Development and Validation of Spatially Explicit Habitat Models for Cavity-nesting Birds in Fishlake National Forest, Utah

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Abstract.—The ability of USDA Forest Service Forest Inventory and Analysis (FIA) generated spatial products to increase the predictive accuracy of spatially explicit, macroscale habitat models was examined for nest-site selection by cavity-nesting birds in Fishlake National Forest, Utah. One FIA-derived variable (percent basal area of aspen trees) was significant in the habitat model; however, the incorporation of FIA stand structure information did not increase model accuracy. Cavity-nesting birds respond strongly to nest-tree attributes unable to be modeled spatially for this study. Future modeling efforts should focus on larger taxa (e.g., ungulates) and richness/diversity studies.

Background

Recent efforts in wildlife habitat modeling have focused developing spatially explicit habitat models (Carroll *et al.* 1999, Dettmers and Bart 1999, Edwards *et al.* 1996, Knick and Rotenberry 1995, Lawler and Edwards 2002, Mitchell *et al.* 2001, Reunanen *et al.* 2002). The ability to build spatially explicit habitat models is desirable for several reasons. First, the models can be used to make spatial predictions across large and remote regions. Second, they often rely on remotely sensed data and/or pre-existing habitat data. These data may be quickly and easily applied to habitat modeling. Field habitat data collection, however, may often be time-consuming and labor intensive (Mitchell *et al.* 2001).

Most spatially explicit habitat models use cover-type information, or macroscale information, to predict species presence (Edwards *et al.* 1996, Lawler and Edwards 2002, Reunanen *et al.* 2002, among numerous others). Despite its ease of use, coarse-scale cover-type information may be too general and limited for predicting species reliant on the structure and condition of individual trees or stands (Lawler 1999, Lawler and Edwards 2002, Schultz and Edwards, unpublished data). Thus, ecologists have begun to incorporate finer-scale forest structural variables (i.e., stand structure) into spatially explicit habitat models (Carroll *et al.* 1999, Reunanen *et al.* 2002).

To incorporate forest structure variables, ecologists are searching for methods of modeling forest structure across space (Frescino *et al.* 2001, Moisen and Edwards 1999, Moisen and Frescino 2002). One technique involves converting statistical models of forest structure to spatially explicit maps of forest attributes (e.g., basal area, snag density, live trees per acre, canopy height, biomass, etc.) (Frescino *et al.* 2001, Frescino and Moisen 2004, Terletzky and Frescino 2004). Pre-existing USDA Forest Service Forest Inventory and Analysis (FIA) field data are used as response variables, and a combination of environmental variables and remotely sensed data are used as predictor variables. The resulting models are converted to spatially explicit prediction maps, and the mapped variables can then be used in wildlife habitat modeling.

The primary objective of this research was to determine whether incorporating FIA-generated spatial products (hereafter mesoscale) improved the predictive accuracy of macroscale habitat models for cavity-nesting bird nests in Fishlake National Forest, Utah. The results were then used to assess both the utility of FIA-generated spatial products in habitat modeling for cavity-nesting birds, and the current abili-

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ty of spatially explicit models to predict the presence of cavity-nesting bird nests in Fishlake National Forest, Utah.

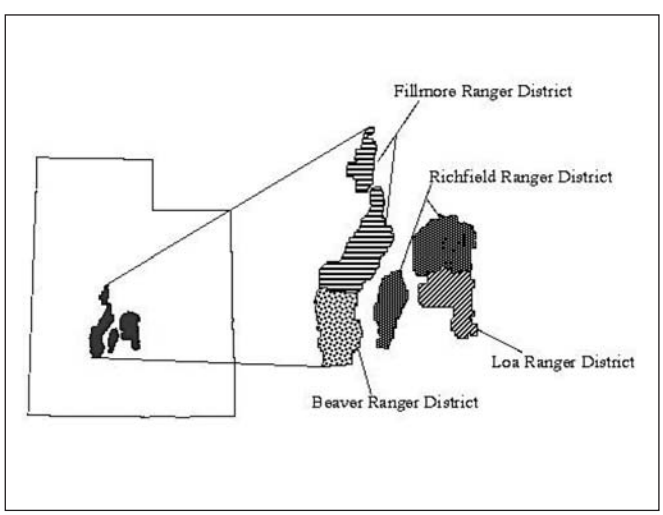
Methods

Study Area

The study area was the Fishlake National Forest, located in southern Utah at the southern end of the Wasatch Mountains (fig. 1). The study area encompassed sections of four ranger districts (Richfield, Loa, Fillmore, and Beaver) across three general mountain areas (fig. 1). This region of Utah is characterized by high mountains (~2,000 m to ~ 4,000 m) consisting of broad, rolling plateaus, large alpine meadows, and large areas of aspen (*Populus tremuloides*) forest.

Vegetation at low-elevation sites on the study area consists primarily of aspen stands interspersed with sagebrush meadows, ponderosa pine (*Pinus ponderosa*), curl-leaf mahogany (*Cercocarpus ledifolius*), gambel oak (*Quercus gambelii*), Utah juniper (*Juniperus osteosperma*) and pinyon pine (*Pinus edulis*). The vegetation at middle to high elevations consists of an aspen/mixed-conifer (Douglas-fir [*Pseudotsuga menziesii*]; Engelmann spruce [*Picea engelmannii*]; white fir [*Abies concolor*]; subalpine fir [*Abies lasiocarpa*]), meadow matrix. The vegetation grades into a spruce-fir forest until upper treeline.

Figure 1.—*The Fishlake National Forest in southern Utah, including the location of ranger districts.*



Study Species

The study species included all cavity-nesting birds found to nest in aspen communities of the forest. The species included six primary cavity-nesting birds: red-naped sapsucker (*Sphyrapicus nuchalis*), northern flicker (*Colaptes auratus*), hairy woodpecker (*Picoides villosus*), downy woodpecker (*Picoides pubescens*), three-toed woodpecker (*Picoides tridactylus*), and red-breasted nuthatch (*Sitta canadensis*); and six secondary cavity-nesting birds: tree swallow (*Tachycineta bicolor*), violet-green swallow (*Tachycineta thalassina*), mountain chickadee (*Poecile gambeli*), mountain bluebird (*Sialia currucoides*), western bluebird (*Sialia mexicana*), and house wren (*Troglodytes aedon*).

Study Design

We built habitat models based on presence/absence data for nests of cavity-nesting birds. To determine if the addition of mesoscale variables improved macroscale model accuracy, we built and validated predictive models using only macroscale variables and additional multiscale models using both macroscale variables and mesoscale variables. Model building data were collected in 2001, and validation data were collected in 2002. We compared model performance using the percent correctly classified (PCC), sensitivity, specificity, and the area under curve (AUC) values.

Nest Searches

Sample locations were identified using a 30-m resolution digital vegetation map from the Utah Gap Analysis Project (Edwards *et al.* 1998, Homer *et al.* 1997). Sample locations were restricted to aspen stands adjacent to meadow and/or conifer cover types. A total of 14 locations were searched during the study. We selected nine locations for model building during the summer of 2001, and reserved five locations for model validation during the summer of 2002. All the model-building locations were located on the Richfield Ranger District and a small section of the Loa Ranger District (fig. 1). To select validation locations for 2002, we stratified the forest geographically and reserved new locations in previously unsearched sections of the national forest. Thus, the 2002 validation locations were located on the Fillmore and Beaver Ranger Districts, and another section of the Loa Ranger District (fig. 1).

We systematically surveyed study locations for active nests of cavity-nesting birds from late May until early July. We considered a nest active if it showed evidence of incubation, presence of eggs, presence of young, and/or feeding activity. To mark the active nests, we recorded the UTM coordinates at each nest using a global positioning system. Several non-nest locations were selected at the end of each breeding season. We considered a non-nest location to be an aspen tree (>10 cm d.b.h. and >1.4 m high) within a previously searched location. We randomly selected non-nest locations that were 100-150 m apart from each other and each active bird nest.

Table 1.—*Habitat variables and their descriptions, Fishlake National Forest, Utah (macroscale variables based on cover-type metrics measured at a 15 ha scale; mesoscale variables obtained from FIA-generated spatial products and measured at a 30-m scale)*

	Variable name	Description
Macroscale	%open	Percent landscape of open land, including meadows
	%aspen	Percent landscape of aspen forest
	%conifer	Percent landscape of conifer forest
	%mixed	Percent landscape of mixed conifer/aspen forest
	Lpopen	Largest patch of open land (% of landscape)
	Lpaspen	Largest patch of aspen forest (% of landscape)
	Edaspen	Edge density of aspen forest (m/ha)
	Pr	Patch richness of the landscape (#)
	Sdi	Simpson's Landscape Diversity Index (%)
Mesoscale	Ba	Live tree basal area (sq ft/acre)
	Crcov	Crown cover (%)
	Stage	Stand age (yrs)
	Tpa	Live trees per acre (trees/acre)
	Vol	Net volume of trees (cu. ft./acre)
	Qmd	Quadratic mean diameter of trees (in)
	Bio	Live tree biomass (tons/acre)
	Aspba	Aspen basal area (%)
	Asprot	Aspen rot (presence/absence)
	Snags	Number of snags
	Avtrht	Average tree height (ft)

Habitat Data Collection

Based on prior statistical analysis, we chose 15 ha as the macroscale for cavity-nesting birds in Fishlake National Forest (Schultz and Edwards, unpublished data). This scale approximates the home-range of the northern flicker, the largest and most abundant bird in the data set (Dunning 1993, Lawrence 1967). All macroscale variables were measured at this scale.

All macroscale variables were generated from 30-m resolution vegetation data layers in Arc/INFO GIS. The vegetation data layers were derived from the 1999 National Land Cover Data set, which was created using Landsat Thematic Mapper imagery and ancillary data (Vogelmann *et al.* 2001). Five general cover types were considered: open land (shrublands, grasslands, wetlands), aspen forest, conifer forest, mixed forest, and an "other" cover type. Using a square moving window centered on each nest and non-nest, we estimated landscape attributes using FRAGSTATS (McGarigal and Marks 1995). We selected nine attributes we felt were relevant to cavity-nesting bird habitat, including the percent landscape of cover types, edge density of aspen, and richness/diversity measurements (table 1).

We used a 30-m pixel to represent the mesoscale, or stand habitat. This scale was the smallest measurement possible in this study. In addition, this scale roughly approximates the size of a 0.04 ha plot, a commonly used field measurement in avian habitat studies (James and Shugart 1970, Noon 1981). Mesoscale measurements were derived from 30-m resolution digital maps of FIA-derived variables, including aspen basal area, number of snags, number of live trees per acre, and canopy height (table 1).

The FIA data were modeled spatially using several different statistical tools, including generalized additive models (GAMs) and multivariate adaptive regression splines (MARS). The models were then converted to spatially explicit prediction maps of mesoscale forest structure, which were then used in habitat modeling (Terletzky and Frescino 2004).

Table 2.—*Estimates of model fit for the stepwise logistic regression habitat models of cavity-nesting bird nesting habitat in Fishlake National Forest, Utah (variables significant at the p=0.05 statistical level)*

Model / variable	R^2	D	Estimate	Standard error
Macroscale	0.063	0.341		
Intercept			-0.406	0.216
%open			0.025	0.006
Multiscale	0.077	0.365		
Intercept			-0.773	0.287
%open			0.029	0.006
Aspba			0.008	0.004

Statistical Models

To reduce redundancy of information in the habitat models, we examined correlations among variables and retained variables we deemed to have high ecological relevance. We chose a Pearson's correlation coefficient of 0.7 to be the minimum value necessary for variable elimination. We used stepwise logistic regression (Hosmer and Lemeshow 1989, SAS version 8) to model the presence of cavity-nesting birds based on habitat associations.

To assess the relative ability of the macroscale and multiscale habitat models to predict nest presence, we searched the five validation locations during the summer of 2002 and observed how well the 2001 models predicted nests and non-nests. We assessed model performance using various measures of model classification accuracy and performance, including percent correctly classified (PCC), sensitivity (true positive fraction), specificity (true negative fraction), and the threshold-independent area under curve (AUC) value from receiver operating characteristic (ROC) analysis (Fielding and Bell 1997, Zweig and Campbell 1993). We used a 0.5 decision threshold for all threshold-dependent classification analyses.

Results

Model Development

We found a total of 227 nests during the course of this study: 165 nests for model building (2001) and 62 nests for model validation (2002). In addition, we selected 170 non-nest locations: 117 for model building and 53 for model validation.

Table 3.—*Relative model performance of the macroscale and multiscale models of cavity-nesting bird nesting habitat in Fishlake National Forest, Utah (PCC, sensitivity, and specificity values based on a 0.5 classification threshold)*

Model	PCC (%)	Sensitivity	Specificity	AUC
Macroscale	63.5	0.774	0.472	0.670
Multiscale	57.4	0.677	0.453	0.680

Cavity-nesting birds increased with the percent of open habitat in both the macroscale and multiscale models (table 2). In the multiscale models, cavity-nesting birds also increased with the percent basal area of aspen. Model fit based on R^2 and Somer's D statistic was low for both models, and fit differed only marginally between the models (table 2).

Model Validation

In general, incorporating mesoscale FIA-derived information did not increase the accuracy of spatially explicit habitat models for cavity-nesting birds (table 3). Overall, classification accuracy was generally poor, with the macroscale model predicting marginally better than the multiscale models (table 3). Sensitivity values were remarkably higher than their corresponding specificity values, suggesting both models tended to overpredict bird habitat. Specificity values were low for both models. AUC values did not differ much between models (table 3).

Discussion

The results of this study suggest that mesoscale FIA-derived information can be applied to wildlife habitat modeling. The positive association between nest presence and aspen basal area supports this conclusion. Although spatially explicit FIA information can be used in habitat modeling, it did not increase the ability to predict nest presence of cavity-nesting birds in this study.

Two factors may account for the inability of mesoscale FIA-derived information to increase model accuracy. First, scale is inevitably an issue of concern in ecology (Levin 1992, Wiens 1989). A 30-m resolution may be too coarse a scale to predict nesting habitat for cavity-nesting birds. The distribution of cavity-nesting bird nests might better be predicted by nest tree attributes and stand structure in areas much smaller than 30 m. Cavity-nesting birds are strongly associated with nest tree attributes, including tree diameter and the evidence of decay (e.g., fungal conks) (Conner *et al.* 1976, Daily 1993, Daily *et al.* 1993, Dobkin *et al.* 1995, Kilham 1971, Lawler 1999). Fungal conks indicate heartrot, which facilitates excavation by cavity-nesting birds. However, the presence of fungal conks is a variable for which we cannot currently build spatially explicit maps. Future habitat modeling efforts for cavity-nesting birds in this and other similar regions should focus on finding macroscale and mesoscale surrogates for fungal conks and/or heartrot.

Second, a habitat model is only as accurate as the data used to build the model. Map error is a concern, and both vegetation modeling error and spatial error may have influenced the accuracy of the habitat models. Future vegetation mapping should focus on more accurate maps of forest structure and rigorous field-validation.

In aspen forests of Fishlake National Forest, ecologists cannot currently predict nest presence of cavity-nesting birds accurately without field habitat data. FIA-generated spatial products may have more utility for other species and issues than cavity-nesting bird nest-site selection. These products may be useful for ungulates and other large animals, where 30-m resolution may be more appropriate. Species richness and diversity studies may also benefit from this information. Future efforts concerning the utility of FIA-generated spatial products in wildlife habitat modeling should continue on these fronts.

Acknowledgment

We would like to extend thanks to Pat Terletzky for assistance with the computer applications in this research. We thank Fishlake National Forest, especially Kreig Rasmussen and Bob Campbell, for making the field component possible. This work would not have been possible without the work of field technicians Darlene Kilpatrick and Rita-Lyle Reitzel.

This project was funded by the USDA Forest Service, Rocky Mountain Research Station in Ogden, Utah, in cooperation with the USGS Biological Resources Division, Utah Cooperative Fish and Wildlife Research Unit, the Fishlake National Forest, and the Utah State University Ecology Center.

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