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A DECISION SUPPORT TOOL FOR SETTING POPULATION OBJECTIVES FOR PRIORITY LANDBIRDS IN THE CENTRAL HARDWOODS AND WEST GULF COASTAL PLAIN/OUACHITAS BIRD CONSERVATION REGIONS

D. Todd Jones-Farrand,[1,6] John M. Tirpak,[2] Frank R. Thompson, III,[3] Daniel J. Twedt,[4] Charles K. Baxter,[2] Jane A. Fitzgerald,[5] and William B. Uihlein, III[2]

[1]*Department of Fisheries and Wildlife Sciences, 302 Anheuser-Busch Natural Resources Building, University of Missouri, Columbia, Missouri 65211, USA;*

[2]*Lower Mississippi Valley Joint Venture, U.S. Fish and Wildlife Service, 2524 South Frontage Road, Vicksburg, Mississippi 39180, USA;*

[3]*Northern Research Station, Anheuser-Busch Natural Resources Building, University of Missouri-Columbia, Columbia, Missouri 65211, USA;*

[4]*U.S. Geological Survey, Patuxent Wildlife Research Center, 2524 South Frontage Road, Vicksburg, Mississippi 39180, USA; and*

[5]*Central Hardwoods Joint Venture, American Bird Conservancy, 8816 Manchester, Suite 135, Brentwood, Missouri 63144, USA*

Abstract. Setting and achieving population objectives for priority landbirds must be informed by, 1) the quantity, quality, and spatial configuration of available habitat, 2) an explicit linkage between habitat condition and population response, and 3) expected future habitat conditions. Based on this philosophy, the Central Hardwoods and Lower Mississippi Valley Joint Ventures collaborated on development of a process to set habitat-based population objectives for priority forest and shrubland landbird species in the Central Hardwoods and West Gulf Coastal Plain/Ouachitas Bird Conservation Regions (BCRs). This process used multi-scale Habitat Suitability Index (HSI) models to assess available habitat for each species based on characterizations of site- and landscape-scale conditions depicted in national geospatial datasets. For the subset of models that were validated, we generated subsection-specific population estimates for individual species within each BCR by linking HSI outputs to abundance estimates derived from Breeding Bird Survey data. We used these HSI models and population linkages to develop a decision support tool that allows users to examine the effects of alternative landscape scenarios (i.e., potential future habitat conditions) on populations in the currency of their planning objectives (i.e., bird abundance). Based on initial use of the tool, we recognize the need for coordinated and strategic conservation across each BCR that also includes private landowners. Clearly, setting regional population objectives will be an iterative process, and use of the decision support tool also identified potential improvements in some HSI models. Thus, this methodology provides a science-based approach to ecoregional landbird planning within an adaptive framework that can incorporate new knowledge and address shifting planning needs.

Key Words: Bird Conservation Region, Central Hardwoods, ecoregion, Habitat Suitability Index, landbird, population objectives, West Gulf Coastal Plain/Ouachitas.

UNA HERRAMIENTA DE AYUDA EN LA TOMA DE DECISIONES PARA ESTABLECER OBJETIVOS DE POBLACIÓN PARA AVES TERRESTRES PRIORITARIAS, EN LAS REGIONES DE CONSERVACIÓN DE AVES, BOSQUE DE MADERA DURA CENTRAL Y LLANURA COSTERA DEL GOLFO OCCIDENTAL/OUACHITA

Resumen. El establecer y lograr objetivos de población para aves terrestres prioritarias debe responder a, 1) la cantidad, calidad y configuración espacial del hábitat disponible, 2) un vínculo explícito entre la condición del hábitat y la respuesta de la población, y 3) previstas condiciones futuras del hábitat. Sobre la base de esta filosofía, las Sociedades Conjuntas del Bosque de Maderas Duras Central y del

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[6] E-mail: tjones-farrand@abcbirds.org

Valle del Bajo Mississippi, colaboraron en el desarrollo de un proceso, para establecer objetivos de población de hábitat para especies prioritarias que habitan en los bosques y malezas de las Regiones de Conservación de Aves (BCR), del Bosque de Maderas Duras Central y la Llanura Costera del Golfo Occidental/Ouachitas. Dicho proceso utilizó modelos multiescala del Índice de Idoneidad de Hábitat (HSI) para evaluar el hábitat disponible para cada especie. Contamos para ello con la caracterización de las condiciones de escala-de-sitio-y-paisaje, representadas en sets de datos geoespaciales nacionales. Para el subconjunto de modelos que validamos, también hemos generado estimados de población específicos a las sub-secciones de cada especie dentro de cada BCR. Para esto, vinculamos el resultado del HSI a los estimados de abundancia derivados de datos de Sondeos de Reproducción de Aves. Hemos utilizado estos modelos del HSI y los vínculos de población, para desarrollar un instrumento de apoyo en la toma de decisiones. Este permite a sus usuarios examinar los efectos de escenarios alternativos del paisaje, es decir, posibles condiciones futuras del hábitat, en poblaciones dentro de su propia línea de planificación de objetivos, es decir, la abundancia de aves. Basados en el uso inicial de la herramienta, reconocemos la necesidad de una conservación coordinada y estratégica en cada BCR, que incluya también a los dueños de tierras privadas. Ciertamente fijar objetivos de población regional será un proceso iterativo. El uso de la herramienta de apoyo en la toma de decisiones, identificó también viables mejoras en algunos modelos HSI. Así, esta metodología proporciona un enfoque de basamento científico a la planificación ecoregional de las aves, dentro de un marco adaptable que puede incorporar nuevos conocimientos y abordar las variables necesidades de planificación.

INTRODUCTION

The North American Landbird Conservation Plan (hereafter, the Plan; Rich et al. 2004) set continental population objectives as a first step towards establishing landscapes capable of sustaining bird populations at prescribed levels range-wide. To achieve this goal, the Plan recommends establishing regional objectives that reflect these continental objectives, a process commonly referred to as "stepping down" continental objectives. Will et al. (2005) reframed the process as "stepping forward" the objectives, recognizing that translating population objectives into population-based habitat targets is an iterative process that inevitably leads to reassessment of the assumptions and methodologies that generated the initial continental objectives. Further, they outlined a process for producing and achieving biologically-based, spatially-explicit, landscape-oriented habitat objectives for supporting and sustaining bird populations.

The Central Hardwoods and Lower Mississippi Valley Joint Ventures collaborated to develop a scientific methodology in support of this approach to setting regional population objectives. Our efforts focused on two Bird Conservation Regions (BCRs) in the central and southern U.S.: the Central Hardwoods BCR and the West Gulf Coastal Plain/Ouachitas BCR. We applied multi-scale habitat suitability index (HSI) models (Tirpak et al. 2009b) to national geospatial datasets (e.g., National Land Cover Dataset, Forest Inventory and Analysis database) to assess the quantity, quality, and spatial configuration of available habitat (Tirpak et al. 2009a). Evaluation of model outputs using Breeding Bird Survey data provided an explicit linkage between habitat conditions and population response for 27 species (Tirpak et al. 2009c).

An optimal landscape (i.e., one that maximizes the conservation value of the collective conservation estate and its habitat delivery network) can be identified by iterative modifications of model input data that simulate expected or desired future habitat conditions and assessment of the resultant changes in habitat suitability. However, running these geospatial models requires long processing times and considerable digital storage space. For example, assessing a single set of parameters for one species in one BCR required between 4 and 72 hours and generated nearly 20 gigabytes of data. Moreover, modifying input data can be time-consuming and requires some familiarity with the format and structure of the data itself.

To overcome these hurdles, we developed a spreadsheet-based decision support tool that allows non-GIS users to access the information contained in the models quickly and in units meaningful to conservation delivery (e.g., acres of forest restoration). The tool can answer many difficult questions, such as:

1. How much habitat is needed regionally to ensure achievement of the continental population objective for a given species?
2. How will management for one species affect the abundance of another species?
3. Where will habitat restoration have the greatest benefit?
4. What is the landscape design alternative that is ecologically sustainable for the greatest number of species?

The tool can address multiple planning and conservation scenarios, including habitat modification, restoration, and loss. Despite several simplifying assumptions (see Discussion), its ease of use, speed, and ability to examine effects across multiple species simultaneously make it the most practical means to quicky examine

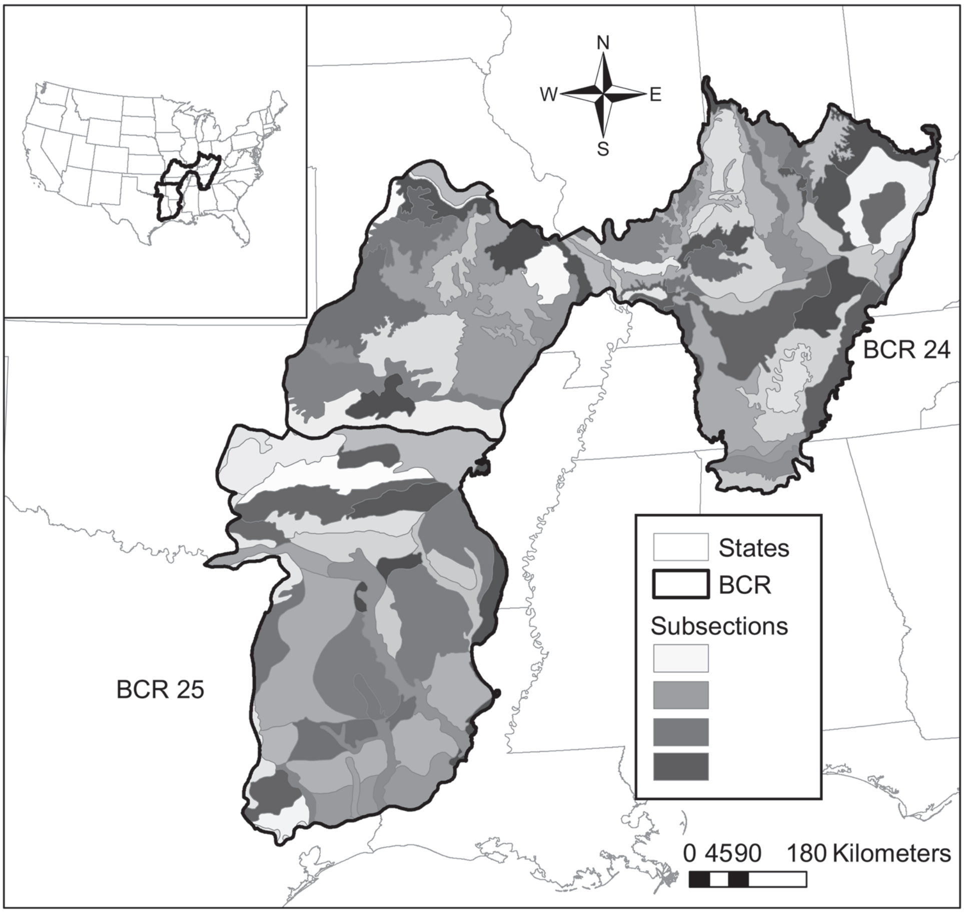

FIGURE 1. Distribution of subsections across the Central Hardwoods and West Gulf Coastal Plain/Ouachitas Bird Conservation Regions (BCR). The Central Hardwoods (BCR 24) encompasses portions of 10 states in the central U.S., whereas the West Gulf Coastal Plain/Ouachitas (BCR 25) encompasses portions of 4 states in the southcentral U.S. (inset).

numerous potential landscape design alternatives. After using this decision support tool to identify a smaller pool of plausible landscape scenarios, more rigorous assessment of competing alternatives can be performed by modifying input data used within our original geospatial models.

METHODS

Study Area

The Central Hardwoods BCR encompasses ~33 million ha within portions of 10 states straddling the Mississippi River (Fig. 1). The region is dominated by extensive oak (*Quercus* spp.)—hickory (*Carya* spp.) forests that provide habitat for forest-associated landbirds such as the Cerulean Warbler (*Dendroica cerulea*), Worm-eating Warbler (*Helmitheros vermivorum*), and Louisiana Waterthrush (*Seiurus motacilla*). For many species, this region likely serves as a population source for surrounding areas (U.S. NABCI Committee 2000). The West Gulf Coastal Plain/Ouachitas BCR covers ~22 million ha in portions of four states in the south-central U.S. (Fig. 1). This BCR is dominated by pine (with loblolly [*Pinus taeda*], shortleaf [*P. echinata*], and longleaf [*P. palustris*] pines dominant) and bottomland hardwood forests. These forests provide habitat for Red-cockaded Woodpeckers (*Picoides borealis*), Brown-headed Nuthatches (*Sitta pusilla*), Bachman's Sparrows (*Aimophila aestivalis)*; and Swainson's Warblers (*Limnothlypis swainsonii*) (U.S. NABCI Committee 2000).

To facilitate summary of HSI model outputs, we used the ecological subsection boundaries from the National Ecological Unit Hierarchy

(Cleland et al. 1997) for each BCR. These subsections reflect relatively homogenous regions of topography, geology, climate, and potential natural communities. We revised some subsection boundaries to eliminate small sliver polygons at the edges of each BCR. This resulted in 88 subsections across the Central Hardwoods (*n* = 59) and West Gulf Coastal Plain/Ouachitas (*n* = 29) BCRs; subsections ranged from approximately 69 000 to 3 500 000 ha (Fig. 1).

Background on Available Habitat and Population Linkage

To understand the quantity, quality, and spatial configuration of available habitat within our study area, we developed multi-scale HSI models implemented in a GIS environment (Tirpak et al. 2009b). We selected forest- and shrubland-associated bird species for modeling based on priority rankings and conservation status (U.S. Fish and Wildlife Service 2002, Panjabi et al. 2005). For each species, we developed separate models from a suite of site- and landscape-scale variables that could be derived from readily-available national geospatial data. We evaluated model performance using Breeding Bird Survey (BBS) data (Tirpak et al. 2009c), which resulted in 27 models being validated for BCR-wide planning. For these 27 species, model validation produced predictive equations that enabled linkage of habitat condition to population size. This methodology relied on the assumptions outlined in Rosenberg and Blancher (2005) for estimating population sizes for individual species from BBS abundance; however, we incorporated heterogeneous habitat quality in our equations by including average HSI score within subsections of each BCR as a predictor variable (D. T. Jones-Farrand, unpublished data).

Decision Support Tool

Development

We first identified a set of 12 forest communities [4 ecotypes (early-successional, savanna, woodland, and multi-layered) x 3 forest types (deciduous, evergreen, woody wetland)] that are frequently the focus of management actions in these 2 BCRs. Next, based on ecological descriptions by Nelson (2005) and consultations with a forester (J. Kabrick, pers. comm.), we developed a four-dimensional hyperspace defined by forest type, average diameter size class (i.e., successional age class), canopy cover, and midstory tree density to describe the variation within and across these forest communities (Table 1). We extracted forest type from the National Land Cover Dataset (NLCD), whereas canopy cover, average diameter size class, and midstory tree density were derived from Forest Inventory and Analysis (FIA) data. Unique combinations across these dimensions were associated with a single forest community; combinations that did not meet the criteria for a focal forest community were lumped into an all-inclusive "Other"

TABLE 1. Matrix defining forest communities as the intersection of four variables: three derived from Forest Inventory and Analysis data (canopy cover, average diameter size class, and midstory tree density) and one (forest type) extracted from National Land Cover data. Communities within each forest type are defined as: early-successional forest (ESF), savanna (SAV), woodland (WL), multi-layered forest (MLF), closed-canopy woodland (CCW), and closed-canopy forest (CCF). Combinations that did not occur are designated with "n/a."

	Forest Type [b]						
	Deciduous		Evergreen		Woody Wetland		
Canopy Cover [a]							Average Diameter Size Class [a, c]
0 – 10.0	ESF	n/a	ESF	n/a	ESF	n/a	Seed/Sap
	ESF	n/a	ESF	n/a	ESF	n/a	Pole/Saw
10.0 – 30.0	ESF	n/a	ESF	n/a	ESF	n/a	Seed/Sap
	SAV	Other	SAV	Other	SAV	Other	Pole/Saw
30.0 – 80.0	Other	Other	Other	Other	Other	Other	Seed/Sap
	WL	MLF	WL	MLF	WL	MLF	Pole/Saw
80.0 – 100	n/a	n/a	n/a	n/a	n/a	n/a	Seed/Sap
	CCW	CCF	CCW	CCF	CCW	CCF	Pole/Saw
	Open	Dense	Open	Dense	Open	Dense	
	Midstory Tree Density [a, d]						

[a] See Tirpak et al. (2009a) for a description of how these variables were derived.

[b] Shrubland land cover was included in the deciduous class in the Central hardwoods BCR but in the evergreen class in the West Gulf Coastal Plain/Ouachitas BCR.

[c] Categories of average diameter size class (i.e., successional age class) were defined as seedling/sapling (Seed/Sap) and pole/saw timber (Pole/Saw).

[d] Categories of midstory tree density were defined as <50% cover (Open) and >50% cover (Dense).

TABLE 2. Occurrence of forest communities by landform type. Forest types are defined as: bottomland hardwood/woody wetland (B), deciduous (D), and evergreen (E). Landforms that do not support a particular community are designated with "n/a."

	Landform Type [a]					
Forest Community	Floodplain	Valley	Mesic	Terrace	Xeric	Ridge
Early-successional Forest	B, D	B, D	D	D, E	D, E	D, E
Savanna	B	B	n/a	D, E	D, E	D, E
Woodland	B	B	D	D, E	D, E	D, E
Multi-layered Forest	B, D	B, D	D, E	D	n/a	n/a
Closed-canopy Woodland	B	B	D	D, E	D, E	D, E
Closed-canopy Forest	B, D	B, D	D, E	D	n/a	n/a

[a] See Tirpak et al. (2009a) for a description of how these variables were derived.

category. Closed-canopy woodland and closed-canopy forests were categorized separately as potential targets of future management actions. All non-forest land cover types were categorized as "Non-forest". We restricted each forest community to appropriate landforms (e.g., savannas on xeric but not mesic slopes) based on descriptions in Nelson (2005) and consultation with an ecologist (T. Nigh, pers. comm.; Table 2). Forest communities occupying unrealistic landforms were reclassified as "Other". This classification system produced 63 potential landform-forest community combinations [(12 focal communities + 6 closed-canopy communities + Other + Non-forest) x 6 landforms] and 5 544 potential landform-forest community zones (63 combinations x 88 subsections).

Landform-forest community zone datasets were created for both BCRs. For each species with a validated model, we calculated the mean HSI score within each zone. The mean HSI score for any species in any subsection (a necessary component of the habitat-population linkage) was calculated by a simple area-weighted average of the HSI scores in each zone.

The decision support tool allows users to alter forest community composition by adding to or subtracting from the area of one or more forest communities in one or more subsections. The user enters the acreage of the community type(s) in the subsection(s) they wish to change on the "Scenario" page. We used acres as an areal unit to reflect the spatial units most familiar to our conservation partners. Currently, the tool only allows the acreage of the 4 ecotypes within a single forest type to be altered simultaneously; future versions that allow users to make changes across forest types simultaneously are being considered. User-defined changes are proportionally allocated across the proper landforms for a specific forest type. Unless the user specifies that changes are new acreage, total forest area does not change in the simulation. Rather, acreage is shifted to the focal community proportionally from the available closed-canopy (woodland and forest) and "Other" forest communities occurring on the corresponding landforms. For example, if the user specifies an increase of 10 000 acres of deciduous woodland in a subsection that has 10% closed-canopy woodland, 20% closed-canopy forest, and 10% "Other" forest spread equally across the landforms where woodland occurs, then the tool reduces closed-canopy forests by 5000 acres and both the closed-canopy woodland and the "Other" forest classes by 2500 acres each. If the user-specified acreage exceeds available closed-canopy and "Other" acres, a warning is activated. If new acreage of a specific forest community is specified (either positive or negative), "Non-forest" area changes on appropriate landforms.

After the user specifies changes, the tool recalculates the mean HSI for all affected subsections by multiplying the HSI value for each zone by the updated acreages of each zone. Updated mean HSI values for subsections are input into the equations linking HSI scores to population values for each species, and the tool provides the user with the absolute and relative change in population summarized for each species by subsection (Sub Outputs page) and BCR (BCR Outputs page).

Landscape Design Scenarios

To demonstrate the application of the decision support tool, we report results of four landscape scenarios: national forest management, forest loss, reforestation, and savanna restoration. In the first scenario, we implemented changes based on the Mark Twain National Forest Management Plan (Mark Twain National Forest 2005). This forest plan specifies community restoration goals as ranges of National Forest land acreage within BCR subsections (e.g., woodland restoration on 3–6% of National Forest lands in a subsection). For this scenario, we focused on the Meramec River Hills subsection in eastern Missouri, USA (subsection

TABLE 3. CALCULATED ACREAGES FOR LOW, MEDIUM, AND HIGH LEVELS OF IMPLEMENTATION SUCCESS IN THE MARK TWAIN NATIONAL FOREST'S FOREST PLAN (MARK TWAIN NATIONAL FOREST 2005) IN THE MERAMEC RIVER HILLS SUBSECTION OF THE CENTRAL HARDWOODS BIRD CONSERVATION REGION (BCR).

	Implementation Success [a]		
Deciduous Forest Community [b]	Low (2.4%) [c]	Medium (3.5%) [c]	High (4.1%) [c]
Early-successional Forest	10	10	10
Savanna	0	4208	7333
Woodland	25 250	30 299	31 468
Multi-layered Forest	0	2525	4561

[a] Implementation acreages based on goals to impact 0-6% of National Forest land within the subsection for each forest community type.

[b] Only deciduous forest types were included in this scenario because the Forest Plan focused on upland forests and deciduous forests dominate the Central Hardwoods BCR.

[c] Values in parentheses indicate the proportion of the subsection area impacted by each implementation level of this scenario.

222Ae, Central Hardwoods BCR; Cleland et al. 1997), where the forest plan targeted 4 community types with the goal of impacting between 2.4% and 4.1% of the subsection. We separated management goals for this subsection into high (4.1%), medium (3.5%), and low (2.4%) implementation rates to reflect the range of potential restoration effort (Table 3). In the second scenario, we reduced the overall forest area in the White River Hills subsection (subsection 222Ag, Central Hardwoods BCR) in southwestern Missouri by 50 000 acres (20 243 ha, 1.6% of the subsection) to examine the impacts of potential future urbanization around the city of Branson. In this scenario, changes were made across all 4 deciduous focal communities in proportion to their occurrence in the White River Hills. In the third scenario, we expanded bottomland hardwood forests within the Red River Alluvial Plain subsection (subsection 234Ai, West Gulf Coastal Plain/Ouachitas BCR) in southwest Arkansas and northwest Louisiana, USA by 50 000 acres (20 243 ha, 2.2% of the subsection) to examine the impact of forest restoration. Similar to the second scenario, acreages were added to all bottomland hardwood focal communities in proportion to their occurrence in the Red River Alluvial Plain. In the final scenario, we implemented savanna restoration in all subsections to examine the magnitude of effort necessary to achieve continental objectives for savanna-associated species (e.g., Bachman's Sparrow). To reflect their dominant forest types, this scenario was implemented as 5% deciduous savanna in the Central Hardwoods BCR and 5% evergreen savanna in the West Gulf Coastal Plain/Ouachitas BCR.

RESULTS

Species response varied for each level of the National Forest management scenario (Table 4); however, relative population changes were small with just six species showing >1% change in the subsection-level population size. Under the lowest level of implementation, over half the species (15 of 27) were predicted to increase. Under the more complex habitat changes (i.e., more acres of more community types) at the high level of implementation, only 13 species were predicted to increase with four species exhibiting smaller increases than under the low implementation level.

Most species (23 of 27) declined under the forest loss scenario (Table 5). Eight species declined disproportionately to the amount of forest loss, losing 2–7% of their subsection population in response to a land use change affecting <2% of the subsection area. Several species that inhabit non-forested cover types or require an interspersion of forest and open landcovers [e.g., Field Sparrow (*Spizella pussilla*) and chuck-wills-widow (*Caprimulgus carolinensis*)] increased under this scenario. The bottomland hardwood forest restoration scenario (Table 5) showed the opposite pattern, with 18 of 27 species increasing. Nine species increased disproportionately to the amount of forest gain, increasing 3-11% of their subsection population in response to a land use change affecting only 2% of the subsection area.

The savanna restoration scenario predicted a mix of species' responses (Table 6). Although most species showed BCR-wide declines, response varied among subsections. Fifteen species in the Central Hardwoods BCR and 10 species in the West Gulf Coastal Plain/Ouachitas BCR had at least one subsection with a population increase and one subsection with a population decrease. Several species showed unexpected widespread declines under this scenario, including Blue-winged Warbler (*Vermivora pinus*), Field Sparrow, Prairie Warbler (*Dendroica discolor*), and Yellow-breasted Chat (*Icteria virens*).

DISCUSSION

Predicting the impacts of multiple simultaneous habitat changes across ecoregions presents

TABLE 4. Total predicted population change in numbers of birds (Pop) and the proportional change in population size at the subsection (%SUB) and Bird Conservation Region (BCR; %BCR) levels under three levels of implementation of the Mark Twain National Forest's 2005 Forest Plan (Mark Twain National Forest 2005) for the Meramec River Hills subsection of the Central Hardwoods BCR.

	Low			Medium			High		
AOU Code	Pop	%BCR	%Sub	Pop	%BCR	%Sub	Pop	%BCR	%Sub
ACFL	-2	0.00	-0.02	-21	0.00	-0.20	-35	-0.01	-0.32
BACS	0	0.00	-0.09	0	0.00	-0.13	0	0.00	-0.15
BAWW	78	0.05	0.99	113	0.07	1.43	132	0.08	1.67
BGGN	502	0.01	0.41	689	0.01	0.56	780	0.01	0.63
BHNU	-1	-0.02	-1.53	-2	-0.03	-2.21	-2	-0.04	-2.57
BWWA	-4	-0.01	-0.36	-6	-0.01	-0.51	-7	-0.01	-0.58
CACH	-31	0.00	-0.10	-41	0.00	-0.13	-44	0.00	-0.15
CERW	26	0.03	1.53	36	0.05	2.09	41	0.05	2.36
CHSW	-3	0.00	-0.02	-5	0.00	-0.03	-6	0.00	-0.04
CWWI	3	0.00	0.04	4	0.00	0.06	4	0.00	0.08
EAWP	20	0.00	0.11	13	0.00	0.07	6	0.00	0.03
FISP	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
HOWA	28	0.01	0.45	-3	0.00	-0.05	-28	-0.01	-0.45
KEWA	48	0.02	0.68	66	0.02	0.93	74	0.03	1.05
LOWA	4	0.01	0.56	5	0.01	0.62	5	0.01	0.60
NOPA	32	0.01	0.26	20	0.00	0.16	9	0.00	0.07
PABU	1	0.01	0.62	2	0.01	1.05	2	0.01	1.31
PIWO	-9	-0.01	-0.47	-12	-0.01	-0.63	-13	-0.01	-0.69
PRAW	-22	-0.01	-0.58	-31	-0.02	-0.82	-35	-0.02	-0.94
PROW	0	0.00	-0.02	-1	0.00	-0.07	-1	0.00	-0.10
WEWA	51	0.03	0.94	68	0.04	1.25	75	0.04	1.39
WOTH	73	0.01	0.37	51	0.00	0.26	29	0.00	0.14
WPWI	2	0.00	0.05	3	0.00	0.07	4	0.00	0.09
YBCH	-11	0.00	-0.06	-15	0.00	-0.08	-18	0.00	-0.10
YBCU	-16	0.00	-0.12	-21	0.00	-0.16	-22	0.00	-0.17
YTVI	14	0.01	0.48	11	0.01	0.39	8	0.01	0.27
YTWA	2	0.00	0.05	0	0.00	-0.01	-3	0.00	-0.05

a Herculean challenge for landbird conservation. Each change affects each species differently, and changes of the same magnitude may have different effects depending on their ecological context. Modeling habitat relationships for individual species provides a means to tease apart these complex interactions and reveal patterns hidden in the community response (e.g., bird species richness or diversity). However, this approach necessitates a large investment of time and resources. To use the wealth of available information to iteratively develop regional population objectives and population-based habitat targets, we needed to develop a decision support tool that allowed us to quickly access model outputs to meet our information needs. The tool allows us to generate answers for the difficult questions posed above (e.g., how much habitat do we need?). However, because this decision support tool is essentially just another model, users should view results critically and use it in conjunction with ancillary knowledge. Those interested in using the tool should contact the lead author.

Several simplifying assumptions used to develop this tool affect its results. First, we assumed forest community zones are accurately defined. This includes the four-dimensional hyperspace used to define forest communities, as well as the landforms on which those communities occur. Errors in defining the axes of the hyperspace are likely systematic across both BCRs because the underlying variables are derived from national geospatial datasets that should have consistent classification schemes. The evergreen class in the NLCD may be an exception, as this forest class is predominantly associated with pine in the West Gulf Coastal Plain/Ouachitas BCR and eastern redcedar (*Juniperus virginiana*) in the Central Hardwoods BCR. This difference in species composition affects the habitat quality of these sites.

Errors in relegating communities to landforms also may not produce consistent bias. Rather, there are likely subsection-specific effects given that landforms represent broad classes that may not capture fine-grain differences. For example, savannas may occur on mesic slopes in areas of former rolling prairie but not in areas with steep river banks. We assumed savannas would never occur on mesic slopes. Current research in the Central

TABLE 5. Total predicted population change in numbers of birds (Pop) and the proportional change in population size at the subsection (%SUB) and Bird Conservation Region (BCR; %BCR) levels under two scenarios: loss of 50 000 acres of forest in the White River Hills subsection of the Central Hardwoods BCR, and addition of 50 000 acres of bottomland hardwood forest in the Red River Alluvial Plain subsection of the West Gulf Coastal Plain/Ouachitas BCR.

	Forest Loss Scenario			Forest Restoration Scenario		
AOU Code	Pop	%BCR	%Sub	Pop	%BCR	%Sub
ACFL	-174	-0.03	-0.58	230	0.06	1.66
BACS	0	0.00	-0.01	0	0.00	-0.04
BAWW	-497	-0.31	-6.72	474	0.16	6.68
BGGN	-8698	-0.13	-2.99	6865	0.18	4.71
BHNU	0	0.00	0.00	0	0.00	0.00
BWWA	-30	-0.05	-1.24	0	0.00	0.00
CACH	-511	-0.03	-0.63	988	0.04	1.05
CERW	-82	-0.11	-2.55	0	0.00	0.03
CHSW	9	0.00	0.02	-158	-0.03	-0.48
CWWI	80	0.02	0.38	-195	-0.01	-0.29
EAWP	-442	-0.05	-1.00	81	0.02	0.62
FISP	2425	0.16	3.14	-116	-0.07	-2.13
HOWA	-487	-0.25	-4.59	1285	0.11	5.55
KEWA	-329	-0.12	-2.45	246	0.12	3.60
LOWA	-19	-0.04	-1.01	16	0.12	3.45
NOPA	-554	-0.10	-2.11	232	0.14	3.82
PABU	-40	-0.21	-5.57	1168	0.27	10.56
PIWO	-66	-0.08	-1.55	60	0.08	2.33
PRAW	-107	-0.06	-1.33	0	0.00	0.00
PROW	-6	-0.01	-0.17	189	0.18	4.22
WEWA	-429	-0.25	-4.33	1	0.00	0.07
WOTH	-706	-0.07	-1.57	361	0.09	2.30
WPWI	-114	-0.03	-0.79	35	0.04	1.56
YBCH	-81	-0.01	-0.16	-1	0.00	0.00
YBCU	-20	0.00	-0.05	10	0.00	0.03
YTVI	-80	-0.05	-1.19	64	0.07	1.70
YTWA	-153	-0.06	-1.17	102	0.09	2.89

Hardwoods BCR to develop potential vegetation maps based on land type associations (a level of resolution higher than subsections) may provide a way to refine the tool and address this potential source of error (L. O'Brien, pers. comm.).

We also assumed that effects of landscape configuration (patch size, connectedness, etc.) within a subsection did not change from the initial conditions. Landscape configuration was used in the HSI models and is therefore implicitly incorporated in the mean HSI values that form the baseline conditions in the tool. User-defined changes, however, were not spatially explicit beyond restriction to an appropriate landform in a particular subsection. Thus, habitat changes implemented in the tool assume no change, on average, to the components of habitat suitability affected by landscape configuration. This assumption is tenuous, at best, for some scenarios (e.g., urban growth patterns and public land management).

Another simplifying assumption inherent in our approach relates to time. The changes we modeled with the tool (e.g., forest restoration) are processes that occur over time. The results of scenarios implemented in this decision support tool have no definite time scale. Instead, they represent a future point in time when the habitat modification is complete. Avian populations may exhibit distributional shifts due to habitat and environmental variation (e.g., Johnson 2000) or changes in resource availability (e.g., Hughes 1999), and associated site-level changes in abundance may not reflect actual changes in total population size. Habitat modifications may produce similar shifts as birds move from low quality to high quality habitats. By assuming no definite time frame, we avoid the complication of short-term distributional shifts because we assume that populations have had time to adjust to the new conditions. Therefore, any population increase predicted by this tool is assumed to represent new, additional individuals.

The addition of new individuals hinges on another set of assumptions related to predictive uncertainty. Essentially, the tool assumes the underlying relationships are known with 100% certainty—an obvious falsehood. There are 2 sources of uncertainty that are of concern here,

TABLE 6. Total predicted population change in numbers of birds (Pop), the proportional change in population size at the Bird Conservation Region (BCR; %BCR) level, and the range of proportional changes in population size at the subsection (%SUB) level from converting 5% of each subsection to savanna. Savanna was defined as deciduous savanna in the Central Hardwoods BCR and as evergreen savanna in the West Gulf Coastal Plain/Ouachitas BCR in accordance with the dominant upland forest types.

	Central Hardwoods BCR				West Gulf Coastal Plain/Ouachitas BCR			
			%Sub				%Sub	
AOU Code	Pop	%BCR	Min	Max	Pop	%BCR	Min	Max
ACFL	-18 680	-2.74	-4.85	-0.79	-10 558	-2.86	-4.60	-0.51
BACS	0	-0.10	-1.45	0.01	171	1.07	-1.87	22.94
BAWW	3301	2.05	-3.66	7.74	-26 816	-9.31	-12.54	-7.04
BGGN	27 638	0.43	-3.20	3.08	-148 188	-3.79	-6.07	-2.53
BHNU	-175	-3.04	-10.18	-0.29	9525	5.68	-6.78	16.62
BWWA	-653	-1.14	-6.53	0.00	-14	-1.87	-4.42	-0.01
CACH	-8654	-0.46	-1.48	0.55	-876	-0.03	-2.67	0.60
CERW	456	0.60	-8.40	7.70	-10	-0.51	-3.41	0.00
CHSW	-6428	-0.53	-2.61	-0.01	-1453	-0.27	-2.08	0.26
CWWI	925	0.20	-0.52	1.39	-4214	-0.22	-2.16	2.13
EAWP	-6381	-0.68	-1.97	0.81	-993	-0.28	-2.64	1.32
FISP	-2187	-0.15	-1.25	0.00	-1416	-0.84	-2.93	-0.01
HOWA	-17 264	-8.88	-13.09	-2.47	-99 611	-8.46	-15.11	-3.03
KEWA	1249	0.44	-2.37	2.28	-9760	-4.65	-7.07	-2.67
LOWA	-214	-0.51	-3.30	5.39	-490	-3.78	-6.39	-2.19
NOPA	-12 996	-2.30	-4.28	0.79	-7961	-4.69	-7.91	-3.16
PABU	2154	10.92	-11.88	75.30	3329	0.78	-11.28	35.67
PIWO	-992	-1.15	-4.16	5.00	-467	-0.62	-4.49	5.79
PRAW	-3095	-1.71	-7.90	0.00	-4125	-3.23	-7.78	-0.01
PROW	-350	-0.45	-3.13	0.00	-1498	-1.42	-3.68	-0.05
WEWA	-1063	-0.61	-7.83	5.90	-1538	-3.09	-6.97	-0.16
WOTH	-42 816	-4.00	-6.63	-1.34	-16 578	-3.98	-6.87	-2.53
WPWI	1951	0.59	-0.92	4.38	349	0.42	-7.74	4.23
YBCH	-1393	-0.11	-0.74	0.00	-33 903	-2.91	-4.77	-0.02
YBCU	-2188	-0.24	-0.44	-0.01	-905	-0.10	-0.23	-0.06
YTVI	-4148	-2.73	-4.41	-0.45	-2334	-2.38	-4.46	-1.36
YTWA	-1838	-0.68	-2.39	1.32	-2073	-1.91	-6.55	0.55

model error and link error. The former denotes error in predicting the relationship between forest and landscape structure and habitat suitability, while the latter denotes error in predicting the relationship between habitat suitability and bird abundance. Model error is difficult to assess, but has been minimized by only including those models that have passed verification and validation tests (Tirpak et al. 2009c). However, some models performed better than others in these tests, and research is underway to refine all HSI models with point count survey data. Link error can be assessed by placing confidence intervals on the population estimates. Currently, the tool does include confidence intervals on the baseline (current) conditions, but not on scenario estimates. Thus, the tool provides some insight on our ability to detect population change by visual assessment of the predictions relative to the confidence interval around the initial estimate (but only if the predicted change is non-zero). We are considering including confidence intervals on all population estimates in future tool updates.

Another area of potential improvement in the tool is the allocation of land to management objectives. In its current form, the tool first adds forest communities to landforms proportionally to their occurrence (e.g., if more woodland is present on ridges than xeric slopes, then any new acres of woodland are added more to ridges than xeric slopes). This assumption is reasonable if management focuses on enlarging or connecting existing blocks. However, some managers may choose to restore communities to landforms where they once occurred but are currently rare. Second, the tool currently removes acreage proportionally from closed-canopy and "Other" forest classes to account for management actions. Alternatively, one may disproportionately convert closed-canopy forest prior to targeting "Other" forest communities if economics are a consideration. Finally, the tool currently allows users to implement changes in only one forest type at a time per subsection. The ability to implement changes in multiple forest types (e.g., deciduous upland forest and bottomland hardwood forest) in a single subsection simultaneously may prove a useful modification.

Development of the tool provided other benefits, including additional insight into the HSI models. Where results from the tool agree with our predictions on how species are distributed among forest communities and landform types, we have increased confidence in the utility of the models for conservation planning. Where results do not agree, there is an indication that either the assumptions of the tool or the HSI models need reexamination. For example, we expect savanna restoration to improve habitat quality for most early-successional species, but the tool predicts a decline. This discrepancy may be a function of the HSI models for these species classifying pole and sawtimber successional age class stands as unsuitable irrespective of canopy cover or basal area. As a result, mean HSI values for these species are lower than expected within savanna communities, and these species exhibit a limited response to savanna restoration in the tool. Modifying the models for Blue-winged Warbler, Field Sparrow, Prairie Warbler, and Yellow-breasted Chat to reflect the suitability of pole and sawtimber successional age class stands associated with low basal areas and open canopies, would alleviate this problem. This change would be consistent with observations of these species in deciduous savannas (F. R. Thompson, unpublished data). However, it may overestimate the quality of savannas if management includes frequent fire intervals that reduce the availability of shrubs for nesting. Other early-successional species [i.e. Bachman's Sparrow, Painted Bunting (*Passerina cyanea*)] were less drastically affected because their models already identified pole or sawtimber stands as potential habitat.

This decision support tool illuminates the ability of conservation activities to contribute to the continental objectives set by the North American Landbird Conservation Plan (Rich et al. 2004). The first three scenarios revealed that management efforts in a small portion (1.6–4.1%) of a single subsection have little impact on the subsection's avian populations and a negligible effect at the BCR scale. Even in the fourth scenario, where changes were implemented in every subsection, no species showed more than a 13% change in population numbers despite impacting ~3.8 million acres in the Central hardwoods BCR and ~2.6 million acres in the West Gulf Coastal Plain/Ouachitas BCR. This result does not invalidate the goals set forth in the North American Landbird Conservation Plan or imply that these BCRs do not contribute significantly towards the continental objectives. Rather, it suggests that Joint Venture partners may have to focus efforts strategically and coordinate across ownerships. Independent, opportunistic efforts are less likely to contribute substantially to regional goals (sensu, National Ecological Assessment Team 2006, Twedt et al. 2006). These results also highlight the critical role of private landowners, as the area of public ownership within any subsection does not provide sufficient acreages on which to achieve most landbird population objectives.

The Central Hardwoods and Lower Mississippi Valley Joint Ventures are currently in the process of developing regional population objectives and population-based habitat objectives. Setting and achieving population objectives for landbirds requires knowledge of the quantity, quality, and spatial configuration of available habitat, an explicit linkage between habitat condition and population response, and expectations of future conditions. Although all landbird species may not be limited by the quantity and quality of breeding habitat, obtaining this knowledge is a crucial first step in designing effective conservation strategies because it underlies our ability to understand what factors are limiting populations and which conservation actions are likely to generate desired effects. We concur with Will et al. (2005) that objective setting needs to be an iterative and adaptive process. As we use these HSI models and this decision support tool to develop and assess regional objectives, opportunities will arise to update, modify, and improve these tools and in turn revise and refine our objectives. Further, habitat models for additional species can be developed and incorporated into the process. This methodology generates a science-based approach to ecoregional planning, and provides an adaptable framework for incorporating new knowledge and addressing shifting planning needs.

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