Old Regrowth Forest Patches as Habitat for the Conservation of Avian Diversity in a Southwest Ohio Landscape

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Abstract. Landscape fragmentation and chronic habitat loss are potentially profound obstacles to the protection of mature forest birds in the eastern deciduous forest of the Corn Belt agricultural region. Because of the general absence of large remnant forests, conservation efforts need to better understand the role of very small 'regrowth' patches for bird conservation. This study investigated how small old regrowth forests contribute to regional bird diversity and differ in composition in relation to their physical, ecological, and landscape attributes. From May to late June 2009, we measured forest composition and structure, and conducted avian point count surveys in nine regrowth patches, 0.9 - 11.2 ha, embedded in the Miami University Natural Areas, Butler County, Ohio. These small patches conserved 68 percent of the recorded regional birds, including 94 percent of mature forest breeders. Site differences among the nine patches explained the designation of avian community types as primarily upland, floodplain, and transitional between these settings. These findings demonstrate the conservation significance of small, old regrowth patches for mature forest birds and support the conservation of these forests across a range of physical, ecological, and landscape settings.

OHIO J SCI 110 (4): 86-93, 2010

INTRODUCTION

The consequences of landscape fragmentation are potentially profound for the conservation of forest-associated bird species in the eastern deciduous forest of the midwestern United States (Robinson and others 1997). Prior to European-American settlement, forests were extensive and defined the habitat conditions for nearly all mature forest birds (Haney and Schaadt 1996). Some area-sensitive, interior-dwelling avifauna require intact, mature forest stands, such as the ovenbird (*Seiurus aurocapilla*), scarlet tanager (*Piranga olivacea*), and wood thrush (*Hylocichla mustelina*), a species of national conservation concern (BNA 2011). However, the development and intensive management of the Corn Belt agricultural region in the Midwest contributed to a land-use history of chronic habitat loss, fragmentation, and sustained human modification (Burgess and Sharpe 1981; Ebinger 1997). 'Terrestrial islands' of forests are now the primary remaining habitat available for many of these 'pre-settlement' forest birds (Burgess and Sharpe 1981).

Because of the general absence of large remnant stands across the Midwest (Parker 1989; Schwartz and van Mantgem 1997), conservation efforts must focus on the conservation value of 'regrowth' forests and their habitat attributes. For example, only fourteen publicly accessible old-growth remnant patches at least 150 years old remain in Ohio (McCarthy 1995). However, old regrowth forests are typically >100 years old and have regrown to maturity after the original habitat was lost due to early agricultural development or settlement (Medley and Krisko 2007). Old regrowth forests, with their history of intensive land-use management, are more abundant throughout the Midwest and may contribute significantly to the conservation of mature forest-associated bird species.

We investigated between May and late June 2009, the diversity of bird species found in small old regrowth stands located in the Miami University (MU) Natural Areas of southwestern Ohio. When these lands were acquired by the university and during their early management until the mid 1970's, most of the land was in cultivation, pasture, or grazed woodland, with only small patches protected from utilization (Medley and Gramlich-Kaufman 2001; Medley and Krisko 2007). We focused on the conservation of avian diversity in those small patches of now old regrowth forests embedded in successional lands. First, the study asked: to what extent do old regrowth patches contribute to regional bird diversity, particularly the conservation of mature forest-associated species? For this question, we compared the community structure of bird populations recorded during the 2009 field survey in a sample of old regrowth stands with the breeding species reported by the Ohio Breeding Bird Atlas II, a regional compilation by citizen scientists (bird watchers) and field technicians (OBBA II 2011). Secondly, the study asked: how do old regrowth patches differ in their diversity of bird species in relation to their physical, ecological, and landscape attributes? We hypothesize that the diversity of remnant forest avian species may be preserved by the protection of old regrowth forest patches and examine how they differ in their site conditions through the integrated analysis of their physical, ecological, and landscape attributes.

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METHODS AND DATA

Study Area

The MU Natural Areas protect over 405 ha of land located mainly east of Miami University's Oxford campus, including eleven different reserves acquired by the university since the 1960's (Fig. 1). Harker's Run and Four Mile Creek flow south through the reserve and Collin's Run flows west, forming a landscape of floodplain, sloped, and upland settings (Medley and Gramlich-Kaufman 2001). Mature forests may be dominated by American beech (*Fagus grandifolia* Ehrh.) and sugar maple (*Acer saccharum* Marsh.) or by oaks (*Quercus* spp.) and hickories (*Carya* spp.), demonstrating the unique ecotonal position of the site between the beech-maple and western mesophytic forest associations (Braun 1950) and a diversity of forest community types in relation to local physical-environmental conditions and human-historical processes (Medley and Krisko 2007). MU Natural Areas are embedded within a regional landscape for which the avian community is documented by the Ohio Breeding Bird Atlas II (OBBA II) survey. These data are entered at a resolution of 25.9 km^2 "atlas blocks," using the Delorme Ohio Atlas TM where we focused on the "Oxford 3" and "Millville 1" blocks (Fig. 1, OBBA II 2011).

We overlaid, digitized, and compared the forest boundaries of georeferenced (1:20,000) air photos for 1938 and 2005 to map the location of old regrowth forest patches in the MU Natural Areas. These land areas were in closed forest in 1938, estimated to be at least 40 years old, and were undisturbed thereafter. Each patch, defined by its digitized boundaries from the photos, was then field-checked using a GPS, where we confirmed the physical-site conditions and ecological boundaries with the surrounding vegetation. For example, we located old wire fences, planted osage-orange [*Maclura pomifera* (Raf.) Schneid.] fence rows, and distinct plant community contrasts in the field to further define the boundaries of the regrowth patches. Nine old regrowth patches, from 0.9 ha to 11.2 ha, were selected for study out of approximately 15 identified in the MU Natural Areas, and together they represent a range of different topographic settings (Table 1).

Data Collection and Analyses

The field study conducted from May to late June 2009 followed the Breeding Biology Research & Monitoring Database (BBIRD) protocol for conducting point counts and vegetation samples (Martin and others 1997). We located the first plot at a random location in each patch and then located the center of each subsequent plot 100 meters apart to lower the possibility of double-counting birds (Fig. 2). A total of 33 plots were situated along mostly north to south or east to west transects. All points were 50 meters from the edge to minimize edge effects except in two small patches (Beck Corridor and Bachelor North Loop, Table 1) where points placed in the patch center were slightly less than 50 meters from the edge.

We conducted point count surveys from late May to late June 2009, in accordance with MAPS' (Monitoring Avian Productivity and Survivorship) designated breeding dates (Nott and others 2003). Point counts were performed for ten-minute periods after a two-minute settling down period to minimize disturbance on the birds after entering the plot (Bibby and others 1992; Martin and others 1997). They were only conducted under favorable weather conditions and commenced no earlier than thirty minutes before sunrise (5:50 am) and ended during the late morning (11 am) when local bird activity and vocalizations began to decline (see Martin and others 1997 for the Breeding Bird Survey guidelines). We compiled species occurrences (presence/absence), species richness, and the number of breeding birds by species at each point (Martin and others 1997), and combined these data for the points in each patch.

We also collected field data on the physical-environmental, ecological, and landscape habitat attributes at each point count location included in the avian surveys for the nine sampled regrowth patches. Topographic aspects and slopes were collected using a clinometer and we averaged measures for each of the regrowth patches. In an 11.3 m radius circular plot (401.15 m^2) at each point count plot center we confirmed species occurrences, measured diameters at breast height (dbh), and recorded heights for all canopy-subcanopy trees >10 cm dbh. The occurrences and heights of understory saplings and shrubs <10 cm dbh and >1 m in height were then measured in a nested 5 m radius plot (78.54 m^2). We then measured percent canopy cover above >1.5 m and coarse woody debris by averaging densiometer readings and percent of ground estimates, respectively, from four quadrants in the 11.3 m^2 plot (Martin and others 1997), and measured the stem diameters of standing snags >10 cm dbh to compute their basal areas (m^2/ha). Each patch was then compared on the 2005 air photos to record

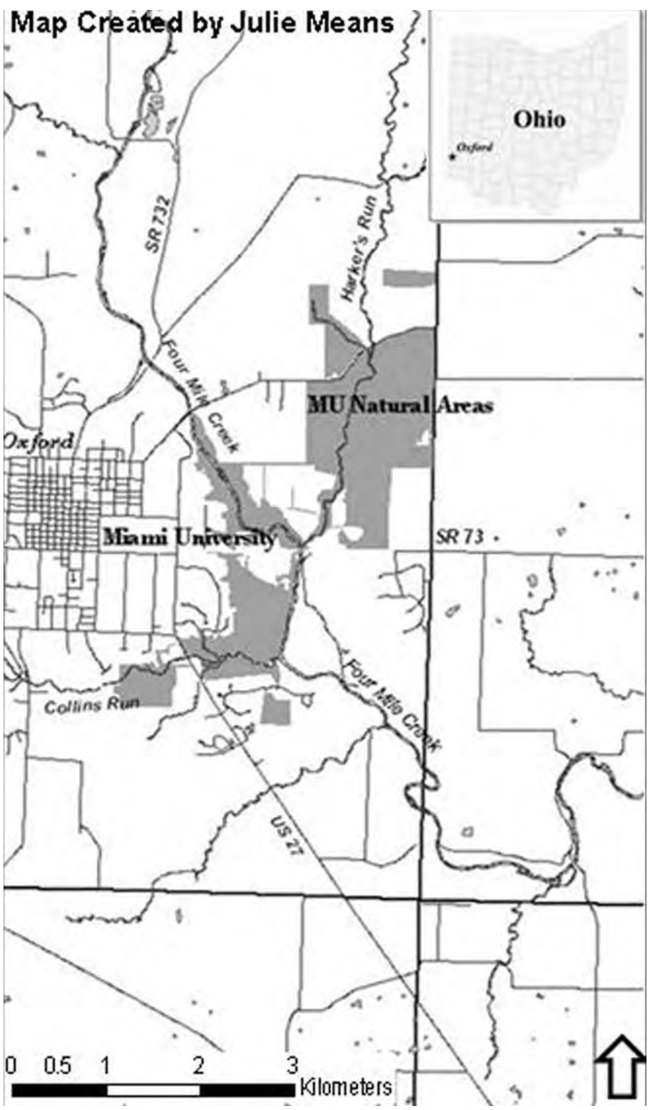

Figure 1. Location map, showing the Miami University Natural Areas and the extent of the Ohio Breeding Bird Atlas (OBBA) II survey region compared in the study.

Table 1

The nine old regrowth patches selected for the study. Patch sizes were calculated from the 1938 aerial photos, showing the boundaries of mature forest at that time.

Old Regrowth Patches	Landform Position	Size (ha)
Beck Corridor	Lowland-Floodplain	0.9
Harker's Run	Lowland-Floodplain	5.3
Marcum Loop	Floodplain and Sloped	6.0
Bachelor Pine Gullies	Sloped-Concave	6.9
Bachelor North Loop	Sloped	1.9
Western Woods	Upland-Convex	6.2
Bachelor East Loop	Upland-Convex	11.2
Kramer Preserve	Upland-Sloped	4.7
College Woods	Upland	8.1

its perimeter and surrounding land-cover types (Fig. 2).

Question one investigated the regional contribution of old regrowth forests for the conservation of bird populations. We first compared the vegetation composition and structure of the sampled regrowth forest stands with published ecological records for old-growth and/or mature forests in the region, and regional land-cover provided by the U.S. Geological Survey. Our analyses pooled the data from all points to calculate the richness, density, basal area, and relative importances of canopy-subcanopy tree species, and structural heterogeneity as measured by canopy and understory heights, percent canopy cover, standing snag basal area, and coarse woody debris. Second, we compared species occurrences (presence/absence), species richness, and the relative percent of species identified during the point count surveys with regional data compiled by the Ohio Breeding Bird Atlas II, which focuses on the composition, abundance, and distribution of bird species designated as possible, probable, or confirmed breeders from 2006-2010 (OBBA II 2011). Habitat preferences for these birds were characterized from field knowledge of Ohio birds and descriptive summaries provided by the *Birds of North America* online series available from the Cornell Lab of Ornithology (BNA 2011, cf. Sibley 2001).

Question two focused on how the sampled regrowth forests varied in their habitat conditions and respective bird populations. We first determined how the mean patch slope and overall orientation (aspect) varied among the patches as a measure of topographic heterogeneity and in relation to their landform position (Table 1). We then compared forest ecological (compositional and structural) attributes among the patches, focusing on how canopy tree and understory richness, the relative importances of canopy species, mean canopy and understory density and height, percent canopy cover, standing snag basal area, and percent coarse woody debris differed among the sampled patches. Finally, we compared the sizes and edge conditions for the old regrowth patches as comparative measures of their landscape settings.

These data on the forests were then related to the interpretation of bird species richness, species occurrences, and abundance patterns among the sampled forests and their habitat preferences (BNA 2011). Detrended correspondence analysis (DCA; McCune and Grace 2002) was employed as a multivariate technique to compare relative community similarities and differences among the forest stands based on the total number of individual birds per species recorded for the regrowth patches, respectively. From a plot of the scores along two axes, we identified distinctive bird communities in relation to their physical-environmental, ecological, and landscape attributes. Pearson correlations tested relationships between old regrowth habitat attributes and measures of bird species richness, bird abundances, and the DCA ordination scores.

RESULTS

Old Regrowth Forests in the Conservation of Regional Bird Diversity

The nine regrowth patches are representative of closed-canopy deciduous forests with a well-developed understory. They had a cumulative canopy (>10 cm dbh) richness of 30 tree species and an understory (>1 m ht. and <10 cm dbh) richness equal to 25. We measured an average canopy-subcanopy height of 17.6 m and canopy cover at 91.5 percent. The basal area of trees >10 cm dbh in the sampled patches equaled 35.80 m^2/ha, which may be partially explained by the occurrence very large American sycamore (*Platanus occidentalis* L.) and eastern cottonwood (*Populus deltoides* Bartr.) trees in the flood plain sites and a high density of trees (414 individuals/ha) contributing to the basal area at the canopy layer. The average standing snag basal area of the regrowth forests was 4.63 m^2/ha and the percent coarse woody debris equaled 17.9 percent, documenting an ecological structure of live and dead biomass similar to that predicted for old-growth stands in the region (Runkle 1996, Swanson and Vankat 2000). These old regrowth patches, however, differ distinctly from the dominant land-cover for southwestern Ohio. USGS maps a dominance of agriculture (55 percent), a fragmented distribution of forest cover (25 percent), and

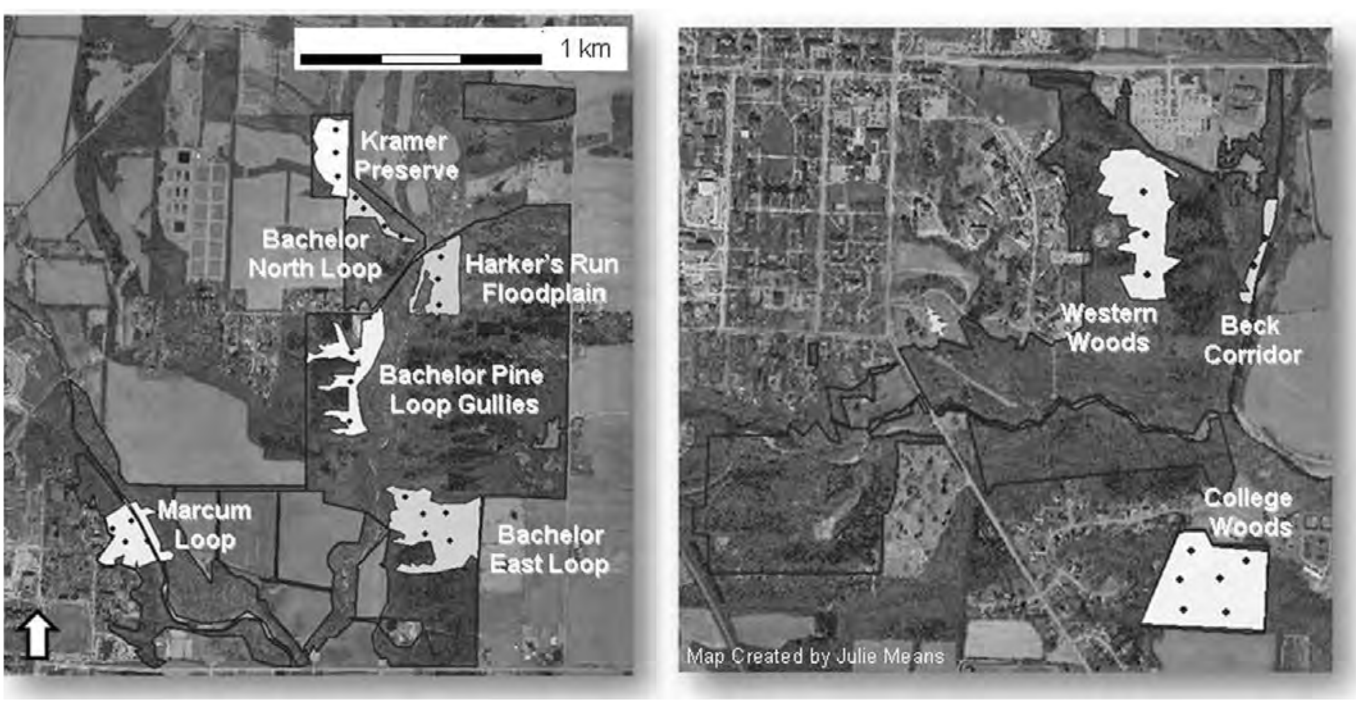

FIGURE 2. The location of the 33 sample points in the nine old regrowth patches in the MU Natural Areas.

Table 2

Record of bird species documented by the OBBA II compared with those same species recorded in the nine sampled old regrowth forests. Mature forest-associated bird species are identified with an asterisk.

Ohio Breeding Bird Atlas II Regional Data for Oxford 3 and Millville 1 Atlas Blocks	Species	Alpha Code (see USGS Bird Banding Laboratory)	MU Natural Areas Regrowth Forests	Ohio Breeding Bird Atlas II Regional Data for Oxford 3 and Millville 1 Atlas Blocks	Species	Alpha Code (see USGS Bird Banding Laboratory)	MU Natural Areas Regrowth Forests
great blue heron	*Ardea herodias*	GBHE	√	Northern flicker	*Colaptes auratus*	NOFL	√
Canada goose	*Branta canadensis*	CAGO	√	*pileated woodpecker	*Dryocopus pileatus*	PIWO	√
wood duck	*Aix sponsa*	WODU	√	*Eastern wood-pewee	*Contopus virens*	EAWP	√
mallard	*Anas platyrhynchos*	MALL		willow flycatcher	*Empidonax traillii*	WIFL	
black vulture	*Coragyps atratus*	BLVU		*Acadian flycatcher	*Empidonax virescens*	ACFL	√
turkey vulture	*Cathartes aura*	TUVU	√	Eastern phoebe	*Sayornis phoebe*	EAPH	√
*cooper's hawk	*Accipiter cooperii*	COHA	√	*great crested flycatcher	*Myiarchus crinitus*	GCFL	√
*red-shouldered hawk	*Buteo lineatus*	RSHA	√	Eastern kingbird	*Tyrannus tyrannus*	EAKI	
red-tailed hawk	*Buteo jamaicensis*	RTHA	√	warbling vireo	*Vireo gilvus*	WAVI	√
American kestrel	*Falco sparverius*	MAKE		white-eyed vireo	*Vireo griseus*	WEVI	√
wild turkey	*Meleagris gallopavo*	WITU	√	*red-eyed vireo	*Vireo olivaceus*	REVI	√
Northern bobwhite	*Colinus virginianus*	NOBO		*yellow-throated vireo	*Vireo flavifrons*	YTVI	√
killdeer	*Charadrius vociferous*	KILL	√	*blue jay	*Cyanocitta cristata*	BLJA	√
spotted sandpiper	*Actitis macularia*	SPSA		*American crow	*Corvus brachyrhynchos*	AMCR	√
American woodcock	*Scolopax minor*	AMWO		horned lark	*Eremophila alpestris*	HOLA	
rock pigeon	*Columba livia*	ROPI		barn swallow	*Hirundo rustica*	BARS	
mourning dove	*Zenaida macroura*	MODO	√	Northern rough-winged swallow	*Stelgidopteryx serripennis*	NRWS	√
*black-billed cuckoo	*Coccyzus erythropthalmus*	BBCU		tree swallow	*Tachycineta bicolor*	TRES	√
*yellow-billed cuckoo	*Coccyzus americanus*	YBCU	√	purple martin	*Progne subis*	PUMA	
long-eared owl	*Asio otus*	LEOW		*Carolina chickadee	*Poecile carolinensis*	CACH	√
Eastern screech-owl	*Otus asio*	EASO		*tufted titmouse	*Baeolophus bicolor*	TUTI	√
great horned owl	*Bubo virginianus*	GHOW		*white-breasted nuthatch	*Sitta carolinensis*	WBNU	√
barred owl	*Strix varia*	BAOW	√	Carolina wren	*Thryothorus ludovicianus*	CARW	√
chimney swift	*Chaetura pelagic*	CHSW	√	house wren	*Troglodytes aedon*	HOWR	√
*ruby-throated hummingbird	*Archilochus colubris*	RTHU	√	*blue-gray gnatcatcher	*Polioptila caerulea*	BGGN	√
belted kingfisher	*Ceryle torquata*	BEKI	√	Eastern bluebird	*Sialia sialis*	EABL	
*red-bellied woodpecker	*Melanerpes carolinus*	RBWO	√	*wood thrush	*Hylocichla mustelina*	WOTH	√
*downy woodpecker	*Picoides pubescens*	DOWO	√	American robin	*Turdus migratorius*	AMRO	√
*hairy woodpecker	*Picoides villosus*	HAWO	√	gray catbird	*Dumetella carolinensis*	GRCA	√

TABLE 2 (cont.)

Record of bird species documented by the OBBA II compared with those same species recorded in the nine sampled old regrowth forests. Mature forest-associated bird species are identified with an asterisk.

Ohio Breeding Bird Atlas II Regional Data for Oxford 3 and Millville 1 Atlas Blocks	Species	Alpha Code (see USGS Bird Banding Laboratory)	MU Natural Areas Regrowth Forests
Northern mockingbird	*Mimum polyglottos*	NOMO	
brown thrasher	*Toxostoma rufum*	BRTH	
cedar waxwing	*Bombycilla cedrorum*	CEDW	√
European starling	*Sturnum vulgaris*	EUST	√
*Northern parula	*Parula Americana*	NOPA	√
yellow warbler	*Dendroica petechia*	YWAR	
*cerulean warbler	*Dendroica cerulean*	CERW	
prairie warbler	*Dendroica discolor*	PRAW	
*yellow-throated warbler	*Dendroica dominica*	YTWA	√
*American redstart	*Setophaga ruticilla*	AMRE	√
common yellowthroat	*Geothylpis trichas*	COYE	√
*Kentucky warbler	*Oporornis formosus*	KEWA	√
*Louisiana waterthrush	*Seiurus motacilla*	LOWA	√
*ovenbird	*Seiurus aurocapillus*	OVEN	√
*hooded warbler	*Wilsonia citrina*	HOWA	√
yellow-breasted chat	*Icteria virens*	YBCH	
*scarlet tanager	*Piranga olivacea*	SCTA	√
indigo bunting	*Passerina cyanea*	INBU	√
*Northern cardinal	*Cardinalis cardinalis*	NOCA	√
Eastern towhee	*Pipilo erythrophthalmus*	EATO	√
chipping sparrow	*Spizella passerina*	CHSP	√
field sparrow	*Spizella pusilla*	FISP	√
grasshopper sparrow	*Ammodramus savannarum*	GRSP	
Henslow's sparrow	*Ammodramus henslowii*	HESP	
song sparrow	*Melospiza melodia*	SOSP	√
*Baltimore oriole	*Icterus galbula*	BAOR	√
Orchard oriole	*Icterus spurius*	OROR	
Eastern meadowlark	*Sturnella magna*	EAME	
red-winged blackbird	*Agelaius phoeniceus*	RWBL	
common grackle	*Quiscalus quiscula*	COGR	√
brown-headed cowbird	*Molothrus ater*	BHCO	√
house sparrow	*Passer domesticus*	HOSP	
American goldfinch	*Carduelis tristis*	AMGO	√
house finch	*Carpodacus mexicanus*	HOFI	√

urban development (19 percent) as the main land cover types for the OBBA II atlas blocks included in the regional survey (Fig. 1).

For the sample region in southwestern Ohio, OBBA II recorded 92 total bird species, including species associated with human-modified habitats, mature forest-associated species, and open, successional forest-associated species that are not typically found in mature forest stands (Table 2). The sampled old regrowth forests conserve a significant percentage of this regional avian diversity. We identified 66 total bird species within the sampled old regrowth patches (Table 2) or 68 percent of the birds reported for the region. Birds not detected in the regrowth patches included primarily successional forest and open field-associated birds, including the yellow warbler (*Dendroica petechia*), willow flycatcher (*Empidonax traillii*), and eastern meadowlark (*Sturnella magna*; BNA 2011).

Among the mature forest-associated breeders (BNA 2011) detected in the region, 94 percent were also recorded in the sampled regrowth patches (Table 2). The high density and stature of canopy trees in the regrowth patches supported a high number of upper-canopy nesting bird species such as the yellow-throated vireo (*Vireo flavifrons*), scarlet tanager (*Piranga olivacea*), and eastern wood-pewee (*Conoptus virens*). We measured a significant standing snag basal area and percentage of coarse woody debris in all nine of the old regrowth patches, which correlated to the number of birds detected that rely on these structural attributes for foraging and nesting activities. The nocturnal barred owl (*Strix varia*), which also utilizes standing snags for nesting, was seen in four of the old regrowth patches during daylight hours. The high density of saplings and shrubs in the understory layer of the regrowth forest patches also provided habitat for a high number of understory-associated bird species such as the Kentucky warbler (*Oporornis formosus*), hooded warbler (*Wilsonia citrina*), and American redstart (*Setophaga ruticilla*). Finally, the typically open forest, edge-dwelling species such as the northern cardinal (*Cardinalis cardinalis*) and the parasitic brown-headed cowbird (*Molothrus ater*) were also abundant in forest interiors of many of the larger regrowth patches, suggesting that these forests support edge species in competition with birds restricted to 'old regrowth' habitat

These findings support a high richness of both mature forest-associated species and species representative of the diverse habitat types that occur throughout the broader region. Only two mature forest bird species were not recorded as probable breeders in the regrowth forests: the black-billed cuckoo (*Coccyzus erythropthalmus*) and cerulean warbler (*Dendroica cerulean*). The cerulean warbler, which we did detect as a spring migrant, tends to inhabit larger forest tracts (BNA 2011). The black-billed cuckoo prefers higher elevations and more expansive and heavily forested woodlands (Eaton 1988 for New York, BNA 2011).

The point count data for the old regrowth forest patches also recorded three bird species that were not documented in the OBBA II regional list: the black-throated green warbler (*Dendroica virens*), black-and-white warbler (*Mniotilta varia*), and summer tanager (*Piranga rubra*). The old regrowth forests provide open edges and canopy gaps (typical of older forests) that the summer tanager prefers and dense understory layers that the black-and-white warbler typically inhabits (BNA 2011). The regrowth patches also provide areas of mixed deciduous-coniferous forest along pine plantation edges where the black-throated green warbler often occurs (Collins 1983).

Habitat Variability among Old Regrowth Forest Patches

The study captured a range of variation in the physical, ecological, and landscape habitat conditions of old regrowth forests in the nine sampled patches in the MU Natural Areas. The physical-site conditions of these regrowth patches varied due to their landform position (Table 1) and accordingly by their topography. Harker's Run and Beck Corridor (mean slope = 0.0°) were located on the floodplain along Harker's Run and Four Mile Creek, respectively, and College Woods and Kramer Preserve were mostly situated on uplands (slope <5.0°). The other sites however, varied from convex settings that included steep slopes and flat uplands (Western Woods: range = 2.0°-19.0° and Bachelor East Loop: range = 0.0°-15.0°), concave settings with steep slopes and gradual lowlands (Bachelor Pine Gullies: range = 4.0°-10.0°), to one site where the regrowth patch was restricted to a steep slope (Bachelor North Loop: mean slope = 19.5°). The sloped sites also varied by their aspect, depending on their position in relation to the main stream drainages. For example, Marcum Loop and Western Woods sloped east toward Four Mile Creek, Bachelor East Loop sloped west toward Harker's Run, Bachelor North Loop sloped north toward Harker's Run, and Kramer Preserve and the Bachelor Pine Gullies had variable slopes in relation to the tributary streams that flowed through the sites.

These physical-site conditions help to explain the community (compositional) similarities and dissimilarities among the sampled old regrowth patches based on the relative importance of canopy-subcanopy trees >10 cm dbh. All of the sampled regrowth patches showed a high relative importance by sugar maple (>19 percent-40 percent), where it was the most important tree on the upland and sloped sites. American sycamore was the most important tree on sites restricted to floodplains (20.4 percent in Beck Corridor; 21.1 percent in Harker's Run) where it co-occurred with box elder (*Acer negundo* L.) and eastern cottonwood and occurred as a co-dominant in Marcum Loop (20.3 percent), where it was restricted to the stream corridor. White ash (*Fraxinus Americana* L., which was among the three most important trees for all the patches, was more important in upland-mesic patches, including Bachelor East Loop (16.7 percent), Western Woods (18.3 percent), and on the slopes (e.g., Marcum Loop: 12.9 percent). Oaks (*Quercus* spp.) and hickories (*Carya* spp.) dominated the convex uplands and slopes at College Woods and Bachelor North Loop, respectively. These data show that the diverse topographic positions of the old regrowth patches relate to differences in the ecological composition and relative importances of canopy trees among the patches.

The nine regrowth patches each support a diverse composition of bird species and vary little in their number of recorded species (richness= 33-41). The more mesic, upland sites had lower species richness (e.g., Bachelor East Loop, 33), whereas the patches on topographically variable sites, between upland and floodplain settings, had higher species richness (e.g., Marcum Loop, 39). For example, Kramer Preserve supported both mesic, upland-associated species, such as the wood thrush and scarlet tanager, and also floodplain-associated species, such as the Louisiana waterthrush (*Seiurus aurocapillus*) and Northern parula (*Parula Americana*). The small differences in avian richness among the patches showed non-significant correlations with the measured habitat attributes (prob. >0.05). In contrast, patch size had a significant positive correlation in relation to the total number of individuals per patch ($r = 0.78$, prob. <0.05). The number of individuals ranged from smaller patches, such as Beck Corridor (86), Kramer Preserve (87), and Western Woods (87), to relatively larger patches such as College Woods (108), Marcum Loop (110), Bachelor Pine Gullies (110), and Bachelor East Loop (137).

Bird community types, when compared using a DCA ordination based on the total number of individual birds per species corresponds with physical-environmental, ecological, and landscape differences among the sampled regrowth patches (Fig. 3). Axis one, which explains 83.9 percent of the variation among bird community types, relates to the landform setting of the forest patches. Distinctive avian communities are identified as upland, floodplain, or 'transitional' between these two physical settings. Mesic, upland-associated bird species, such as the ovenbird and hooded warbler, formed a distinctive avian community type and had lower scores along Axis one in contrast to lowland, floodplain-associated species, such as the yellow-throated warbler (*Dendroica dominica*) and northern parula, which showed intermediate-to-higher scores along Axis one (BNA 2011). Bird species that are found among a broad range of habitat types, such as the Carolina chickadee (*Poecile carolinensis*) contributed to a mixed bird species composition for several patches with mixed topographic ('transitional') conditions. Bird species found in more xeric oak-hickory forests, like the great crested flycatcher (*Myiarchus crinitus*) and yellow-billed cuckoo (*Coccyzus americanus*), also fell within the larger 'transitional' bird community on the DCA graph.

The distribution of bird communities along Axis 2, which explains 4.1 percent of the variability, appears to be more related to the landscape setting of the patch, which varies from embedded patches surrounded by successional forest such as Harker's Run, Bachelor Pine Gullies, and Western Woods (low Axis 2 scores), to patches that occur adjacent to agricultural and developed lands that experience greater edge-effects, such as Kramer Preserve (highest Axis 2 score). Percent agricultural edge was significantly correlated with Axis two scores ($r = 0.81$, prob. < 0.05). A diversity of edge compositions influenced avian species occurrences among the regrowth forest patches. For example, patches embedded in pine plantations had higher numbers of the sometimes conifer-associated yellow-throated warbler, northern parula, and chipping sparrow (*Spizella passerine*). Whereas, stands embedded within agriculture supported particularly high numbers of more open, edge-dwelling species such as the field sparrow (*Spizella pusilla*), eastern towhee (*Pipilo erythrophthalmus*), and indigo bunting (*Passerina cyanea*), adding edge-associated species to the regrowth patches. Kramer Preserve, which was embedded in 40 percent agriculture (the highest percentage among the stands), had the highest bird species richness

(41) among the regrowth forest patches. In contrast, regrowth forest patches embedded within younger successional forests support a greater mature forest avian community composition than those regrowth patches embedded in developed and disturbed landscapes where many species associated with human-modified habitats are abundant. In our study, Bachelor East Loop supported a higher composition of interior-dwelling, area-sensitive avian species of conservation concern, including the scarlet tanager (five individuals), ovenbird (eight), and wood thrush (five) compared to College Woods, which supported only one scarlet tanager.

Marcum Loop provides an interesting example of the effect of topographic and ecological heterogeneity on bird populations in a regrowth forest patch. This 6.0 ha patch contains lowland-floodplain forest, and also steep slopes and upland settings. The physical-environmental heterogeneity contributes to a diverse avian community composition. We recorded riparian-associated bird species such as the Baltimore oriole (*Icterus galbula*) and indigo bunting in the floodplain forest setting, whereas the interior-dwelling wood thrush and scarlet tanager occurred on the slopes and uplands. The diverse physical-environmental settings embedded within Marcum Loop supported the second highest bird species richness (39), followed by the second highest number of individual birds (110) among the regrowth stands.

DISCUSSION

Landscape fragmentation in the Midwest creates a particular challenge for the long-term management and conservation of mature forest birds, especially since few regional remnant old-growth stands persist in the landscape (Parker 1989, McCarthy 1995, Shafer 1997). The greater implications of this research focus first on whether small regrowth patches can support a diverse composition of bird species, particularly mature forest species, in an otherwise highly modified landscape, and secondly on how to best conserve regrowth forests to support bird diversity. The old regrowth stands in our study meet criteria that define old-growth forest in mixed-mesophytic systems (Parker 1989, Martin 1992, McCarthy 1995; Runkle 1996). They are high in richness (>20 canopy tree species and >20 breeding bird species), have an uneven-aged structure, have large basal areas (≥25 m^2/ha), and have standing snags (≥10 cm dbh) and fallen logs (≥30 cm mid-diameter) that form tree fall gaps in the canopy (cf. Runkle 1982). The forests are similar in their composition and stature to old growth stands, but also reveal successional attributes (e.g., high canopy density) and some unique human disturbances [e.g., Medley and Krisko 2007 for invasion by amur honeysuckle, *Lonicera maackii* (Rupr.) Herder] that influence their ecological structure and potential as bird habitat.

Our study supports the development of criteria that should guide the selection and management of nature preserves for bird

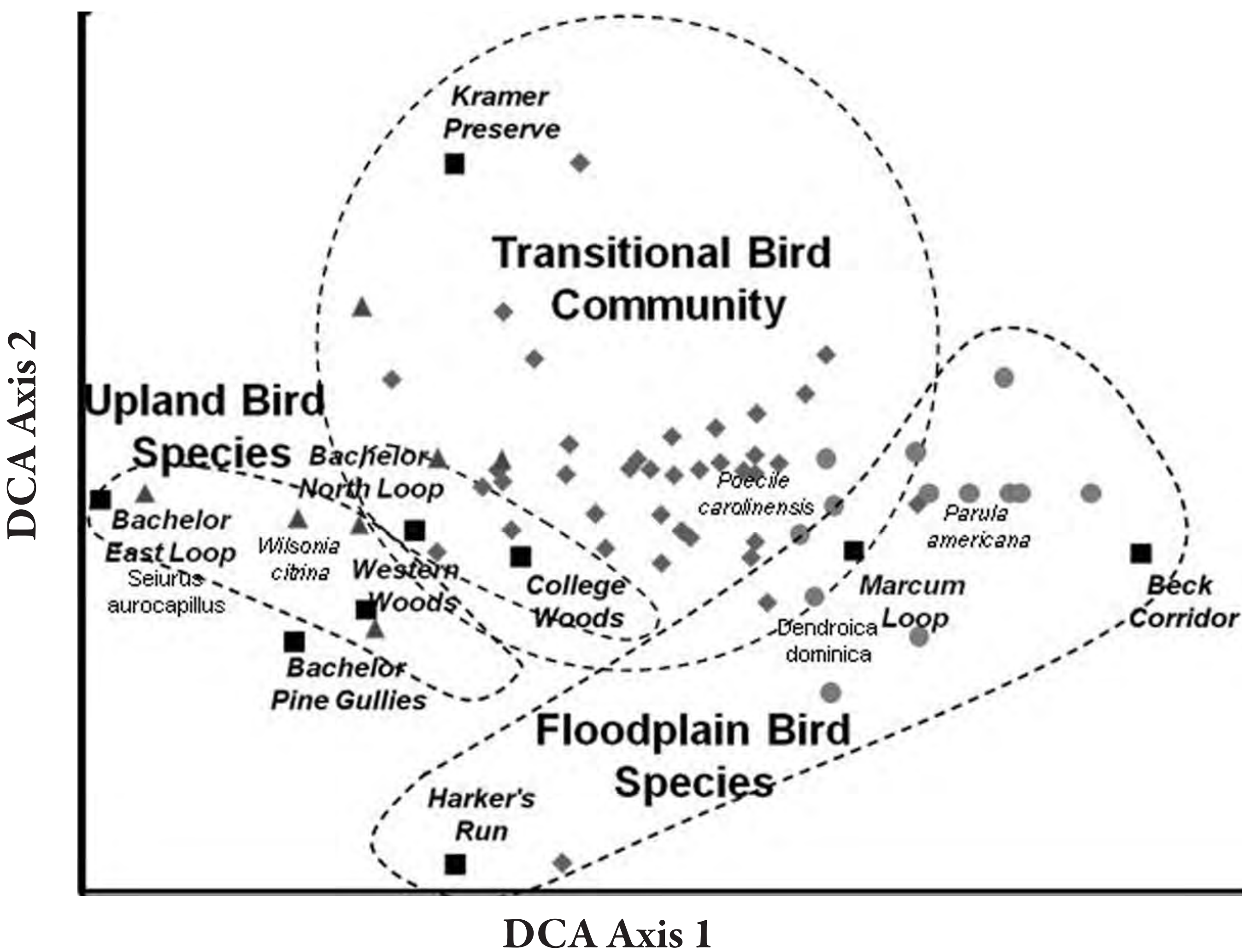

FIGURE 3. DCA ordination plot of the nine regrowth patches based on the total number of individual bird species per patch. Patches are plotted as squares and labeled. Bird species are plotted as circles for floodplain-associated species, triangles for upland-associated species, and squares for transitional species between these settings. Five representative species for the settings are labeled.

populations in the midwestern U.S. (Shafer 1997). The avian community composition surveyed in these old regrowth forest stands, while similar in richness for the stands, varies in the composition and structure of that diversity among stands in different settings. Topographically diverse old regrowth patches with variable landscape conditions increase cumulative bird species richness, encouraging land managers and conservationists to preserve a diversity of formerly disturbed regrowth forests.

The unique eco-tonal position of southwestern Ohio provides diverse physical-topographic settings among the regrowth patches, resulting in differences in the ecological composition and structure that correlate to the avian community compositions of each patch (cf. Braun 1950, McCarthy and others 1987). Avian foraging specialists and cavity nesters reliant on the ecological characteristics of mature forests to fulfill habitat requirements for their nesting and foraging regimes were abundant in the old regrowth patches with high standing snag basal areas and percent coarse woody debris. These ecological structural attributes should be considered when conserving and managing for mature forest bird populations in regrowth forest stands. Moreover landscape conditions, especially edge composition, have a significant influence on avian community composition in old regrowth forest patches. These results support the conservation of old regrowth patches with diverse site conditions that are or can be embedded in successional forests; these patches potentially support bird populations most characteristic of 'pre-settlement' forests (Haney and Schaadt 1996). Our findings, therefore, promote a management agenda that allows for forest regrowth and the restoration of intensively used lands for forest birds. Moreover, small and isolated regrowth patches, even when surrounded by development, support high bird species richness that should be preserved, as the proximity of developed and other land uses can be beneficial to many bird species that rely on adjacent areas of human-modified landscapes as breeding habitat (Haney and Schaadt 1996).

Too often emphasis is put on the conservation of the largest or oldest (old-growth) tracts or the 'biggest' and the 'best;' however, these land units are much too rare across intensively managed landscapes (Schwartz and van Mantgem 1997). Small preserves remain regionally important in conserving bird diversity and preserving heterogeneous habitat types within highly modified landscapes. The conservation of mature forest must go beyond the preservation of existing primary old-growth remnant stands and promote the re-establishment and succession of young forests to reach their "old regrowth" status (Medley and Krisko 2007), as much of the regional landscape available as bird habitat occurs in successional stages (Luken 1990). Buffer regrowth of remnant patches increases patch size, promotes remnant viability through successional processes, and creates a network of interconnected patches in the landscape as habitat for bird diversity (Shafer 1997). Although the MU Natural Areas is a highly modified nature preserve, the small old regrowth stands embedded within the Natural Areas are critical to the protection of mature forest birds in an otherwise chronically fragmented landscape.

Acknowledgements. This research is derived from MA research completed by Julie Means, working with Kim Medley. The authors thank the Department of Geography for logistical and financial support during her academic program, committee members Dave Russell and Mary Henry for their comments on the thesis, and comments on the manuscript provided by two anonymous reviewers.

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