Spatially explicit models of songbird occupancy as tools for selecting and monitoring management indicator species on the Kaibab National Forest (Arizona, USA)

STEIN FOSTER, VALERIE K.[1] Matthew A. Williamson[2], Brett G. Dickson[3], Steven E. Sesnie[3], Chirre Keckler[1], Ariel G. Leonard[1]
[1]U.S. Forest Service – Kaibab National Forest, Williams, AZ, 86046; [2]Grand Canyon Trust, Flagstaff, AZ, 86001;
[3]Northern Arizona University – Lab of Landscape Ecology and Conservation Biology, Flagstaff, AZ, 86001

Introduction

Management Indicator Species (MIS) are designated by the U.S. Forest Service as species whose population changes are believed to "indicate the effects of management activities." Songbirds are commonly selected as MIS because they are thought to be responsive to a variety of "environmental quality" attributes, and are subsequently monitored to assess the impacts of management activity due to their sensitivity to changes in vegetation structure and composition (Saracco et al. 2008; Dickson et al. 2009). Their status is typically assessed by measuring changes in density or abundance over time and in response to management actions; however, common statistical techniques for estimating these changes are often constrained by small sample size or limited study duration and fail to provide a direct link between habitat change and population trends. Spatially explicit occupancy modeling techniques can be used in a monitoring context to estimate the current state (e.g., proportion of area occupied) of a population and provide information on trends, while controlling for detection probability and requiring comparatively fewer detections. Further, these methods allow managers to make inferences about the effects of habitat change (both natural and human caused) as it relates to population trend. Within the context of the National Forest Land Management Plan revision process, occupancy models were developed to meet the following objectives for the Kaibab National Forest (KNF):

Objectives

1) Evaluate the suitability of three future potential MIS
2) Establish baseline trend estimates for MIS monitoring and analyses
3) Incorporate adaptive management into the KNF monitoring process and subsequent management decisions.

Methods

Avian Surveys: Conducted by the US Forest Service and Rocky Mountain Bird Observatory across the Kaibab National Forest from 2006 – 2009 (Hanni et al. 2009).

Habitat Covariates: Habitat covariates were derived based on USDA Forest Service Forest Inventory and Analysis plots, interagency LANDFIRE data for vegetation type, and derivatives of the National Elevation Dataset. All data were standardized and smoothed to 125m to coincide with the area of the bird survey transects.

Occupancy estimates: Probability of occupancy for use in spatial models was generated using the single season framework of MacKenzie et al. (2006). Parameter estimates were model-averaged to account for model uncertainty (Burnham & Anderson 2002). Trends in occupancy were estimated using the multi-season framework of MacKenzie et al. (2006). All models were fit in PRESENCE (v2.2; Hines 2006).

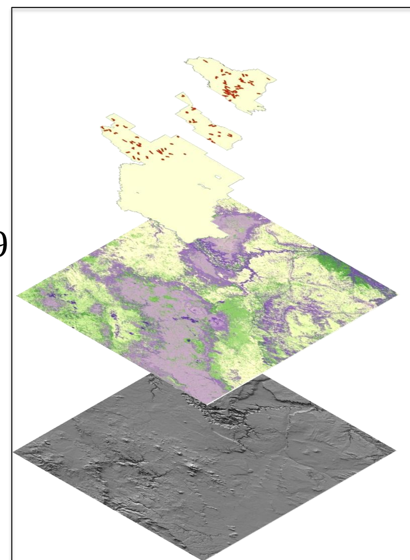

Figure 1. Depiction of development of spatial models. Models were implemented in Spatial Analyst (ArcGIS v9.3.1, Environmental Systems Research Institute, Inc., Redlands, CA).

RESULTS

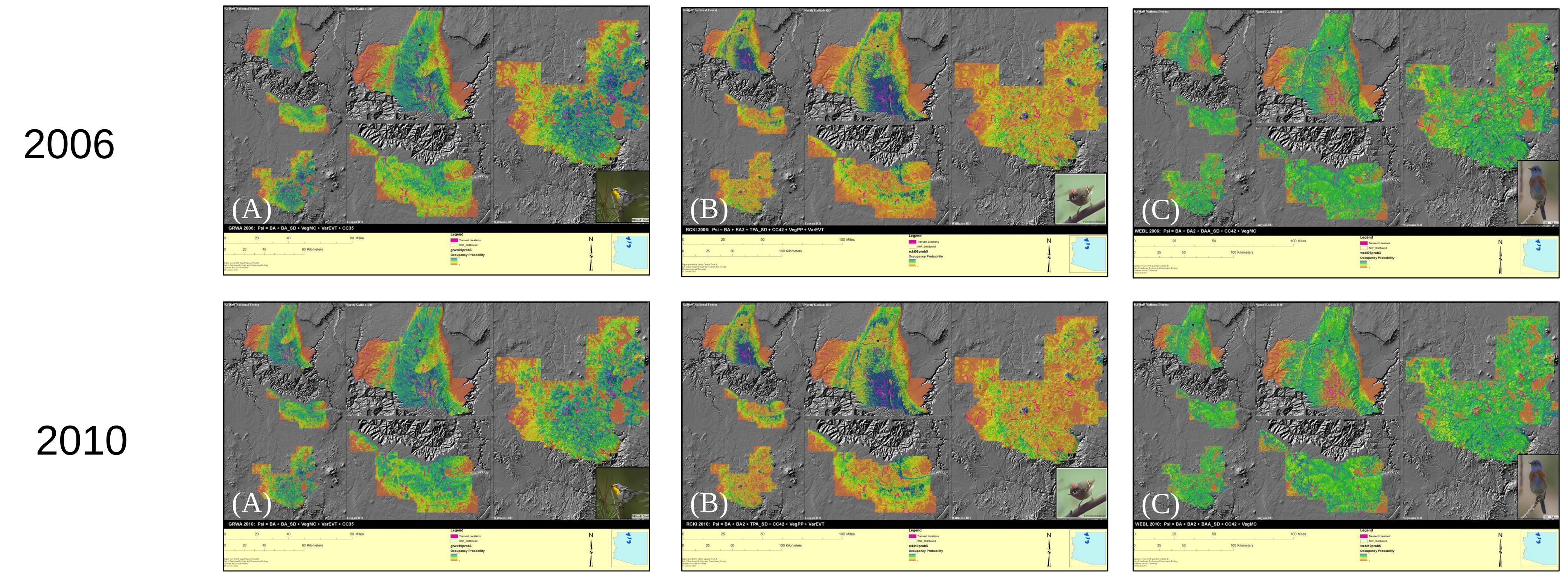

Figure 2. Spatially explicit model of Grace's Warbler (GRWA,A), Ruby-crowned Kinglet (RCKI,B), and Western Bluebird (WEBL,C) occupancy on the Kaibab National Forest (Arizona, USA) in 2006 (top row) and 2010 (bottom row). Models of occupancy were developed using 2006 and 2010 forest structural data and species observations from 2006-2009. Models were as follows: ψ_{GRWA} = Basal Area (BA) + Standard Deviation of Basal Area (BA_SD) + Mixed Conifer Vegetation Type (VegMC) + Variation in Vegetation Type (VarEVT) + Canopy Cover < 35% (CC35); ψ_{RCKI} = Basal Area (BA) + Basal Area^2(BA2) + Standard Deviation of Tree Density (TPA_SD) + Canopy Cover $21\% \leq x < 42\%$ (CC42) + Ponderosa Pine Vegetation Type (VegPP) + Variation in Vegetation Type (VarEVT); ψ_{WEBL} = Basal Area (BA) + Basal Area^2(BA2)+ Standard Deviation of Basal Area (BA_SD) + Mixed Conifer Vegetation Type (VegMC). Insets detail occupancy estimates for each ranger district of the Kaibab National Forest.

- Focus on "management relevant" covariates – likely additional covariates that are "biologically meaningful"
- All models performed substantially better than random (ΔAIC >11 for all species)
- All models contained at least one strong ($Z > |2|$) predictor related to forest structural covariates.
- Spatial models allow detection of local changes in occupancy that result from alteration of forest structure (Figure 2).
- Explicitly accounting for detection probability reduces bias (Figure 3).
- Multi-season occupancy models can identify changes in habitat with sufficient detections (Figure 4).

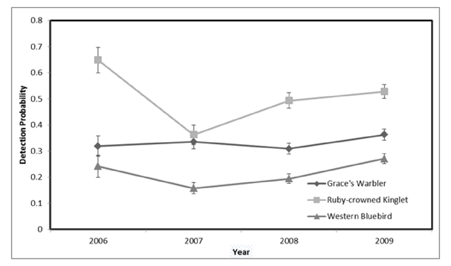

Figure 3. Annual estimates ($\pm$1 SE) of detection probability for Grace's Warbler, Ruby-crowned Kinglet, and Western Bluebird on the Kaibab National Forest (Arizona, USA).

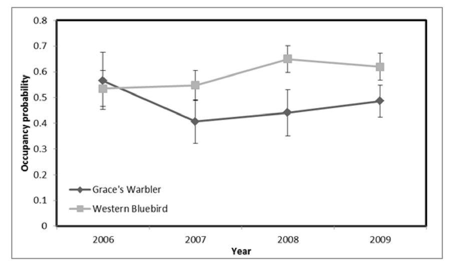

Figure 4. Annual estimates ($\pm$1 SE) of occupancy for Grace's Warbler and Western Bluebird on the Kaibab National Forest (Arizona, USA). Annual estimates for Ruby-crowned Kinglet are not presented due to insufficient sample size.

Management Implications

Evaluating bird population trends can serve as an "early warning" system for land managers tasked with providing sustainable habitat and viable wildlife populations. Using multiseason occupancy methods, we were able to derive trends for all three species of interest. This work establishes a baseline through which to evaluate future changes in species and habitat trends and can provide land managers with valuable information regarding the cumulative impacts of ongoing management activities. Additionally, for datasets with small sample sizes, annual estimates of occupancy can be more precise than those of density or abundance, and may yield trend information sooner than alternative methods, providing a more cost efficient monitoring tool.

Figure 5. A Kaibab National Forest stand before and after a restoration treatment.

The probabilistic surfaces generated using these models reflect occupancy under current conditions. These models can serve as valuable tools for analyzing potential impacts of future management and assessing the effects of those actions once they are implemented. Satellite images can be "refreshed" with new imagery over time, and then used to derive new estimates for the forest structural variables. Models can then be re-implemented to monitor landscape-scale effects of management actions (or large scale disturbance) on select species.

Previously, species have proven largely ineffective as MIS due to sampling difficulty, lack of clear linkage to the conditions they are meant to indicate , occur in areas too limited to maintain a population of the species, and are rarely validated (a priori) through empirically based methods. These models adhere to Forest Service direction to use "best available science" as a basis for policy and decision making and should help to inform better management decisions over time.

This analysis suggests that these three MIS are capable of representing specific forest attributes: open park-like conditions and overstory structure in ponderosa pine (GRWA), presence of understory vegetation in ponderosa pine forest (WEBL), and the presence of mixed-conifer forest (RCKI). The models suggest a strong association between these species and the habitat they were chosen to represent as well as several structural attributes likely to change with management. This should make them valuable species for evaluating the potential effects of future management. Finally, these models provide a basis for adaptive management. As projects are implemented, post treatment data can be collected on forest structural variables to assess how well management prescriptions meet the needs of these species over time.

Future work

Predictive scenario models are being used to evaluate planning alternatives for MIS as part of the Final Environmental Impact Statement for the revised KNF land management plan. That is, select forest structural variables would be modified based on hypothetical forest "treatments" (Figure 5) and the models re-implemented to determine potential "treatment" outcomes (i.e. implementation of plan alternatives). Unlike past planning efforts which have relied largely on qualitative changes in forest composition and stand structure, these spatially explicit habitat models provide a robust and data driven means to quantitatively assess and predict the effects of different planning alternatives on long-term population viability and habitat suitability (Figure 6). These tools provide the Kaibab National Forest with an empirically based platform for assessing wildlife habitat and species population change over time under each planning alternative, and provide a basis for refining future management actions.

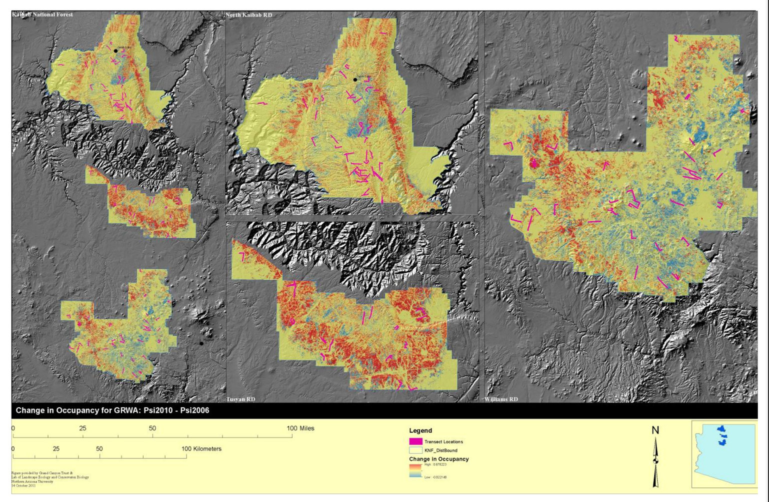

Figure 6. Spatial depiction of change in occupancy for Grace's Warbler as a result of changes in forest structural conditions.

Literature cited

Burnham, K. P., and D. R. Anderson 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer-Verlag, New York, NY.

Dickson, B. G., E. Fleishman, D. S. Dobkin, and S. R. Hurteau. 2009. Relationship between avifaunal occupancy and riparian vegetation in the central Great Basin (Nevada, USA). Restoration Ecology 17:722-730.

Hanni, D. J., C. M. White, J. A. Blakesley, G. J. Levandoski, and J. J. Birek. 2009. Point transect protocol. 37pp. Rocky Mountain Bird Observatory, Brighton, CO.

Lindenmayer and Likens. 2009. Adaptive monitoring: a new paradign for long-term research and monitoring.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines 2006. Occupancy estimation and modeling: Inferring patterns and dynamics of species occurrence. Academic Press, San Diego, CA.

Saracco, J. F., D. F. Desante, and D. R. Kaschube. 2008. Assessing landbird monitoring programs and demographic causes of population trends. Journal of Wildlife Management 72:1665-1673.

Zylstra, E. R., R. J. Steidl, and D. E. Swann. 2010. Evaluating survey methods for monitoring a rare vertebrate, the Sonoran Desert Tortoise. Journal of Wildlife Management 74:1311-1318.

Acknowledgments

We thank Rocky Mountain Bird Observatory, especially Jennifer Blakesley and David Pavlacky, for providing avian survey information. Aaryn Olsen and the Lab of Landscape Ecology helped develop forest structural covariates. Finally, we thank the U.S. Forest Service Kaibab National Forest for funding this work.

For Additional Information:

Contact Valerie Stein Foster (vkstein@fs.fed.us) or Matt Williamson (mwilliamson@grandcanyontrust.org). Also visit the Lab of Landscape Ecology and Conservation Biology webpage at: http://www.cefns.nau.edu/Academic/CSE/Lab/