# Integrating Bird-Habitat Modeling into National Forest Planning for Bird Conservation in the Southern Appalachians[1]

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## Abstract

We developed spatially-explicit bird-habitat models with a variety of site-specific and landscape parameters to predict avian species distributions on southern Appalachian National Forests to aid National Forests with bird conservation planning. These models can be used to assess the effects of different forest management alternatives on long-term population viability for a variety of avian species. Unlike past planning efforts on National Forests which were based on qualitative attempts at interpreting changes in forest type and age class distributions on avian species, use of spatially-explicit habitat models can provide quantitative estimates of how habitat availability is changing for a given species and also evaluate the significance of management decisions on spatial configurations of avian habitats. Using the Chestnut-sided Warbler (*Dendroica pensylvanica*) as an example, we demonstrate how these models work and how different forest management alternatives may affect Chestnut-sided Warbler habitat in the future.

*Key words:* bird, Chestnut-sided Warbler, conservation, *Dendroica pensylvanica*, habitat, model, National Forest, planning, population viability.

## Introduction

Bird conservation planning on U. S. National Forests is driven in part by the planning regulations enacted under the National Forest Management Act of 1976 (NFMA). These regulations require that National Forests periodically review conditions on the forest and assess the likelihood that various management alternatives will meet long-term management goals. These goals, to a certain extent, have been based on bird management goals identified through the Partners in Flight planning process, but also are based on other goals, such as timber production, recreation, and protection of endangered species.

The 1982 Planning Rules designed to implement the planning process under NFMA require that on individual U. S. National Forests "...fish and wildlife habitat shall be managed to maintain viable populations of existing native and desired non-native vertebrate species in the planning area" (Federal Register Vol. 47:43037, 30 Sep 1982). A viable population is defined for planning purposes as "...one which has the estimated numbers and distribution of reproductive individuals to insure its continued existence is well distributed in the planning area." The planning rules recognize that habitat is critical to supporting viable populations and further recognize a spatial component in that "...habitat must be well distributed so that those individuals can interact with others in the planning area." The southern Appalachian National Forests are undergoing a plan revision process following the 1982 standards and guidelines.

In December 1997, a Committee of Scientists was formed under the Secretary of Agriculture's directive to reexamine the planning process under NFMA. The committee recommended maintenance of long-term ecological sustainability as the foundation for development of National Forest management plans. In 2000, new planning rules were developed that guide the National Forests in achieving this goal. In terms of specific provisions related to fish and wildlife habitat, the new rules stipulated that the National Forests should "….provide for ecological conditions that provide a high likelihood of supporting the viability of native and desired non-native species well distributed throughout their ranges in the plan area" (Federal Register Vol. 65, No. 218:67574, 9 Nov 2000). So, in

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spite of the new emphasis on ecological sustainability in the 2000 planning rules, there still remains the need to evaluate species viability on individual National Forests and to ensure those species are "well-distributed" across individual National Forests.

There have been several different approaches to evaluation of population viability including genetic, demographic, and habitat-based methods (Soulé 1987, Shaffer 1990, Roloff and Haufler 1997, White et al. 1997, White 2000; for review see Young and Clark 2000). Because the U.S. Forest Service is legally mandated to provide habitat capable of supporting viable populations under NFMA, we have chosen to use a habitat-based modeling approach. In this paper, we describe our approach used to develop spatially-explicit bird-habitat models from standard 10-min point-count data and then develop an example of how these models can be used to evaluate different forest management alternatives. Finally, we discuss the difficulties in following such an approach in the plan revision process currently being undertaken by southern Appalachian National Forests.

## Methods

### Developing Spatially Explicit Avian-Habitat Models

Our goal in model development has been to develop spatially-explicit models that predict the likelihood that a given forest stand on a National Forest will be occupied by a breeding pair for a suite of 25 avian species regularly occurring in the region. The models were developed based on 10-min point-counts conducted by various individuals from southern Appalachian National Forests (Cherokee National Forest, Tennessee; Chattahoochee National Forest, Georgia; George Washington-Jefferson National Forest, Virginia; Francis Marion-Sumter National Forest, South Carolina; and Nantahala and Pisgah National Forests, North Carolina). Avian census methods utilized were those that have been standardized for the Southeast (Hamel et al. 1996). Data used in this example were part of the U. S. Forest Service Region 8 bird monitoring database (R8bird) and included point-counts from Virginia, Tennessee, and Georgia covering the period of 1992-1996. Sample sizes differed among individual forests; >1500 individual point-count sites were included in the analysis. We developed one set of models for forests in the "northern" part of the southern Appalachians (northern Cherokee, North Carolina National Forests, and George Washington-Jefferson) and one set of models for the "southern" part of the southern Appalachians (southern Cherokee, Francis Marion-Sumter, Chattahoochee) because classification and regression tree analysis showed differences from north to south in bird-habitat relationships.

Habitat variables were derived from the Southern Appalachian Assessment (SAA; SAMAB 1996), compiled by Hermann (1996) and U.S. Forest Service CISC (Continuous Inventory of Stand Condition) databases. The SAA database was derived from remotely sensed data and covered both private and public land in the region whereas the CISC database was comprised of information assigned to the forest stand by U.S. Forest Service district silviculturists (forest type, stand age, condition class, site index). Forest stand characteristics and landscape metrics were assigned to individual bird-habitat sampling points.

Both habitat databases existed in a geographic information system (GIS) and our analysis was conducted at a 30 m x 30 m resolution, which was a spatial scale pertinent to our target species. We used stepwise logistic regression with $P < 0.10$ level to stay in the model (SAS 1990) to build habitat models to predict the likelihood of occurrence of a given species based on 17 explanatory variables (*table 1*). Logistic regression has proven to be an effective approach for developing bird-habitat models with high predictive power from point-count data (Dettmers et al. 2002). Final model selection was determined by a combination of the lowest Akaike Information Criterion value (Burnham and Anderson 1998) and the Hosmer-Lemeshow goodness-of-fit statistic (Hosmer and Lemeshow 1989). We assessed model performance for each species based upon changes in concordance and the max-rescaled $R^2$-value. Concordance measured the overall predictability of the model and the $R^2$-value was indicative of the variation explained by the model.

### Applying Models to Southern Appalachian National Forests

Bird-habitat models (logistic regression equations) developed for each avian species were applied using ArcView (ESRI, Redlands, California) back across each individual 30 m x 30 m pixel on each individual National Forest to create a coverage of suitable habitat for that species (*fig. 1*). Initially, a species coverage represented a probability surface that depicted the likelihood that a singing male of a given species occurred in given pixels, with possible values ranging from 0 to 1. We determined the cutoff point at which pixels were deemed as suitable or unsuitable habitat based on two criteria. First, we used a threshold for sensitivity of 0.75 (probability of occurrence). If sensitivity was always greater than 0.75, we used a 'false positive' rate of 0.25 (probability of occurrence). Based on this approach, the overall correct classification was typically high and the false positive rate was relatively low, thereby making this cutoff point

**Table 1**—*Habitat variables derived from the Southern Appalachian Assessment (Hermann 1996) and U. S. Forest Service Continuous Inventory Stand Condition (CISC) databases used to construct avian habitat-models in the southern Appalachians.*

| Variable Description | Range | Source |
|---|---|---|
| Elevation (m) | 294 – 1,554 | Hermann (1996) |
| Distance to nearest stream (m) | 0 – 257 | Hermann (1996) |
| Slope (%) | 1 – 31 | Calculated from elevation SLOPE command Arc/Info |
| Relative slope position | 0 –98 | Calculated from elevation based on Wilds (1996) |
| Average solar exposure | 91- 454 | Calculated from elevation HILLSHADE command Arc/Info |
| Aspect (Beers et al. 1996) | 0.0 – 2.0 | Hermann (1996) |
| Terrain Relative Moisture Index | 0 – 60 | Parker (1982) |
| Terrain Shape Index | -37 – 44 | Hermann (1996) |
| Planiform Curvature | -2.1 – 1.8 | Calculated from elevation CURVATURE command Arc/Info |
| Forest cover within 1 km (%) | 0 – 100 | SAA land cover map |
| Forest cover within 5 km (%) | 0 – 100 | SAA land cover map |
| Forest cover within 10 km (%) | 0 – 100 | SAA land cover map |
| Tree species diversity within 1 km | 1 – 6 | Hermann (1996) |
| Tree species diversity within 5 km | 3 – 8 | Hermann (1996) |
| Tree species diversity within 10 km | 4 – 8 | Hermann (1996) |
| Hardwood dominant forest type at 1 km | 1 or 0 | Hermann (1996) |
| Pine dominant forest type at 1 km | 1 or 0 | Hermann (1996) |
| Mixed pine-hardwood forest at 1 km | 1 or 0 | Hermann (1996) |
| Land cover-type diversity within 5 km | 5 – 14 | Hermann (1996) |
| Land cover-type diversity within 10 km | 10 -15 | Hermann (1996) |
| Cove hardwood forest type | 1 or 0 | U.S.F.S CISC database |
| Hemlock-White Pine forest type | 1 or 0 | U.S.F.S CISC database |
| Mixed Pine-Hardwood forest type | 1 or 0 | U.S.F.S CISC database |
| Northern Hardwoods forest type | 1 or 0 | U.S.F.S CISC database |
| Oak-Hickory forest type | 1 or 0 | U.S.F.S CISC database |
| Yellow Pine forest type | 1 or 0 | U.S.F.S CISC database |
| Forest stand age | 0 – 150 | U.S.F.S CISC database |
| Forest stand site index | 40 – 110 | U.S.F.S CISC database |

relatively conservative. Using spatial-analyst tools in ArcView, we aggregated pixels that were deemed suitable into patches, better reflecting the continuous nature of the habitat. Aggregation only occurred for those pixels that were adjacent.

We converted these pixels of suitable habitat into an estimate of the potential to support a given breeding population. We summed the total suitable acreage for a given species across each National Forest and multiplied the total by the average breeding density of that species from Hamel (1992). Habitat patches that were less than one territory in size were not counted as occupied because they may not have supported a breeding pair. Habitat patches that could have supported a fraction of a breeding pair (e.g., 2.3 pairs) were rounded down to the nearest whole number (e.g., 2 pairs).

## Creating a Virtual Forest

For this example, we created a virtual National Forest by taking current forest conditions in a GIS coverage and projecting these conditions across a sixty-year time horizon. This was done using a SAS-based forest model developed by Klaus (1998) that simulated both even-aged and uneven-aged timber harvests and aged the forest for unharvested stands. We developed hypothetical management alternatives that differed across forest type, total area harvested per 10-yr interval, the relative proportions of even-aged to uneven-aged harvests, group sizes, and percents of stands harvested. Ideally, we could have used actual alternatives for a given forest for this analysis but those alternatives had not been specified for southern Appalachian National Forests at the time of the development of this example. Specific variations on intensities and harvest method were based upon past harvest practices and expert opinion of the district silviculturists for this example. Because our target species was associated with early succession habitat, we also needed to model natural disturbance regimes. Consequently, we modeled five natural disturbance types based upon existing literature and historical averages for this region. Natural disturbances including fire, ice storms, wind, southern pine beetle, and hemlock wooly adelgid were assigned randomly to forest stands that plausibly could be affected by that type of disturbance (e.g., southern pine beetle did not impact northern hardwood stands). For each simulation, virtual forests were updated every 10 years.

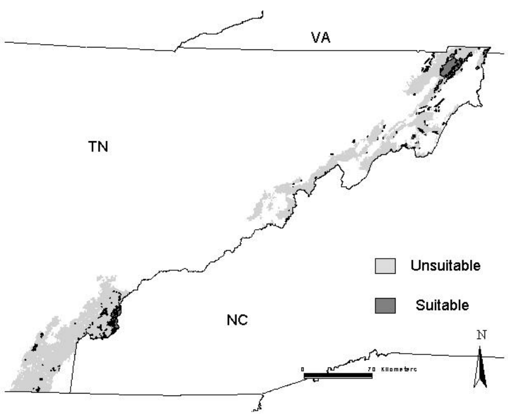


**Figure 1—**Predicted distribution of potential habitat for Chestnut-sided Warbler on the Cherokee National Forest, Tennessee.

Five scenarios were simulated, each with a different intensity of disturbance: 1) no timber harvest or natural disturbance, 2) no harvest but natural disturbance included, 3) expected level of harvest plus natural disturbance, 4) 200 percent of expected harvest plus natural disturbance, and 5) 300 percent of expected harvest plus natural disturbance. These scenarios offered a range of disturbance intensities and also allowed us to assess the relative significance of management compared to natural disturbances. Using the spatial analyst extension of ArcView, we calculated the area of each habitat patch for each simulation. The size of the potential population was calculated for each simulation at each 10-yr interval and graphed to compare the habitat potential under each disturbance scenario.

## Modeling Results

The current distribution of Chestnut-sided Warblers (*Dendroica pensylvanica*) from the modeling illustrated that on the Cherokee National Forest, habitat for this species was currently well-distributed across the forest (*fig. 1*). We estimated that this habitat had the potential to support 1,400 breeding pairs, which would probably be considered a viable population by most population viability standards (Soulé 1987). In addition, this particular analysis did not take into account the opportunities for Chestnut-sided Warblers to occupy roadsides that provided additional habitat. So considering within-stand habitat and roadside edges, this species appears to have sufficient potential habitat currently to support viable populations.

Evaluation of the effect of disturbance on future habitat potential showed that this species was likely to be sustained under all management alternatives evaluated (*fig. 2*). With little disturbance in the form of management or natural disturbance, this species would decrease in the number of pairs supported whereas with forest management, it was likely to increase. In all cases, viable populations were likely to be sustained for this species, especially if breeding pairs along roadside edges were included in the analysis.

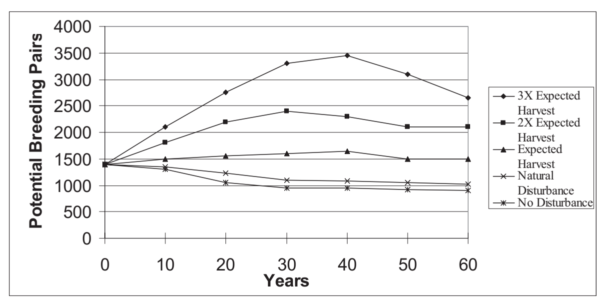


**Figure 2—**Predicted number of breeding pairs of Chestnut-sided Warblers supported on the Cherokee National Forest, Tennessee under various management scenarios.

## Discussion

Chestnut-sided Warblers require early successional habitats, including second growth hardwood forests, and old fields with scattered saplings (Hamel 1992). Given the legal mandates under NFMA, our modeling approach demonstrated that Chestnut-sided Warblers were likely to be sustained under any management alternative we evaluated. It is important to note that the level of timber harvest evaluated in this example (expected harvest and two-three times expected), represented relatively long rotations (e.g., >100 years) and relatively small area disturbed for each 10-yr interval. Some concern about the isolation of these populations might be expressed because this species typically was found at higher elevations (i.e., >1000 m) in the southern Appalachians that were isolated across the landscape. This modeling approach allowed forest managers to quantify how various management alternatives may ultimately affect habitat potential and hence population viability for wildlife species inhabiting the National Forest.

We have encountered limitations with this modeling approach in several important areas that are worth mentioning. Although we were able to create a virtual forest to model current conditions and identified plausible forest management alternatives, we were unable to simulate actual forest management alternatives under the southern Appalachian National Forest plan revision process. The problem arose because of the inability to tie forest growth models to specific stands in a spatially explicit environment on the forest so we could model the spatial configuration of habitat, an important part of our modeling process. We also had difficulty modeling habitat potential for rare species based on the R8bird database. For example, Cerulean Warblers (*Dendroica cerulea*) and Golden-winged Warblers (*Vermivora chrysoptera*) are high-priority species that occur rarely across the region. These species were not recorded with enough frequency (<5 records) on standard point-counts to allow for development of reliable habitat models. The problem lies in the R8 bird monitoring approach, however, rather than in the actual modeling approach we have demonstrated here.

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