USING LANDSCAPE-LEVEL DATA TO PREDICT PRESENCE OF HAMMOND'S FLYCATCHER, DUSKY FLYCATCHER, AND GRAY FLYCATCHER IN DRY-PINE FORESTS OF NORTH-CENTRAL WASHINGTON

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ABSTRACT

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I develop a model to predict the presence of three species of flycatcher; Hammond's Flycatcher (*Empidonax hammondii*), Dusky Flycatcher (*Empidonax oberholseri*), and Gray Flycatcher (*Empidonax wrightii*) using landscape-level data, statistical software packages, and ArcGIS software that were readily available via the internet. Point-count data used in the study were collected as part of a United States

Department of Agriculture (USDA) Forest Service Birds and Burning study in north-central Washington. The geospatial data for this study included three 30-m resolution Landsat Thematic Mapper (LTM) raster files and a 30-m resolution Digital Elevation Model (DEM) raster file covering the study area. Model development was achieved using logistic regressions and habitat selection calculations. Arc GIS raster calculator was used to create a predictive raster layer for each target species representing those habitats selected in the modeling process. Predictive raster layers were compared to point-count stations where presence/absence for each species was known and percent concordance was recorded. The Hammond's Flycatcher model had an 81.0% concordance with point-count stations where the species was present. The Dusky Flycatcher model accurately predicted the species presence 78.0% of the time, and the model for Gray Flycatcher achieved 30.0% concordance. Predictive models were compared to randomly generated points to test model performance. The mean percent concordance between the Hammond's Flycatcher model and random sites was 66.9% (SD = 12.2), 22.3% (SD = 8.80) for Dusky Flycatcher, and 21.7% (SD = 8.70) for Gray Flycatcher. Results of *t*-tests suggest that model performance was significantly better at predicting species presence than random sites. The analysis procedures presented in this study differed from other methods in their relative simplicity, yet achieved results similar to other predictive models with an average model concordance of 63% for all three models.

I. INTRODUCTION

Studies of habitat use and availability are common in biology and wildlife (Edge et al. 1987, Clark et al. 1993, Erickson et al. 1998). Traditionally, studies of habitat associations have focused on a fine scale; whereas, processes underlying observed patterns may actually take place on a much broader scale (Mitchell et al. 2001). Assessing the amount or location of habitat over large areas in a manner that is neither labor intensive nor prohibitively time-consuming holds many benefits for managers and researchers on large-scale issues (Dettmers and Bart, 1999). Recent developments in geospatial technologies have made it possible to conduct studies at a much larger scale and even multiple scales simultaneously. Habitat variables derived using geospatial technologies provide flexibility in solutions for habitat selection analysis (Erickson et al. 1998). These same geospatial technologies, when coupled with readily available statistical software applications, have dramatically increased the investigator's ability to develop accurate predictive models of species habitat selection and distribution.

Accurate predictive models of species distributions have become valuable tools for management planning (Fleishman et al. 2001). Predictive habitat models of large geographic areas have broad application in conservation biology and wildlife management, including such sub-disciplines as ecosystem management and landscape ecology (Hunter 1996). If such predictive models can be developed using widely available broad-scale GIS data without the requirement of field visits, it would be considerably beneficial for managers (Fleishman et al. 2001). Numerous methods have been used to develop predictive models capable of quantifying habitat characteristics associated with species presence, with many achieving statistically significant results (Dettmers and Bart 1999, Fleishman et al. 2001, Mitchell et al. 2001). Many of these analytical procedures were geared toward answering specific research questions or adapted to meet unique environmental conditions. Such procedures lack the broad applicability and economic efficiency necessary to facilitate widespread use by land managers. A standardized, easily replicated, and cost effective method of analyzing spatial data to predict species presence is warranted.

The purpose of this study was to determine whether certain aspects of the field of predictive modeling could be adapted to produce a modeling procedure that was time efficient, cost effective, and useful to those land managers lacking the requisite expertise needed to deploy previously developed predictive models. Using landscape-level data, statistical software packages, and ArcGIS software that were readily available via the internet, I developed a model to predict the presence of three species of Empidonax flycatchers; Hammond's Flycatcher (*Empidonax hammondii*), Dusky Flycatcher (*Empidonax oberholseri*), and Gray Flycatcher (*Empidonax wrightii*). Two consecutive years of point-count data were used to develop and test the predictive models.

II. METHODS

Point-count Data

Point-count data were collected as part of a United States Department of Agriculture (USDA) Forest Service Birds and Burning study in north-central Washington (Fig. 1). A Before/After Control/Impact study design was implemented to measure the effects of prescribed fire on dry, mixed-conifer forests within the Methow River watershed. Six sites totaling approximately 2100 ha were selected based on similar topographic and vegetative characteristics. Three sites were randomly selected to receive prescribed fire treatments, and three served as controls. Twenty point count stations were established in each of the six sites at 250 m intervals. Each point-count station was surveyed three times between May and July from 2002 to 2006. Three observers conducted the point-counts and rotated between sites to reduce observer bias. Both visual and aural bird detections were recorded. Prior to each field season, all field-crew members were trained in avian vocalization identification and detection distance estimation. Detection distances were estimated to 100 m from the center of each station and recorded in 10-m increments (i.e., 1-10 m = 10 m, 11-20 m = 20 m, etc.). Point-count station and site boundary locations were recorded in the field using GPS technology.

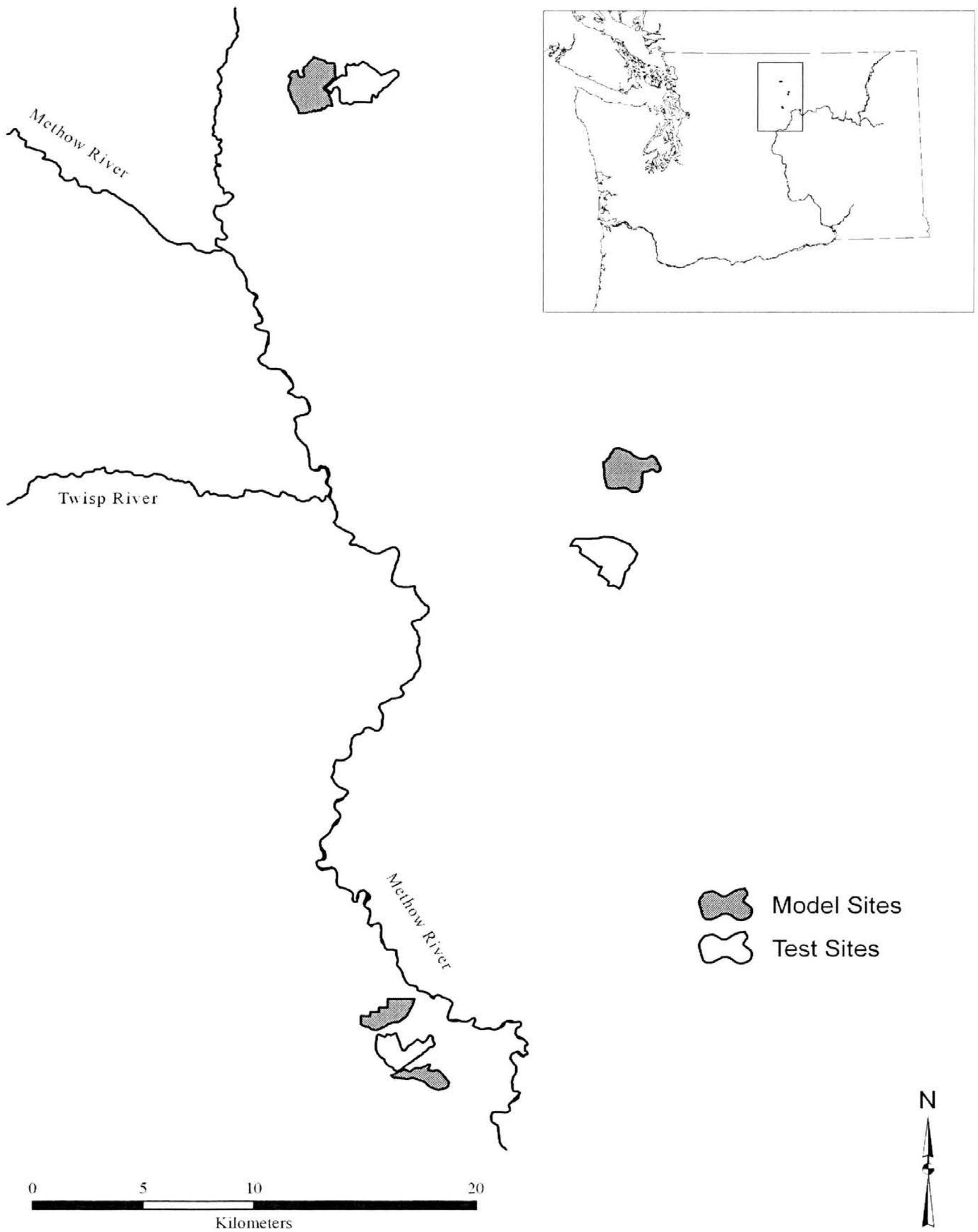

Figure 1. Location of six study sites on the Okanogan National Forest in north-central Washington where data for this analysis were collected.

Geospatial Data and Presence analysis

Point-count data for Hammond's Flycatcher, Dusky Flycatcher, and Gray Flycatcher in pre-treatment years 2002 and 2003 were selected for analysis to minimize change in habitat conditions. The six sites were randomly divided into two groups; three sites were used to develop the predictive models (model sites), and three sites were used to test the predictive models (test sites). The geospatial data included three 30-m resolution Landsat Thematic Mapper (LTM) raster files and a 30-m resolution Digital Elevation Model (DEM) raster file covering the study area. The LTM files were obtained from the Okanogan and Wenatchee National Forest Headquarters, Wenatchee, Washington, and the DEM was acquired from a United States Geological Survey (USGS) geospatial database via the internet. The LTM files were categorized for vegetative type (29 categories), canopy closure (background, 0-19%, 20-39%, 40-59%, and 60-100% canopy closure), and canopy layer (background, single, and multi-layer canopy) by USDA Forest Service GIS personnel. Aspects were derived from the DEM file using ArcGIS (ver. 9.2, ESRI, Redlands, Ca.) spatial analyst tool and grouped in increments of 45° (1°-45°, 46°-90°, etc.). Study site elevation ranged from 500 m-1636 m and was re-classified into 100-m categories.

The program Presence (ver. 2.0, USGS) was used to calculate the probability of detection for each of three target species of flycatchers. Detection probabilities were calculated for each site to determine site effect.

Predictive Model Development

Predictive habitat models for each of the target species were developed through a multi-stepped procedure. Point-count stations were treated as sampling points ($n = 60$) to describe the habitat of the model sites. One-hundred meter buffers were created around each station using Arc GIS software. The GIS extension Hawth's Tools (ver. 3.26, SpatialEcology.com) was used to count the number of pixels for each value of interest within the 100-m buffers (Fig. 2), and data were entered into a binomial spreadsheet reflecting the presence of each target species and the majority pixel value for each habitat category (Table 2). The statistical program *R* was used to run logistical regressions on 25 different combinations of habitat categories and to determine model selection.

Based on the results of the logistical regression model selection analysis, a second analysis was conducted to determine which variables within model categories were important to target species. The percentage of pixel values for each habitat variable was separately calculated for the 60 model sites and sites where the presence of target species was known. These percentages were compared to determine if a habitat variable's use was greater than, equal to, or less than its availability. If a use/availability ratio for a given habitat variable was > 1:1, the variable was designated as selected for. A ratio equal to 1:1 signified habitat use in proportion to availability, and a ratio < 1:1 indicated avoidance. Habitat variables with a ≥ 1:1 use/availability ratio were used to predict the presence of the target species (see Manley et al. 1993 for a complete discussion of habitat selection).

Arc GIS raster calculator was used to create a predictive raster layer for each target species representing those habitats selected in the modeling process. One-hundred meter buffers reflecting the distance out to which species were recorded in the field were used to calculate the percent concordance between the predictive model and test site point-count stations where target species were determined present (Fig. 3).

Figure 2. Landsat Thematic Mapper vegetative data raster layer with site boundary, point-count stations, and 100-m buffers.

Figure 3. Predictive model raster layer depicting areas of predicted species presence with site boundary, point-count stations, and 100-m buffers.

Predictive Model Testing

A series of random sites ($n = 15$) were generated using the Arc GIS software extension Hawth's Tools. The number of random sites generated was based on the frequency of occurrence of the target species (Hammond's Flycatcher = 70, Dusky Flycatcher = 110, and Gray Flycatcher = 49). In addition, random sites were restricted to within the boundaries of the study area. The percent concordance between the predictive raster layer and each series of randomly generated sites was recorded. A one-tailed *t*-test was used to determine whether the percent concordance between the predictive model and random sites was less than the percent concordance between the predictive model and sites where species were determined as present.

III. RESULTS

The probability of detection for the three target species varied across all sites (Hammond's Flycatcher 74.0%, Dusky Flycatcher 95.5%, and Gray Flycatcher 78.5%, Table 1). Of the 60 sites used for model development, Hammond's Flycatchers occurred at 38 (63.3%), Dusky Flycatchers 57 (95.0%), and Gray Flycatchers 34 (56.0%). The dominant habitat variable for each habitat category as determined by GIS analysis of the LTM files were: vegetation (ponderosa pine/Douglas fir, 32.0%), canopy layer (single layer, 86.0%), canopy closure (40-59% closure, 32.0%). The dominant aspect for study sites was SSW (20.0%), and the dominant elevation categories were 1000-1100 m and 1100-1200 m at 19.0% each.

Model Development

Habitat models created using logistic regression determined categories most closely associated with the presence of the three target species. The habitat model for Hammond's Flycatcher included canopy layer and aspect (k =11, AICc = 81.49, AICwt. = 0.4032). The Dusky Flycatcher model indicated presence was most closely associated with vegetation, canopy layer, and aspect (k = 16, AICc = 75.6, AICwt. = 0.9984). The model for the Gray Flycatcher revealed the most important habitat variables were vegetation, canopy layer, and elevation (k = 17, AICc = 92.22, AICwt. = 0.9175). Selection analysis of the predictive model habitat variables separated the target species along biological habitat requirements with Gray Flycatchers showing a stronger preference for open canopy structure than either Hammond's or Dusky Flycatchers (Table 3). Where vegetation was included in the model, Gray Flycatchers selected for more xeric vegetative communities than Dusky Flycatchers. The predictive models both for Hammond's and Dusky Flycatchers included aspect but differed slightly in preference for this variable. Elevation was included in the predictive model for Gray Flycatchers, and the selection analysis indicated preference for lower elevations by Gray Flycatchers.

Model Testing

The predictive models for each flycatcher were compared to the test site point-count stations where each species was present and percent concordance recorded. Of 60 sites used for testing the predictive models, Hammond's Flycatchers occurred at 32 (53.3%), Dusky Flycatchers at 53 (88.3%), and Gray Flycatchers at 15 (25.0%). The Hammond's Flycatcher model had an 81.0% concordance with point-count stations where the species was present. The Dusky Flycatcher model accurately predicted the species presence 78.0% of the time, and the model for the Gray Flycatcher achieved 30.0% concordance. Model tests of randomly generated sites produced variable results. The mean percent concordance between the Hammond's Flycatcher model and random sites was 66.9% (SD = 12.2), 22.3% (SD = 8.80) for the Dusky Flycatcher model, and 21.7% (SD = 8.70) for the Gray Flycatcher model. Model performance was significantly better at predicting species presence than random sites (Table 4).

IV. DISCUSSION

Attempts to predict species presence using large-scale landscape features have produced mixed results. Predictive model success for forest birds varied from 25-91% depending on migratory status (Mitchell et al. 2001), which illustrates the biological complexity of habitat associations and challenges of predicting where a species will occur. Current predictive models incorporate a wide range of habitat variables and other spatially related factors in an effort to improve model performance. The unwieldy nature of these often data heavy and statistically cumbersome models may reduce their utility for land managers. The analysis procedures presented in this study differed from other methods in their relative simplicity, yet achieved results similar to other predictive models with an average model concordance of 63% for all three models.

Predictive models often include a wide range of habitat variables including basal area, snag density, canopy layer and closure, vegetation type and age, habitat continuity or fragmentation (Mitchell et al. 2001), land cover, integrated moisture index, slope, surface curvature and morphology (Dettmers and Bart 1999). Mitchell et al. (2001) tested both macrohabitat and microhabitat features and found model fit using macrohabitat features was greater for Neotropical migratory bird data than short-distance migratory or resident bird data and proposed model success may be related to a general trend of Neotropical migrants being habitat specialists. Habitat specialists may perceive the landscape on a scale more conducive to predictive models based on large-scale features such as "forest type" rather than the much smaller scale of micro-habitat features (Mitchell et al. 2001). The three species in this study are Neotropical migratory species, which likely contributed to the success of the models. Since short-distance migrant and resident species were not included in this analysis, model performance for these guilds cannot be verified.

Numerous factors (behavior, vegetation, topography, weather conditions, and observer ability) can affect the probability of detecting a given species of bird. Detection probabilities were calculated to establish a statistical link between the species and point-count stations where the species was present because of the inherent heterogeneity of detection probability between bird species and sites. Detection probabilities for the Dusky Flycatcher showed little variation ranging between 87-98% over six visits. Detection probabilities for the Hammond's Flycatcher (31-97%) and the Gray Flycatcher (<0.01-99%) had greater variation. Those sites with low detection probabilities for these two species had <10 detections over six visits, while sites with >13 detections over six visits had >84% detection probabilities. This suggests the lower detection probability at these sites was likely due to the species absence and not missed detections. Habitat analysis of sites with low probability of detection indicated these sites did not provide adequate habitat for the species, which further supports the hypothesis that low detection probabilities were likely due to the species absence. The assumption that species were present where indicated by habitat is supported by the relatively high overall detection probability for each species.

Selecting habitat characteristics for inclusion in predictive models has been approached using a variety of statistical procedures including linear regression, logistic regression, principle component analysis, canonical correlation analysis, classification and regression tree (Dettmers and Bart 1999). I used logistic regression to determine which of five habitat categories (Vegetation, Canopy layer, Canopy closure, Aspect, and Elevation) were most closely associated with species presence. In addition, habitat selection calculations further reduced the number of variables in each model. This two-step process systematically eliminated habitat variables not associated with a species presence in a biologically intuitive, statistically supported manner, using habitat preference (selection) calculations (Manley et al. 1993). For example, Dusky Flycatchers were somewhat evenly distributed across the study area with occurrence at 95% of model sites and 83% of test sites. GIS models based solely on habitat samples collected at each point-count station where Dusky Flycatchers were present would have likely produced a model reflecting most, if not all, habitat types. The basic premise of predictive modeling is to acquire as many sites with the species occurrence while simultaneously avoiding sites where the species is absent. With 78% concordance at sites where Dusky Flycatchers were recorded present and 22.3% concordance with random sites, the performance of the Dusky Flycatcher model was approximately three times better than random despite the species occurrence throughout the study area.

Model performance was not equal for the three flycatcher species. Compared to the performance of the Hammond's Flycatcher and Dusky Flycatcher models, the Gray Flycatcher model did not perform as well as expected. The Gray Flycatcher model performed only slightly better than random by signifying 30% of sites where Gray

Flycatchers were present compared to 22% of random sites. A 30% success rate would likely not prove useful to the majority of land managers. Possible issues that could explain the low performance of the Gray Flycatcher model included: habitat samples did not include habitat characteristics important to the species or were collected from areas representing marginal habitat for the species; and the scale at which Gray Flycatchers perceive important habitat characteristics may have occurred outside the range of scales tested in this study.

In areas where all three species occurred during the breeding season, habitat preferences for Hammond's, Dusky, and Gray Flycatchers followed a moisture gradient from mesic to xeric, respectively, with some overlap between species. In Washington, Gray Flycatchers tend to occupy dry shrub land habitat with little or no overstory (Lavers 1975, Sterling 1999). Hammond's Flycatchers prefer habitat at the upper end of this moisture gradient where precipitation and canopy cover are present in greater amounts (Sedgwick 1994). Dusky Flycatchers occupy areas intermediate to these extremes (Sedgwick 1993). Gray Flycatcher density is negatively correlated with stem density and basal area of trees (Sterling 1999). Shrub land habitat type represented <6.0% of areas sampled. Because shrub land habitat was poorly represented in my study, the model for the Gray Flycatcher was possibly based on erroneous habitat characteristics or marginal breeding habitat. Predictive models based on inappropriate or marginal habitat could fail to detect habitat characteristics important to a species, thus affecting model performance.

The 100-m buffers used to acquire spatial data represent a scale of approximately 3 ha each, while the 30-m resolution of spatial data corresponds to approximately 0.09 ha on the ground. If Gray Flycatchers associate with habitat on a scale below the resolution of the data and/or beyond the scale of sampling effort, the scale used for this analysis may have been inappropriate. Since Hammond's, Dusky, and Gray Flycatchers are biologically similar in many respects, and the models for these species were developed using the same procedures, it is difficult to determine whether sample size or scale had a greater affect on the Gray Flycatcher model performance. Since female Yellow-headed Blackbirds (*Xanthocephalus xanthocephalus*) in Washington selected nesting areas and nesting sites based on habitat characteristics occurring at different scales (Orians and Wittenberger 1991), further exploration of these issues is warranted.

Management Implications

Recent shifts in focus from single species management to ecosystem management coupled with advancements in geospatial analysis have raised the level of interest and greatly increased the possibilities of predicting habitat use by multiple species at a regional scale (Carroll et al. 1999). Land managers at all levels are beginning to realize the utility of geospatial analysis, and new agency mandates have led to the increasing availability of regional scale data on both species distribution and habitat attributes (Carroll et al. 1999). Developing a predictive modeling technique that can successfully integrate emerging geospatial technologies and databases with practical and readily available solutions for land managers has proven elusive. The techniques presented here are a step toward providing a practical solution to this problem.

Additional tests are necessary to address the issues presented in this paper, especially those regarding the performance disparity between the Hammond's/Dusky Flycatcher models and the Gray Flycatcher model. In the future, the technique should be applied to multiple scales and other vertebrate and invertebrate species including short-distance migrators and resident bird species, mammals, reptiles, and amphibians. If the results of future tests are comparable to the results found in this study, this technique could provide land managers with an efficient and cost effective solution for what has been up until now a vexing issue.

Table 1. Probability of detection analysis results for each species of flycatcher. There were 20 point-count stations per site visited six times over a two-year period (n = 120). Detection count indicates visits with detections. POD indicates the probability of detection for each species over six visits.

Species		Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Hammond's	Detect. count	44	25	31	33	9	6
Flycatcher	POD	0.97	0.84	0.93	0.94	0.45	0.31
Dusky	Detect. count	56	60	33	50	48	53
Flycatcher	POD	0.98	0.98	0.87	0.97	0.96	0.97
Gray	Detect. count	27	0	13	28	33	22
Flycatcher	POD	0.93	0.00	0.93	0.92	0.99	0.94

Table 2. Representative logistical regression binomial spreadsheet for habitat category Canopy Layer. Habitat variables in this category include single-layer, multi-layer, and background.

Point-count Station	Present*	Single-layer**	Multi-layer	Background
1	0	1	0	0
2	0	1	0	0
3	1	1	0	0
4	1	1	0	0
5	1	1	0	0
6	1	1	0	0
7	1	1	0	0
8	1	1	0	0
9	1	1	0	0
10	1	1	0	0
11	1	1	0	0
12	1	1	0	0
13	1	1	0	0
14	1	1	0	0
15	1	1	0	0
16	1	1	0	0
17	1	1	0	0
18	0	1	0	0
19	1	1	0	0
20	1	1	0	0

* Species present (y/n)
** Majority pixel value for related point-count station.

Table 3. Canopy layer selection results for Hammond's Flycatcher, Dusky Flycatcher, and Gray Flycatcher showing percent available, percent use, *w^i*, and *Bi* of the total pixel count for each habitat variable within the model sites.

Species		Background	Single-layer	Multi-layer
Hammond's Flycatcher	% Avail.	0.139	0.809	0.052
	% Use	0.117	0.858	0.025
	w^i	0.844	1.060	0.484
	*Bi**	0.353	0.444	0.202
Dusky Flycatcher	% Avail.	0.139	0.809	0.052
	% Use	0.142	0.809	0.048
	w^i	1.022	1.001	0.932
	*Bi**	0.347	0.339	0.316
Gray Flycatcher	% Avail.	0.139	0.809	0.052
	% Use	0.202	0.785	0.013
	w^i	1.456	0.970	0.248
	*Bi**	0.545	0.363	0.093

* Inclusion in predictive model based on a *Bi* value ≥ 0.33.

Table 4. Results of *t*-test analysis for Hammond's Flycatcher, Dusky Flycatcher, and Gray Flycatcher predictive models when compared to random sites.

Model	*t*	df	*P*
Hammond's Flycatcher	-4.3042	14	< 0.001
Dusky Flycatcher	-23.953	14	< 0.001
Gray Flycatcher	-3.5528	14	0.001

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VITA

John Lindsey was born on December 24th 1964 in Irving, Texas where he graduated from MacArthur High School in 1983. Mr. Lindsey attended Stephen F. Austin State University earning a B.S. in Aquatic Biology in December of 1990. After graduation, Mr. Lindsey succeeded in fulfilling his dream of thru-hiking the Appalachian Trail when he climbed Mount Katadin in central Maine on October 7th 1991. He passed the next several years hiking and climbing the peaks and valleys of North America before hiring on with the USDA Forest Service in 1997.

In 2003 while visiting family, Mr. Lindsey met Ms. Ellen Shannon and the two eventually got married in October of 2005. John and Ellen currently live in Austin, Texas with their two children Hadley and Sophie and dog Missy.

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