122 -0.1615 1.0000 0.0285 0.0681 -0.0804 -0.0686 -0.2573 -0.2293 -0.0030 -0.2028 -0.1271 0.0285 1.0000 -0.5937</td><td>Std_Elev Slope Aspect Rough Water_body Fire FVS_QMD FVS_TPA FVS_Can_Cov FVS_BA Std_Lat 1.0000 0.3833 -0.1137 0.2619 -0.1510 -0.2149 -0.2573 0.1689 0.3264 0.1750 0.7270 0.3833 1.0000 -0.1444 0.8929 -0.0598 -0.1102 -0.2293 0.2158 0.1214 0.0962 0.3707 -0.1137 -0.1444 1.0000 -0.0776 -0.0645 -0.0030 -0.0976 -0.0800 -0.0334 -0.0282 0.2619 0.8929 -0.1214 1.0000 -0.0776 -0.1122 -0.2028 0.2043 0.0827 0.0557 0.2720 -0.1510 -0.0598 0.0958 -0.0776 1.0000 -0.1615 -0.1271 0.0651 -0.0831 -0.0723 0.1217 -0.2149 -0.1102 -0.0645 -0.1122 -0.1615 1.0000 0.0285 0.0681 -0.0804 -0.0686 -0.3677 -0.2573</td></td<>	Std_Elev Slope Aspect Rough Water_body Fire FVS_QMD FVS_TPA FVS_Can_Cov FVS_BA 1.0000 0.3833 -0.1137 0.2619 -0.1510 -0.2149 -0.2573 0.1689 0.3264 0.1750 0.3833 1.0000 -0.1444 0.8929 -0.0598 -0.1102 -0.2293 0.2158 0.1214 0.0962 -0.1137 -0.1444 1.0000 -0.0598 -0.0645 -0.0030 -0.0976 -0.0800 -0.0334 0.2619 0.8929 -0.1214 1.0000 -0.0776 -0.1122 -0.2028 0.2043 0.0827 0.0557 -0.1510 -0.0598 0.0958 -0.0776 1.0000 -0.1615 -0.1271 0.0651 -0.0831 -0.0723 -0.2149 -0.1102 -0.0645 -0.1122 -0.1615 1.0000 0.0285 0.0681 -0.0804 -0.0686 -0.2573 -0.2293 -0.0030 -0.2028 -0.1271 0.0285 1.0000 -0.5937	Std_Elev Slope Aspect Rough Water_body Fire FVS_QMD FVS_TPA FVS_Can_Cov FVS_BA Std_Lat 1.0000 0.3833 -0.1137 0.2619 -0.1510 -0.2149 -0.2573 0.1689 0.3264 0.1750 0.7270 0.3833 1.0000 -0.1444 0.8929 -0.0598 -0.1102 -0.2293 0.2158 0.1214 0.0962 0.3707 -0.1137 -0.1444 1.0000 -0.0776 -0.0645 -0.0030 -0.0976 -0.0800 -0.0334 -0.0282 0.2619 0.8929 -0.1214 1.0000 -0.0776 -0.1122 -0.2028 0.2043 0.0827 0.0557 0.2720 -0.1510 -0.0598 0.0958 -0.0776 1.0000 -0.1615 -0.1271 0.0651 -0.0831 -0.0723 0.1217 -0.2149 -0.1102 -0.0645 -0.1122 -0.1615 1.0000 0.0285 0.0681 -0.0804 -0.0686 -0.3677 -0.2573

The correlations are estimated by REML method.

Scatterplot Matrix



Ponderosa Pine (GRWA) Habitat Association Model Results

Stepwise Fit Response:

GRWA Precence

Stepwise Regression Control

Prob to Enter 0.250 Prob to Leave 0.100

Direction: Mixed

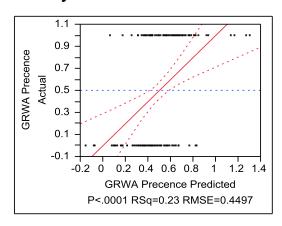
Current I	Estimates
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	SSE	DFE	MSE	RSquare		RSquare Adj	Ср	AICc
	31.142097	154	0.2022214	0.2311		0.1961	10.212764	211.7765
Lock	Entered	Parameter	Estin	nate	nDF	SS	"F Ratio"	"Prob>F"
Χ	X	Intercept	0.36648	893	1	0	0.000	1
	X	Std_Elev	0.19220	745	1	2.626297	12.987	0.00042
		Slope		0	1	0.215384	1.066	0.30358
		Aspect		0	1	0.48835	2.437	0.12053
		Rough		0	1	0.036473	0.179	0.67248
		Water_body		0	1	0.513213	2.564	0.11141
	X	Fire (2000-2009)	4.9528	3e-5	1	1.402351	6.935	0.00932
	Χ	PNVT - MC	-0.6059	407	1	0.700366	3.463	0.06465
		PNVT - Oak		0	0	0		
		PNVT - Grasslands	;	0	1	0.037102	0.182	0.66984
		PNVT - PIPO		0	1	0.037102	0.182	0.66984
		FVS_QMD		0	1	0.224568	1.111	0.29346
		FVS_TPA		0	1	0.07737	0.381	0.53795
	Χ	FVS_TPA 24	0.240	727	1	1.810011	8.951	0.00323
		FVS_TPA 16		0	1	0.043961	0.216	0.64255
		FVS_TPA 8		0	1	0.043564	0.214	0.64405
	Χ	FVS_TPA 0	-0.0001	937	1	1.858999	9.193	0.00285
		FVS_Can_Cov		0	1	0.087758	0.432	0.51182
		FVS_Can_Cov 24		0	1	0.246222	1.219	0.27123
		FVS_Can_Cov 16		0	1	0.061564	0.303	0.58277
		FVS_Can_Cov 8		0	1	0.074092	0.365	0.5467
		FVS_Can_Cov 0		0	1	0.010644	0.052	0.81939
		FVS_BA		0	1	0.047473	0.234	0.62957
	X	FVS_BA 24	-0.0512	683	1	1.452836	7.184	0.00815
		FVS_BA 16		0	1	0.029421	0.145	0.7042
		FVS_BA 8		0	1	0.019493	0.096	0.75732
	X	FVS_BA 0	0.00486	374	1	0.588971	2.913	0.08991

Step History Step Para

Step	Parameter	Action	"Sig Prob"	Seq SS	RSquare	Ср	р
1	Std_Elev	Entered	0.0011	2.626636	0.0649	31.978	2
2	Fire (2000-2009)	Entered	0.0095	1.574378	0.1037	26.08	3
3	FVS_TPA 24	Entered	0.0174	1.281042	0.1354	21.655	4
4	FVS_TPA 0	Entered	0.0108	1.423988	0.1705	16.512	5
5	FVS_BA 24	Entered	0.0163	1.223069	0.2007	12.377	6
6	PNVT - MC	Entered	0.0790	0.639819	0.2165	11.167	7
7	FVS_BA 0	Entered	0.0899	0.588971	0.2311	10.213	8
8	Water_body	Entered	0.1114	0.513213	0.2437	9.6384	9
9	Water_body	Removed	0.1114	0.513213	0.2311	10.213	8

Response GRWA Presence Whole Model Actual by Predicted Plot



Summary of Fit

RSquare	0.231059
RSquare Adj	0.196107
Root Mean Square Error	0.44969
Mean of Response	0.5
Observations (or Sum Wgts)	162

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	7	9.357903	1.33684	6.6108
Error	154	31.142097	0.20222	Prob > F
C. Total	161	40.500000		<.0001*

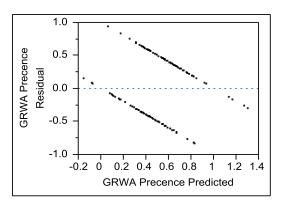
Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	153	30.642097	0.200275	0.4006
Pure Error	1	0.500000	0.500000	Prob > F
Total Error	154	31.142097		0.8838
				Max RSq
				0.9877

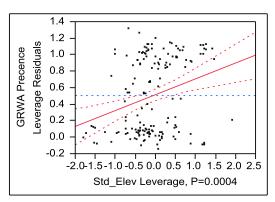
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	0.3664889	0.068438	5.36	<.0001*
Std_Elev	0.1922075	0.053335	3.60	0.0004*
Fire (2000-2009)	4.9528e-5	1.881e-5	2.63	0.0093*
PNVT - MC	-0.605941	0.325598	-1.86	0.0646
FVS_TPA 24	0.240727	0.080463	2.99	0.0032*
FVS_TPA 0	-0.000194	6.389e-5	-3.03	0.0029*
FVS_BA 24	-0.051268	0.019127	-2.68	0.0082*
FVS_BA 0	0.0048637	0.00285	1.71	0.0899

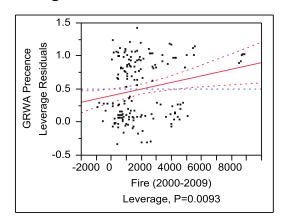
Residual by Predicted Plot



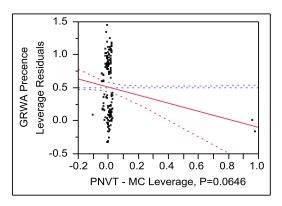
Std_Elev Leverage Plot



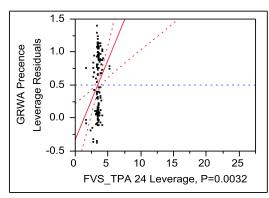
Fire (2000-2009) Leverage Plot



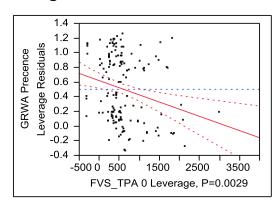
PNVT - MC Leverage Plot



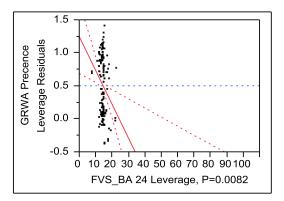
FVS_TPA 24 Leverage Plot



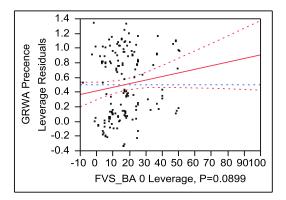
FVS_TPA 0 Leverage Plot



FVS_BA 24 Leverage Plot



FVS_BA 0 Leverage Plot



Ponderosa Pine (HAWO) Habitat Association Model Results

Stepwise Fit Response:

HAWO Presence

Stepwise Regression Control

Prob to Enter 0.250 Prob to Leave 0.100

Direction: Mixed

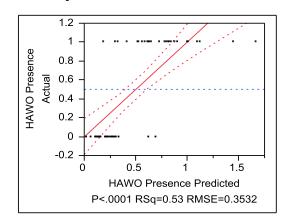
Current Estimates

0 0	SSE	DFE	MSE	•	RS	Square Adj	Ср	AICc
	6.3627835	51	0.1247605	0.5287		0.5102	2.5033536	46.58171
Lock	Entered	Parameter		Estimate	nDF	SS	"F Ratio"	"Prob>F"
Χ	X	Intercept		0.00975465	1	0	0.000	1
		Std_Elev		0	1	0.182663	1.478	0.22982
		Slope		0	1	0.084786	0.675	0.41512
		Aspect		0	1	0.012942	0.102	0.75088
		Rough		0	1	0.062918	0.499	0.48306
		Water_body		0	1	0.225179	1.834	0.1817
	X	Fire (2000-2009)		0.00016341	1	4.387275	35.166	2.64e-7
		PNVT - MC		0	0	0		
		PNVT - Oak		0	0	0		
		PNVT - Grasslands	3	0	0	0		
		PNVT - PIPO		0	0	0		
		FVS_QMD		0	1	0.025404	0.200	0.65631
		FVS_TPA		0	1	0.004071	0.032	0.85873
		FVS_TPA 24		0	1	0.031188	0.246	0.62188
		FVS_TPA 16		0	1	0.003926	0.031	0.86124
		FVS_TPA 8		0	1	0.001007	0.008	0.92945
		FVS_TPA 0		0	1	0.004204	0.033	0.85647
		FVS_Can_Cov		0	1	0.007119	0.056	0.81389
		FVS_Can_Cov 24		0	1	0.022532	0.178	0.67517
		FVS_Can_Cov 16		0	1	0.008745	0.069	0.79415
		FVS_Can_Cov 8		0	1	0.003929	0.031	0.86119
		FVS_Can_Cov 0		0	1	0.020499	0.162	0.68939
		FVS_BA		0	1	0.03287	0.260	0.61261
		FVS_BA 24		0	1	0.056792	0.450	0.50528
	X	FVS_BA 16		0.00931938	1	1.904583	15.266	0.00028
		FVS_BA 8		0	1	0.004739	0.037	0.84771
		FVS_BA 0		0	1	0.031322	0.247	0.62113

Step History

Step	Parameter	Action	"Sig Prob"	Seq SS	RSquare	Ср	р
1	Fire (2000-2009)	Entered	0.0000	5.232633	0.3876	15.621	2
2	FVS_BA 16	Entered	0.0003	1.904583	0.5287	2.5034	3
3	Water_body	Entered	0.1817	0.225179	0.5454	2.716	4
4	Water_body	Removed	0.1817	0.225179	0.5287	2.5034	3

Response HAWO Presence Whole Model Actual by Predicted Plot



Summary of Fit

RSquare	0.528683
RSquare Adj	0.5102
Root Mean Square Error	0.353214
Mean of Response	0.5
Observations (or Sum Wgts)	54

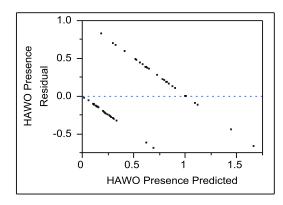
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	7.137217	3.56861	28.6037
Error	51	6.362783	0.12476	Prob > F
C. Total	53	13.500000		<.0001*

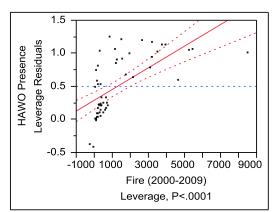
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	0.0097546	0.08946	0.11	0.9136
Fire (2000-2009)	0.0001634	2.756e-5	5.93	<.0001*
FVS BA 16	0 009319 <i>4</i>	0.002385	3 91	0 0003*

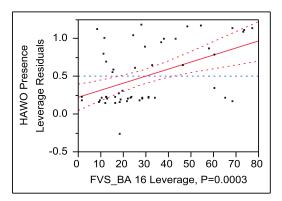
Residual by Predicted Plot



Fire (2000-2009) Leverage Plot



FVS_BA 16 Leverage Plot



Ponderosa Pine (WEBL) Habitat Association Model Results

Stepwise Fit Response: WEBL Presence

Stepwise Regression Control

Prob to Enter 0.250 Prob to Leave 0.100

Direction: Mixed

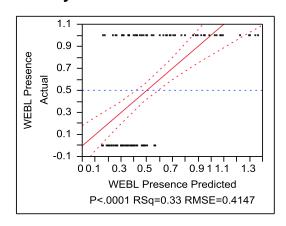
Current Estimates

	SSE 20.116861	DFE 117	MSE 0.171939	RSquare 0.3294	RS	Square Adj 0.3180	Cp 4.8633434	AICc 134.5811
Lock	Entered	Parameter		Estimate	nDF	ss	"F Ratio"	"Prob>F"
Χ	Χ	Intercept		0.09995642	1	0	0.000	1
		Std_Elev		0	1	0.036711	0.212	0.64601
		Slope		0	1	0.25443	1.486	0.22532
		Aspect		0	1	0.007117	0.041	0.83979
		Rough		0	1	0.067151	0.389	0.53431
	Χ	Water_body		0.00016841	1	1.343421	7.813	0.00606
	Χ	Fire (2000-2009)		0.00012136	1	9.262715	53.872	3.1e-11
		PNVT - MC		0	1	0.086427	0.501	0.48069
		PNVT - Oak		0	0	0	•	
		PNVT - Grasslands		0	1	0.242344	1.414	0.23674
		PNVT - PIPO		0	1	0.332794	1.951	0.16512
		FVS_QMD		0	1	0.075631	0.438	0.50952
		FVS_TPA		0	1	0.021913	0.126	0.72274
		FVS_TPA 24		0	1	0.36185	2.125	0.14764
		FVS_TPA 16		0	1	0.128796	0.747	0.38906
		FVS_TPA 8		0	1	0.421837	2.485	0.11769
		FVS_TPA 0		0	1	0.036277	0.210	0.64797
		FVS_Can_Cov		0	1	0.007353	0.042	0.83719
		FVS_Can_Cov 24		0	1	0.418666	2.465	0.1191
		FVS_Can_Cov 16		0	1	0.053489	0.309	0.57921
		FVS_Can_Cov 8		0	1	0.387996	2.281	0.13366
		FVS_Can_Cov 0		0	1	0.180441	1.050	0.30766
		FVS_BA		0	1	0.062108	0.359	0.5501
		FVS_BA 24		0	1	0.453116	2.673	0.10477
		FVS_BA 16		0	1	0.133079	0.772	0.38127
		FVS_BA 8		0	1	0.407385	2.398	0.12424
		FVS_BA 0		0	1	0.077371	0.448	0.50468

Step History

Step	Parameter	Action	"Sig Prob"	Seq SS	RSquare	Ср	р
1	Fire (2000-2009)	Entered	0.0000	8.539718	0.2847	10.801	2
2	Water_body	Entered	0.0061	1.343421	0.3294	4.8633	3
3	FVS_BA 24	Entered	0.1048	0.453116	0.3445	4.186	4
4	FVS BA 24	Removed	0.1048	0.453116	0.3294	4.8633	3

Response WEBL Presence Whole Model Actual by Predicted Plot



Summary of Fit

RSquare	0.329438
RSquare Adj	0.317975
Root Mean Square Error	0.414655
Mean of Response	0.5
Observations (or Sum Wgts)	120

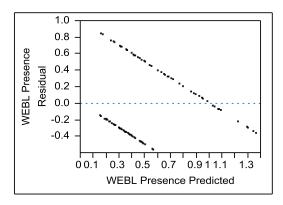
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	9.883139	4.94157	28.7402
Error	117	20.116861	0.17194	Prob > F
C. Total	119	30.000000		<.0001*

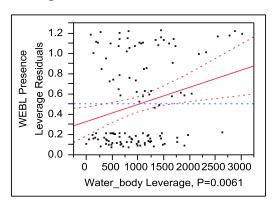
Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	0.0999564	0.080913	1.24	0.2192
Water_body	0.0001684	6.025e-5	2.80	0.0061*
Fire (2000-2009)	0.0001214	1.653e-5	7.34	<.0001*

Residual by Predicted Plot



Water_body Leverage Plot



Fire (2000-2009) Leverage Plot

