ILLINOIS NATURAL HISTORY SURVEY

EFFECTS OF OAK SAVANNA RESTORATION ON AVIAN POPULATIONS AND COMMUNITIES IN ILLINOIS

Final Report

Submitted by:

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FINAL REPORT

SUMMARY

The use of prescribed fire to restore oak savannas and woodlands is becoming a common management practice in the Midwest. Little is known, however, about the effects of fire and restoration on constituent animal populations and communities. A study was conducted in Illinois from 1994-1996 to assess these effects on birds. Studies were conducted at a series of established savannas/woodlands, sites undergoing restoration, and undisturbed closed-canopy forests. Abundances of breeding birds and rates of nest success were compared on disturbed and undisturbed habitats.

Analyses of estimated abundances indicated that of the 30 species considered, nine were significantly more common in disturbed sites, 17 species were not significantly affected by restoration, and four species were more common in undisturbed forest habitat. The species favored by burning and periodic disturbance included Northern Bobwhites, Red-headed Woodpeckers, Indigo Buntings, Summer Tanagers, and Baltimore Orioles. Those more common in closed-canopy forests included Ovenbirds, Wood Thrushes, and Veerys. Overall, avian community structure was moderately distinctive on disturbed and undisturbed sites.

Reproductive success was generally greater within disturbed habitat. Data from over 600 nests indicated that 10 of 12 species had greater nesting success in savanna or

woodland habitat. The difference was significant for Rose-breasted Grosbeaks, Indigo Buntings, and Blue Jays. No species had significantly greater nesting success in closed-canopy forest. Rates of brood parasitism by Brown-headed Cowbirds were unaffected by restoration. Within savannas, the size of tract had little effect on nesting success. Analyses of nesting habitat indicated significant differences between nesting habitat in burned versus unburned sites, but differences between successful and unsuccessful nests were slight.

Historically, savannas were somewhat transitional habitats between grasslands and forest and may have been fragmented naturally. Small tracts may therefore be ideal sites for restoration. "Landscape burns" should be considered in moderate to large size tracts with the aim of introducing a habitat mosaic that may have formerly existed. Maintenance of some shrubs is an important management consideration for birds in restoration sites.

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INTRODUCTION

Managers in Illinois are faced with a fundamental problem concerning the welfare and sustainability of forests and wildlife populations. Oak-hickory forests throughout the Midwest are apparently not regenerating at historical (i.e., post-glacial) levels (Ebinger 1986, Abrams 1992, Taft 1996, Packard and Mutel 1997). As a result, oaks are being gradually replaced by shade tolerant species - especially Sugar Maples (*Acer saccharum*). The oak-hickory forest-type has dominated much of the southern and central Midwest for nearly 8,000 years (McClain 1991). Thus, a process is ongoing that may fundamentally change the landscape and terrestrial ecosystems of Illinois and surrounding areas (Nuzzo 1986).

The ecological factors underlying this conversion process are not entirely understood, but lack of fire and disturbance are likely involved (Lorimer 1985, Abrams 1992, Taft 1996). Therefore, there is considerable interest in use of prescribed fire (and removal of maples or other mesophytic species) as a management technique to insure the perpetuation of oak woodlands in at least a semi-natural state (Packard and Mutel 1997). The specific effects of prescribed fire and savanna restoration will vary depending on the frequency of application and a myriad of physical and biotic factors (Johnson 1993), but two inevitable outcomes are changes in floristic composition and stand structure.

Juxtaposed with the problem of oak regeneration is concern for the viability of populations of forest wildlife and how it relates to fire and disturbance (Niemi and Probst 1990).

The situation is ambiguous for birds. The population ecology of many species of birds in North America and the Midwest may be associated with periodic disturbance via fire or some other natural agent (Brawn et al. in prep). Therefore, in principle, many species may benefit from comparatively open, savanna-like or woodland conditions. Many forest birds, however, benefit from a continuous, closed-canopy with a well developed layer of shade tolerant saplings. Studies of prescribed burning from geographic areas and forest types outside Illinois offer no consensus. In Florida, for example, cutting and burning within a forest-prairie interface had little effect on avian communities (Fitzgerald and Tanner 1992). In contrast, cool fires in the Ponderosa Pine (*Pinus ponderosa*) forests of Arizona and South Dakota had profound positive effects on several species (Bock and Bock 1983, Brawn and Balda 1988).

Prior to the present study, few data from the forests of Illinois or the lower Midwest were published with respect to fire or savanna restoration. Therefore, the effects of fire and associated changes in habitat on birds are largely unknown for a large area where oak savannas were historically widespread (Packard and Mutel 1997). Given current interest in prescribed fire, ecosystem restoration, and the management of midwestern oak forests, this lack of information poses a problem for managers.

Population trends of birds in Illinois are highly suggestive that periodic disturbance is an important element in the habitat ecology of many species. For the breeding season in Illinois, I categorized 40 species into a group that can be called - albeit roughly - either savanna or woodland birds (Table 1, note revision from Brawn 1994). In many cases the decision to include or exclude a species was subjective. To be included in this category, a species had to have an important or exclusive habitat association during the breeding season with oak savannas or woodlands. Generally, species must occur or have occurred somewhere in

Table 1. List of species that breed in Illinois with exclusive or important habitat associations with oak savannas and woodlands.

Species	Migratory Status	Status or Trend in Illinois[1]
Cooper's Hawk	Short distance mig. / perm res.	Uncommon / Increas.
Swainson's Hawk	Long Distance Migrant	Rare
Northern Bobwhite	Permanent resident	Decreasing
Mourning Dove	Short distance migrant	Stable
Yellow-billed Cuckoo	Long distance migrant	Decreasing
Black-billed Cuckoo	Long distance migrant	Stable
Common Barn Owl	Permanent resident	Rare
Common Nighthawk	Long distance migrant	Decreasing
Whip-poor-will	Long distance migrant	Decreasing
Ruby-throated Hummingbird	Long distance migrant	Stable
Red-headed Woodpecker	Short distance migrant	Decreasing
Northern Flicker	Short distance migrant	Decreasing
Eastern Wood-Pewee	Long distance migrant	Stable
Great Crested Flycatcher	Long distance migrant	Decreasing
Eastern Kingbird	Long distance migrant	Decreasing
Tree Swallow	Long Distance Migrant	Decreasing
Cliff Swallow	Long Distance Migrant	Increasing
Blue Jay	Short distance mig. / perm. res.	Decreasing
White-breasted Nuthatch	Permanent resident	Increasing

Table 1, continued

Species	Migratory Status	Status or Trend in Illinois[1]
House Wren	Long distance migrant	Increasing
Bewick's Wren	Short Distance Migrant	Rare
Blue-gray Gnatcatcher	Short distance migrant	Stable
Eastern Bluebird	Short distance mig. / permanent res.	Increasing
American Robin	Short distance mig. / permanent res.	Increasing
Gray Catbird	Short distance migrant	Increasing
Brown Thrasher	Short distance migrant	Decreasing
Loggerhead Shrike	Short distance mig. / permanent res.	Decreasing
Yellow-throated Vireo	Long distance migrant	Increasing
Summer Tanager	Long distance migrant	Decreasing
Northern Cardinal	Permanent resident	Increasing
Rose-breasted Grosbeak	Long distance migrant	Increasing
Indigo Bunting	Long distance migrant	Decreasing
Eastern Towhee	Short distance migrant	Stable
Lark Sparrow	Short distance migrant	Decreasing
Field Sparrow	Short distance migrant	Decreasing
Brown-headed Cowbird	Short distance migrant	Increasing
Eastern Meadowlark	Short distance migrant	Decreasing
Western Meadowlark	Short distance migrant	Stable

Table 1, continued

Species	Migratory Status	Status or Trend in Illinois[1]
Orchard Oriole	Long distance migrant	Stable
Baltimore Oriole	Long distance migrant	Increasing
American Goldfinch	Short distance migrant	Stable

[1]Judgement based on analyses of Breeding Bird Survey data (1966-1996, see Sauer et al. 1997), Bohlen 1989, or personal observation

Illinois in numbers that elevate it above "accidental." Nor were ubiquitous species such as American Crows included. Finally, many species more characteristic of old fields and shrublands *per se* were not included. Savanna and woodland species in Illinois comprise an ecologically and taxonomically diverse group that includes raptors, neotropical migrant songbirds, and many permanent residents (Table 1). Breeding Bird Survey data and other sources indicate that over one-half of these species declined significantly from 1966-1996 or are very rare in the state.

Another indication of the extent of the conservation situation with savanna birds is the various regional lists of "priority species" generated by Partners in Flight - a group dedicated to the conservation of birds in the New World. Many lists for the regions in the Midwest include birds associated open canopy forests. For example, the Red-headed Woodpecker (scientific names for all bird species mentioned in this report appear in Appendix 1) is a species of conservation concern over much of its range (Jane Fitzgerald *personal communication*).

Many factors underlie declines in a group of species as ecologically diverse as "savanna birds," but these data clearly suggest that loss of oak savannas and woodlands in the Midwest may be having an adverse effect on at least some constituent animal populations. Forest and wildlife managers clearly need baseline data; otherwise, policy will not derive from a clear picture of what fire will do to *all* pertinent resources and components of Illinois' biodiversity.

In 1994, a study was initiated to assess the effects of prescribed fire and savanna restoration on the population and community ecology of birds in Illinois. The specific objectives of this study were: 1) To assess how burning and restoration affects the local abundances and community structure of birds; 2) To assess how burning and restoration affects the reproductive success and viability of bird populations; and 3) To determine the conservation implications of restoration for managers with respect to birds and to establish appropriate management guidelines. This reports presents and summarizes results of fieldwork conducted from 1994-1996 at several sites throughout central and northern Illinois.

METHODS

Study Areas

I established several study areas that included established savannas, unrestored sites, and sites "in restoration." Nearly all work from 1994-1996 was carried out on study areas in the Illinois River Valley within an region from northern Peoria southwest through Mason County (Fig. 1). These areas included several sites within the "Peoria Wilds" region of the Peoria Park District, Sand Ridge State Forest, and the Sand Prairie Scrub-Oak. The exception was the Hooper Branch Savanna, located in the Iroquois County Conservation Area in northeast Illinois, and several sites within the Forest Preserve District of Cook County (FPDCC). Nest searching was not conducted in the FPDCC sites until 1997 and these data will not be considered in this report. General features of the study sites are listed in Table 2. Overall, fieldwork was conducted in diverse - but generally fragmented - landscapes that included sandy and fine textured (also called "black") soil substrates and a wide range of land-use histories. Therefore, with the exception of southern Illinois, the study areas are representative of a reasonable range of physiognomic characteristics in Illinois where restoration has occurred or is planned.

Sampling Methods

Avian Abundances. - Avian abundances were estimated using the point count method (Ralph et al. 1995). Each point count consisted of an observer recording all visual and auditory

Table 2. General descriptions of study areas visited from 1994-1996.

Site	County	Size (ha)	Soil Texture	Status
Singing Woods	Peoria	387	Fine	Unrestored/Restored[1]
Robinson Park	Peoria	61[2]	Fine	Unrestored/Restored[1]
Sand Ridge State Forest	Mason	243[3]	Coarse	Unrestored/Restored[4]
Sand Prairie Scrub-Oak Nature Preserve	Mason	594	Coarse	Restored
Hooper Branch Nature Preserve	Iroquois	196	Coarse	Restored
Swallow Cliff	Cook	160	Fine	Unrestored/Restored[1]
Caps Sauers Holdings Nature Preserve	Cook	607	Fine	Restored
McClaughry Springs	Cook	102	Fine	Unrestored
Redgate Woods	Cook	650	Fine	Unrestored
Palos/Paddock Woods	Cook	102	Fine	Unrestored/Restored[1]

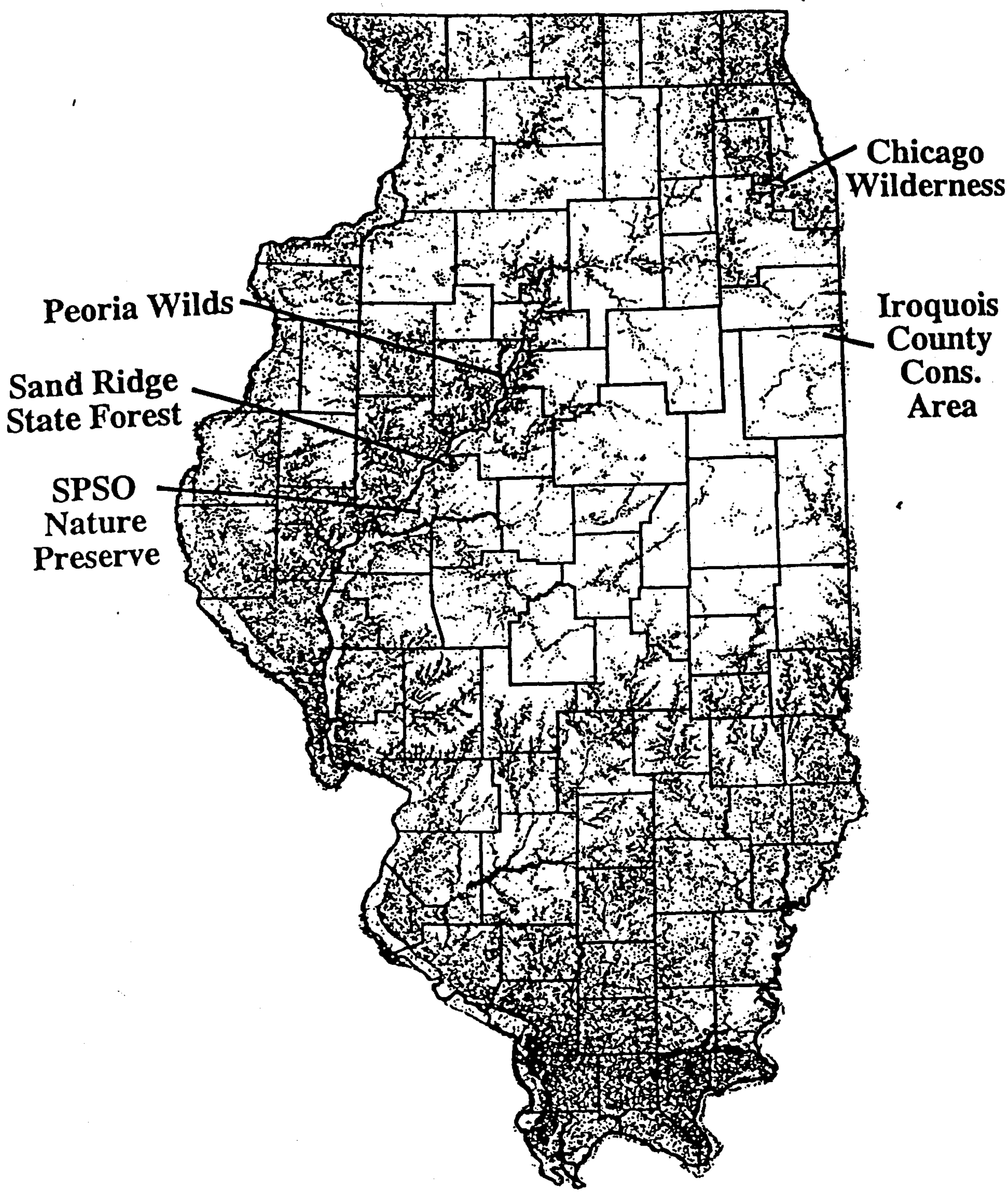
[1]Burn units and closed-canopy forest were censused within this site

[2]Indicates area censused, total tract area was about 300 ha

[3]Indicates area censused, total area of forest is 3050 ha

[4]Approximately 40 ha were burned, much of the area is "savanna-like" owing to the dry and sandy soil conditions

Fig. 1. Location of study sites



contacts with birds for a five minute period. Unlimited radius counts were conducted, but distance and direction from observers to birds were estimated. Points were established at 150 m intervals along transects that were selected to systematically cover study sites or burn units. Each transect consisted of 5 to 12 points. All counts were conducted from dawn until about 10:00 AM and counts were not conducted in strong wind or rain. Each point was visited 2-4 times each breeding season and counts were typically conducted between 25 May and 10 July. The principle investigator visited each point at least once in each breeding season; several assistants also conducted point counts.

Rates of Nest Success. - Reproductive success in restored and unrestored sites was estimated by locating and monitoring nests. Located nests were subsequently visited every three days until the nest failed or young were fledged. Contents of nests were recorded each visit. Nests were inspected carefully for the presence and number of Brown-headed Cowbird eggs or nestlings.

Nesting habitat. - Analyses of nesting habitat included measurements of several traits at and near each located nest. A subset of these measurements were also taken at randomly located vegetation plots throughout the following study sites ($N \approx 30$ / site): Singing Woods, Sand Ridge State Forest, and Sand Prairie Scrub-Oak Nature Preserve. Habitat measurements at each nest included; height of the nest, position of the nest (on branch, tree hole, etc.), exposure of the nest (0-359°), type of substrate (ground, shrub, tree, or "other"), species of substrate (except for ground nests), height and dbh (cm) of substrate (when applicable), canopy height (m) above the nest, canopy closure (%) above the nest, and ground cover (%) as leaf litter, herbaceous plants, woody plants, and bare ground. Habitat measurements centered at each nest included slope (in degrees) and basal area (m^2 / ha). To characterize the structure and floristic composition of nesting habitat around nest sites, five point-quarter sampling points were established. One point was always located at the nest. The four other points were selected at random distances along transects that extended in each of the four cardinal directions from the nest. Standard point-quarter sampling (Brower and Zar 1977) was then conducted at each of the five points. Importance values (IV) were then calculated for each tree or shrub species. Canopy closure and ground cover (% cover within a 1 m^2 area) were also estimated at each of the point-quarter sampling points. Canopy closure was estimated with a convex densiometer, heights and slopes were estimated with a clinometer, basal area was estimated using a 4X prism.

Statistical Analyses

Changes in local abundances and community structure. – The effects of fire and restoration on local abundances of selected species and overall avian community structure were assessed using several techniques. Virtually all comparisons pooled sites that were undergoing restoration or already in savanna-like condition into a single category. This category included sites with "open" (i.e., 20-70% closure) canopies even if the area had not been recently burned. Sites that were in a closed-canopy condition were categorized as "Undisturbed" or Closed Canopy."

Changes in local abundances attributable to disturbance were assessed by analysis of variance with repeated-measures. Transects were used as the unit of replication for these analyses. Counts at individual points along a given transect were averaged and counts from multiple visits to a point within a season were also averaged for a given point. Every transect was not visited each year from 1994-1996. Therefore, a repeated-measures model for unbalanced data was used for many comparisons. This technique permits use of user-defined covariance matrices and generates parameter estimates via maximum likelihood or restricted maximum likelihood procedures (BMDP 1993). Hypothesis tests (e.g., abundances on disturbed versus undisturbed sites) were based on Wald-type chi-square statistics. Species that were comparatively rare or frequently absent in restored sites and unrestored sites were not analyzed. Therefore, about 30 species were considered in detail.

Variation in overall community structure owing to disturbance and restoration was assessed using discriminate function analyses, again using the transect as the sampling unit and "disturbed" versus "undisturbed" as the grouping factor. Abundances of species were the variables or traits included with each transect. Species that were generally absent in disturbed and undisturbed sites were not included in the DFA. The number of species used and the number of sampling sites generally led to "overspecified" DFA models where the significance of between group variation tends to be inflated. Therefore, these analyses are intended more as an exploratory technique than for formal hypothesis testing. An important objective of the DFA was to identify the species (if any) that are "diagnostic" in differentiating savanna/woodland habitats from closed-canopy forests.

Variation in nest success

Estimated rates of nest success were derived as daily predation rates (DPR) or the related quantity of daily survival rates (1 – DPR). DSR was calculated by methods developed by Mayfield (1975). Nests for a given species were generally pooled into those from disturbed (i.e., burned) and undisturbed habitat. Nest from different years were combined since, for this report, annual variation was not of intrinsic interest. Hypothesis tests for differences in DSR between habitat types were carried out using the program CONTRAST which implements methods developed by Sauer and Williams (1989) for general analyses of differences in rates. Rates of cowbird parasitism in disturbed and undisturbed habitats were compared using Fisher's Exact Tests.

Variation in nesting habitat

Nesting habitat was compared using discriminant function analyses (DFA) for the following group identities: disturbed versus undisturbed sites; successful versus unsuccessful nests, and random versus occupied sites. All these comparisons were made within species. Choice of species for these analyses was contingent on sample size. In general, the minimum sample size deemed acceptable was 3X the number of predictor variables entered into the DFA model by a stepwise procedures. Notwithstanding, the models were often overspecified and confirmation of results awaits accumulation of larger samples sizes.

RESULTS

Effects of Restoration and Burning on Local Abundances

Univariate Analyses of Selected Species. - Analyses of estimated abundances revealed considerable variation in the responses of birds to restoration and prescribed fire. Nine species were more common in restored savannas/woodlands, others were less common (N = 4), and several were not affected significantly (N = 17, Table 3, Fig. 2). Species significantly more common in the restored sites included Red-headed Woodpeckers, Baltimore Orioles, Mourning Doves, and Summer Tanagers (Table 3). The Red-headed Woodpecker and the Summer Tanager and the Northern Bobwhite Quail were relatively restricted to restored sites and were not detected while censusing closed-canopy forests unless open habitat was in proximity. Those species less common on savannas and woodlands were the Ovenbird, the Veery, the Wood Thrush, the White-breasted Nuthatch, and the Scarlet Tanager. These species – especially the White-breasted Nuthatch - were not totally restricted to closed-canopy forest. Variation in estimated abundances among years was significant in 13 of the 31 species considered. Interactions between changes in abundances over time and differences in habitats were significant in only 5 species. Therefore, patterns of change over time (when present) were generally similar in forest and savanna/woodland habitat

The species that were more common in savannas and woodlands were ecologically and taxonomically diverse. Nest sites of these species varied from tree holes (Red-headed Woodpeckers and Great Crested Flycatchers) to shrubs (e.g.., Indigo Bunting and Brown Thrashers) to ground nests (Northern Bobwhite). The general foraging habits of these species were also diverse and included specialized insectivores (Summer Tanagers), granivores (Quail) and aerial feeders (Great Crested Flycatchers, Red-headed Woodpeckers). Six of the nine species that were more common in savannas and woodlands are decreasing in Illinois (of these, four are neotropical migrants), one is increasing (Baltimore Orioles), and two have been comparatively stable from 1966 to 1996 (Table 1).

The species with similar abundances in the restored and unrestored sites included many that are very common in Illinois and were rarely absent from any of the sites visited (Fig. 2). This group included American Robins, Blue Jays, Brown-headed Cowbirds, Eastern Tufted Titmice, Eastern Wood Pewees, House Wrens, and Northern Cardinals. Overall, 13 of the species in this group are species with important habitat associations with open habitats (see Table 1). Of these, estimated abundances of 10 were greater in the more open habitats. Exceptions to this trend were Brown-headed Cowbirds, Northern Cardinals and Gray Catbirds.

Three species exhibiting significant decreases in savannas and woodlands (the Ovenbird, the Veery, and the Wood Thrush) either forage extensively or nest in forest litter. Ovenbirds were rarely observed in open habitats, although consistent exceptions were both census transects of savanna/woodland habitat in the Sand Ridge State Forest. The White-breasted Nuthatch was exceptional in that it was the only species with an important habitat association with open habitats that was significantly less common in savannas and woodlands. In the Forest Preserve District of Cook County, Veeries were rarely observed in restored habitat. In contrast, Wood Thrushes were often observed in low numbers in open habitats throughout the state.

Estimates of trends for Veeries are not available for Illinois, but trends are positive and negative for nearby states and generally negative for the region. Nor are trends for Ovenbirds available for Illinois, but the trend is generally positive for the Midwest. Scarlet Tanagers are increasing in Illinois and in the Dissected Till Plain physiographic region (trends statements based on analyses of Breeding Bird Survey data).

Multivariate comparisons of community structure in savanna/woodland vs. closed-canopy forests. – I detected significant differences in local abundances between savannas/woodlands and forest habitat for nearly one-half of the species analyzed; therefore, it was of interest to examine the effects of restoration for overall community structure. Again, the primary objectives of these analyses were to explore and identify the species that are most diagnostic in distinguishing the overall structure of breeding bird communities according to habitat.

Table 3. Analyses of estimated abundances 30 bird species during the breeding season in savanna/woodland habitat and closed-canopy forests. For habitats comparisons, average abundances from the 1994 to 1996 breeding seasons were combined . Test statistics are based on ANOVA with repeated measures (see text).

	Estimated Abundance $\bar{x}$ / 10 points[1] (SE)		Analyses		
Species	Savanna/Woodland	Closed Canopy	χ^2	D.F.	Probability
Northern Bobwhite	2.0 (0.83)	0.2 (0.14)	6.3	1	0.011
Mourning Dove	2.4 (0.61)	0.7 (0.37)	7.1	1	0.006
Yellow-billed Cuckoo	1.1 (0.25)	1.0 (0.27)	0.1	1	0.845
Red-bellied Woodpecker	4.5 (0.49)	4.0 (0.32)	0.3	1	0.605
Red-headed Woodpecker	3.1 (0.69)	0.8 (0.22)	14.7	1	<0.001
Yellow-shafted Flicker	3.4 (0.91)	2.0 (0.46)	1.7	1	0.210
Eastern Wood-Pewee	6.9 (1.12)	5.6 (0.60)	1.6	1	0.200
Great Crested Flycatcher	4.9 (0.41)	3.9 (0.31)	3.6	1	0.058
Blue Jay	14.7 (1.23)	13.7 (1.35)	0.7	1	0.411

Table 3, continued:

	Estimated Abundance $\bar{x}$ / 10 points[1] (SE)		Analyses		
Species	Savanna/Woodland	Closed Canopy	χ^2	D.F.	Probability
White-breasted Nuthatch	4.1 (0.73)	5.3 (0.35)	2.9	1	0.087
Eastern Tufted Titmouse	7.0 (1.46)	6.7 (1.40)	0.2	1	0.900
Black-capped Chickadee	4.0 (1.62)	5.0 (0.53)	0.3	1	0.583
House Wren	4.3 (0.48)	4.4 (0.37)	0.01	1	0.988
Blue-gray Gnatcatcher	0.5 (0.17)	0.6 (0.17)	0.3	1	0.755
American Robin	12.8 (3.50)	11.2 (1.73)	0.5	1	0.493
Wood Thrush	1.4 (0.31)	2.7 (0.46)	6.5	1	0.011
Veery[2]	0.1 (0.07)	3.7 (1.66)	4.7	1	0.030
Gray Catbird	0.7 (0.20)	0.8 (0.30)	<0.01	1	0.989
Brown Thrasher	0.5 (1.49)	0.1 (0.02)	6.8	1	0.001

Table 3, continued:

	Estimated Abundance $\bar{x}$ / 10 points[1] (SE)		Analyses		
Species	Savanna/Woodland	Closed Canopy	χ^2	D.F.	Probability
Red-eyed Vireo	2.1 (0.60)	4.1 (0.66)	1.8	1	0.171
Ovenbird	1.1 (0.38)	5.1 (0.97)	13.8	1	<0.001
Hooded Warbler[2]	1.0 (0.91)	1.6 (0.41)	0.5	1	0.464
Northern Cardinal	3.1 (0.58)	4.0 (0.48)	1.4	1	0.233
Rose-breasted Grosbeak	2.3 (0.69)	2.2 (0.66)	<0.1	1	0.858
Eastern Towhee	3.7 (1.20)	0.9 (0.30)	5.4	1	0.021
Indigo Bunting	6.7 (1.67)	2.1 (0.26)	10.0	1	0.002
Brown-headed Cowbird	5.5 (0.56)	6.6 (0.70)	2.3	1	0.127
Baltimore Oriole	2.7 (0.49)	1.2 (0.31)	3.2	1	0.065
Scarlet Tanager	1.8 (0.44)	3.3 (0.60)	5.6	1	0.018

Table 3, continued:

	Estimated Abundance $\bar{x}$ / 10 points[1] (SE)		Analyses		
Species	Savanna/Woodland	Closed Canopy	χ^2	D.F.	Probability
Summer Tanager	2.4 (0.65)	0.2 (0.15)	8.6	1	0.004
American Goldfinch	1.4 (0.36)	1.1 (0.27)	1.9	1	0.171

[1]Estimates based on 5 minute, unlimited radius point counts (see text)

[2] Only sites in the Forest Preserve District of Cook County were used for this species

Fig. 2. Representative examples of avian abundances on restored and unrestored sites. Each bar represents a transect of points.

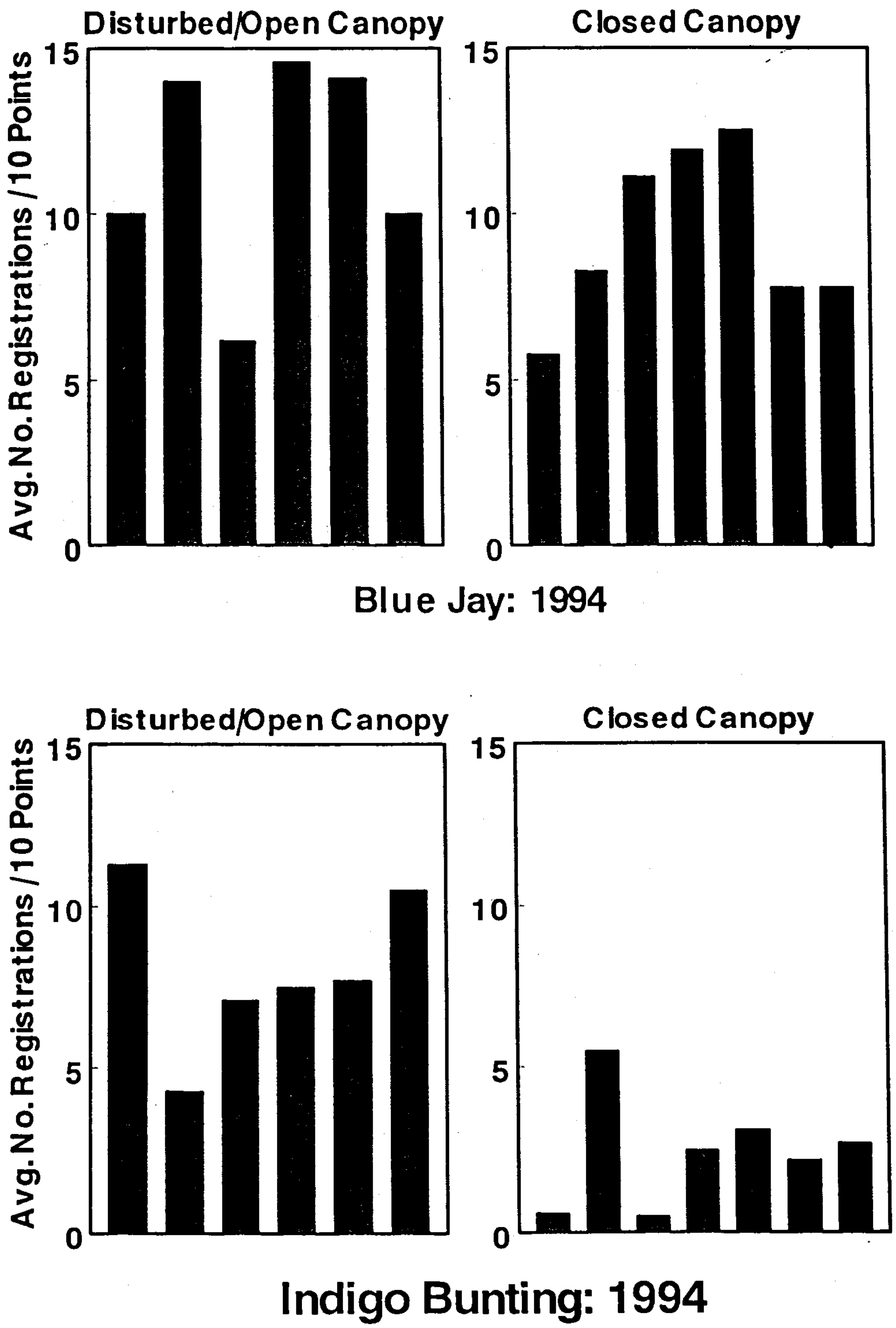
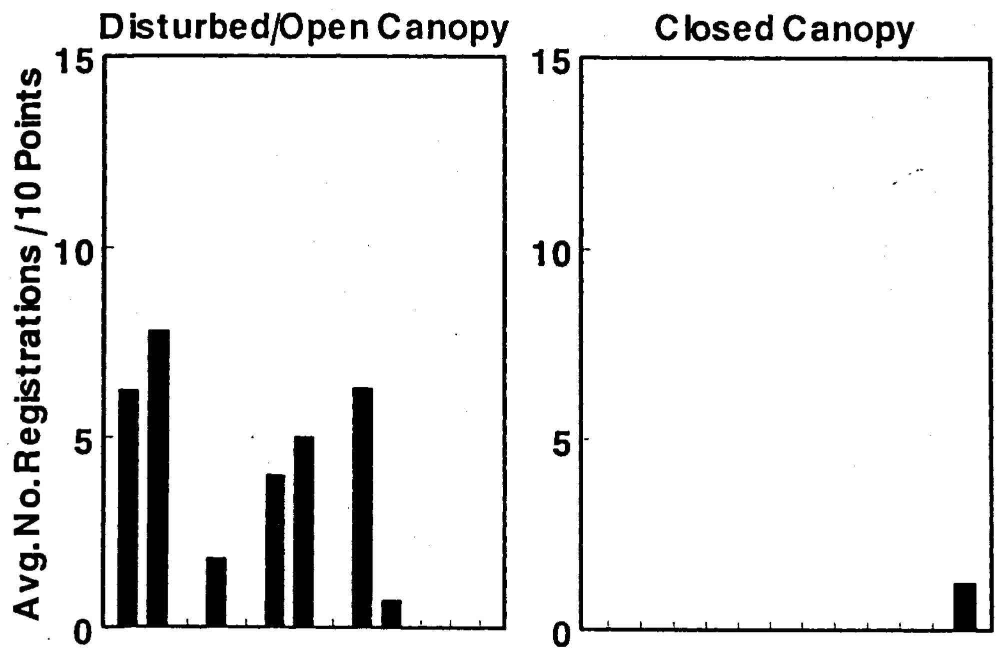
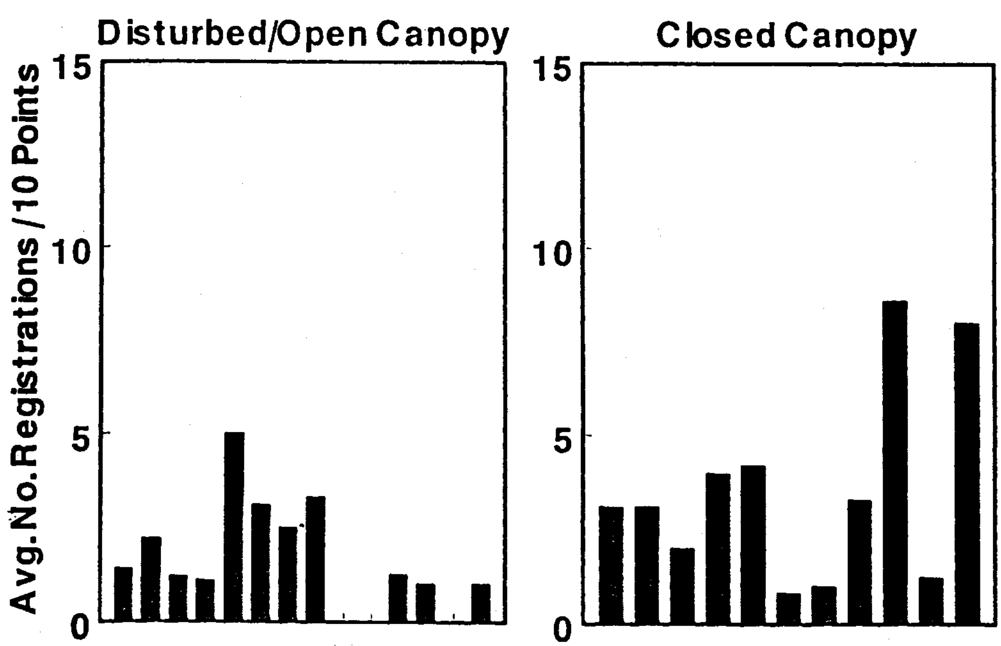


Fig. 2, continued

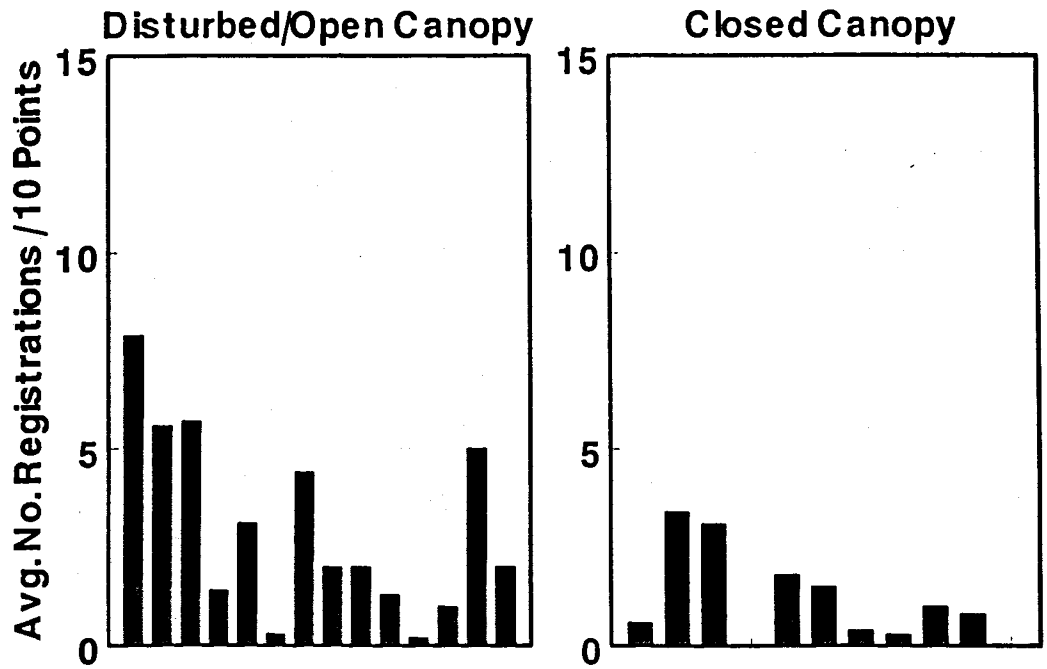


Summer Tanager: 1995

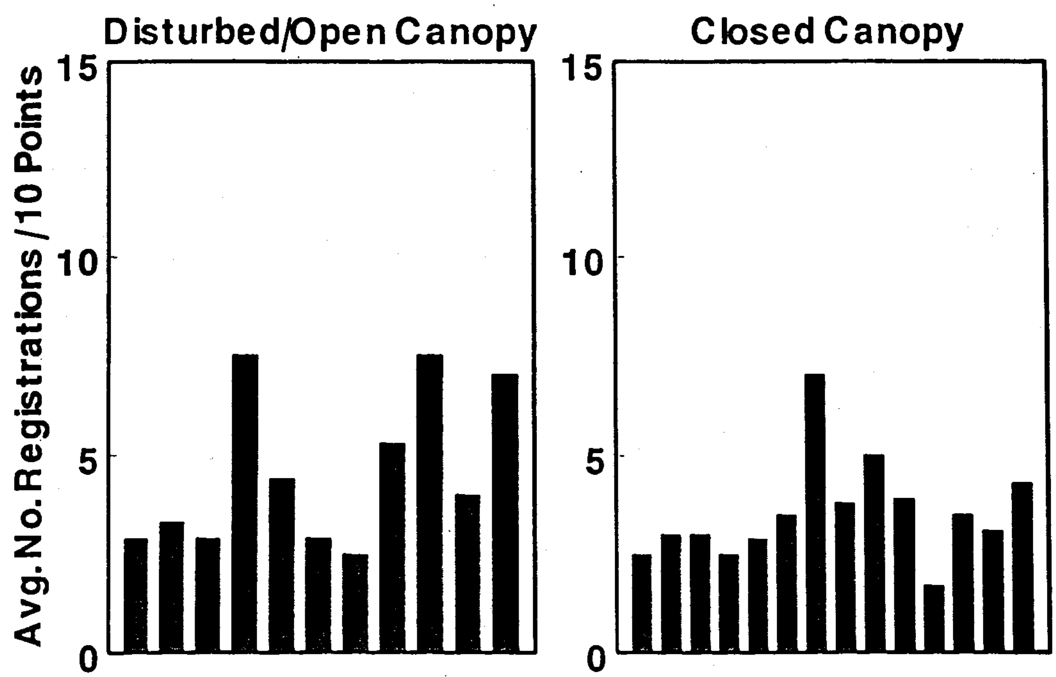


Wood Thrush: 1995

Fig 2, continued

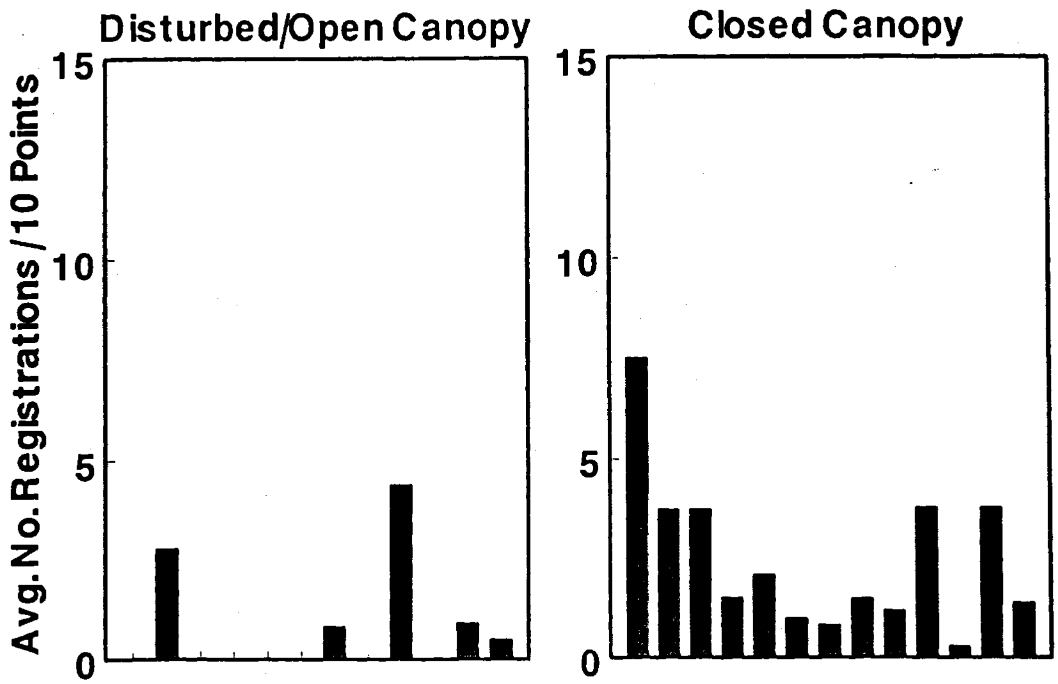


Baltimore Oriole: 1996

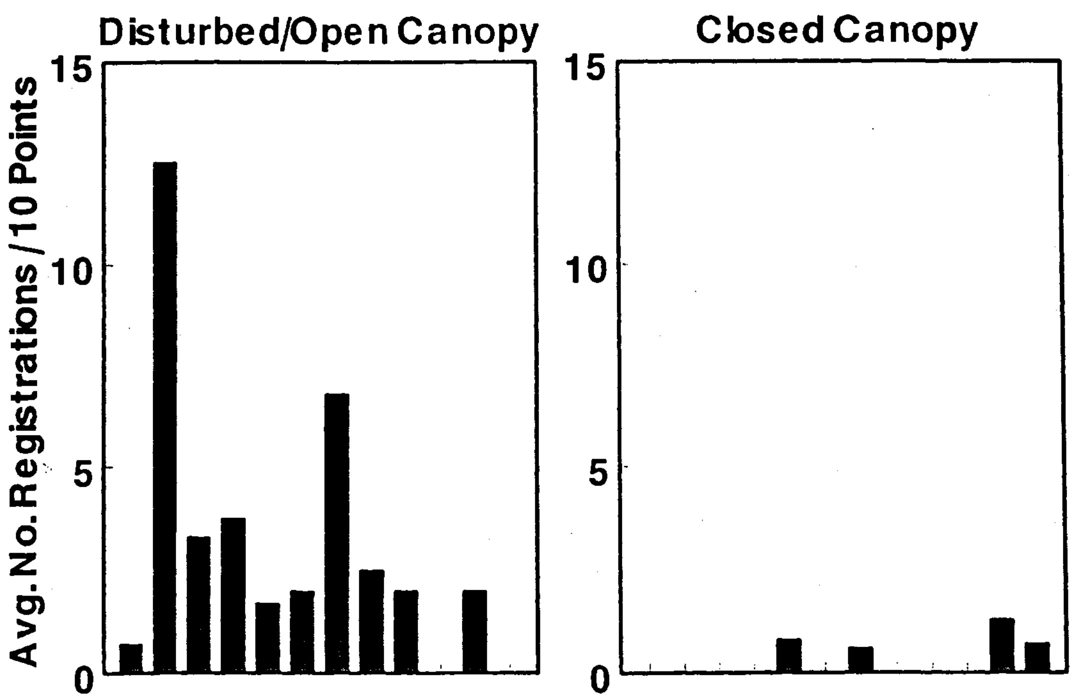


Great Crested Flycatcher: 1996

Fig. 2, continued

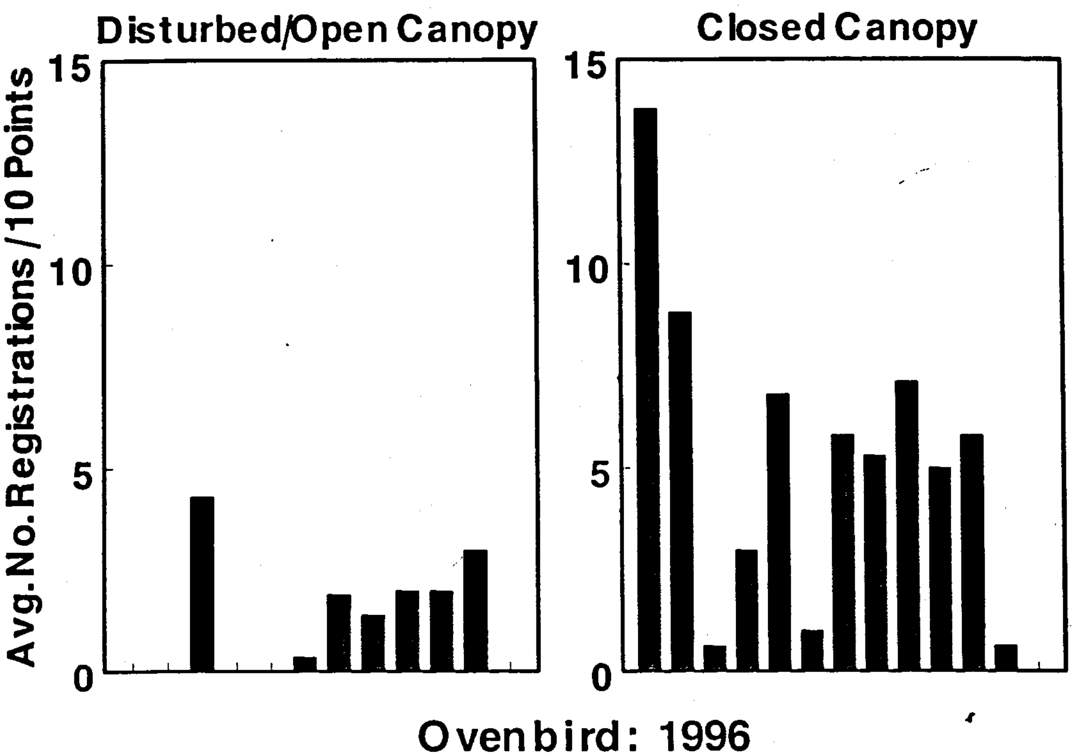


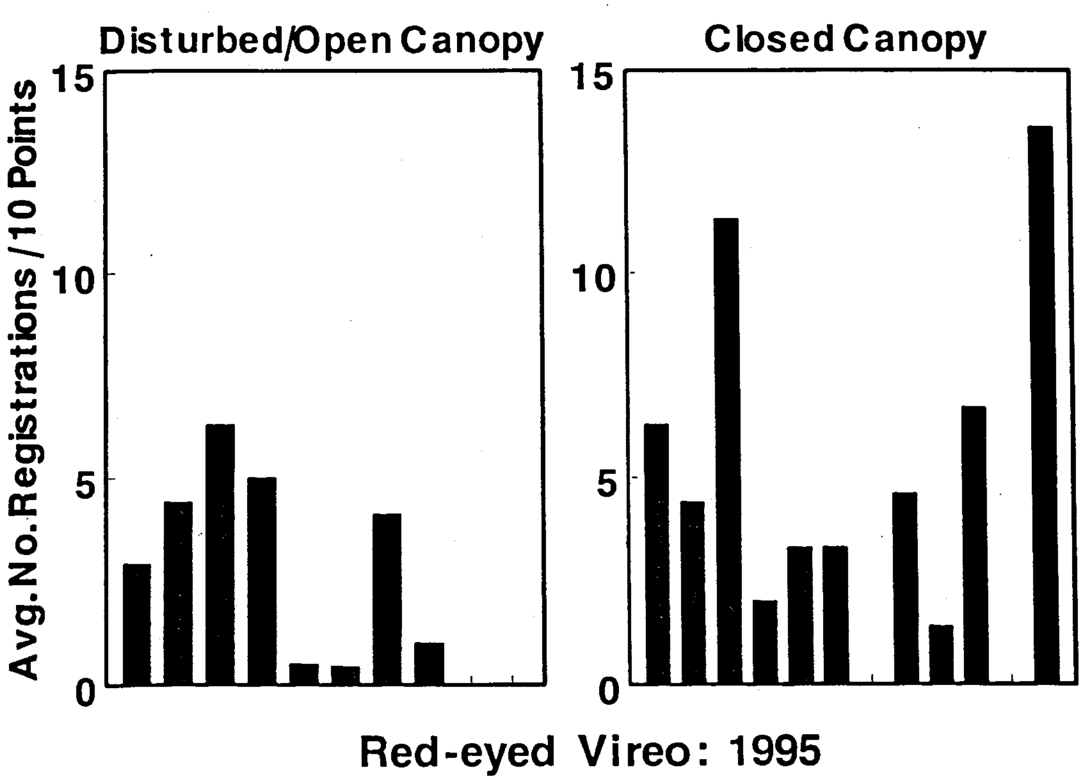
Scarlet Tanager: 1996



Red-Headed Woodpeckers: 1995

Fig. 2, continued



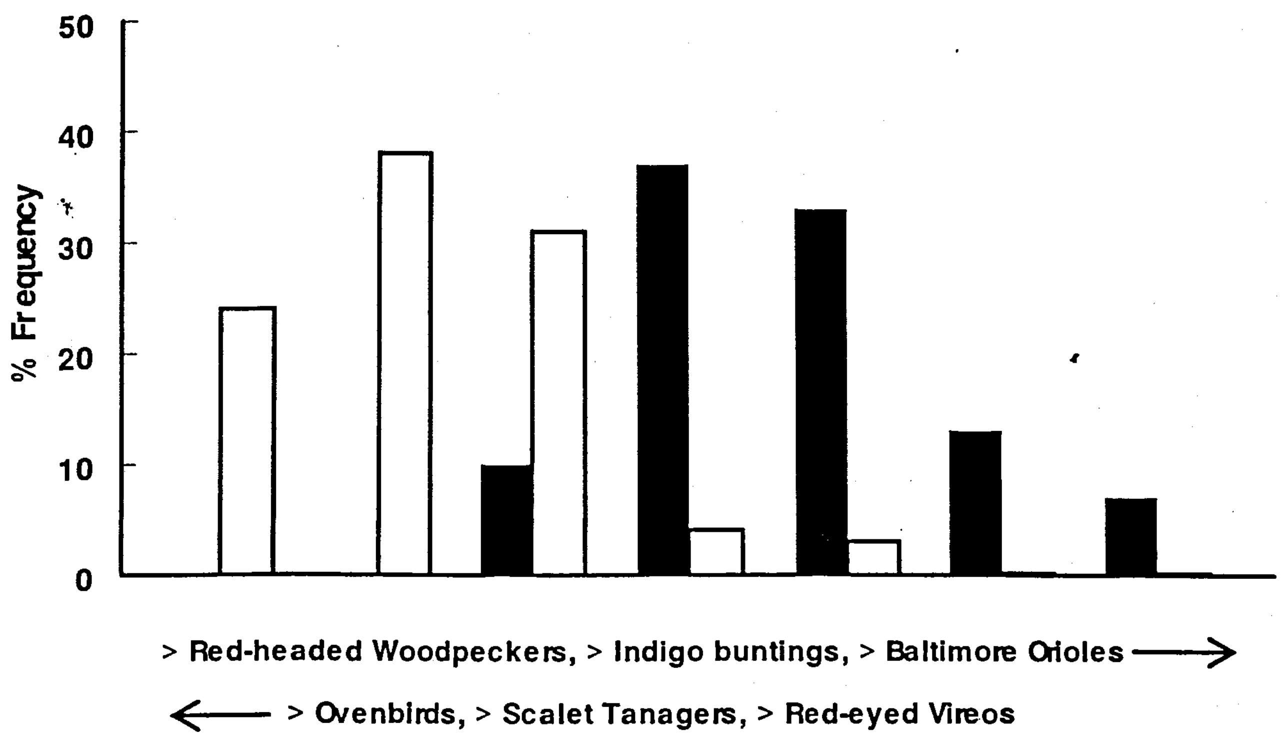


Discriminant function analysis (DFA) models were generated using habitat type as the grouping variable for the species listed in Table 3. Two sets of analyses were run; with and without the Veery and the Hooded Warbler. These two species were omitted from one set of analyses owing their restricted ranges in Illinois (i.e., Cook Co. in the context of this study); notwithstanding, the analyses were nearly identical since these species were not entered into the DFA models.

Overall, differences in the bird communities between savannas/woodland and forested habitats were moderately strong. On average, the two habitats were significantly different in multivariate space (Multivariate F-test, $F_{6,49} = 13.4$, $P < 0.001$), but the magnitude of the eigenvalue associated with the model was not large (1.61). Wilks' λ for the model was 0.37, thus indicating that about 63% of the variation between closed and open habitat bird communities was accounted for by habitat type .

The species included in the model, in order of importance, were: the Red-headed Woodpecker, the Ovenbird, the Blue Jay, the Red-eyed Vireo, the Indigo Bunting, and the Baltimore Oriole. The Ovenbird and the Red-headed Woodpecker loaded into the linear model with different coefficients; more Ovenbirds were indicative of closed-canopy forests and Red-headed Woodpeckers were indicative of open habitat. DFA scores of each community derived from a linear combination of the species listed above indicated that open and closed habitat communities were reasonably distinctive (Fig. 3). A jackknife classification procedure correctly identified 52 or 88% of the 56 cases (a "case" is a community on a site for a given year). The open habitat communities that were misclassified (i.e., those with the most overlap) as closed were Robinson Park 1994, Sand Ridge State Forest North 1995, and Singing Woods A in 1996.

Fig 3. Results of discriminant function analysis of breeding bird communities in disturbed/open habitat (black bars) and closed-canopy forests (open bars). Bars indicate relative frequency of census transects along first discriminant axis.



Note that both the Robinson Park and Singing Woods cases were in comparatively small tracts of habitat in the Peoria Wilds that were undergoing restoration. Closed habitats that were classified as open were Redgate Woods North 1996 and Swallow Cliff North 1996. Both these cases were in the Forest Preserve District of Cook County. Interestingly, the Swallow Cliff site was very close to an area that is currently undergoing restoration.

In summary, periodic disturbance and restoration clearly changes breeding bird communities in Illinois. Local abundances of nearly half the species considered were affected by burning and multivariate analyses indicated important differences in overall community structure. All communities in restored or open habitats are not absolutely distinctive from those found in forest habitat. Woodland communities appear to be more similar to forest bird communities than the more open savanna bird communities. The presence of shrubs or equivalent woody substrates that offer suitable nesting and/or habitat for species such as Indigo Buntings, Eastern Towhees, Brown Thrashers, and Summer Tanagers may be an important determinant of bird community structure in disturbed habitats.

Effects of Burning on Avian Reproductive Success

Rates of Nest Success and Cowbird Parasitism in savanna/woodlands vs. forested habitat. – To assess the effects of burning/restoration on nesting success, I pooled all nests into "burn" or "disturbed" and "no burn" or "closed-canopy" and then compared rates of nest success. Close inspection of rates of nest success among the different study sites indicated relatively little variation within a habitat-type. The nesting data reported here were collected at the Illinois River Valley sites from 1994 through 1996. During this period, over 650 nests were located and monitored; of these, 530 nests yielded information usable in assessing rates of nest success. Final sample sizes for several species such as Red-eyed Vireos, Red-headed Woodpeckers, Lark Sparrows and Yellow-billed Cuckoos were too small to perform meaningful analyses. Samples sizes were sufficiently large for 12 species and, overall, 233 usable nests were located in burned or restored sites with the remaining 265 found in unrestored sites.

Overall, rates of nesting success in the Illinois River Valley sites were low and consistent with other studies of reproduction in Illinois (Robinson et al. 1995, Brawn and Robinson 1996). Rates of nesting success for the Northern Cardinal, Indigo Buntings, and Eastern Towhees were especially low whereas those of the Baltimore Oriole were comparatively high (Table 4).

Ten of 12 species experienced greater nesting success in the burned / open habitat. Variation between habitats in daily survival rate of nests (DSR = [1 – daily predation rate]) ranged from about 4.5% greater in burned habitat for the Rose-breasted Grosbeak to 6.5% greater in the unburned habitat for Northern Cardinals. In several cases (N = 9), the individual differences were insignificant, but a binomial test revealed an overall significant effect of habitat ($p = 0.039$); that is, the probability 10 of 12 species having greater nesting success in burned habitat is remote by random chance alone. For individual species, all the significant differences were cases in which nesting success was greater in the burned sites and included the Blue Jay, the Rose-breasted Grosbeak, and the Indigo Bunting. The Whip-poor-will and Northern Cardinal experienced greater nesting success in unburned habitat, but the differences were not significant. In terms of the expected proportion of nests fledging at least one young (derived by raising the DSR to the number of days in the nesting cycle), the differences between habitats were important (Fig. 4) . For example, the overall probability of nest success was 7% for Indigo Buntings in unburned habitat and nearly 30% in burned sites.

Table 4. Rates of avian nesting success in burned and unburned habitats at several sites in the Illinois River Valley. Data are from 1994 to 1996.

	Habitat		Analysis	
Species	Burned[1]	Unburned[1]	χ^2 Statistic[2]	Significance
Whip-poor-will	.949 (.013) 4 (59)	.966 (.014) 11 (167)	0.28	0.59
Eastern Wood-Pewee	.983 (.008) 13(237)	.978 (.016) 6 (89)	0.08	0.78
Blue Jay	.981 (.005) 43(798)	.955 (.014) 21 (276)	4.93	0.03
American Robin	.958 (.011) 25 (312)	.955 (.008) 57 (649)	0.05	0.83
Wood Thrush	.981 (.019) 5 (73)	.976 (.009) 20 (290)	0.06	0.81
Brown Thrasher	.971 (.029) 15 (171)	.942 (.016) 16 (222)	0.77	0.38
Summer Tanager	.952 (.029) 4(21)	.948 (.048) 6 (58)	0.01	0.94

Table 4, continued.

	Habitat		Analysis	
Species	Burned[1]	Unburned[1]	χ^2 Statistic[2]	Significance
Northern Cardinal	.880 (.042) 9 (59)	.945 (.030) 51 (582)	2.29	0.13
Rose-breasted Grosbeak	.965 (.011) 22 (258)	.908 (.009) 17 (163)	5.37	0.02
Indigo Bunting	.951 (.013) 27 (273)	.897 (.020) 27 (224)	5.12	0.02
Eastern Towhee	.915 (.031) 9 (82)	.894 (.030) 11 (167)	0.24	0.63
Baltimore Oriole	.998 (.004) 47 (678)	.975 (.032) 22 (237)	0.51	0.48

[1]Daily survival rate (SE)
Number of nests (exposure days)

[2]Based on Williams and Sauer 1989

Similarly, overall rates of nest success for the Rose-breasted Grosbeak in burned and unburned sites were 41% and 9%, respectively. The largest difference where expected nest success was greater in the unburned habitat was for the Northern Cardinal.

Rates of parasitism by Brown-headed Cowbirds were highly variable among species, but generally unaffected by habitat structure (Table 5). In no case were the proportion of nests parasitized different between habitats (Fisher's Exact Tests, $P > 0.10$ in all cases). Nor was the intensity of parasitism (based on the number of eggs or nestlings / nest) different between habitats. Further, cowbird abundances were similar in the two types of habitats (Table 3). Thus, if a species accepts cowbird eggs, its probability of parasitism is apparently not affected by habitat.

Nesting Habitat

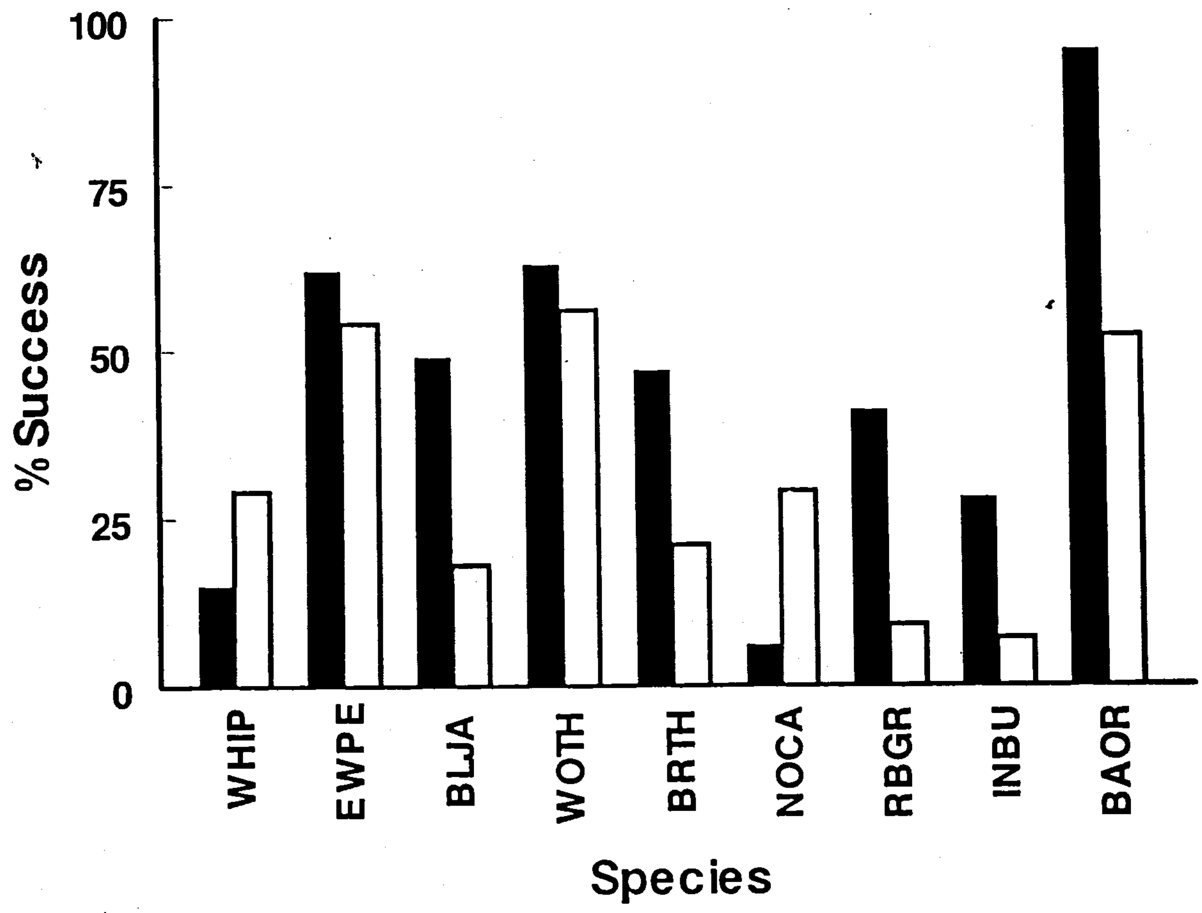
Nesting habitat of selected species was compared between burned/open and unburned/closed-canopy habitats, between successful and unsuccessful nests, and between occupied and randomly selected sampling sites. Overall, the nesting habitat was significantly different between burned and unburned sites; however, the distinction between successful and unsuccessful nests was slight. Sample size requirements limited most analyses to American Robins, Rose-breasted Grosbeaks, Blue Jays, Baltimore Orioles, and Indigo Buntings.

Variation in nesting habitat between burned and unburned habitats was significant within all five species considered (Table 6). Interestingly, differences between the two type of habitats were dominated by floristic composition rather than variables related to structural differences. Floristics were the only significant variables for the American Robin, the Rose-breasted

Table 5. Rates of brood parasitism (% of nests [N]) by Brown-headed Cowbirds in burned and unburned habitats.

	Habitat	
Species	Burned	Unburned
Eastern Wood-Pewee	22 (9)	20 (5)
Blue Jay	3 (35)	0 (21)
American Robin	0 (25)	2 (57)
Wood Thrush	100 (3)	95 (19)
Brown Thrasher	0 (16)	0 (15)
Northern Cardinal	33 (9)	51 (51)
Rose-breasted Grosbeak	17 (23)	33 (15)
Indigo Bunting	76 (33)	71 (28)
Eastern Towhee	89 (9)	62 (13)

Fig. 4. Mayfield adjusted rates of nest success in disturbed/open (black bars) and closed-canopy forest habitats (open bars). Species depicted are (left to right): Whip-poor-will, Eastern Wood Pewee, Blue Jay, Wood Thrush, Brown Thrasher, Northern Cardinal, Rose-breasted Grosbeak, Indigo Bunting, and Baltimore Oriole.



Grosbeak, and the Indigo Bunting. Not surprisingly, greater dominance by oak species on the restored site was a common differences. Black Cherry and Hackberry were less dominant around nests on the restore sites. The most important structural variable for DFA models with the Blue Jay and the Baltimore Oriole was the level of herbaceous ground cover which was greater on the restored sites.

Differences between habitat at nest sites and randomly selected vegetation plots were assessed for the Sand Prairie Scrub-Oak Natural Area. Sample sizes were insufficient for comparable analyses within the other sites. With the exception of the Indigo Bunting, these analyses were generally uninformative (Table 7). Therefore, species nesting in the restored sites are generally unselective with respect to small-scale habitat features for nesting. Importantly, analyses of more species, study sites, and – possibly- other habitat variables are needed to confirm this pattern. For Indigo Buntings, nest site were associated with comparatively open sites with less woody duff and less Black Cherry. Baltimore Orioles also nested within comparatively open areas within the restored site.

Analyses of differences in nesting habitat between successful and unsuccessful nests were insignificant for all species considered (Table 8). The DFA habitat models for the Rose-breasted Grosbeak explained the most variation, but nearly 75% of the variation in fates of nests was unrelated to measured nesting habitat. Therefore, although analyses of more species are needed, probability of nest predation appears be independent of micro-habitat around the nest.

In sum, analyses of nesting habitat indicate that, for the species considered, the scale of comparison is important. The larger-scale comparison of burned versus unburned nesting habitat was informative owing to differences in floristic composition. The smaller-scale comparisons within habitats were generally insignificant.

Table 6. Results of analyses for differences in nesting habitat between burned and unburned sites. Discriminant function analyses were used to distinguish habitats in the two groups.

Species	Eigenvalue	Variance Explained[1]	Important Variables[2]
Blue Jay	1.7	64%	< Slope[3] > Herbaceous Ground Cover > White Oak
American Robin	2.4	71%	> Black Oak > White Oak < Maple < Black Cherry
Rose-breasted Grosbeak	1.2	55%	> White Oak > Black Oak > Blackjack Oak
Indigo Bunting	5.4	84%	< Hackberry < Black Cherry
Baltimore Oriole	2.6	72%	> Herbaceous Ground Cover < Leaf Litter < Hackberry

[1]Based on average squared cannonical correlation

[2]As determined by stepwise procedures

[3]All comparisons are burned habitat to unburned habitat

Table 7. Results of analyses for differences between nest sites and randomly selcted sites within the Sand Prairie Scrub-Oak Nature Preserve. Discriminant function analyses were used to distinguish habitats in the two groups.

Species	Eigenvalue	Variance Explained[1]	Important Variables[2]
Blue Jay	0.15	13%	< Black Oak
American Robin	0.32	24%	≥ Chinkapin Oak
Rose-breasted Grosbeak	0.19	16%	< Canopy Closure
Indigo Bunting	4.01	81%	< Basal Area < Ground Cover as Wood < Elm < Black Cherry
Baltimore Oriole	0.64	39%	< Basal Area < Canopy Closure

[1]Based on average squared cannonical correlation

[2]As determined by stepwise procedures

[3]All comparisons are nest sites to randomly selected sites

Table 8. Results of analyses for differences in nesting habitat between successful and unsuccessful nests. Discriminant function analyses were used to distinguish habitats in the two groups.

Species	Eigenvalue	Variance Explained[1]	Important Variables[2]
Blue Jay	0.31	14%	> Herbaceous Ground Cover > Back Jack Oak
American Robin	0.10	9%	< Herbaceous Ground Cover
Rose-breasted Grosbeak	0.34	25%	> Canopy Height
Indigo Bunting	0.15	14%	> White Oak
Baltimore Oriole	0.42	29%	< Leaf Litter < Canopy Height < Black Cherry

[1]Based on average squared cannonical correlation

[2]As determined by stepwise procedures

[3]All comparisons are successful to unsuccessful nests

DISCUSSION AND MANAGEMENT RECOMMENDATIONS

The fundamental result from this study is that management and restoration for savannas or woodlands in Illinois has a strong effect on constituent populations and communities of birds. Local abundances of most species change in response to restoration and bird community structure is significantly different. Moreover, the effects of habitat fragmentation on avian reproductive success appear less important within savanna/woodlands than within forest ecosystems. Whereas the mechanism is unknown, the general effect of burning is to increase reproductive success. More demographic data are needed, but these results suggest that for several species burning can take what is otherwise a population sink and drive the site towards being a population source. The conservation implications of these trends for birds are profound.

Severe fragmentation appears to have a generally adverse effect on the reproductive success of forest birds throughout Illinois and other regions of the (Robinson et al. 1995). For example, rates of nest predation for forest birds in Illinois' nature preserves are typically 70-80% (Robinson et al. 1997) in sites that occur throughout the state and range in size from 19 to over 1400 ha. Therefore, populations of forest birds in small forest fragments (i.e., < 2000 ha) do not appear to be self-sustaining. This unfortunate phenomena has led to a realization that effective management strategies for forest birds may need to function at the regional scale. The mobility of birds and apparent importance of source-sink dynamics as a cause of variation in local abundances suggests that plans for forest birds in Illinois may need to include management considerations in Missouri and Wisconsin where large tracts of forest still exist (Robinson et al. 1995, Brawn and Robinson 1996). The direct influence of managers on the abundances and viability of local forest bird populations may be minimal within chronically fragmented landscapes.

Another issue is the role of sinks in helping or hindering conservation strategies for forest birds. One school of thought holds that sinks promote regional stability of metapopulations (Howe et al. 1991). Sinks may serve as holding areas for, say, young birds until they can recruit into higher quality sites where the prospects for successful reproduction are greater (Brawn and Robinson 1996, Scott Robinson *personal communication*). Alternatively, poor quality habitat may simply decrease regional productivity and lead to lower overall abundances (Rodenhouse et al. 1997). Worse yet, sinks may act as "ecological traps" whereby birds are attracted to an area over and over even when they experience poor reproductive success (Gates and Gysel 1978). Land managers in Illinois are therefore faced with somewhat of a dilemma because managing small tracts for forest birds may actually hurt the conservation prospects of target species.

The results presented here suggest that at least *some* small tracts may better serve avian conservation if they are restored into oak savanna or woodland habitat. Historical accounts suggest that pre-settlement savanna and woodlands were not necessarily extensive tracts of contiguous habitat (Taft 1997). Rather, these habitats or ecosystems may have always existed in a fragmented state as transitions between prairie and closed-canopy forests. If so, then the constituent animal populations may be less prone to the adverse effects of anthropogenic fragmentation. While not conclusive, results of this study support this possibility. For many savanna and woodland birds, habitat "quality" seems to be more important than tract size. Results from this study indicate that if suitable habitat is made available, then savanna and woodland birds will colonize and breed with comparatively high prospect for success.

The question therefore arises concerning choice of tracts for restoration - a decision with complex considerations. Notwithstanding, to the extent that bird conservation is a management priority, it is recommended that small tracts (≈ 100 ha or less) of closed-canopy forest be given strong consideration for restoration – especially where soil, topography, and floristic traits (see Taft 1997, Packard and Mutel 1997) indicate that savanna or woodland habitats were once predominant . The latter caveat is important as this recommendation should not be interpreted as a "carte blanche" to burn all small tracts. In relatively mesic sites such a ravines, for example, it is less likely that fires were less frequent. General physical and phytosociological correlates of presettlement savanna and woodlands can be found in Taft (1997). Note that in small tracts, burning and management tends to be relatively intense; the effects of intensive management viz. the importance of shrubs is discussed below.

For moderate sized tracts (≈ 200 to 800 ha), where evidence clearly indicates a likelihood of pre-settlement savannas and woodland, it is recommended that the "landscape burn" method of restoration be adopted. This, somewhat less intensive, style of management facilities habitat heterogeneity since some areas will burn more frequently and intensively than others. Ideally, a landscape mosaic will result (Taft 1997).

Large tracts (≈ 1000 ha or more) are rare in Illinois and can be comparatively valuable for forest birds (S. Robinson, *personal communication*). Therefore, restoration within these sites needs to be considered carefully with respect to avian conservation. Again, many factors will influence this decision, but a large tract that is configured with considerable area away from edges may be relatively valuable for forest birds. Alternatively, a large tract that is comparatively linear with a lot of edge habitat would be a better candidate for restoration.

Many of the species that responded favorably to restoration either nest or forage in shrubs or small trees. These species include Indigo Buntings, Brown Thrashers, and Summer Tanagers. Restoration for a full compliment of savanna and woodland birds must accommodate these species. Historically, shrubs were associated with savanna-like habitats (McPherson 1997, Taft

1997), but intensive management with annual burning could result in a shrubless understory. This possibility is more likely in small tracts than large (Taft 1997). Therefore, restoration that allows for the continued presence of shrubs on at least part of the burn unit should be considered. Specific recommendations for the frequency of burning are not feasible since local conditions vary; the "bottom-line" consideration for savanna birds is that even within restoration sites, a mosaic of habitats is desirable.

RESEARCH NEEDS

Several important issues remain unanswered or were prompted by this study. Information about these questions are needed to develop a full understanding of the associations between savanna restoration and avian conservation in the Midwest.

1) What are the factors underlying the general trend of increased reproductive success in burn units? A fundamental question is whether there are simply fewer nest predators in savannas or whether the nest are less vulnerable. A related question is the extent to which variation in reproductive success and variation in local abundances are coupled for savanna birds. Are return rates of adults or fledged-young different in savanna-like habitats versus those in closed-canopy forests? The data are central is we are to determine if restoration can tranform a sink inot a source.

2) What are the effects of restoration on other components of biodiversity and how do these related to trends in birds? The effects of restoration on local arthropod abundances are of great interest and are being studied, but extant data are few. If floristic composition is changed then it

is likely that the arthropod communities will also be affected. How these putative change affect avian foraging efficiency, reproductive success, and community structure merit investigation. A study of avian foraging in restored and closed-canopy forests in Illinois indicated that restoration had significant effect on the foraging ecology of several species (Hartung 1997) but data on arthropod abundances are needed. Related questions such as the structure bird communities on sites that are dominated by one or two canopy species (such as blackjack oak on the Sand-Prairie Scrub-Oak Natural Area) versus those where floristic diversity is higher merit investigation.

4) How are migrants affected by restoration? This study was conducted during the breeding season, but an important aspect of restoration may be the use of savanna-like habitats as stop-over sites for spring and fall migrants.

5) How important is the landscape context of savanna restoration? Given that savannas and woodlands were transitional habitats between grassland and prairies, it is important to determine if and how savanna bird communities in the context of a grassland ecosystems differ from those in or near closed-canopy forests. Although area effects were not important in this study a more systematics study of area effects on community structure and viability is needed.

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Literature Cited

Abrams, M.D. 1992. Fire and the development of oak forests. BioScience 42:346-353.

BMDP. 1993. BMDP Manual, Version 7.0. University of California Press. 679 pp.

Bock, C. E., & J. H. Bock. 1983. Responses of birds and deer mice to prescribed burning in ponderosa pine. J. Wildl. Manage. 47:836-840.

Bohlen, H. D. 1989. The birds of Illinois. Indiana University Press. Blloomington, IL

Brawn, J. D. 1994. An overview of avian communities in North American savanna habitats: current knowledge and conservation needs. Pages 145-146 in J. S. Fralish,, R. C. Anderson, J. E. Ebinger, and R. Szafoni, editors. Proc. of the North Amer. Conf. on Barrens and Savannas. U.S. EPA, Great Lakes-National Program Office, Chicago, IL.

Brawn, J. D. & R. P. Balda. 1988. The influence of silvicultural activity on ponderosa pine forest bird communities in the southwestern United States. Bird Conservation 3:3-21

Brawn, J. D. & S. K. Robinson. 1996. Source-sink dynamics may complicate the interpretation of long-term census data. Ecology 77:3-12.

Brawn, J.D. F. Thompson III, & S. K. Robinson. In Prep. The influence of disturbance on the ecology and conservation of North American Birds. Current Ornithology.

Brower, J. E., & J. H. Zar. 1977. Field and laboratory methods for general ecology. W. C. Brown Co. Dubuque, Iowa.

Ebinger, J. E. Sugar maple, a management problem in Illinois forests? Trans. Ill. Acad. Sci. 79:25-30.

Fitzgerald, S. M. & G.W. Tanner. 1992. Avian community response to fire and mechanical shrub control in south Florida. J. Range Manage. 45:396-400.

Gates, J. E. & L. W. Gysel. 1978. Avian nest dispersion and fledging success in field-forest ecotones. Ecology 59:871-883.

Hartung, S. C. 1997. Effects of habitat structure and tree species on the foraging behavior of insectivorous songbirds in Midwestern open-canopy and closed-canopy forests. M.S. Thesis, Department of Natural Resources and Environmental Sciences, University of Illinois, Urbana, IL.

Howe, R. W., G. J. Davis, & V. Musca. 1991. The demographic significance of sink populations. Biol. Conserv. 57:239-255.

Johnson, P. S. 1991. Perspectives on the ecology and silviculture of oak-dominated forests in the Central and Eastern States. USDA Forest Serv. Gen. Tech. Rept. NC-153, St. Paul, MN. 28 pp.

Lorimer, C. G. 1977. The presettlement forest and natural distribance cycle of northeastern Maine. Ecology 58:139-148.

McClain, W. E. 1991. A proposal for the use of prescribed burning in oak hickory forests. Draft Report. Division of Natural Heritage, Illinois Department of Natural Resources, Springfield, IL. 29 pp.

McPherson, G. R. 1997. Ecology and management of North American savannas. Univ. of Arizona Press. Tucson, Arizona. 209 pp.

Mayfield, H. 1975. Suggestions for calculating nest success. Wilson Bull. 87:456-466.

Niemi, G. J. & J. R. Probst. 1990. Wildlife and fire in the upper midwest. Pages 31-46 in J. M. Swenny, editor. Management of dynamic ecosystems. North Central Section, The Wildlife Society, West Lafayette, IN.

Nuzzo, V. A. 1986. Extent and status of Midwest oak savanna: presettlement and 1985. Nat. Areas Journal 6:6-36.

Packard, S. & C. F. Mutel, Editors. 1997. The tallgrass restoration handbook. Island Press, Washington, D. C. 463.

Ralph, C. J., J. R. Sauer, and S. Droege, Tech. Editors. 1995. Monitoring birds by point counts. USDA For. Serv. Gen. Tech. Rept. PSW-GTR-149. Albany, CA. 187 pp.

Robinson, S.K., F. M. Thompson, III, T. M. Donovan, D. R. Whitehead, & J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267:187-1990.

Robinson, S. K., J. D. Brawn, & J. P. Hoover. 1997. Pages 154-179 in M. Schwartz, Editor. Conservation in highly fragmented landscapes. Chapman and Hall, New York, NY. 436 pp.

Rodenhouse, N. L., T. W. Sherry, & R. T. Holmes. 1997. Site-dependent regulation of population size: a new synthesis. Ecology 78:2025-2042.

Sauer, J. R. & B. K. Williams. 1989. Generalized procedures for testing hypotheses about survival and recovery rates. J. Wildl. Manage. 53:137-142.

Sauer, J. R., J. E. Hines, G. Gough, I. Thomas, & B. G. Peterjohn. 1997. The North American Breeding Bird Survey Results and Analysis. Version 96.4. Patuxent Wildlife Research Center, Laurel, MD

Taft. J. B. 1997. Savanna and open-woodland communities. Pages 24-54 in M. Schwartz, Editor. Conservation in highly fragmented landscapes. Chapman and Hall, New York, NY. 436 pp.

Appendix 1. Common and scientific names of birds mentioned in text.

Common Name	Scientific Name
Cooper's Hawk	*Accipiter cooperi*
Swainson's Hawk	*Buteo swainsoni*
Northern Bobwhite	*Colinus virginianus*
Mourning Dove	*Zenaida macroura*
Yellow-billed Cuckoo	*Coccyzus americanus*
Black-billed Cuckoo	*Coccyzus erthropthalmus*
Common Barn Owl	*Tyto alba*
Common Nighthawk	*Chordeiles minor*
Whip-poor-will	*Caprimulgus vociferus*
Ruby-throated Hummingbird	*Archilochus colubris*
Red-headed Woodpecker	*Melanerpes erythrocephalus*
Northern Flicker	*Colaptes auratus*
Eastern Wood-Pewee	*Contopus virens*
Great Crested Flycatcher	*Myiarchus crinitus*
Eastern Kingbird	*Tyrannus tyrannus*
Tree Swallow	*Tachycineta bicolor*
Cliff Swallow	*Hirundo pyrrhonota*

Common Name	Scientific Name
Blue Jay	*Cyanositta cristata*
White-breasted Nuthatch	*Sitta carolinensis*
Eastern Tufted Titmouse	*Parus bicolor*
Black-capped Chickadee	*Parus atricapillus*
Bewick's Wren	*Thryomanes bewickii*
House Wren	*Troglodytes aedon*
Blue-gray Gnatcatcher	*Polioptila caerulea*
Eastern Bluebird	*Sialia sialis*
Veery	*Catharus fuscescens*
Wood Thrush	*Hylocichla mustelina*
American Robin	*Turdus migratorius*
Gray Catbird	*Dumetella carolinensis*
Brown Thrasher	*Toxostoma rufum*
Loggerhead Shrike	*Lanius ludovicianus*
Yellow-throated Vireo	*Vireo falvifrons*
Red-eyed Vireo	*Vireo olivaceus*
Ovenbird	*Seiurus aurocapillus*
Hooded Warbler	*Wilsonia citrina*
Summer Tanager	*Piranga rubra*
Scarlet Tanager	*Piranga olivacea*
Northern Cardinal	*Cardinalis cardinalis*
Rose-breasted Grosbeak	*Pheucticus ludovicianus*

Common Name	Scientific Name
Indigo Bunting	*Passerina cyanea*
Eastern Towhee	*Pipilo erythrophthalmus*
Lark Sparrow	*Chondestes grammacus*
Field Sparrow	*Spizella pusilla*
Brown-headed Cowbird	*Molothrus ater*
Eastern Meadowlark	*Sturnella magna*
Western Meadowlark	*Sturnella neglecta*
Orchard Oriole	*Icterus spurius*
Baltimore Oriole	*Icterus galbula*
American Goldfinch	*Carduelis tristis*