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Habitat Characteristics and Occupancy Rates of Lewis's Woodpecker in Aspen

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HABITAT CHARACTERISTICS AND OCCUPANCY RATES OF LEWIS'S

WOODPECKER IN ASPEN

by

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Approved:

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ABSTRACT

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Lewis's woodpeckers (*Melanerpes lewis*) are generally associated with open ponderosa pine (*Pinus ponderosa*), open riparian, and burned pine habitats in the West; however, this species has recently been found to nest in aspen (*Populus tremuloides*) stands in Utah. This study describes the habitat characteristics of Lewis's woodpecker nest sites in aspen and investigates how well aspen stand characteristics predict Lewis's woodpecker occupancy. I surveyed for Lewis's woodpeckers at previously occupied nesting locations in aspen and took habitat measurements at nest sites. In addition, nest-centered Forest Inventory and Analysis (FIA)-type plots provided stand-level habitat characteristics. I used logistic regression to determine which stand-level habitat variables were associated with nest locations; significant variables were then used to select FIA plots in Utah that contained predicted suitable nesting habitat. Criteria used to select FIA plots were aspen type stands, percent canopy cover less than 46%, and average tree diameter at breast height greater than 27.9 cm (11 inches). I then conducted occupancy surveys at FIA plots predicted to contain “suitable” and “non-suitable” Lewis’s woodpecker habitat to field validate the predictive model. No predicted non-suitable plots (*n*=26) were occupied and only one predicted suitable plot (*n*=49) was occupied. My results indicated that Lewis’s woodpeckers are rare throughout Utah in aspen stands even though there seems to be abundant nesting habitat available. My results also indicated that variables measured by FIA do not, in isolation, provide sufficient capability to predict Lewis’s woodpecker nesting habitat or actual use, and that more data are needed to accurately predict Lewis’s woodpecker nesting habitat, such as distance to, age, and severity of fires.

(62 pages)

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Amy M. Vande Voort

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BACKGROUND

As habitats have changed across the globe, certain species have shown habitat plasticity by being able to adapt to novel habitats. Habitat plasticity can be defined as the ability of an organism to utilize habitats with dissimilar characteristics (Simon et al. 2003) or newly introduced plant species, as seen with the Southwestern willow flycatcher (*Empidonax traillii extimus*) in exotic saltcedar (*Tamarix ramosissima*). The Southwestern willow flycatcher was historically associated with willow (*Salix* spp.) and cottonwood (*Populus* spp.) habitats; however, the species has been documented using sites now dominated by nonnative saltcedar (Sogge et al. 2003), thus exhibiting plasticity in habitat use.

Other species that have been documented using non-historic novel habitats include piping plover (*Charadrius melodus*) (McGowan et al. 2007) and little owls (*Athene noctua*) (Zmihorski et al. 2009). Piping plovers typically nest on unvegetated sand or gravel substrates, but have recently been documented nesting among cottonwood saplings on a sandbar in the Missouri River constituting a novel habitat (McGowan et al. 2007). Another example is the little owl population in Europe, which has declined during the last two decades because of a decline in grasslands and an increase in developed areas. Zmihorski et al. (2009) found a higher proportion of buildings in occupied territories, which suggests a tendency of the little owl to colonize more urban areas and suggests a high degree of habitat plasticity. Often times, species are able to exhibit plasticity in habitat use because their basic requirements (i.e., nesting sites, food, and shelter) are present in the novel habitat.

Recently, Lewis's woodpeckers (*Melanerpes lewis*) have been found nesting in aspen (*Populus tremuloides*) stands in central and northern Utah (UDWR, unpublished data), with aspen being a novel habitat. Lewis's woodpecker distribution has been closely linked to that of ponderosa pine (*Pinus ponderosa*) in the western United States (Diem and Zeveloff 1980, Saab and Vierling 2001). Their typical breeding habitat also includes open riparian cottonwoods and burned conifer forests; they are often referred to as "burn specialists" (Bock 1970, Saab and Dudley 1998, Saab and Vierling 2001). Previous to this study, habitat characteristics of aspen stands had not been measured; however, stand structure appeared similar to other Lewis's woodpecker nesting habitats, i.e., large diameter trees with open canopy that favors understory development and associated insect prey (Bock 1970). Studies investigating the habitat characteristics of these aspen stands have not previously been conducted even though aspen is the dominant deciduous tree in the Intermountain West and is an important nesting tree for many cavity-nesting birds (Dobkin et al. 1995).

Lewis's woodpecker is the fourth largest North American woodpecker. Adults range in size from 26 to 27 cm long with wingspans between 49 to 53 cm, and weights from 88 to 116 g (Tobalske 1997). Because they lack several anatomical adaptations (i.e., thickened skull and fused vertebrae) that allow for wood excavation (Goodge 1972), Lewis's woodpeckers rarely excavate trees for insects; instead, they primarily use fly-catching techniques (Tobalske 1996). The lack of these adaptations is also thought to be the reason why Lewis's woodpeckers demonstrate a propensity for secondary cavity nesting and nest in highly decayed or soft-wooded trees and snags (Tobalske 1997).

Lewis's woodpeckers nest from May through August. Snow (1941) reported nest excavation in the first two weeks of April in Utah with incubation starting around mid-April and lasting an average of 14 days. Both adult woodpeckers develop brood patches and at least one adult remains at the nest throughout incubation (Bock 1970). Earlier breeding dates were reported in southern regions and lower elevations within the woodpecker's range (Bock 1970). Lewis's woodpeckers lay one clutch per year with 5 to 11 eggs reported in the United States (Dudley and Saab 2003), and lower clutch sizes of 2 to 8 eggs reported in British Columbia (Campbell et al. 1990). Nestlings emerge from the cavity at 28 to 34 days old (Bock 1970, Tashiro-Vierling 1994, Dudley and Saab 2003).

During the breeding season, Lewis's woodpecker diets consist mainly of insects but change to mast and grain crops during the winter months when insects are less abundant. Lewis's woodpeckers cache food and are territorial around cache locations, especially during fall and winter (Snow 1941).

The Utah Division of Wildlife Resources (UDWR) listed Lewis's woodpeckers as a State Sensitive Species in 2007 and indicated that there was "credible scientific evidence to substantiate a threat to continued population viability" (UDWR 2007). The Lewis's woodpecker is also a Level II species of concern [at risk because of very limited and declining numbers, range, and habitat, making it vulnerable to global extinction or extirpation in the state] in Montana (Montana Natural Heritage Program 2004), Wyoming (Wyoming Game and Fish Commission 2005), and Oregon (Oregon Natural Heritage Information Center 2007); a Type III species of conservation need [vulnerable: at moderate risk because of restricted range, relatively few populations, recent and widespread declines, or other factors that make it vulnerable to range wide extinction or extirpation] in Idaho (Idaho Fish and Game 2006), Nevada (Nevada Natural Heritage Program 2007), and New Mexico (Natural Heritage New Mexico 2008); and is a state candidate species for review as a possible State Endangered, Threatened, or Sensitive species in Washington (Washington Department of Fish and Wildlife 2010). Lewis's woodpecker has been on the British Columbia Wildlife Branch Blue List since 1996 due to declining populations and threats to habitat (B.C. Wildlife Branch 1996).

Threats to the continuing decline of Lewis's woodpeckers include fire suppression and timber harvest. Efforts to suppress wildfire and some timber harvesting practices have greatly altered forest structure over the past century by increasing stem densities and reducing shrub and grass understories (Morgan 1994). Detrimental timber harvesting practices include clearcutting and selective cutting. Clearcutting usually creates a stand of dense, even aged trees while selective cutting decreases the number of large diameter trees required for nesting. Forestry practices that increase canopy closure make habitat unsuitable for Lewis's woodpecker breeding by reducing food base and decreasing foraging space (Wisdom et al. 2000).

Aspen stands exist in two forms on the landscape—seral and stable (DeByle et al. 1987). It is generally accepted that aspen is a seral tree species and that without fire or a stand-replacing agent aspen will succeed to conifers. However, aspen also acts as a climax stable species in certain sites where conifers do not succeed the aspen and the aspen is able to replace itself (DeByle et al. 1987). Initial nesting observations of Lewis's woodpeckers in Utah aspen (UDWR unpublished data) seemed to correspond to aspen stands where succession was not present.

Aspen stands in the Intermountain West are ecologically important due to their high biodiversity, and are subject to several threats to sustainability. Two of the primary threats are intertwined (i.e., fire suppression and conifer succession). Following a disturbance such as a fire, seral aspen will sprout profusely because the root system often survives. Conifers are not well adapted to regenerating abundantly after a disturbance. Thus, lack of disturbance in the ecosystem allows shade tolerant species (i.e., conifers) to encroach into aspen stands. As shade tolerant species encroach into aspen stands, aspen shoots do not receive sufficient sunlight and aspen recruitment is diminished. Without disturbance creating openings and promoting aspen regeneration, the aspen will eventually die out in the stand (Shepperd et al. 2006). With an increase in shade tolerant conifers, aspen stands appear to become unsuitable for Lewis's woodpeckers due to a decrease in foraging space, a potential decrease in stem diameter with higher stem densities, and an excurrent (i.e., spruce-like) tree growth habit that does not seem conducive for Lewis's woodpecker nest cavities.

Another threat to aspen ecosystems is over-use by domestic and wild ungulates. In areas with heavy grazing pressure, aspen cannot produce sufficient sprouts to overcome the browse pressure and regenerate (Shirley and Erickson 2001). Shirley and Erickson (2001) showed exclosures were effective at relieving browse pressure and allowing aspen to regenerate at small scales. Fencing becomes difficult, however, when large areas are targeted for restoration.

Over the past several decades, fire suppression and overgrazing in aspen communities have resulted in many aspen stands becoming old growth. Old growth aspen stands are defined as being stable in the short-term without any stand-replacing disturbance (Spies 2004). Mature trees in the stand cannot successfully regenerate due to dead roots, new shoots being browsed, or shoots not receiving enough sunlight. As these factors affect aspen stands year after year, the vigor of the stands are reduced and the stands will eventually be lost from the landscape; because of this, old growth aspen stands are frequently targeted for restoration (Bartos 2001). However, many old growth aspen stands in Utah exhibit open canopies and large diameter trees capable of supporting Lewis's woodpecker nesting. So while a lack of disturbance is detrimental to long-term persistence of aspen stands, interim old growth stands can provide nesting areas for Lewis's woodpeckers. This leads to a management conundrum: treatment of mature aspen stands to promote regeneration may threaten Lewis's woodpeckers, but without restoration, aspen stands may eventually die out or be replaced by conifers.

INTRODUCTION

Lewis's woodpeckers are typically associated with open ponderosa pine, lowland riparian, and burned conifer forest habitats (Bock 1970, Diem and Zeveloff 1980, Saab and Dudley 1998, Saab and Vierling 2001). Recently, however, Lewis's woodpeckers have been found nesting in old growth aspen habitats in central Utah (UDWR unpublished data). Old growth aspen stands are defined as being stable in the short-term without any stand-replacing disturbance (Spies 2004).

Populations of Lewis's woodpeckers are thought to be declining across the western United States and Canada (Cooper et al. 1998); however, data from Breeding Bird Survey results (Sauer et al. 2001) are inconclusive. Due to the local and patchy distribution of Lewis's woodpeckers, range-wide population estimates are not known. Lewis's woodpeckers were first placed on the National Audubon Society's Blue List in 1975 (Tate 1981), and in 2007 they were put on the National Audubon Society's WatchList. They are currently categorized as a red species—either rapidly declining, having a very small population or limited range and face conservation threats (National Audubon Society 2010).

In Utah's Salt Lake and Davis counties, Lewis's woodpeckers declined dramatically between 1932 and 1986 (Sorenson 1986) and have been extirpated from most of their historical breeding range along the Wasatch Front (Sauer et al. 2001). Because of limited distribution, threats to habitats, and population declines, Lewis's woodpeckers were ranked as the top species "in most need of conservation" by Utah Partners in Flight (Parrish et al. 2002). Also, the Utah Division of Wildlife Resources listed Lewis's woodpeckers as a State Sensitive Species because Utah represents a substantial portion of the species' breeding range and that range has been much reduced within the state. For these same reasons, Lewis's woodpeckers were listed as a Tier II Wildlife Action Plan species in Utah (Sutter et al. 2005).

Most surveys conducted for Lewis's woodpeckers have been presence only or nesting surveys after major wildfires or in areas where forest treatments were planned or had occurred. These methods typically do not include probability of detection and cannot be reliably used to estimate abundance, density, or occupancy rates over larger areas (Thompson 2002, MacKenzie et al. 2006). No occupancy surveys have been published on Lewis's woodpeckers in any part of their range.

Because of the small number of studies and observations of Lewis's woodpeckers in aspen stands and their sensitive species status (Sutter et al. 2005), this study was undertaken to address the following objectives:

1) identify and describe characteristics of aspen habitat at Lewis's woodpecker nest sites using a modified James and Shugart protocol (James and Shugart 1970) and Forest Inventory and Analysis (FIA) data;

2) develop a predictive Lewis's woodpecker aspen habitat model based on FIA data from known nest sites and evaluate the usefulness of an extant database (USDA FIA database) in selecting suitable habitat for a specific avian species;

3) conduct occupancy surveys for Lewis's woodpecker at model-predicted sites to field validate the predictive model.

METHODS

Study Area

The study area (Fig. 1) was forested public land statewide and a portion of forested tribal land in Duchesne County in Utah. Study sites were restricted to aspen forest, however there were occasionally other tree species mixed in with the aspen. These included lodgepole pine (*Pinus contorta*), Douglas fir (*Pseudotsuga menziesii*), Engelmann's spruce (*Picea engelmannii*), juniper (*Juniperus* spp.), single leaf pinyon pine (*Pinus monophylla*), Colorado pinyon (*Pinus edulis*), and Gambel oak (*Quercus gambelii*). Shrubs found within the study area included sagebrush (*Artemisia* spp.), mountain snowberry (*Symphoricarpos oreophilus*), rose (*Rosa* spp.), mountain mahogany (*Cercocarpus* spp.), choke cherry (*Prunus virginiana*), and serviceberry (*Amelanchier* spp.). Elevation of the surveyed aspen habitat ranged from 1800 – 3200 m, daily temperatures during the breeding season (May – July) ranged from -3°C for a low and over 37°C for highs (National Weather Service 2010), and the average annual precipitation ranged from 25 – 64 cm (Utah Center for Climate and Weather 2009).

Nest Data Collection

I conducted surveys for Lewis's woodpecker nests from May through July during 2009 and 2010. Surveys were conducted by visiting previously recorded nest areas in aspen and areas with aspen habitat similar to nest areas (i.e., open stands with large diameter trees) identified by United States Forest Service (USFS) silviculturists. Aspen stands were searched by walking transects 200 m apart throughout the aspen stand.

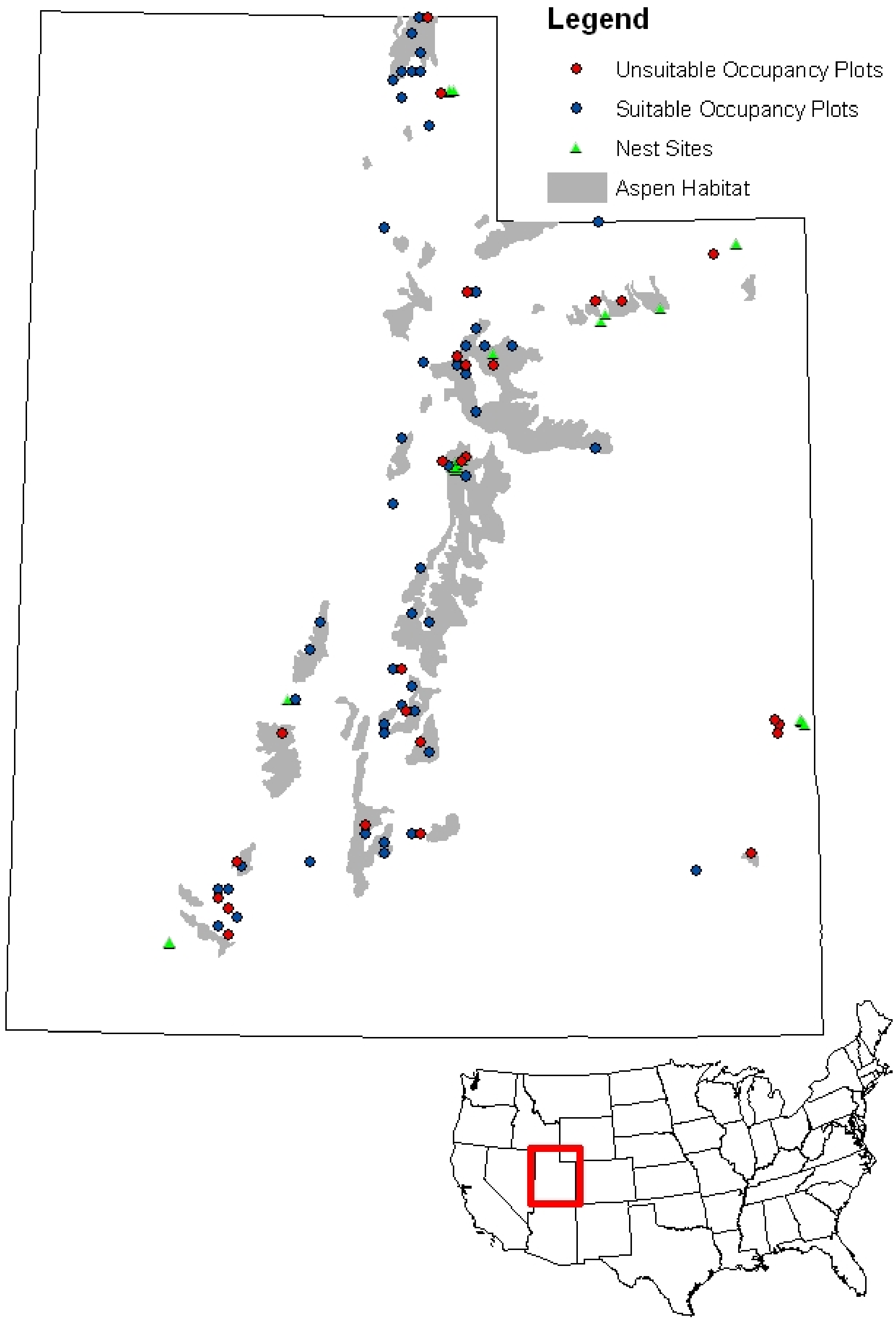


Figure 1. Lewis's woodpecker nest locations from 2009 and 2010 and suitable and unsuitable occupancy locations sampled in 2010 overlaid on the aspen dominant vegetation layer from LANDFIRE (http://www.landfire.gov/).

When adults were found, nests were located by observing behavior (e.g., courtship, carrying food, interactions with other nesting pairs, young heard food begging) to determine if the cavity was a nest or a food cache. Coordinates of nests were obtained with a handheld Global Positioning System (GPS) unit (Garmin GPSmap 60CSx). Several nests were visited multiple times throughout the summer to determine when Lewis's woodpeckers left the aspen stands after chicks fledged. These nests were also used to develop an occupancy survey protocol including determining the appropriate size of plots for the 2010 field season.

Habitat Measurements

Forest Inventory and Analysis plots centered on active nest sites were set up at each of the 16 occupied nests in 2009 to measure stand-level habitat characteristics (United States Forest Service 2007). Forest Inventory and Analysis plots consisted of a center plot and three subplots—one each at 36.6 m (120 ft) from the center at 120°, 240°, and 360° azimuths (Fig. 2). The FIA protocol was modified only in that habitat variables were collected in non-forested sub-plots that fell just outside the occupied stands to obtain more detailed stand-level habitat characteristics. Center plots and subplots had a 7.3-m (24 ft) radius and each of these plots had a 2.1-m (6.8 ft) radius microplot that was 3.7-m (12 ft) at 90° from the center of the plots.

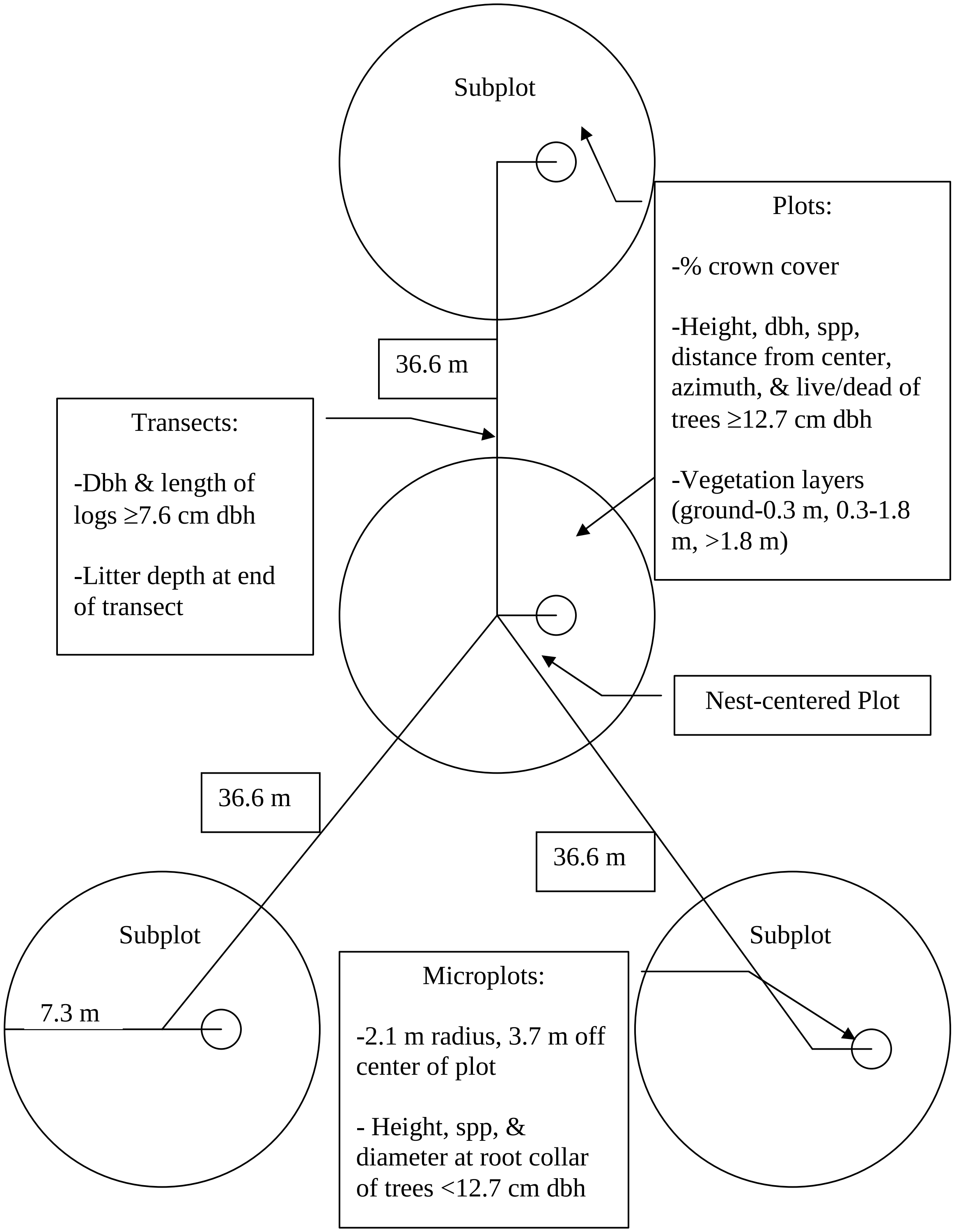


Figure 2. Forest Inventory and Analysis plot diagram depicting how plots were set-up to measure stand level habitat characteristics at Lewis's woodpecker nest sites in 2009.

Forest Inventory and Analysis crews measured over 100 habitat variables at each 0.1-hectare plot, which included a center plot and three subplots (United States Forest Service 2007). Stand and tree variables measured included percent crown cover, tree species, diameter at breast height (dbh), heights, distance, and azimuth from center for all trees ≥12.7 cm (5 in) dbh. Species of any grass, forb, shrub, or tree <12.7 cm dbh were identified if they had at least 5% cover within the plot. Dominant vegetation form (i.e., grass, forb, shrub, or tree) in each vegetation layer above the ground (<0.3 m, 0.3 m-1.8 m, >1.8 m) was also identified and the percent shrub cover in each layer was measured. At least two representative aspen trees were cored to determine the age of the stand.

In the microplots, every tree that was <12.7 cm dbh was measured for height, species, distance from center, azimuth, live/dead, and diameter at root collar. To measure down, coarse, and fine woody debris, 36.6 m transects between the center plot and subplots were walked. The diameter, length, species, and rot class were measured wherever the center of the transect crossed any downed material >7.6 cm in diameter. Three classes (0.025 cm-0.61 cm, 0.62 cm-2.53cm, 2.54 cm-7.4 cm) of fine woody debris were counted in the last 3.0 m of the transects; the smallest class was only counted in the last 1.8 m. The classes were measured by counting the number of pieces in each class that the center of the transect crossed. Litter depth was measured at the end of each transect. From these measured variables, other variables are derived, such as number of live trees and snags per hectare, stand basal area, and stand age (United States Forest Service 2007).

In addition to the FIA plots set up at the occupied nest sites, an 11.3-m radius (0.04 ha) circular plot with a nested 5-m radius circular subplot were established, both centered on the nest tree at 28 occupied Lewis's woodpecker nest sites in 2009 and 2010. Plot design and methods follow a modified James and Shugart (1970) protocol. The modified James and Shugart plots were set up for easier comparison to previous studies that used this method.

Plots were divided into 4 quadrants with the initial bearing being randomly selected and the following transects being perpendicular (Fig. 3). In the 11.3-m plot, dominant shrub species and heights and dbh of each tree >1.37 m tall with a diameter at breast height of ≥20 cm were measured. Tree species, condition (live or dead), number of cavities, and number of fungal conks on each tree was also measured. Number of fungal conks was not used to assess the level of decay in the stand, but only used to determine if heartrot (*Phellinus tremulae*) or other diseases were present because the presence of fungal conks is not a good indicator for the degree of decay (Schepps et al. 1999). Percent canopy cover and lengths of logs ≥20 cm dbh were measured in the 11.3-m plot, too. To measure percent canopy cover, an ocular tube was used to measure the amount of canopy cover every one meter from the center of the plot in four perpendicular directions for a total of 44 measurements. These measurements were averaged and converted to a percentage of canopy cover. For each nest tree, tree species, dbh, height, nest cavity height, condition, number of cavities, and number of fungal conks was measured. In the 5-m subplot, the number of aspen shoots <20 cm dbh, the number of woody stems between 0.5 – 1.37 m tall and <20 cm dbh, and the number and species of conifers no matter what size were counted. Heights of shrubs and percent green ground cover in a 1-m^2 area every one meter starting from the center of the plot in four perpendicular directions were measured for a total of 20 measurements. From the center

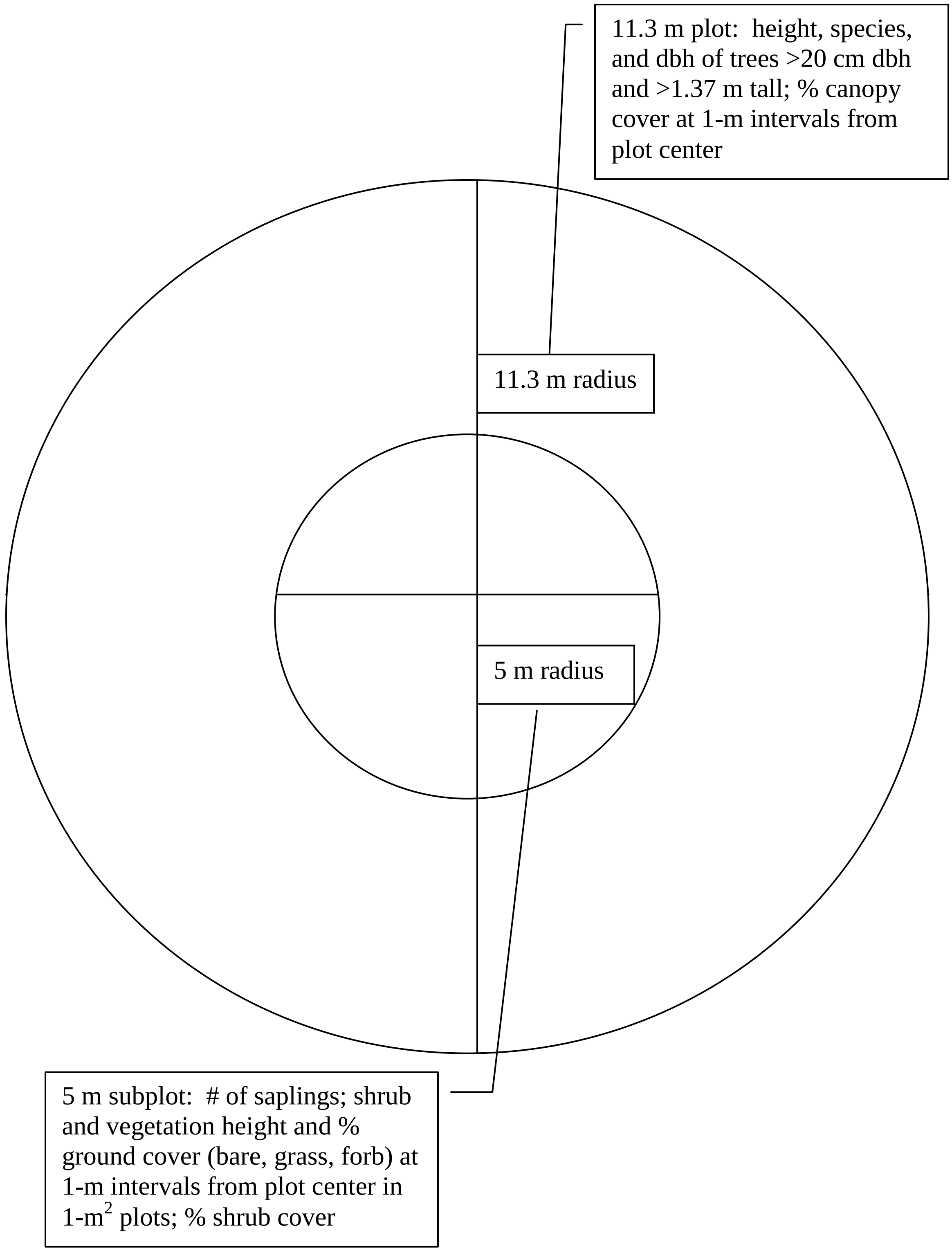


Figure 3. Modified James and Shugart plot diagram depicting how plots were set-up to measure nest-site habitat characteristics at Lewis's woodpecker nest sites in 2009 and 2010. Plots were centered on the nest tree.

of the plot, slope, aspect, elevation, distance to nearest edge, and nearest alternate habitat were measured. Stand size was determined based on National Agriculture Imagery Program (NAIP) 2009 aerial imagery in ArcMap Version 9.3.

Logistic Model For Nest Site Prediction

To develop the initial habitat model, FIA data from the aspen stands occupied by Lewis's woodpeckers in 2009 were analyzed using Program SAS (SAS Institute 2007). I used 100 randomly selected aspen FIA plots from the FIA database and used these as the non-nest locations in the analysis. I used Proc LOGISTIC to obtain the Maximum Likelihood Estimates for the FIA variables to determine if there was any relationship between these variables and presence of a nest (Table 1). Presence of a nest was the response variable and the FIA habitat measurements were predictor variables.

Table 1. Forest Inventory and Analysis habitat variable associations with nest occurrence of Lewis's woodpeckers in Utah aspen (n = 16 known occupied sites in 2009) using logistic regression in Program SAS.

Parameter	Max. likelihood estimate	SE	Wald χ^2	$P > \chi^2$
Average dbh	0.4588	0.2138	4.6069	0.0318
% crown cover	-0.1494	0.0767	3.7907	0.0515
Average tree height	-0.6933	0.3615	3.6776	0.0551
% shrub cover	-0.1058	0.0622	2.8883	0.0892
# of snags	-0.5820	0.4613	1.5919	0.2071
Snags >20cm dbh/Total trees	2.6542	2.3755	1.2484	0.2639
Total snags/Live trees	1.3997	2.0154	0.4823	0.4874
Snags >20cm dbh	0.4069	0.5862	0.4818	0.4876
# Trees >20cm dbh	0.1072	0.1706	0.3950	0.5297
Intercept	1.2817	4.0611	0.0996	0.7523
Total # of trees	-0.0251	0.102	0.0607	0.8054
Total snags/Total trees	-0.7790	4.4234	0.0003	0.9860

[a]Degrees of freedom = 1.

Significant variables from the logistic regression were used in a backward stepwise regression. Backward stepwise regression selects the model with the fewest number of predictor variables adding in all the variables to the model and then removing variables until the change in model fit is no longer significant at the $P \leq 0.05$ level. I used stepwise regression to determine which stand-level FIA habitat variables best described Lewis's woodpecker nest habitat (Table 2). Model fit (R^2) was calculated using fit=1-(intercept and covariates/intercept only) from the –2logL values obtained from the Model Fit Statistics output. I used Proc MEANS to obtain means, standard deviations, and 95% confidence intervals of selected significant habitat variables. I classified FIA plots as potentially suitable based on mean + 2 SD for crown cover because it encompassed a similar but somewhat larger range of what Lewis's woodpecker have been reported using and it gave a more conservative selection of sites to be more inclusive of aspen habitat types. Reported ideal canopy cover values for Lewis's woodpecker nest sites are <30% (Sousa 1983, Linder and Anderson 1998). Mean – 1 SD for average dbh was also used for classifying FIA plots as potentially suitable because Lewis's woodpeckers cannot nest in smaller diameter trees due to their body size (Abele et al. 2004) so surveying plots with smaller diameter trees would not have been beneficial. The smallest previously reported nest tree diameters at breast height (41.3 cm ± 15.3) were in riparian aspen (Newlon and Saab 2011). Plots that fell within these parameters were selected for occupancy surveys in 2010 and labeled as suitable. These suitable plots were paired with FIA plots that were within 80 km and aspen type but did not meet the requirements for either crown cover or average dbh; these plots were labeled as unsuitable.

Table 2. Habitat variable significance using stepwise regression in Program SAS on occupied Lewis's woodpecker nest sites (n = 16) and randomly selected Utah aspen Forest Inventory and Analysis plots (n = 100).

Parameter	Max. likelihood estimate	SE	Wald χ^2	$P > \chi^2$
Intercept	-3.4468	1.6818	4.2003	0.0404
Average DBH	0.1922	0.0732	6.8920	0.0087
% crown cover	-0.0781	0.0202	14.9043	0.0001

[a]Degrees of freedom = 1.

To analyze James and Shugart habitat variables, I used Program SAS Proc MEANS to obtain means, standard deviations, and 95% confidence intervals of measured habitat variables to enable comparison to other studies (Table 3).

Table 3. Summary statistics for selected habitat variables measured at Lewis's woodpecker nest sites (n = 28) in Utah aspen stands following a modified James and Shugart method.

Covariate	$\bar{x}$	± 1 SD	Range	Lower 95% C.I.	Upper 95% C.I.
Nest height (m)	4.49	2.12	(0.76, 9.97)	3.71	5.27
Nest tree dbh (cm)	35.79	5.89	(25.90, 50.80)	33.51	38.08
Average nest tree height (m)	12.16	4.60	(4.60, 21.70)	10.38	13.94
Aspen saplings/ha	207.15	288.10	(0, 1300)	95.43	318.85
Percent canopy cover	29.22	22.77	(0.0, 71.48)	20.39	38.05
Number of woody stems	23.86	33.29	(0, 150)	10.95	36.77
Percent green ground cover	62.94	16.69	(30, 97.75)	56.46	69.41
Vegetation height (m)	0.37	0.19	(0.12, 0.89)	0.30	0.45
Shrub height (m)	0.30	0.43	(0.0, 1.34)	0.13	0.47
Percent shrub cover	7.96	15.71	(0.0, 60)	1.87	14.06
Average tree dbh (cm)	27.41	10.76	(0.0, 40.9)	23.23	31.58
Stand size (ha)	4.33	4.58	(0.4, 16.2)	2.56	6.11
Distance to edge (m)	19.52	15.05	(0.0, 65.8)	13.69	25.35
Percent slope	7.79	5.51	(0, 24)	5.65	9.92

Estimating Detectability and Occupancy

Three occupied nest sites that were not located within FIA plots were used in 2010 to determine baseline detectability of Lewis's woodpeckers; this was done to generate an estimate of detection probability in case too few FIA plots were occupied. The three occupied nest sites were visited at least 12 times throughout the nesting season. Plots were 400 m x 200 m which was based on an average Lewis's woodpecker home range size of 8 hectares (Ministry of Environment, Lands, and Parks 1999). Each plot was visited by at least two people who did not know the nest location to avoid bias in detection. Surveys consisted of a transect walked lengthwise through the middle of the plot for 30 minutes including 5 minute stops at beginning, middle and end; surveys were conducted between half hour after sunrise and half hour before sunset under favorable weather conditions (light winds, no precipitation). All surveys were conducted after Lewis's woodpeckers were observed in aspen stands in the spring and before the birds migrated to their wintering habitat (based on observations during 2009 and 2010). Once a Lewis's woodpecker was found, the survey was stopped to avoid disturbing the nesting birds.

Occupancy sampling (MacKenzie et al. 2006) was conducted by trained UDWR biologists in 400 m x 200 m plots centered on selected FIA sites with predicted suitable (n = 49) and predicted unsuitable (n = 26) Lewis's woodpecker habitat during May through July in 2010. Based on observations during 2009 and 2010, woodpeckers were reliably detected in nesting areas during May through July, so I considered this period as a single season for occupancy analysis.

All plots (n = 75) were visited three times by at least two different people. Visits were at least one week apart; during one visit, I assessed whether the plots were "suitable" or not to evaluate the accuracy of the predictive model. If a Lewis's woodpecker was detected, the occupancy survey was stopped, but searchers continued to look for other Lewis's woodpeckers in the area for at least 10 additional minutes. Each sighting of a Lewis's woodpecker was marked with a GPS, and I followed up each sighting to look for a nest in the area.

I analyzed three different data sets: 1) all 12 visits to the three detectability plots; 2) a random selection of three visits from each of the detectability plots and data from the single occupied occupancy plot; 3) occupancy data from the 49 suitable FIA plots. I used Program MARK to obtain detection (p) and occupancy rates (ψ) for each of the datasets. Data were analyzed using a single species, single season occupancy model. Program MARK does not allow for occupancy to vary using a single season occupancy model or detection rates cannot be calculated. Researchers should be able to determine an appropriate season length based on the species' biology to design surveys that are unlikely to violate this assumption. Based on field observations, Lewis's woodpeckers consistently occupied plots throughout the survey period, thus justifying holding occupancy constant in a single season model.

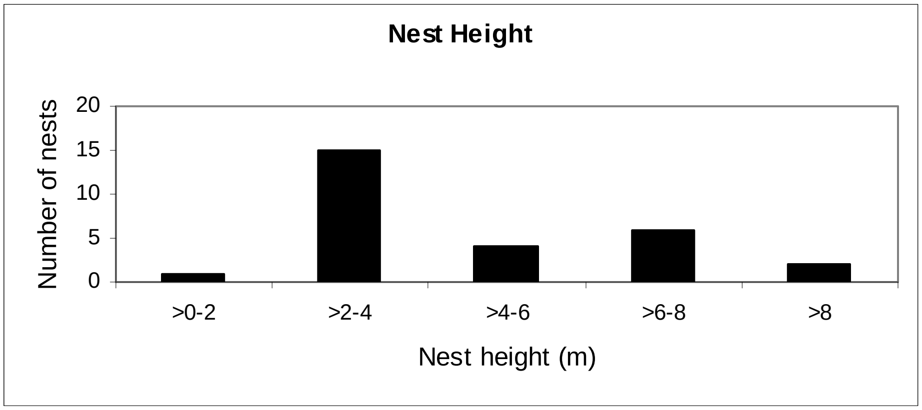
Three a priori models were used for the occupancy data. The first model held detection probability constant; this assumes no change in detectability throughout the season. The second model allowed the detection probability to differ over time; this accounts for change in detectability due to the birds' behavior. For example, this might be seen if the birds are more vocal during courtship, silent during incubation, and then more active once young hatch, so detection probability can increase or decrease throughout the sampling period. The third model added in a trend for detection probability. This allows for a directional change in detection probability due to changes in the birds' behavior. For example, an increasing detectability trend might be seen if woodpeckers became more active (and visible) as eggs hatch and young leave the nest.

RESULTS

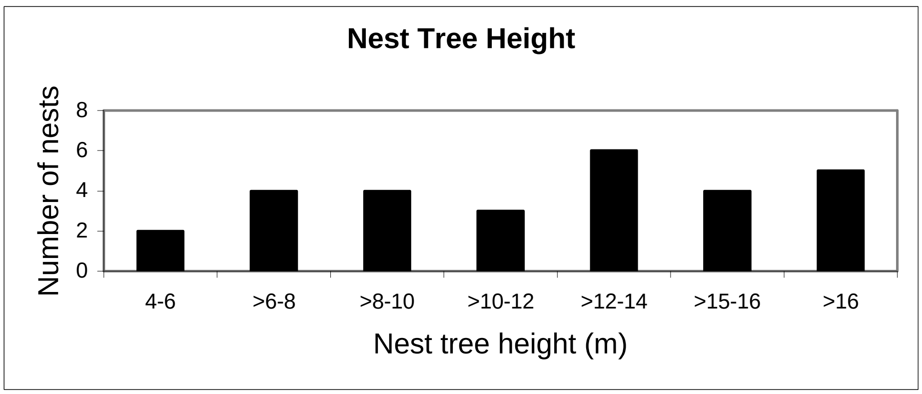
Habitat Measurements

Forest Inventory and Analysis and James and Shugart habitat measurements both gave similar habitat results around nest sites of large diameter trees and little canopy or crown cover. James and Shugart measurements gave nest level habitat characteristics, whereas, FIA measurements gave stand level habitat characteristics. James and Shugart habitat measurement summary descriptive statistics are given in Table 3 and Figure 4. Key results from these measurements are that Lewis's woodpeckers use large diameter trees in areas with <30% canopy cover. Aspen stands with Lewis's woodpecker nest locations also had aspen regeneration below what is required for successful regeneration of the stand (Crouch 1983, Barnett and Stohlgren 2001, Kilpatrick et al. 2003). Another key result was the relatively small average size of the aspen stands (ca. 4 ha), which makes mapping these aspen stands difficult at large scales because they are surrounded by other dominant vegetation types. Only one of the 16 FIA measured nest sites had conifers present, indicating that nest sites appeared to be primarily located in stable aspen stands.

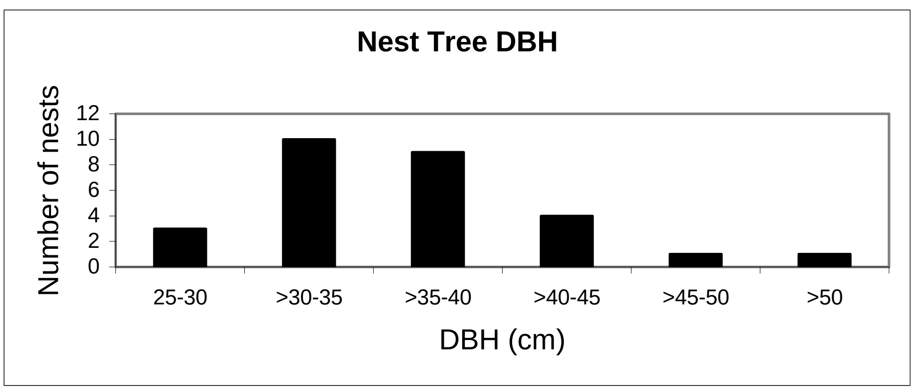
a.


Nest Height
Number of nests
0
5
10
15
20
>0-2
>2-4
>4-6
>6-8
>8
Nest height (m)

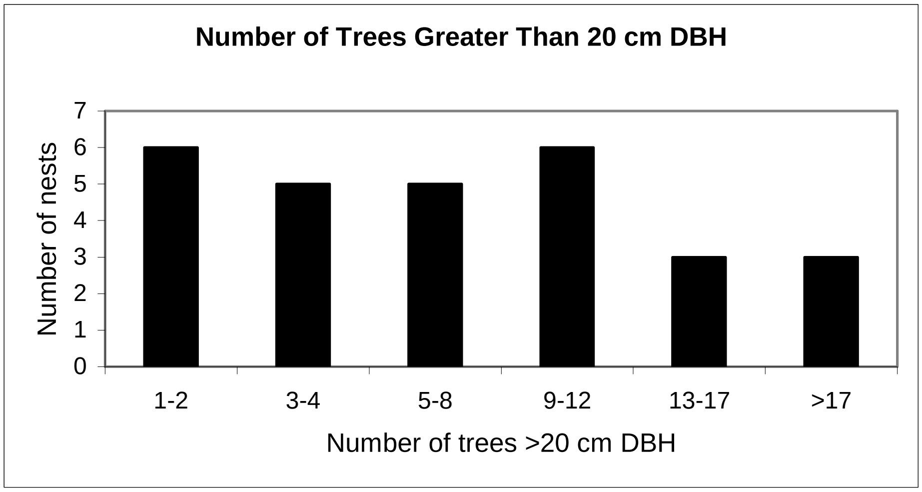
b.


Nest Tree Height
Number of nests
0
2
4
6
8
4-6
>6-8
>8-10
>10-12
>12-14
>15-16
>16
Nest tree height (m)

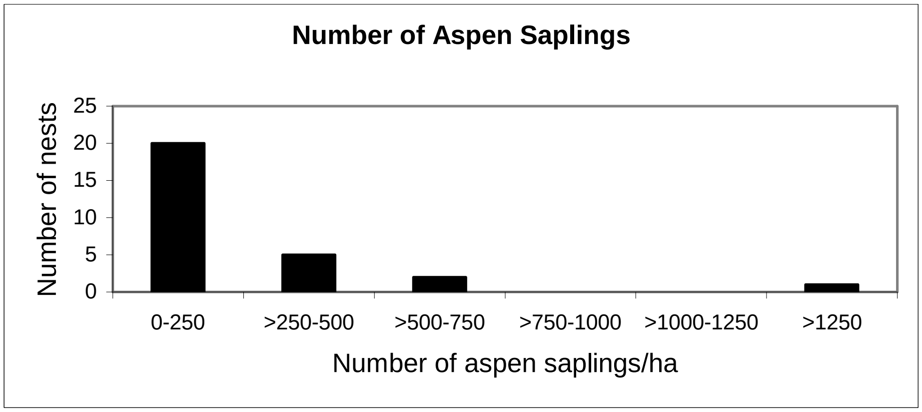
c.


Nest Tree DBH
Number of nests
0
2
4
6
8
10
12
25-30
>30-35
>35-40
>40-45
>45-50
>50
DBH (cm)

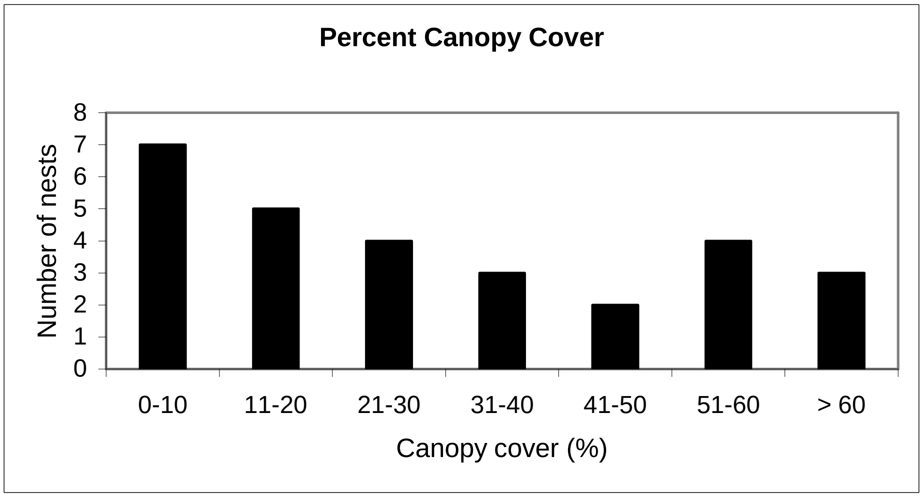
d.


Number of Trees Greater Than 20 cm DBH
Number of nests
0
1
2
3
4
5
6
7
1-2
3-4
5-8
9-12
13-17
>17
Number of trees >20 cm DBH

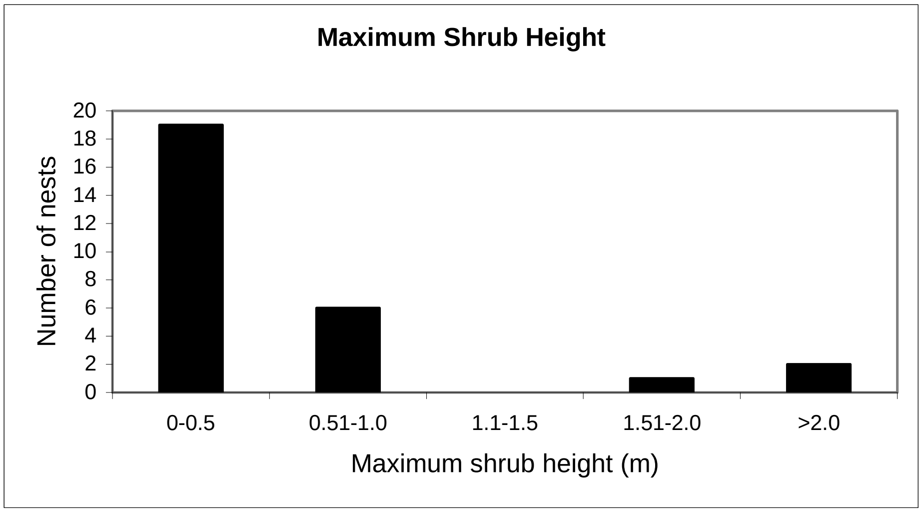
e.


Number of Aspen Saplings
Number of nests
0
5
10
15
20
25
0-250
>250-500
>500-750
>750-1000
>1000-1250
>1250
Number of aspen saplings/ha

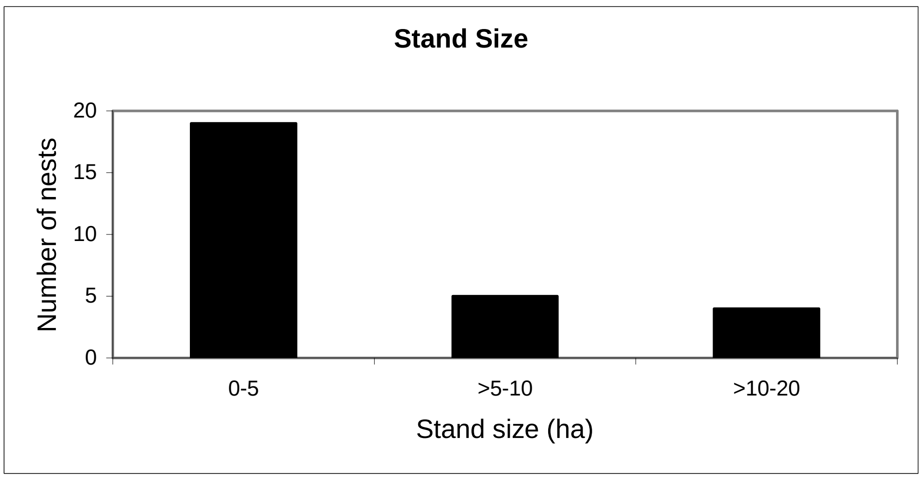
f.


Percent Canopy Cover
Number of nests
0
1
2
3
4
5
6
7
8
0-10
11-20
21-30
31-40
41-50
51-60
> 60
Canopy cover (%)

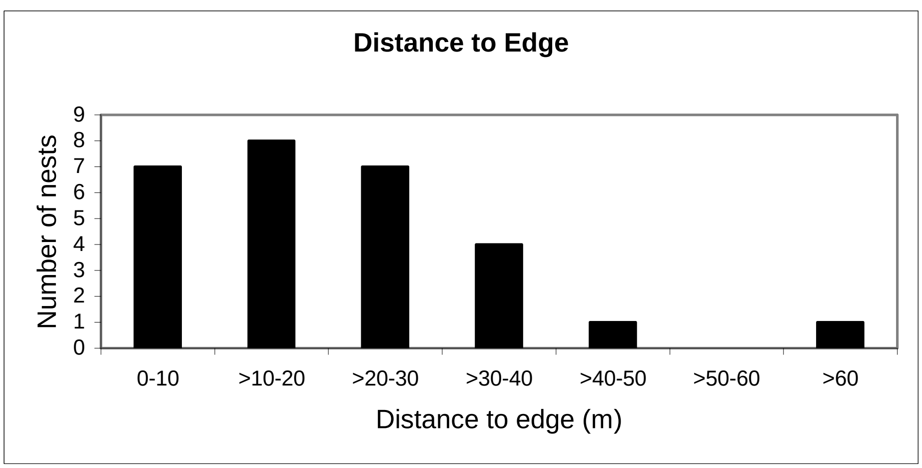
g.


Maximum Shrub Height
Number of nests
20
18
16
14
12
10
8
6
4
2
0
0-0.5
0.51-1.0
1.1-1.5
1.51-2.0
>2.0
Maximum shrub height (m)

h.


Stand Size
Number of nests
20
15
10
5
0
0-5
>5-10
>10-20
Stand size (ha)

i.


Distance to Edge
Number of nests
9
8
7
6
5
4
3
2
1
0
0-10
>10-20
>20-30
>30-40
>40-50
>50-60
>60
Distance to edge (m)

j.

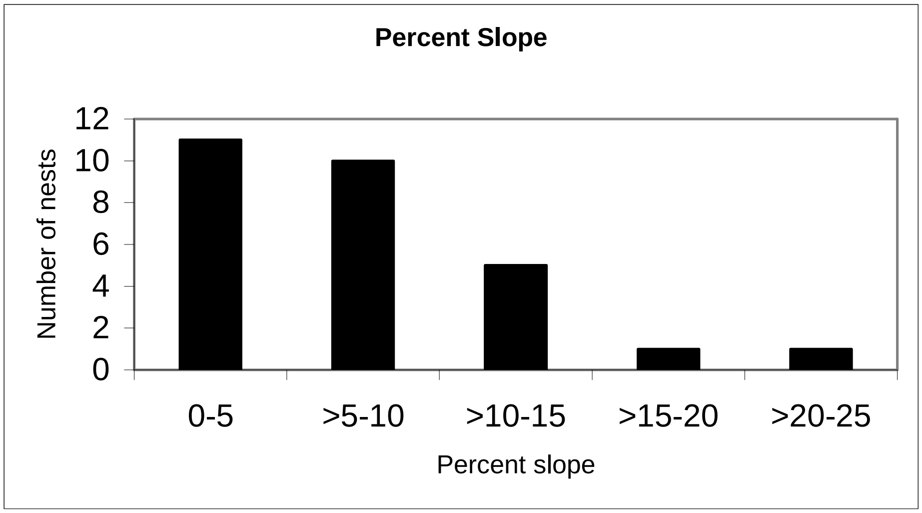


Figure 4. Frequency distribution of nest tree covariates (a. nest height; b. nest tree height; and c. diameter at breast height) and nest site covariates (d. number of trees; e. number of aspen saplings; f. percent canopy cover; g. maximum shrub height; h. stand size; i. distance to edge; and j. percent slope) for 28 Lewis's woodpecker nests in mountain aspen stands in Utah, 2009-2010.

Logistic Model For Nest Site Prediction

According to the logistic regression results, crown cover and average diameter at breast height ($P \leq 0.05$) were associated with Lewis's woodpecker nest occurrence (Table 1). Crown cover was negatively associated with nest occurrence ($P = 0.05$) indicating that less crown cover is favorable. Average diameter at breast height ($P = 0.03$) was positively associated indicating that larger diameter trees are characteristic of Lewis's woodpecker nesting areas. Average tree height ($P = 0.06$) and percent shrub cover ($P = 0.09$) had $P < 0.1$, which I would suggest using for future iterations of the model; however, fewer variables were used for a more inclusive initial model. Average tree height and percent shrub cover were negatively associated with nest occurrence, possibly indicating more broken-topped, and thereby shorter, trees and less shrub cover around nest sites. Based on the classification cutoff of 0.5, where *P* > 0.5 were classified as nests and *P* < 0.5 were classified as non-nest sites, the logistic model correctly predicted 87.1% of the nest and non-nest sites using all the habitat variables. Model fit (R^2) equaled 0.678.

Backward stepwise regression indicated that only crown cover and average diameter at breast height met the *P* < 0.05 significance level for entry into the model (Table 2). The resulting model correctly predicted 85.3% of the nest and non-nest sites. Model fit equaled 0.378, which was substantially lower than the model fit for all the variables; however, model fit will decrease with a decrease in number of variables. Crown cover and average diameter at breast height explain almost 40% of the model fit and the addition of ten more variables increases model fit by only about 30%, an average of 3% per variable. Crown cover ($\bar{x}$ = 24.4%, SD = 11.2%), diameter at breast height ($\bar{x}$ = 31.6 cm, SD = 4.19 cm), and forest type dominated by aspen were used to select suitable FIA plots for the 2010 field season. Plots that contained predicted unsuitable habitat were also aspen type, but either had a higher percentage of crown cover or did not have at least one tree 27 cm dbh. Forty-nine plots in Utah met the predicted suitable criteria; 26-paired plots were classified as predicted unsuitable. The 49 predicted suitable aspen plots represent 14% of the total aspen FIA plots in Utah.

Estimating Detectability and Occupancy

Occupancy surveys were conducted at 75 FIA sites. Forest Inventory and Analysis plots with predicted Lewis's woodpecker habitat met each of the following criterion: aspen type, open canopy with <46% crown cover, and at least one tree >26 cm dbh. Sites that did not contain predicted Lewis's woodpecker habitat were aspen type but either had a higher percentage of crown cover or did not contain a tree ≥27 cm dbh.

Twelve of the 49 predicted suitable plots appeared unsuitable and three of the 26 predicted unsuitable plots appeared suitable. These errors can be seen in a confusion matrix (Table 4) where *a* and *d* denote correct classifications and *b* and *c* are interpreted as errors. Element *b* is a measure of commission (false positive or overprediction) and *c* is a measure of omission (false negative or underprediction) (Fielding and Bell 1997). Only one predicted suitable plot was occupied by a pair of Lewis's woodpeckers, and no predicted unsuitable plots were occupied.

Table 4. A confusion matrix used to calculate accuracy measurements for the predicted Forest Inventory and Analysis plots (*n* = 75) used for the Lewis's woodpecker occupancy sampling in Utah 2010.

		Actual	
		Present	Absent
Model	Present	*a* (37)	*b* (12)
	Absent	*c* (3)	*d* (23)

From the confusion matrix derived accuracy measurements (Table 5), sensitivity (0.925) and specificity (0.657) are both relatively high; omission (0.075) of the predictive model is low; commission (0.343) is high when compared to omission. The correct classification rate (0.8) for the predictive model was also high. The following ranges for the Kappa (K) statistic were suggested by Landis and Koch (1977): poor $K < 0.4$; good $0.4 < K < 0.75$ and excellent $K > 0.75$. Kappa for this study (0.592) falls in the good category.

Table 5. Confusion matrix derived measures of classification accuracy for the predicted Forest Inventory and Analysis plots (*n* = 75) used for Lewis's woodpecker occupancy sampling in Utah 2010.

Measure	Result
Correct classification rate	0.800
Sensitivity	0.925
Specificity	0.657
False positive rate (Commission)	0.343
False negative rate (Omission)	0.075
Kappa	0.592

Three detectability plots were surveyed 12 times throughout the summer 2010. During at least one survey, the Lewis's woodpeckers were not on the plot at the time of the survey, but were observed from the plot during the survey. On average, Lewis's woodpeckers were detected in each plot 10 of the 12 visits.

For the two datasets that included the three detectability plots, the model that was ranked highest allowed detection to vary with time and had over 99% of the model weight. The other two models were not competitive (>10 AIC_c) with the highest model. The trend model was ranked second and showed an increase in detectability towards the end of the survey season for the dataset with the 12 detectability visits (Table 6). For the dataset with the occupied occupancy plot data included, the trend model showed a decrease in detectability during the second survey (Table 7). The last ranked model was the null model, which did not allow for any trend or differences in detection over time.

Table 6. Models fit in Program MARK to Lewis's woodpecker detectability plots (n = 3) visited 12 times from May-July 2010 in Utah.

Model	Δ AICc	*w*	*Npar*	Deviance	ψ	SE (ψ)	p_1	SE(p_1)
ψ(.)p(t)	0.000	0.995	13	11.457	1	$0.368e^{-21}$	0.667	0.272
ψ(.)p(T)	10.787	0.005	14	22.154	1	$0.132e^{-19}$	0.853	0.061
ψ(.)p(.)	21.437	0.000	2	21.803	1	$0.860e^{-8}$	0.853	0.061

Model	p_2	SE(p_2)	p_3	SE(p_3)	p_4	SE(p_4)	p_5	SE(p_5)
ψ(.)p(t)	0.667	0.272	1.000	$0.443e^{-21}$	1.000	$0.443e^{-21}$	0.667	0.272
ψ(.)p(T)	0.674	0.049	0.725	0.059	0.771	0.066	0.811	0.069
ψ(.)p(.)	.	.	.	.	.	.	.	.

Model	p_6	SE(p_6)	p_7	SE(p_7)	p_8	SE(p_8)	p_9	SE(p_9)
ψ(.)p(t)	1.000	$0.369e^{-21}$	0.667	0.272	1.000	$0.369e^{-21}$	1.000	$0.369e^{-21}$
ψ(.)p(T)	0.845	0.068	0.874	0.066	0.899	0.061	0.919	0.056
ψ(.)p(.)	.	.	.	.	.	.	.	.

Model	p_{10}	SE(p_{10})	p_{11}	SE(p_{11})
ψ(.)p(t)	1.000	$0.369e^{-21}$	0.500	0.354
ψ(.)p(T)	0.935	0.050	0.948	0.044
ψ(.)p(.)	.	.	.	.

[a]Δ AICc is the relative difference in AICc values compared with the top-ranked model; *w* is the AICc model weight; *Npar* is the number of parameters. Estimates of occupancy (ψ) and its standard error (SE(ψ)) and estimates of detection probabilities (*p*) and its standard error are given.

Table 7. Models fit in Program MARK to data from three randomly chosen visits from the Lewis's woodpecker detectability plots and one occupied occupancy plot (n = 4) visited from May-July 2010 in Utah.

Model	Δ AICc	w	$Npar$	Deviance	ψ	SE (ψ)	p_1	SE(p_1)
ψ(.)p(t)	0.000	0.999	4	0.000	1	0.000	1.000	0.000
ψ(.)p(T)	14.127	0.001	5	2.127	1	$0.106e^{-18}$	1.000	$0.329e^{-9}$
ψ(.)p(.)	50.385	0.000	2	2.385	1	0.000	0.917	0.080

Model	p_2	SE(p_2)	p_3	SE(p_3)
ψ(.)p(t)	1.000	0.000	0.750	0.217
ψ(.)p(T)	0.821	0.128	0.884	0.119
ψ(.)p(.)	.	.	.	.

[a]Δ AICc is the relative difference in AICc values compared with the top-ranked model; w is the AICc model weight; $Npar$ is the number of parameters. Estimates of occupancy (ψ) and its standard error (SE(ψ)) and estimates of detection probabilities (p) and its standard error are given. T = trend; t = time.

Of the three models tested for the occupancy plots, all of which held occupancy constant, the model that was ranked highest held detection rates constant, was the most parsimonious, and had 71% of the weight; the trend model was competitive at 2.3 AICc units away from the top model and 23 % of the weight (Table 8). A high probability of detection estimate, i.e., approaching 1.0, that is constant through the breeding season is consistent with field observations (Fig. 5).

Table 8. Models fit in Program MARK to Lewis's woodpecker occupancy data (n = 49) from 2010 in Utah.

Model	Δ AICc	*w*	*Npar*	ψ	SE (ψ)	p_1	SE(p_1)
ψ(.)p(.)	0.000	0.706	2	0.021	0.021	1	$0.87e^{-8}$
ψ(.)p(T)	2.279	0.226	3	0.021	0.021	1	$0.25e^{-21}$
ψ(.)p(t)	4.664	0.069	4	0.021	0.021	1	0.00

Model	p_2	SE(p_2)	p_3	SE(p_3)
ψ(.)p(.)	.	.	.	.
ψ(.)p(T)	1	$0.87e^{-20}$	1	$0.12e^{-24}$
ψ(.)p(t)	1	$0.15e^{-7}$	1	$0.15e^{-7}$

[a]Δ AICc is the relative difference in AICc values compared with the top-ranked model; *w* is the AICc model weight; *Npar* is the number of parameters. Estimates of occupancy (ψ) and its standard error (SE(ψ)) and estimates of detection probabilities (p) are given. T = trend; t = time. Naive occupancy estimate is 0.0204 (1 of 49 sites had one or more detections).

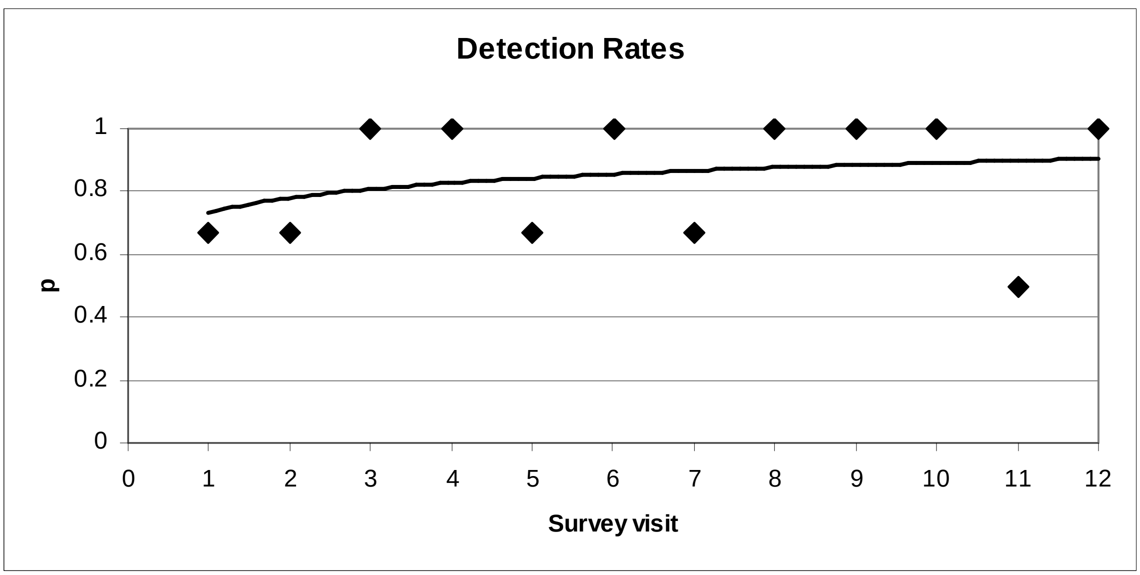


Figure 5. Detection rates of Lewis's woodpecker from occupancy surveys conducted May-July 2010 in aspen stands in Utah. Detection rates are from 12 visits to three occupied sites.

DISCUSSION

In this study, I identified and described characteristics of aspen habitat at Lewis's woodpecker nest sites using a modified James and Shugart protocol (James and Shugart 1970) and FIA data, developed a Lewis's woodpecker aspen habitat model based on FIA data from known nesting sites, and conducted occupancy surveys for Lewis's woodpecker at model-predicted sites to validate the predictive model. Aspen habitat characteristics of Lewis's woodpecker nest sites have not been described previously in the literature. Forest Inventory and Analysis data also has never been used to predict suitable and unsuitable habitat for Lewis's woodpecker, only for quantifying the amount of suitable Lewis's woodpecker habitat in Utah (Witt 2009).

This project illustrates the initial process required to build a reliable habitat model—collecting and analyzing data, building a preliminary model, and validating the preliminary model by visiting predicted suitable and unsuitable sites. This process can be difficult with a rare species due to the paucity of data available on habitat use. Also, many studies fail to complete this entire process because of the extended time and expense required to collect data on a rare species. It may take several field seasons to collect enough data (from occupied locations) to develop a preliminary model and then field validate the model. Many studies (Homer et al. 1993, Hirzel et al. 2002, Elith et al. 2006) build models from existing data and test the models using independent data sets, thus decreasing the amount of time required for this process. Model revisions and repeated validations may be required to enhance model precision depending on the accuracy from the first validation (this study) and new data that becomes available.

The FIA database worked well in predicting unsuitable Lewis's woodpecker aspen stands; however, it did not work as well in predicting suitable aspen stands (Table 5). The latter could be due to the broad criteria that were used to select plots to maximize sample size. The use of FIA to predict suitable aspen stands might be improved by using more restrictive lower and upper bounds for the variables, such as <35% canopy cover or by adding variables such as percent shrub cover. However, using these stricter criteria would decrease the resultant sample size of potentially suitable FIA plots unless the study area were to be increased to include FIA plots outside of Utah.

Stricter criterion may help to decrease the commission and omission errors and increase K (Table 5). A high commission rate is of less concern than a high omission rate. A high omission rate becomes a concern in conservation and management because species presence cannot be predicted and this may lessen the amount of habitat that is conserved for that species. A high commission rate would result in habitat being conserved for Lewis's woodpecker; however, additional non-suitable habitat would also be needlessly protected. Correct classification rate is a measure of correctly predicting presences and absences and is an overall measure of model predictive capability; the higher the correct classification rate the more likely the correct habitat will be conserved for Lewis's woodpecker. Sensitivity measures the ability to detect true habitat presence; specificity measures the ability to detect true habitat absence. Only one measure incorporates all the information from the confusion matrix—K (Fielding and Bell 1997). Kappa is an overall measure of the model predictive capability that include omission and commission errors. Kappa falls in the good category so the predictive power of the model is adequate but could still be improved in future iterations.

Derived data (e.g., snags per hectare, stand age, etc.) were not available for the FIA plots set up at Lewis's woodpecker nest sites due to the length of time it took to have the FIA data entered and available for the subsequent field season. These variables could be analyzed to assess whether they are significant enough to add to a second iteration of the habitat model.

Forest Inventory and Analysis data is not collected for the purpose of building habitat models for wildlife species. As such, some FIA variables might not be meaningful in terms of wildlife habitat depending on the species of interest. Furthermore, most wildlife projects collect habitat data based on species or taxon-specific protocols or even ad hoc protocols that do not match up well with FIA variables. In addition, scale may be an issue in that FIA uses expansion factors to extrapolate raw data to the hectare level. However, where habitat variables can be transformed to match FIA variables, FIA-based wildlife habitat models are potentially viable. I was able to collect data using FIA crews and their exact protocol at occupied plots, so our model was not subject to transformation errors. Nonetheless, it does not appear that FIA data alone are sufficient to develop a reliable Lewis's woodpecker habitat model. Forest Inventory and Analysis data does not allow the selection of pure aspen stands easily; measured trees for each plot would have to be searched to determine if only aspen trees were measured on the plot. I did not find any Lewis's woodpeckers in mixed aspen-conifer stands so being able to specify pure aspen could improve model accuracy. I did find two nests in pure aspen stands that had adjacent conifer stands. Also, FIA plots are set 5 km (3 mi) apart so the scale may not be sufficient to effectively capture the patchy aspen stands where I found Lewis's woodpeckers. Because FIA plots are essentially dots on the landscape, FIA cannot spatially model habitat without the use of some other data.

In future models, I would add shrub cover and shrub height variables to the model. While shrub cover had a $P = 0.09$ in the logistic regression analysis, the main reason why plots appeared unsuitable was due to a high shrub layer and dense understory. Very little shrub cover or aspen regeneration occurred at Lewis's woodpecker nest sites in aspen, which is similar to Newlon and Saab's (2011) findings in riparian aspen in Idaho. Sites with little shrub cover did have high grass and forb cover, so understory substrate may still play a role in suitability. This is in contrast to other literature, which suggests high shrub cover is important for Lewis's woodpeckers (Thomas et al. 1979, Sousa 1983).

Literature also suggests that proportion of snags to total trees (Thomas et al. 1979) is important for Lewis's woodpecker nest sites. Adding derived FIA variables, such as snags per hectare, may help build a better model. Higher proportions of snags to total trees might indicate less canopy cover. Size of snags might also play a role in Lewis's woodpecker nest site selection. I would suggest separating snags from live trees in future analyses to see if one is more important. Other derived variables include live trees per acre and stems per acre. These variables give an indication of how dense the stand is in the overstory and understory, which appear to be important factors for nest areas. More trees per acre could indicate higher canopy cover and possibly smaller diameter trees on the FIA plots.

More reliable Lewis's woodpecker predictive models may be possible by combining FIA data with other data sources. LANDFIRE (http://www.landfire.gov/)

data was examined but was not at a sufficiently fine scale and did not match up well with my Lewis's woodpecker nest site and aspen stand observations. For example, a Lewis's woodpecker nest found in a small stand of aspen might be identified by LANDFIRE (30 m resolution) as occurring in vegetation type dominated by juniper or sagebrush. The majority of occupied aspen stands were five hectares or less.

Another potential data source that could supplement FIA's usefulness is Landsat Thematic Mapper (http://landsat.gsfc.nasa.gov/), which has multi-spectral satellite imagery to 30 m resolution. Forest Inventory and Analysis plots could be used to select areas in which to look at Landsat imagery and then sample plots could be selected from the Landsat imagery with those characteristics. Another option is Feature Analyst, an extension to geographic information systems (GIS), which enables GIS programs to collect vector feature data from aerial imagery. This program could be used to delineate aspen stands with similar characteristics as those that are occupied by Lewis's woodpeckers.

Parrish et al. (2002) classified Lewis's woodpeckers as rare to uncommon in Utah. My occupancy sampling results indicate that Lewis's woodpeckers are indeed rare in Utah aspen even though predicted suitable habitat is not uncommon. Aspen FIA plots comprise 9% of the total FIA plots in Utah. Of those aspen stands, 14% were predicted as suitable habitat for Lewis's woodpecker with my predictive model. Witt (2009) extrapolated FIA data to quantify the amount of nesting and foraging habitat for Lewis's woodpecker in Utah to obtain acreage totals; total acreage for all forest types was estimated at 1.5 million ha of which 65,000 ha was aspen forest type. This converts to approximately 10% of the total aspen forest type in Utah being considered suitable for

Lewis's woodpecker, which is similar to my 14% even with the additional variables used in Witt's analysis. Suitability was based on "key ecological attributes" using an Ecological Integrity Table (EIT) (Oliver 2009). Witt (2009) used the following criterion to determine available Lewis's woodpecker habitat for each forest type: 5-52% tree canopy cover, ≥13% shrub crown cover <5 m in height, and >1.25 snags ≥30.5 cm dbh and ≥9.1 m tall per ha. Available habitat increased as fewer criterion were used.

While occupancy surveys should be unbiased, the detectability surveys in my study were biased to some extent because surveyors knew the sites were occupied. What is not known is if a site is unoccupied at the start of the season, can it become occupied later? So far, the evidence from this study suggests that it will not become occupied later in the season; none of the unoccupied occupancy plots became occupied as the season progressed. This does not mean that a site cannot become occupied in future seasons.

Occupancy surveys can be a useful tool to survey for rare species, especially when detection probability is high, as it was for Lewis's woodpeckers in this study. When there is a high detection probability, fewer visits are required to be sure of detecting the target species if it is present and more sites can be visited in a season and can increase the spatial extent of the study. Occupancy sampling allows researchers to make an estimate of the proportion of habitat that is inhabited by the target species (MacKenzie et al. 2006). A downfall of occupancy sampling is that reproductive estimates cannot be measured; all that is obtained is whether or not the species of interest is present so actual population numbers can be hard to estimate without additional data. Potential trends in population numbers can be inferred, however, with multi-year survey designs. Repeated visits to the same occupancy sites during multiple years can help managers infer whether population numbers are increasing or decreasing based on increases or decreases in occupancy (MacKenzie et al. 2006).

The number of individuals of the target species present at a location can affect detection probabilities. When more than one individual is present, detectability could increase because of interactions among the individuals or simply due to an increased chance of encountering an individual. Of the 28 occupied sites, I detected only one adult bird at five of those sites; one of the 28 sites had 3 adults present; the remaining 22 sites had two adults present before young fledged. Lewis's woodpeckers have been described as being semi-colonial nesters, sometimes with more than one nesting pair in a single tree (Bock 1970). Semi-colonial nesting may be due to limited available habitat or because the habitat is extremely productive (Wiacek 2008).

Weather and time of year can also affect detection rates. For example, most bird species are more vocal during the breeding season and therefore easier to detect. My study avoided these issues by not surveying when it was raining or when the wind was ≥4 on the Beaufort scale, and surveys were only conducted during the nesting season. According to my findings, Lewis's woodpeckers were consistently detectable throughout the nesting season and not just during the courtship period. Detectability was consistently above 67% except for one visit in one of the models when detectability dropped to 50% (Fig. 5).

Additional research on Lewis's woodpecker behavior and ecology, especially dispersal, migration, and site fidelity could also improve habitat models. Only a few studies have been done specifically on Lewis's woodpeckers (Snow 1941, Bock 1970, Tashiro-Vierling 1994, Saab and Vierling 2001) and even fewer on Lewis's woodpeckers in aspen (Newlon and Saab 2011); other studies provide findings on Lewis's woodpecker as part of a larger group (i.e., woodpeckers or cavity nesters) (Saab and Dudley 1998, Gentry and Vierling 2008). It is not known if juveniles return to natal areas or if they disperse elsewhere. It is also not known if individual birds or pairs demonstrate nest site fidelity. Also, do birds that nest in a specific area always migrate to the same wintering habitat? Another migration unknown is whether or not nesting sites are related to distance from wintering habitat; it is not known how far Lewis's woodpeckers migrate between nesting and wintering habitat. If it is found that Lewis's woodpeckers only migrate a certain distance from wintering habitat, or vice versa, then a GIS model could be improved to only select habitat within certain distances from known wintering or nesting habitats. Reproductive success of Lewis's woodpeckers that nest singly or semi-colonially could also be compared and differences in behavior assessed.

Because Lewis's woodpeckers are considered "burn specialists" in coniferous habitat, burn data should also be included in any future GIS model that is built. Burn variables that could be important include burn size, burn intensity, time since burn, and distance from nest to burn. Data such as this could be obtained from regional forest service districts and the LANDFIRE database. Inclusion of this data will potentially increase specificity of the habitat model.

The increase in Lewis's woodpecker nests observed in aspen could signal a movement of this species into a novel nesting habitat. Species that are capable of successful movements into new environments are often capable of altering behavior and exhibiting phenotypic plasticity. Phenotypic plasticity is the ability of an animal, based on its environment, to express different phenotypes (Agrawal 2001), such as earlier breeding dates and increased clutch sizes. Successful colonization of a novel environment is dependent on the species being able to adapt to its new setting. For example, a population of dark-eyed juncos (*Junco hyemalis*) from a temperate, montane environment that colonized a Mediterranean climate along the coast exhibited earlier breeding dates and higher fledging rates (Yeh and Price 2004). Two species of finches in Jordan also showed changes in reproductive strategies when they colonized a novel habitat (Khoury et al. 2009). Yeh and Price (2004) suggest that phenotypic plasticity can influence the likelihood of the population persisting in the novel environment and it can also influence the natural selection in heritable differences. Colonization of novel habitats can also cause range expansions, as seen for the black-faced cotinga (Mestre et al. 2009). Colonization of novel habitats by species can have positive population effects if the novel habitats are not reproductive sinks, and hopefully the colonization of aspen stands by Lewis's woodpeckers will have a positive effect on their population trend. Reproductive rates will have to be studied to determine whether aspen stand colonization may lead to an increase in population. Clutch sizes and breeding dates can also be studied to determine if Lewis's woodpeckers show any phenotypic plasticity in adapting to their new nesting habitat.

MANAGEMENT IMPLICATIONS

Results from this study provide several management opportunities for potentially creating more Lewis's woodpecker nesting habitat and helping guide aspen restoration. First, occupancy surveys for Lewis's woodpeckers should be performed in aspen stands that have characteristics similar to our results before any treatment is undertaken on the aspen stand. If it is occupied, then treatment should be avoided so as not to disturb the nests. An option for potentially creating more Lewis's woodpecker nesting habitat is to treat mature stands near or adjacent to occupied stands, leaving large diameter trees with cavities to see if Lewis's woodpeckers expand into those areas.

Several factors may inhibit aspen regeneration including livestock and wild ungulate browsing and conifer encroachment and cause should be assessed prior to treatments. Livestock and wild ungulate browsing have been shown to have additive inhibitive effects on aspen growth (Kay and Bartos 2000). If browsing is the main cause of limited aspen regeneration, then management alternatives need not include tree removal. Livestock grazing could be altered with shorter grazing seasons or seasonal rotation regimes. Fitzgerald et al. (1986) found that cattle favored herbaceous plants early in the growing season, but as grasses matured toward the end of the growing season, cattle more readily grazed aspen. Increased hunting pressure on elk (*Cervus canadensis*) could be applied locally to affect certain stands and the hunting pressure moved to different areas every couple of years to allow different aspen stands time to regenerate. This will provide continual nesting habitat for Lewis's woodpeckers in that aspen stands will continue to survive on the landscape as a changing mosaic with separate stands in different growth stages. Also, different sizes of treatments should be investigated to determine if wild ungulate impacts are overwhelmed in large (ca. 2,000-4,000 ha) treatments, thus allowing for adequate aspen regeneration. The goal for aspen restoration would be to have stable old growth aspen stands on the landscape with younger regenerating aspen stands to replace the old stands as they die out.

If Lewis's woodpeckers are found in seral aspen stands, management opportunities exist to maintain the open, park-like structure of the stable old growth aspen stands that are favored by the woodpeckers. Two management techniques include thinning conifers to maintain an open understory and low-intensity burning to remove encroaching conifers which may also potentially promote aspen regeneration. If Lewis's woodpeckers are found in stable aspen stands, understory burning may be a management option, though stable aspen stands may well maintain an open understory without any active management.

Next steps for this project are to incorporate data as it is collected and see if it strengthens the initial habitat model. Forest Inventory and Analysis plots could be set up at occupied sites from 2010 and this data could be added to the model if FIA is pursued in the future for modeling Lewis's woodpecker habitat. Information on Lewis's woodpeckers habitat structure in ponderosa pine, burns, and lowland riparian could help expand the model to include additional habitats in Utah. This data already exists in the literature so it could be added to the model and then validated in the field. By including all habitat types used by Lewis's woodpeckers, biologists will be able to get a better estimate of available habitat being used by Lewis's woodpeckers and obtain more accurate statewide trend information.

Other aspects of Lewis's woodpecker ecology in aspen and other habitats need more research. These include survival rates, both for adults and juveniles, fledgling success in aspen compared to other habitats, and proportion of non-breeding individuals in a population. If factors such as availability of cavities or too many predators are causing Lewis's woodpeckers not to breed, potential solutions could be undertaken to decrease the proportion of non-breeding individuals, such as providing nest boxes.

It also is not known if nesting and fledgling success is higher or lower in aspen habitat compared to other habitats. If success rates are higher in aspen, aspen conservation would likely increase Lewis's woodpecker populations. However, if success rates are lower in aspen and Lewis's woodpeckers are only using it because there is not enough of their preferred habitat, conservation efforts should focus on traditional habitat types, such as ponderosa pine, burns, and riparian cottonwood.

If aspen is an important component for Lewis's woodpecker nesting, then better scientifically based management needs to be undertaken to ensure suitable aspen habitat is available. This will require a greater understanding of how aspen stands are affected by management actions and how these actions change the progression of aspen towards the old growth stands Lewis's woodpeckers inhabit.

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