FIELD TEST OF A LANDSCAPE MODEL FOR MEXICAN SPOTTED OWL BREEDING HABITAT IN NORTHERN ARIZONA

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INTRODUCTION

In northern and northeastern Arizona, the Mexican spotted owl has been observed in Grand Canyon National Park and canyons of the Kaibab Plateau, and in myriad tributary canyons within the Navajo Tribal Lands (Block et. al 1995). In this region, the owl inhabits rocky canyon habitat within desertscrub and dwarf woodlands that contrast sharply with the mixed conifer and pine forests occupied in the central and southeastern regions of the state (Ganey and Balda 1989, Willey 1995, 1998).

The Mexican spotted owl was listed as a "threatened species" in 1993 by the U.S. Fish and Wildlife Service (USFWS), and was identified within the IIPAM list of sensitive species needing further study in Arizona (Arizona Game and Fish Department Heritage Program, Phoenix, AZ). A debate over the designation of critical habitat by the USFWS is ongoing, and results of this research will contribute valuable and timely information (Michelle James, USFWS, pers. Comm.).

The Mexican spotted owl has been the focus of intense agency and public concern for over a decade because of the owl’s apparent dependency on old growth timber of high economic value (Ganey 1988, USDI 1995). Spotted owls are typically associated with forest habitat (Gould 1977, Forsman et al. 1984, Ganey and

Balda 1989), and they may be declining throughout their range following the loss of breeding habitat due to logging and catastrophic fire (Block et al. 1995, Seamans et al. 1999). In northern Arizona, several subpopulations occur in a rather unusual landscape: arid and rocky canyonlands dominated by desertscrub and Great Basin woodland vegetation communities (Willey 1998). In light of the owl's reputation as an "old growth obligate", its tolerance of high diurnal temperatures and reliance on non-forested habitat types in the north warrants further analysis.

Estimation of Suitable Breeding Habitat

Geographical information systems (GIS) are computer-based systems for the manipulation and analysis of spatially-distributed data. A GIS can be used to 1) analyze temporal change, 2) determine spatial coincidence of physical and biological features, 3) determine spatial characteristics such as proximity, contiguity, and patch size and shape, 4) analyze the direction and magnitude of fluxes of energy, organisms, and material, and 5) produce graphic output and interface with simulation and predictive models to generate new spatial data (Johnson 1990).

Predictive GIS habitat models can be applied over large geographic areas and have broad applicability in conservation biology and wildlife management (Hunter 1996). No research has examined the extent, or characteristics, of Mexican spotted owl breeding habitat in northern Arizona (MacDonald et al. 1990, USDI

1995). Our research was designed to examine habitat suitability using a GIS ecological modeling approach. Our primary goal was to identify the distribution and extent of breeding habitat in northern Arizona north of Interstate Highway 40 (Fig. 1). We believe this research is germane to long-term monitoring of Mexican spotted owl habitat in Arizona and the designation of critical habitat.

Our Study area included all lands north of Interstate 40 within the state boundary of Arizona. Ecological life zones range from Sonoran and Mojavian deserts at the lowest elevation, through Great Basin Woodland and Petran Montane at mid-elevations, and Subapline Forest and Meadows at the highest elevations on the Kaibab Plateau (Brown 1982).

We used a GIS System (ArcInfo, ESRI 1996) combined with expert knowledge of ecological associations (e.g., Ganey 1988, Willey 1998) to estimate the extent of potential breeding habitat in northern Arizona. We defined suitable habitat as the range of environments needed for an owl pair to survive and reproduce during the breeding season, March-August. We based our definition upon results from previous life history studies of the owl in Arizona and southern Utah (Ganey 1988, Ganey and Balda 1989, Willey 1995, USDI 1995). Viewed spatially, we further defined suitable breeding habitat as the sum of resources present in the landscape that made an area suitable, or habitable, for Mexican spotted owl breeding pairs (Caughley and Sinclair 1994, Willey 1998). Here we report the results of field tests of two landscape models that predicted the location of breeding habitat at two spatial scales: in Grand Canyon National Park (the local, or fine-grained scale 1:24,000); and in Northern Arizona (the regional, or coarse-grained scale 1:250:000). Both models relied on physical and biotic GIS themes to predict the extent of potential breeding habitat.

Field testing is a critical step toward validating GIS based predictions of wildlife habitat (Bookhout 1994, Dettmer and Bart 1999). Furthermore, although we urge the continuation of field surveys to document specific patterns of habitat use, we think that the modeling-validation approach can save energy and hours of inventory effort. In addition, together the model and field surveys provide a powerful mechanisms to develop and test spatial hypotheses concerning habitat distribution and abundance for the advancement of knowledge.

Project Objectives

The primary goal of the research was to conduct field tests via implementation of the following objectives:

(1) Identify classes of potential breeding habitat in northern Arizona north of Interstate Highway 40 using a GIS based predictive model at the 1:250,000 spatial scale. Classes included: steep canyon, forested, and steep forest breeding habitat, and non-breeding habitat.

(2) Identify the habitat classes in the core analysis section of Grand Canyon National Park using a GIS based predictive model at the 1:24,000 spatial scale.

(3) Test the habitat models (1:250,000 and 1:24,000) by conducting point surveys for spotted owls within Kanab Creek, within Grand Canyon National Park, and within portions of Navajo Nation Tribal Lands.

(4) Evaluate the success of the model predictions (at both spatial scales) using results of field surveys, and present a draft outline for monitoring habitat trends.

METHODS

The following GIS layers were used for habitat modeling: land cover (canyon, forest, and non-forest); surface geology; earth surface heat and radiation indices; slope; surface curvature and geomorphology (e.g., concave vs. convex land surfaces). We used an existing land cover classification, prepared by the National Park Service (Grand Canyon National Park, Natural Resources Office) to identify various land cover types, e.g., flat, steep, rocky, benchland, talus, forested, nonforest. The radiation layers were derived as a function of solar radiation, slope, and aspect. All other GIS themes were derived from a 7.5 minute digital elevation model (DEM data at a 1:24,000 scale and 30-m resolution) using standard Arc/GRID commands (ESRI 1996).

We used the Supervised Classification procedure and multiple regression analysis within the Arc/GRID module to regress predicted owl presence/absence with training samples of known owl use and non use Universal Transmercator (UTM) locations to produce a final signature file for graphical output of the model. The output was 1:250,000 scale maps that depicted spatial predictions of habitat suitability in the study areas. The maps were evaluated using field tests with point surveys for Mexican spotted owls during March-September 1998 and 1999.

Field procedures were patterned after protocols developed by owl survey experts in the western U.S.A. (Franklin et. al 1990, Rinkevich 1991, Willey 1989). Survey points were selected within four model habitat classes: steep canyon, forest, steep forest, and non-breeding. We generated a random sample of survey point locations within each study area: Kanab Creek, the Kaibab plateau, within Grand Canyon, and within the Navajo Indian Reservation. The survey points were drawn at random using program Arc/GRID. To test our models, we formulated the following null hypothesis:

H_0: there is no difference among the habitat classes in the number of points where owls are detected during nocturnal surveys

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ANOVA was used to assess the differences in the counts of number of owls detected among the habitat types. Significant differences in spotted owl responses across the habitats resulted in a rejection of the null hypothesis ($P \leq 0.10$). Based on our review of owl distribution and habitat use, we predicted the greatest number of owl detections in the steep canyon habitat class (followed by steep forest, then forest, and non-breeding habitat). We randomly selected 30 sample points within each habitat class at the coarse grained scale (i.e., 1:250:000 in northern Arizona). We then selected 15 steep canyon, 20 steep forest, 20 forest, and 20 non-habitat points within Grand Canyon, nested within the coarse grained sample to generate and sampling domain for the fine-grained model. At each sample point (i.e., experimental unit), we placed 3 calling stations (spaced 0.5 to 1.0 km). At each calling station, callers mimicked spotted owls by producing a variety of standard calls (Ganey 1990) for 30 minutes. We conducted two field tests, the first within Grand Canyon during 1998 (fine-grained test), and the second in northern Arizona during 1999 (coarse-grained test). All calling points were surveyed once during each field season 1998 and 1999.

Gross landscape features were recorded at each calling station to describe habitat characteristics. These variables included:

1) Habitat/vegetation cover type: forest type, nonforest: shrubland, desert grassland, bare ground, presence of water.

2) Aspect and slope, and elevation.

3) habitat structural features (slope position and topography): steep, flat, rocky, rolling hills, mesa top, benchland, canyon, and presence of caves and ledges.

4) presence of absence of spotted owls.

5) UTM location of the point, survey route and date.

RESULTS AND DISCUSSION

Model Output

At the fine-grained scale, the habitat model within Grand Canyon predicted that spotted owls occurred within steep canyon and steep forest habitat (Fig. 1). The coarse-grained habitat model predicted potential spotted owl breeding habitat was located in three habitat classes in northern Arizona: steep canyons, rolling forestlands with high canopy closure, and steep mixed-conifer forest (Fig. 2). Overall, predicted suitable habitat primarily occurred within the steeper, and more topographically rugged, landscapes. This suggests that spotted owls in northern Arizona may be habitat “specialists” and require a specific suite of habitat variables provided by a few key habitat classes (Dettmers and Bart 1999).

At the fine-graindеd, or microsite, habitat scale, equivalent to Johnson’s (1980) second and third order habitat selection, steep canyon habitat possessed high coverage of bare ground, steep slopes, great amounts of north-facing landscape, and numerous ledges and caves (Ganey 1988, Ganey and Balda 1989, Willey 1998). On the other hand, non-habitat was dominated by desertscrub and dwarf woodland in a relatively simple and featureless landscape. Whereas the steep canyon habitat class was dominated by a mosaic of vegetation (including desertscrub, pinyon-juniper, and mixed-conifer communities on north facing slopes depending on elevation, slope and aspect); nonbreeding habitat was dominated by dwarf woodland and desertscrub.

Model Evaluation and Testing

Historic owl sites, i.e., locations of owls not used to train the GIS for model output (Joseph Ganey, USFS, unpublished data), were used to evaluate the predicted maps prior to field surveys. Both models performed well in these preliminary tests, for example, steep canyon and forest habitat classes accounted for over 80% of the historic owl locations in northern Arizona. Furthermore, the proportion of observations in these habitat classes was larger than the proportion of the study area delineated as prime habitat, suggesting that the result was not an artifact of sample size and location. The correlation between number of owl locations and amount steep canyon and forest habitat was generally positive within the various study areas.

Following the initial test with historic locations, we analyzed model performance using the results of two independent field tests. The tests utilized field survey data gathered within each habitat class at both fine and coarse-grained scales. Results of the coarse-grained analysis for all of northern Arizona showed that owl presence was most common within the steep canyon habitat class, followed weakly by steep forest habitat. We rejected the null hypothesis (ANOVA, $P = 0.0005$, $F = 6.43$, $df = 119$) of no difference in owl presence among habitat classes at the coarse grained scale and concluded that steep canyon habitat was more strongly associated with spotted owls in northern

Arizona than other habitat classes. At the coarse grained scale, spotted owls were located at 27% of the sample points visited within steep canyon habitat in northern Arizona. The number of survey points within each class with owl presence included: eight points with owls in steep canyon (6 Grand Canyon, 2 on Navajo Lands); 3 points with owls in steep forest (1 on Navajo Lands; 2 adjacent to Flagstaff, AZ); and no points had owls in flat forest and non-habitat.

When we evaluated model performance within the Grand Canyon study area, owls were detected at 6 of 15 steep canyon sample points (40%). No owls were located within any other habitat classes in Grand Canyon (i.e., steep forest; flat forest; and non-habitat). Therefore, we rejected the null hypothesis of no difference among classes (two sample ***t-test***, contrasting 15 steep canyon vs. all other classes, $t = 2.14$, $df = 14$, $P = 0.0013$), and concluded that steep canyon habitat was strongly associated with spotted owls in Grand Canyon National Park at the fine-grained scale.

It is interesting to note that no spotted owls were detected on the North Kaibab Plateau within and area that encompassed large stands of mixed-conifer forest lands on relatively steep slopes. We concluded from our testing that within Grand Canyon National Park, and throughout northern Arizona, steep rocky canyonland habitat is a key limiting landscape type occupied by Mexican spotted owls. We believe that the model and field tests provided more information than, for example, use of survey data alone, without habitat modeling information (Dettmers and Bart

1999), might provide. Although the models can lead to strong insights related to habitat suitability, we caution the premature use of GIS models without field validation, and we caution use of GIS habitat models as replacements for field surveys. We urge the continued use of field surveys to test models and examine owl habitat use.

A Monitoring Framework for Suitable Habitat

Several key products can be derived from the modeling exercise described in the preceding sections of this report:

(1) maps delineating prime habitat for the species in Arizona (appended to this report).

(2) an estimate of the amount of prime habitat within a management area of interest (a simple ArcView operation).

(3) an estimate of the number of potential spotted owl territories within a defined study area (using homerange data with the GIS predicted habitat maps).

Once derived, these products can be used to predict local abundances (testable via mark-recapture or index counts), and evaluate the effects of competing management actions. For example, a manager could use GIS models and life history information to evaluate outcomes of alternative management actions that occur within prime habitat types, e.g., steep canyon and forest classes in northern Arizona. In addition to providing practical applications for management, the modeling approach can reveal new information concerning how environmental variables (both physical and biological) affect habitat quality and quantity for spotted owls (Franklin 1996).

GIS layers and microsite variables that describe land cover types, topography, thermal radiation, and vegetation provide an ecological basis for identifying key habitats for threatened species, like spotted owls. Therefore, modeling can suggest specific GIS layers that are important to owls, or layers associated with features that are important. We think this process can aid in determining microhabitat and macrohabitat features for monitoring habitat quality and quantity (Franklin et al. 1990). For example, our results suggest that landscape curvature (ruggedness), topography, and forest type appear to strongly influence the presence and absence of spotted owls in our study area (Willey 1998). These themes may be critical factors that determine preferred habitat for spotted owls in this region (Franklin 1995, Dettmers and Bart 1999). To monitor habitat status, the GIS ArcInfo signature files for each model can be used to identify habitat areas and generate output habitat maps as baselines that can be monitored each year using remote sensing procedures (Johnson 1989). We recommend that the Recovery Team select a suite of validated models that can be used in an analytical “change assessment” to contrast the status of habitat distribution and quality among 10 one-year monitoring periods (Bill Krausman, USFS, Albuquerque Supervisors Office). Change assessment is a powerful tool from remote sensing and requires a validated basemap in order to evaluate change. We feel strongly that our model outputs can be used to create a monitoring basemaps for change assessment (Thompson et al. 1998). Change in habitat quantity, or effects, could be evaluated using repeated measures ANOVA with appropriate samples sizes and confident limits to detect desired effect sizes (Steidl et al. 1997).

Finally, the recent development of expert system-GIS interfaces offers the greatest prospect of advancement for GIS based resource monitoring in the future. It is now incumbent upon managers, ecologists, and GIS experts to explore the capabilities of GIS for conservation needs for threatened and endangered wildlife and plants.

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Contact Heritage Data Management System (602-789-3618) for information regarding figures and appendices for this report.

Figure 1. Model output showing the predicted distribution of four habitat classes in Grand Canyon National Park, Arizona. Random sampling points for the field surveys are shown (see symbols key on the map).

Figure 2. Model output showing the predicted distribution of four habitat classes in northern Arizona. Random sampling points for the field surveys are shown (see symbols key on the map).

Appendix A: Survey and Habitat field forms and maps of owl detections recorded at model test points in Grand Canyon and Northern Arizona.

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