MANAGEMENT OF CENTRAL HARDWOOD LANDSCAPES FOR THE CONSERVATION OF MIGRATORY BIRDS

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ABSTRACT.— We review major issues in the conservation of neotropical migratory landbirds (NTMB) in Central Hardwood landscapes, with special emphasis on Illinois, Missouri, Indiana, and Ohio. The Central Hardwood Region is dominated by oak forests, but some other forest types such as bottomland hardwoods and oak-pine forests also occur within the region. Historically fire and logging had a major effect on these forests. Of the 128 migratory landbirds that breed in the Central Hardwood States, 70 depend upon forest. Based on the Breeding Bird Survey, roughly equal numbers of species in each State are increasing and decreasing in abundance. Species of high management concern include those that depend upon mature forest and those that depend upon large-scale disturbances to create second-growth, shrub, and savanna habitats. Nest predation and cowbird parasitism levels vary greatly and are related to tract size and forest cover; the whole region may be characterized by "source-sink" population dynamics. The largest forest tracts in the region have the lowest levels of nest predation and brood parasitism and may produce the surplus of young that maintain populations in small tracts, which experience very high levels of parasitism and predation. Forest management practices affect both the abundance and nesting success of NTMB's. The effects of even-aged and uneven-aged silviculture on bird communities differ at the stand and landscape level. The impact of burning on forest birds is not well known, although it may be crucial to maintaining both oak-dominated forests and birds of open forests. Only a few large, heavily forested landscapes remain in the Central Hardwood Region. We believe that a prudent conservation strategy is to maintain a high percentage of forest cover in the few remaining heavily forested landscapes in the Midwest, to maintain the largest forest tracts in the region, and to take advantage of any opportunities to restore and recreate larger forest tracts in more fragmented landscapes. At a more local level land managers should provide appropriate habitats and landscape patterns by planning forest management activities to meet habitat goals, reducing internal edge and disturbances where appropriate, and planning comprehensively across ownerships.

INTRODUCTION

Neotropical migratory landbirds represent a large proportion of the bird community in Midwestern forests. They have recently been the focus of great conservation concern because of declines in some species and concern about the impacts of land-use practices and habitat fragmentation. We review the status and conservation of migrant birds in forested landscapes of the central Midwestern United States. We begin by reviewing the composition, distribution, and ecology of the forests in this region. We describe dominant land-use practices and forest management practices in the region. We then describe the forest bird communities in the region in terms of their abundance and population trends, and review species identified as species of high management concern by the Partners in Flight program. Next, we examine the impacts of land-use practices and disturbances on birds in this

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region, including regional patterns in forest fragmentation and likely source-sink population dynamics. We conclude by synthesizing this information into a conservation strategy for migrant songbirds in the Central Hardwood region.

CENTRAL HARDWOOD REGION

Our focus is predominately on the Central Hardwood Region. This region has been defined as the general area included in the extent of oak-hickory forest type (Sander and Fischer 1989) and it largely corresponds to the Eastern Broadleaf Forest (Continental) Province and Prairie Parkland (Temperate) Province of the United States (McNab and Avers 1994). Because many of the statistics we review here are available by State as opposed to ecological boundaries and because of the midwestern focus of this symposium, we concentrated on the States of Illinois, Indiana, Missouri, and Ohio in this paper.

Forest Types

Oak-hickory forest dominates this area but gives way to mixed hardwoods in the east and oak-pine forest to the south. Bottomland hardwood forest also extends into the region (see Knutson *et al.* 1996). Oak-hickory forest covers approximately 50,166,000 ha or about one-third of all forest in the Eastern United States (Smith *et al.* 1994). The dominant tree species are white, black, scarlet, and northern red oak. Other overstory trees are southern red, post, blackjack, chinkapin, bur, and northern pin oak; bitternut, mockernut, pignut, and shagbark hickories; black gum; yellow poplar; red and sugar maples; white ash; elms; American beech; black walnut; and black cherry. The most common understory trees or shrubs are flowering dogwood, sassafras, redbud, serviceberries, eastern hophornbeam, American hornbeam, witch-hazel, blueberries, mountain-laurel, and beaked hazel (Braun 1950, Eyre 1980, Sander and Fischer 1989).

Oak-pine forests cover 12,932,000 ha in the Eastern United States. This forest type is very similar to the oak-hickory type except shortleaf, loblolly, pitch, and Virginia pine make up 25 to 50 percent of the forest. Mixed hardwoods or the maple-beech-birch forest type are found on moister, more productive sites primarily east of the Mississippi River. Within the Central Hardwood Region beech and birch are minor components. Principal species are yellow poplar, white oak, northern red oak, and sugar maple. Many other species are usually present including white ash, black oak, chestnut oak, red maple, black gum, basswood, buckeyes, black walnut, black cherry, and hickories. Common understory species include flowering dogwood, eastern redbud, serviceberries, sourwood, and sassafras (Braun 1950, Eyre 1980, Sander and Fischer 1989).

Forest History and Ecology

Recent reviews leave little doubt that disturbance has been central to the ecology and evolutionary history of forest ecosystems (Nuzzo 1986, Abrams 1992, Attiwill 1994) and the single most influential agent of periodic disturbance in forests worldwide has been fire (Attiwill 1994, Williams *et al.* 1994). In the Central Hardwood Region there is evidence of repeated burning of oak forests in the moister areas of the east and in the drier forest/prairie interface along the western boundary of the region. The history of uncontrolled burning ended less than a century ago in the Missouri Ozarks. Fires occurred there most frequently between 1785 and 1810 during an influx of Native Americans and early European settlers who practiced slash-and-burn agriculture. Fire frequency decreased with an exodus of Native Americans around 1815 (Guyette and Cutter 1991).

There is some debate about the extent that fire affected oak forests (Beilmann and Brenner 1951, Steyermark 1959) but there is evidence that fire-dependent communities, such as savannas, barrens, and glades, were more pervasive historically than they are now. Historical and paleoecological evidence indicates that these habitat types may have covered up to 13 million ha at the time of European settlement (Nuzzo 1986). In Missouri, oak savannas may have covered as much as one-third of the State (Nelson 1985). Although definitions for these habitats have proved elusive (see White 1994), it is clear that these open-canopy forests now are far less extensive. One estimate indicates that less than 20 percent of the presettlement acreage remains, but most of this has been degraded by over-grazing, fire suppression, and agriculture (Botts *et al.* 1994). Less than 1 percent of the former acreage remains in a high-quality state (Nuzzo 1986).

Logging also substantially affected the area through the 1800's as it followed human expansion. For instance, with the influx of settlers into the Ozarks from 1850 to 1874 came the railroad and a period of accelerated logging during the 1880's (Smith and Petit 1988). The lumber boom came to an end in the Ozarks in the early 1900's, and lumber companies sold much of the land sight unseen through the mail as farmland. Burning and open-range grazing of the forest occurred up until the 1930's in parts of the region. During the 1930's, much of this land became tax delinquent and was purchased by the US Forest Service. This land-use history resulted in widespread oak-dominated stands, many of which are not ecologically stable and will succeed to more tolerant hardwoods without disturbance (Parker and Weaver 1989, Johnson 1993).

Through most of the 20th century the amount of forest in the region declined due to clearing for agriculture and urban expansion. But there are now indications that this decline has leveled off and is reversing in some parts of the region (fig. 1). Recent forest inventories of the Central Hardwood States show 7.5- to 31-percent increases, per State, in the amount of forest land from the 1960's to 1980's (Raile and Leatherberry 1988, Smith and Golitz 1988, Brand and Walkowiak 1991, Hahn and Spencer 1991). The increase in forest land is primarily the result of farmland and pasture reverting to forest. In addition, Central Hardwood forests are becoming older and shifting to shade-tolerant species such as maple and beech (Raile and Leatherberry 1988, Smith and Golitz 1988).

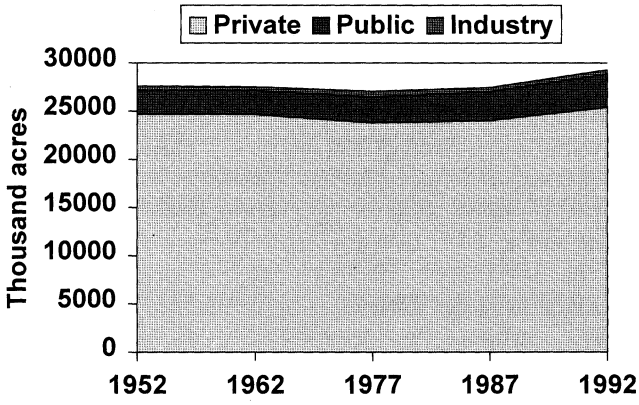


Figure 1.—*Trends in forest area in Missouri, Illinois, Indiana, and Ohio by type of ownership (Powell* et al. *1993).*

The dominance of oaks in Central Hardwood forests is largely the result of their adaptation to disturbance. Oaks in general are intolerant to moderately tolerant of shade. In most forests in the absence of major canopy disturbances, the amount of oak will decline and the numbers of more shade-tolerant species such as maples, blackgum, elms, beech, dogwoods, and redbud will increase. However, canopy disturbances allow light to reach the forest floor and allow young oaks, that have accumulated in the understory, to quickly gain canopy dominance. Recurrent fire promotes the accumulation of oak reproduction by eliminating or reducing the number of fire-sensitive understory competitors (young oaks survive by resprouting) and by reducing overstory density by killing trees with thin, fire-sensitive bark (Johnson 1993).

Not all oak-dominated ecosystems require fire or disturbance to persist. Many xeric oak forests appear to be relatively stable communities that show little evidence of succession to more shade-tolerant or mesophytic species. Probably the largest North American ecosystem of this type occurs in the Ozark Plateau in Missouri where oak reproduction may accumulate in the understory for 50 years or longer. Obtaining the accumulation of oak reproduction necessary for successful regeneration on highly productive sites requires recurrent disturbance. Historically, fire created the necessary conditions (Johnson 1993). Glades and oak savannas are even more dependent on fire than forests because an open canopy and herbaceous ground layer must be maintained by fire. Much evidence indicates that fire is essential to nutrient cycling, floristic composition, and structure of oak savannas (Botts *et al.* 1994).

The current composition of landscapes in the region differs greatly. The dominant land-use in the Region is agriculture and the amount of forest cover ranges from heavily forested to highly fragmented (fig. 2). We overlayed 1,000-ha (approximately) hexagons on a map of forest cover for Missouri, Illinois, Indiana, and Ohio. Only 6 percent of landscapes defined by these hexagons contained >80 percent forest cover and 63 percent had <20 percent forest cover (fig. 3).

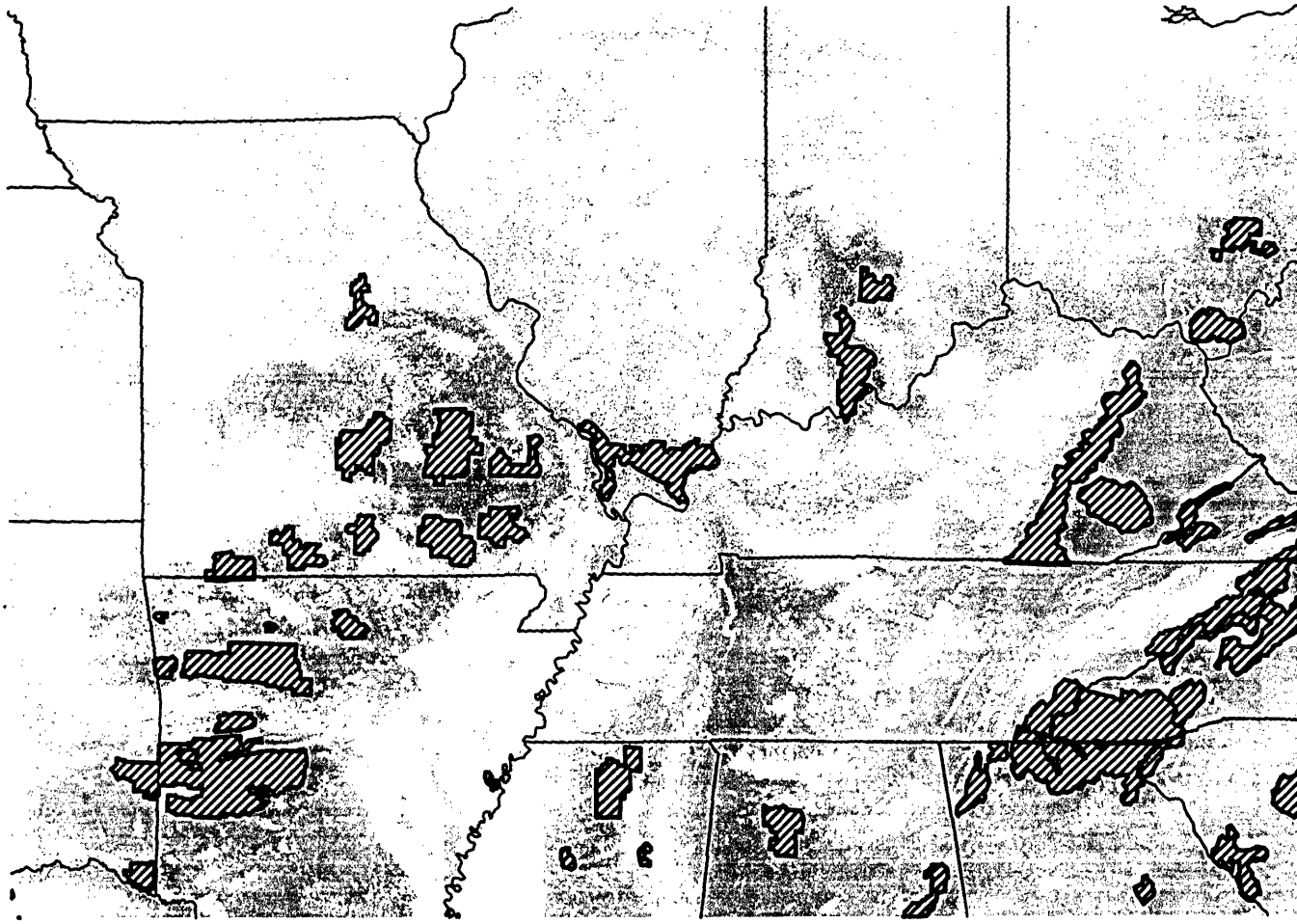


Figure 2.—*Distribution of forest cover in a portion of the Central Hardwood Region and the location of national forest boundaries.*

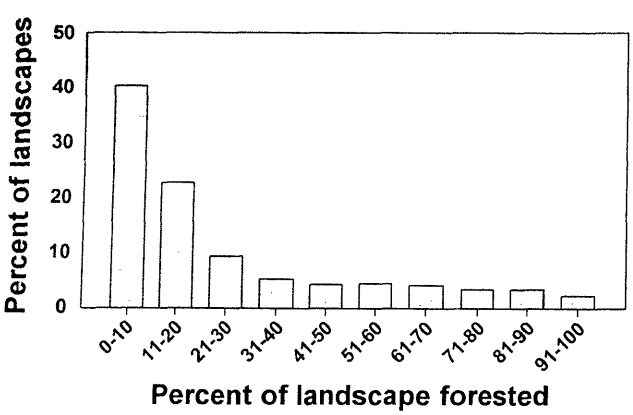


Figure 3.—*The percent forest cover in Central Hardwood landscapes.*

CENTRAL HARDWOOD BIRD COMMUNITIES

There are 128 long- and short-distance migrant landbirds that breed in the Central Hardwood States of Illinois, Indiana, Ohio, and Missouri (Appendix 1). Approximately 70 of these species breed in the forest. We report trends and abundances of many of these species from the Breeding Bird Survey for Illinois, Indiana, Ohio, and Missouri (Appendix 2). Caution, however, should be used when interpreting these data because the BBS is a roadside survey and does not always sample forest-interior birds adequately in these States. For instance, relatively common forest species such as the ovenbird are not detected in several States. Six to 14 forest species in each of these States show long-term population declines, and 5 to 16 species in each State show long-term population increases (Appendix 2).

We identified forest-breeding species of high management concern from the Partners In Flight Database for Illinois, Indiana, Ohio, and Missouri (Carter and Barker 1993) (table 1). Species in the database are scored on 7 criteria reflecting abundance, distribution, population trend, and population threats (Hunter *et al.* 1993). Scores range from 7 to 35; we report species with scores ≥21 as possible management priorities within this region (a score of 21 usually is about the 75th percentile). Species on these lists consistently use a variety of forest habitats. Some of the highest scored species (Bachman's, cerulean, prothonotary, and Swainson's warblers) breed in lowland forest. Golden-winged, blue-winged, chestnut-sided, and prairie warblers breed in young forest or shrub habitats. Worm-eating, black-throated blue, blackburnian, hooded, Northern parula, and Canada warblers; Acadian and great-crested flycatchers; wood thrushes; and scarlet tanagers breed in mid- to late-successional forest.

We synthesized information on abundance of Midwestern NTMBs in forest habitats ranging from glades to mature forest (fig. 4). This list includes common species as well as species identified as a high management concern. We reviewed research and monitoring studies in this region (Annand and Thompson 1997 ; Chambers 1994; S. Robinson, unpubl. data; J. Brawn, unpubl. data; D. Whitehead, unpubl. data) to make our own qualitative assessment of the abundances of these species in a variety of Central Hardwood forest habitats during the breeding season. Importantly, these abundances are only one indication of habitat quality. The quality of breeding habitat ultimately should be based on reproductive success; however, adequate information on the reproductive success of most species across a range of habitats is not available. Considerable differences in abundances of birds across this region complicate interpretations of habitat use, so land managers also must account for geographic patterns in abundance. Habitat relationships of NTMBs within the region varied greatly (fig. 4). Habitat relationships are discussed in the following sections in relation to management practices.

IMPORTANCE OF REGIONAL AND LANDSCAPE PATTERNS

Population size and viability are determined by interactions between local habitat factors and regional or landscape features. An individual may select a nest site based on micro-habitat, and the density of a species might be related to vegetation structure in a habitat patch (Martin 1992). Densities, however, also may be affected by biogeographic patterns in a species' distribution (Thompson *et al.*, in press), and reproductive success may be affected by landscape composition and structure (Robinson *et al.* 1995). Conservation plans, therefore, must address multiple spatial scales. In this section we discuss how regional- and landscape-scale patterns in land use affect forest birds. In the following section we address the effects of forest management on local and landscape factors that affect forest bird populations.

Landscape composition and pattern significantly affect the reproductive success and status of forest bird populations in the Central Hardwood Region. Productivity, source-sink status of populations, or levels of nest depredation or brood parasitism are related to landscape patterns in forest cover (Donovan *et al.* 1995a; Robinson *et al.* 1995; Thompson *et al.*, in press). These studies characterized landscape patterns with measurements such as percent forest cover and mean patch size, in areas defined by 1- to 10-km radii.

Strong regional patterns in the productivity of NTMB's in Central Hardwood forests occur because of the great variation in amount of forest cover (Robinson *et al.* 1995). Populations of forest birds in the Central Hardwood Region are likely structured as population sources and sinks (see Donovan *et al.* 1996). Reproductive rates of some forest birds are so low in some fragmented landscapes that these populations are likely "sinks" that cannot sustain themselves without immigration from more productive "source" populations (Donovan *et al.* 1995a, Robinson *et al.* 1995, Brawn and Robinson 1996). Reproductive rates appear high enough in heavily forested landscapes in the Missouri Ozarks, south-central Indiana, and northern Wisconsin for these areas to act as population sources (Donovan *et al.* 1995a, Robinson *et al.* 1995). Other heavily forested landscapes that potentially could act as sources for species breeding in Central Hardwood forests include portions of Tennessee, eastern Kentucky, and southern Ohio (fig. 2). The small number of large, heavily forested landscapes in the region may be sustaining populations throughout the

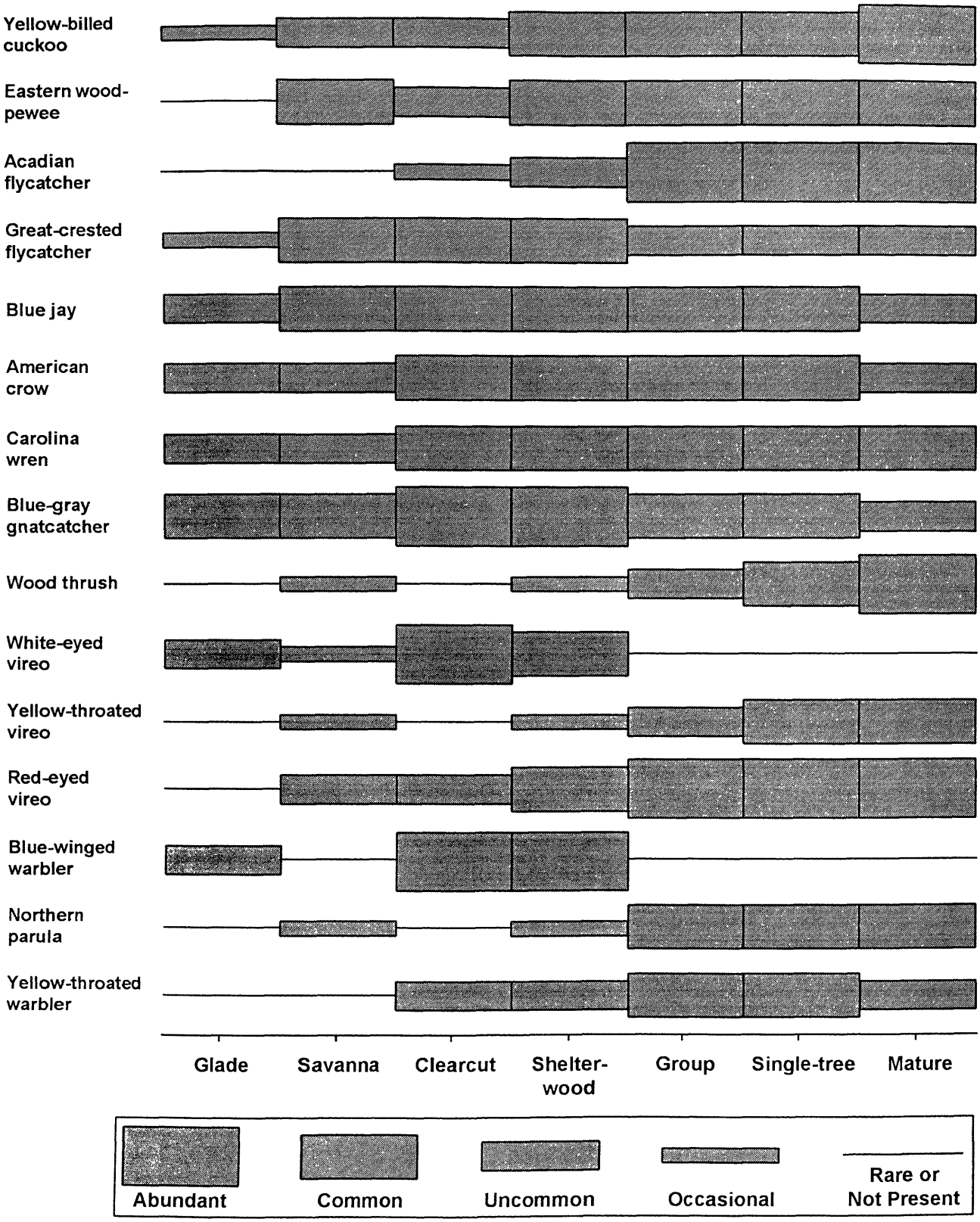


Figure 4.—*Habitat relationships of some breeding neotropical migratory birds in Central Hardwood habitats. Glades and savannas are managed by controlled burning; clearcut, shelterwood, group selection, and single-tree selection refer to forest stands treated within the last 10 years by these regeneration methods; and mature refers to 60- to 100-year-old even-aged forest.*

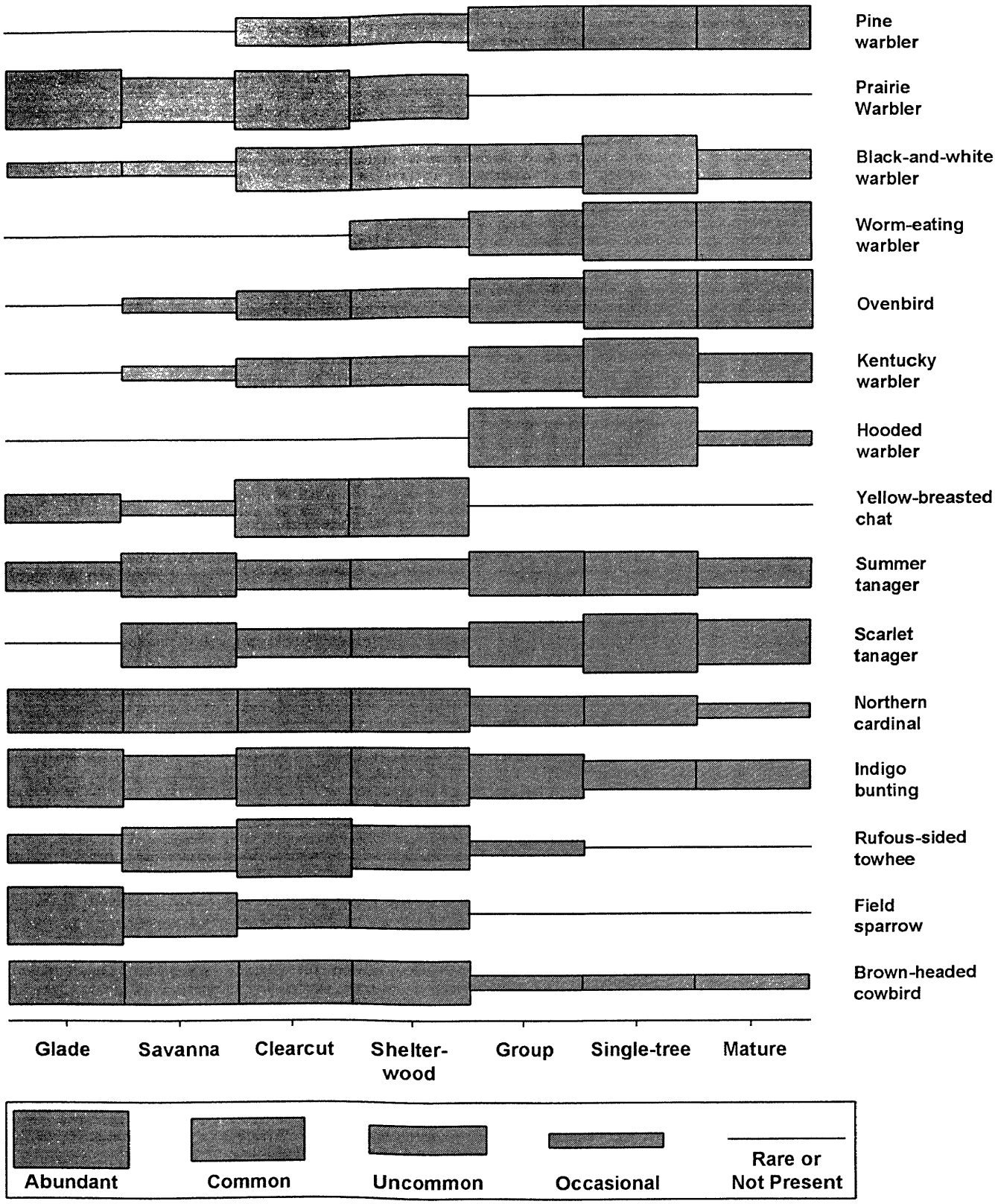

Pine warbler
Prairie Warbler
Black-and-white warbler
Worm-eating warbler
Ovenbird
Kentucky warbler
Hooded warbler
Yellow-breasted chat
Summer tanager
Scarlet tanager
Northern cardinal
Indigo bunting
Rufous-sided towhee
Field sparrow
Brown-headed cowbird
Glade
Savanna
Clearcut
Shelter-wood
Group
Single-tree
Mature
Abundant
Common
Uncommon
Occasional
Rare or Not Present

Table 1.—*Species of high management concern in 4 Midwestern States. Numbers are management concern scores generated by the Partners in Flight program in cooperation with the Colorado Bird Observatory and State conservation agenecies and Partners in Flight working groups. Scores can range from 7 to 35; species with scores >21 are presented as possible conservation priorities in this region.*

Illinois		Indiana		Missouri		Ohio	
25	Cerulean warbler	26	Cerulean warbler	29	Bachman's warbler	27	Cerulean warbler
25	Swainson's warbler	25	Golden-winged warbler	26	Cerulean warbler	26	Golden-winged warbler
24	Black-billed cuckoo	23	Wood thrush	25	Swainson's warbler	25	Blue-winged warbler
24	Golden-winged warbler	23	Blue-winged warbler	24	Prothonotary warbler	24	Chestnut-sided warbler
24	Chestnut-sided warbler	23	Chestnut-sided warbler	24	Worm-eating warbler	23	Great-crested flycatcher
23	Acadian flycatcher	23	Prothonotary warbler	23	Black-billed cuckoo	23	Prothonotary warbler
23	Great crested flycatcher	23	Worm-eating warbler	23	Wood thrush	23	Worm-eating warbler
23	Sedge wren	23	Louisiana waterthrush	23	Chestnut-sided warbler	23	Louisiana waterthrush
23	Wood thrush	22	Black-billed cuckoo	22	Yellow-billed cuckoo	22	Black-billed cuckoo
23	Blue-winged warbler	22	Yellow-billed cuckoo	22	Yellow-throated vireo	22	Yellow-billed cuckoo
23	Prothonotary warbler	22	Acadian flycatcher	22	Prairie warbler	22	Yellow-throated vireo
23	Worm-eating warbler	22	Hooded warbler	22	Louisiana waterthrush	22	Black-throated blue warbler
23	Louisiana waterthrush	21	Great crested flycatcher	22	Hooded warbler	22	Blackburnian warbler
22	Yellow-billed cuckoo	21	Canada warbler	21	Acadian flycatcher	21	Acadian flycatcher
22	Hooded warbler			21	Great crested flycatcher	21	Wood thrush
21	Canada warbler			21	Blue-winged warbler	21	Prairie warbler
21	Scarlet tanager			21	Northern parula	21	Hooded warbler
						21	Canada warbler
						21	Scarlet tanager

region. While observed variation in reproductive rates and population modeling corroborate source-sink population structure, there is no direct evidence of dispersal from sources to sinks.

Much of the forest habitat in the Central Hardwood Region could be sink habitat, and even though populations there essentially are nonviable and dependent on immigrants, they still may be important. A large portion of a species' global population may reside in population sinks at any one time. Sink populations may be important holding areas for surplus breeders (Howe *et al.* 1991). Individuals occupying sink habitat are involved in many ecological processes (Marquis and Whelan 1994), and these interactions may be important despite individual reproductive success.

Such large-scale source-sink population dynamics also could have major implications for interpreting census data such as those of the BBS. A lack of long-term declines in midwestern forest birds may not be an indicator of healthy populations (Brawn and Robinson 1996). Small, isolated woodlots in the Midwest often show no consistent long-term declines even though reproductive success may be far below the levels necessary to maintain local populations (Robinson 1992, Brawn and Robinson 1996). Interpreting results of population trend analyses therefore requires additional data on nesting success to be of most use in making management decisions.

The primary hypothesis for the relationship between the reproductive success of forest breeding birds and landscape composition is that predator and cowbird numbers are greater in landscapes where the forest is fragmented by human activities such as agriculture and development. It appears that any human activities that create cowbird and predator feeding habitat within an otherwise forested landscape will reduce NTMB nesting success. Even a single cowbird feeding area in forested landscapes can reduce nesting success over large areas because cowbirds can commute up to 7 km between feeding and breeding sites (Rothstein *et al.* 1984, Thompson 1994). In practice, however, mostly forested landscapes where there are few feeding opportunities for cowbirds have low numbers of cowbirds and parasitism levels (Thompson *et al.*, in press). Our working hypothesis is that cowbirds are limited by feeding habitat in mostly forested landscapes and by nesting habitat in mostly agricultural landscapes (Robinson *et al.* 1995; Thompson *et al.*, in press). In the agricultural landscapes of Illinois, cowbirds appear to saturate the available landscape and their abundance is determined by host abundance rather than by proximity to edge or pastures (Robinson and Wilcove 1994; Thompson *et al.*, in press).

Because nest predators are so diverse, regional and landscape patterns of nest predation generally are less pronounced than those for cowbird parasitism (Robinson *et al.* 1995). Predators such as raccoons and opossums that forage extensively in agricultural habitats may be a much greater problem in agricultural landscapes than in forested landscapes, as are some corvids (reviewed in Paton 1994, Marini *et al.* 1995). Some snakes also appear to be most abundant near agricultural openings (Durner and Gates 1993). Marini *et al.* (1995) and Heske (1995), however, found no differences in the abundance of mammalian nest predators between agricultural edges and forest interiors in southern Illinois. It is therefore possible that some landscapes may be saturated with nest predators just as they are with cowbirds. Nevertheless, reducing agricultural, suburban, and urban inholdings in forested landscapes likely would also reduce certain kinds of nest predation.

Edge Effects

Although regional effects of forest fragmentation and landscape composition on NTMB nesting success have been well-defined, there is also evidence that local features affect songbird nesting success (reviewed in Robinson 1996). Sometimes edges are associated with higher predation and parasitism levels (Brittingham and Temple 1983, Temple and Cary 1988). Some species in some regions experience variation in local reproductive success at least as great as those seen among landscapes across the region (Robinson *et al.* 1995; Trine *et al.*, in press). One hypothesis is that edge effects are responsible for variation in reproductive success among landscapes because more fragmented landscapes have more edge. While studies have demonstrated local edge-effects, the consequences of edge effects to NTMB populations are largely unknown and depend on whether predators and cowbirds respond numerically or functionally to edges,

and whether NTMB's are attracted to or avoid edges. If both predators or cowbirds and NTMB's are attracted to these edges, they could function as ecological traps (sensu Gates and Gysel 1978).

Edges between forest habitats and non-forest habitats (such as agricultural, suburban, grassland habitats) may affect species abundances' as well as reproductive success (we discuss edge effects from forest management practices in the following section). Some mature forest species such as ovenbirds and red-eyed vireos are less common near agricultural edges than the forest interior, and some early successional species such as blue jays and crows are more common near agricultural edges (Frazer 1992).

Research in southern Indiana compared reproductive success between interior sites (heavily forested sites >5 km from agricultural habitats) to exterior edge sites (forest adjacent to agricultural habitats) (D. Whitehead, unpubl. data). Overall nest survival rates tended to be lower near agricultural edges for 6 of the 7 species monitored. Differences for one species (Acadian flycatcher) approached significance ($p=0.075$), and across all species nest success was significantly lower near agricultural edges. Patterns of nest parasitism were similar; parasitism tended to be higher near edges for 6 of the 7 species. Differences were significant for 2 species (red-eyed vireo and worm-eating warbler), and across all species parasitism was significantly higher near exterior edges (fig. 5).

FOREST MANAGEMENT PRACTICES

Central Hardwood forests are disturbance-adapted ecosystems. Forest management activities, including timber harvest, wildlife management, and fire suppression or prescription, have to some degree replaced natural disturbance patterns. For nongame species, such as migratory birds, a predominant view has been that disturbance is not beneficial (e.g., see Morrison *et al.* 1992). Notwithstanding the clearly adverse effects of habitat loss and fragmentation caused by urbanization or agriculture (see Robinson *et al.* 1995), disturbance is often seen as "unnatural" and negative, especially for those species requiring old-growth. The "non-disturbance" view of habitat management for nongame birds has some merit for those species requiring large, old-growth forest stands, but we believe that disturbance plays a fundamental role in managing forest habitat and molding the structure of landscapes. For instance, small disturbances on the scale of a few trees create hooded warbler habitat, whereas large disturbances (>3 ha) may be required to create prairie warbler habitat.

In this section, we focus on a few dominant forest management practices in the Central Hardwood Region. We review the effects of silvicultural practices on NTMB's, both mitigating their negative effects and in using them to create NTMB habitat. We also present information on the role of fire in NTMB conservation. Fire increasingly is being used to maintain or restore fire-dependent ecosystems.

Impacts of Silviculture

Perhaps the most important management issue in the Central Hardwood Region is determining the best strategy for harvesting timber while conserving NTMB's and other ecosystem attributes (Kurzejeski *et al.* 1994). Central hardwood forests are managed by even-aged and uneven-aged silvicultural systems. These two systems have some fundamental differences in their effects on forest habitats and wildlife (see Thompson *et al.* 1995). In addition to these silvicultural practices, high grading, a practice common on private lands, may range from nearly complete removal of the existing stand (resembling clearcutting) to removal of a few marketable trees (resembling selection methods). The objective of high grading is to harvest marketable trees and not necessarily to regenerate a forest stand that will provide for future commodity or non-commodity values. Forest management generally is implemented at the stand level, resulting in a habitat patch. At this scale we discuss the types of habitats created and the dominant species that breed in them. We also evaluate practices at the landscape scale to assess cumulative impacts (both spatial and temporal) and impacts resulting from the spatial arrangement of habitats.

Even-aged Methods

These regeneration methods harvest an existing stand and result in a young even-aged forest. Throughout most of the Central Hardwood Region rotation ages are 80 to 100 years, although rotations sometimes are extended to

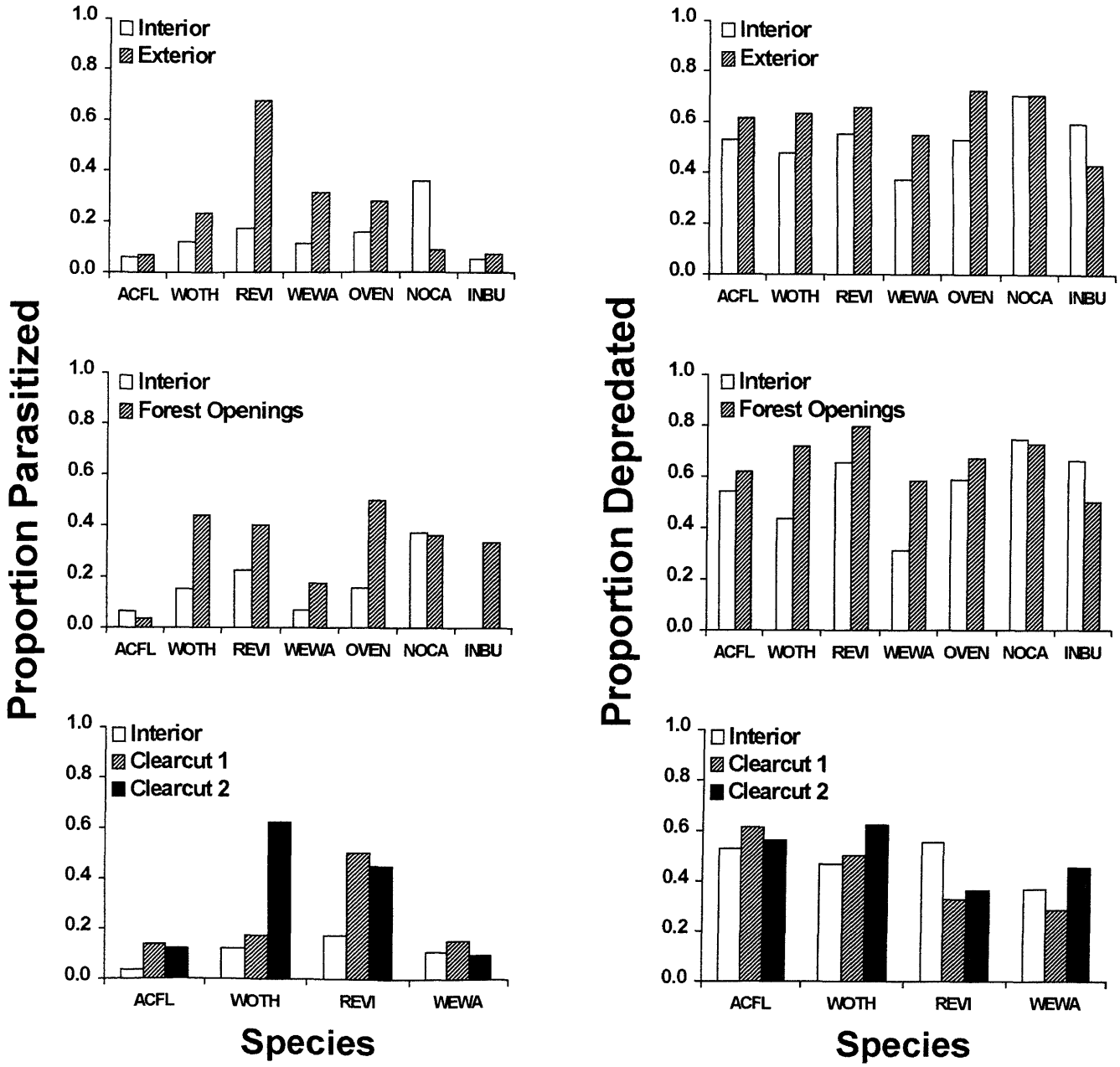


Figure 5.—*Differences in reproductive success of some forest songbirds in forest interior and in forest adjacent to different types of edge in southern Indiana (D. Whitehead, unpubl. data).*

provide stands with some old-growth characteristics. Even-aged regeneration methods differ primarily in the number of trees retained from the previous stand. Under the clearcut method, all trees are removed except for designated den trees or snags. Under the shelter-wood method, up to 60 percent of the canopy may be retained to provide shelter for developing tree reproduction. At some point early in the rotation the shelter generally is removed, but in some instances it may be retained to meet scenic quality, wildlife, or other objectives.

Regenerating stands

The first year after cutting, these stands have abundant herbaceous ground cover, but they quickly become dominated by tree regeneration from sprouting and advance regeneration, resulting in as many as 25,000 stems/ha (Gingrich 1971). The first year after clear-cutting there is usually a drastic reduction in total bird numbers and a nearly complete turnover in species. American goldfinches and field sparrows often prefer cuts at this age because of the abundant annual and perennial vegetation. As tree regeneration begins, numerous other species nest in this habitat. NTMB species of high management concern that breed in these habitats include golden-winged, blue-winged, hooded, chestnut-sided, and prairie warblers. Other birds breeding in these habitats are yellow-breasted chats, indigo buntings, Kentucky warblers, common yellowthroats, white-eyed vireos, gray catbirds, rufous-sided towhees and northern cardinals (Gremel 1989, Frazer 1992, Thompson *et al.* 1992, Annand and Thompson 1997). In shelterwood and seed tree cuts, and clearcuts with residual live trees and snags, some mature-forest, canopy-dwelling species may continue to use the stand. Species richness and total bird density are high during this stage because of the mixture of foraging and nesting substrates (bare ground, grasses and herbs, shrubs and young trees, mature-residual live and dead trees).

Some have speculated that residual trees left in regeneration cuts provide perches for cowbirds and nest predators that might enable them to find nests within the openings. However, there is no direct evidence supporting this hypothesis. Residual trees do have demonstrated value for cavity-nesting wildlife, including NTMB's such as the great-crested flycatcher (Dickson *et al.* 1983).

Sapling stands

Between 10 and 20 years after harvest, the stand is dominated by tree saplings with a closed canopy. At age 20 the number of stems has been reduced to 3,400 to 6,200/ha and the larger trees on good sites have reached 18 cm d.b.h. (Gingrich 1971). Many birds typical of regeneration do not breed here or persist in these stands at lower densities. Black-and-white, worm-eating, and Kentucky warblers seem to prefer the high stem densities and closed canopies this age class provides. Ovenbirds, wood thrushes, and red-eyed vireos may begin using stands at this age (Gremel 1988, Frazer 1992, Thompson *et al.* 1992).

Poletimber stands

From age 20 to 60 years, 90 percent of the trees will die due to competition. The canopy remains closed and there is little understory development. As a result common species tend to be canopy nesters such as red-eyed vireos, scarlet tanagers, eastern wood-pewees, and wood thrushes, or ground nesters such as ovenbirds and black-and-white warblers. Total densities of NTMB's may be lower than in mature forest or regenerating stands (Gremel 1989, Thompson *et al.* 1992)

Mature stands

The structure of mature forests differs widely through the region. Depending on soils, geology, climate, and geography, mature stands may have sparse to dense groundcover and understory. Death and decay of large trees results in cavities, snags, and tree-fall gaps. After 80 years, dominant trees will range from 30 to 46 cm d.b.h. If left undisturbed, these stands will slowly become uneven-aged as they age and individual trees die. However, because of the widespread logging, burning, and grazing in this region in the late 1800's and early 1900's, much of the mature forest here is even-aged ranging from 60 to 100 years old. The most abundant NTMB in mature forests throughout the region is the red-eyed vireo. Other abundant or common species throughout the region are the eastern wood-pewee, wood

thrush, Acadian flycatcher, blue-gray gnatcatcher, ovenbird, worm-eating warbler, scarlet and summer tanager, and blue jay. In oak-pine stands pine warblers and yellow-throated warblers are common.

Community trends and succession

Avian density and diversity generally increase with plant succession in the Southeast US (Johnston and Odum 1956, Karr 1971, Shugart and James 1973, Shugart *et al.* 1975). However, breeding bird densities in regenerating oak hickory or pine hardwood stands usually are similar to or much greater than those in mature stands, and densities are often lowest in mid-successional sapling- and pole-sized stands (Conner and Adkisson 1975, Conner *et al.* 1979, Dixon and Selquist 1979, Probst 1979, Horn 1984, Yahner 1986, Gremel 1989, Thompson and Fritzell 1990, Frazer 1992). Species richness and diversity generally increase with stand age but sometimes also show an early peak in regenerating stands (Conner and Adkisson 1975, Conner *et al.* 1979, Dixon and Segelquist 1979, Probst 1979, Horn 1984, Yahner 1986, Thompson and Fritzell 1990).

Landscape composition and pattern

Even-aged management creates a mosaic of different-aged forest stands in the landscape. Assuming timber harvest is regulated to provide sustained yield over time, rotation age will determine the amount of forest in any given age class. For instance, an oak-hickory forest managed by regulated clearcutting on an 80-year rotation would be comprised of approximately 10 percent 1- to 8-year-old forest, 10 percent 9- to 16-year-old forest, etc. Forests managed by even-aged management could have more or less early successional forest than natural landscapes depending on rotation age and frequency of natural disturbances. Managed Central Hardwood forests, however, generally have more early successional forest and bird species than forest reserved from harvest. In the Missouri Ozarks, for example, the amount of young forest and density of early-successional NTMB's was greater, and the density of forest-interior NTMB's slightly lower, in landscapes managed by clearcutting than those with no recent timber harvest (Thompson *et al.* 1992).

Edge effects

Edges between regenerating stands and mature stands may affect species abundance and diversity. For instance, red-eyed vireos and ovenbirds (Frazer 1992) are less abundant near some forest edges, while hooded warblers, black-and-white warblers, (Frazer 1992) and cowbirds (O'Conner and Faaborg 1992) are more abundant near some forest edges. Reproductive success of some species is lower near even-aged regeneration cuts in some landscapes, but results are highly variable. Research in southern Indiana compared reproductive success of Acadian flycatchers, wood thrushes, red-eyed vireos, and worm-eating warblers between interior sites (heavily forested sites >5 km from agricultural habitats) and forest sites adjacent to clearcuts (D. Whitehead, unpubl. data). Across all species, parasitism was significantly greater near 4 of 5 clearcuts than in the interior site. Acadian flycatcher and red-eyed vireos were parasitized significantly more frequently near 4 of 5 clearcuts; wood thrushes near 1 of 5 clearcuts ($p<0.10$). Across all species, there were significantly higher proportions of depredated nests at 2 of the 5 clearcut sites; no significant differences were detectable at 3 sites. Species-specific comparisons indicate that the proportion of depredated Acadian flycatcher nests was significantly higher at 1 clearcut site (fig. 5).

Uneven-aged Methods

Uneven-aged management creates a wide range of tree sizes or ages within a stand; by definition stands should include a minimum of 3 age classes (Smith 1962). Under the single-tree selection method, individual trees are selected for harvest and under the group-selection method, small groups of trees from 0.04-0.2 ha are selected. The objective of selection cutting is to maintain a defined distribution of tree diameters. The diameter distribution is defined by a "q-value" that represents the ratio of the number of trees in consecutive diameter classes and essentially determines the steepness of the curve. Stands usually are harvested whenever stocking exceeds 80 percent, which on good sites should be every 15 to 20 years (Roach 1963, Law and Lorimer 1989, Marquis 1989). Group selection can successfully regenerate oaks. Single-tree selection tends to favor shade-tolerant species, although it has been used with

some success in maintaining oak forests in xeric ecosystems in the Missouri Ozarks (Johnson 1993).

Unlike even-aged methods, selection cutting does not produce large changes in habitat structure or turnover in bird communities at a stand level, but neither does it provide for the range of species at the landscape scale. Selectively cut stands retain most mature forest species. Selection cutting creates gaps and high vegetation diversity, which benefits many species. However, the selective removal of trees results in fewer large canopy trees and denser understories, which results in lower numbers of some species than in mature even-aged stands (fig. 4).

Canopy gaps resulting from the harvest of single trees or groups of trees provide habitat for a variety of migrant birds. Uneven-aged stands have a well-developed understory and subcanopy because of frequent canopy gaps. The presence of several well-developed vegetation levels and more complex habitat structure than even-aged stands could result in higher within-stand bird species diversity. Species such as the hooded warbler and indigo bunting appear to be able to make use of small gaps typical of single-tree selection, while other species such as yellow breasted chats, blue-winged warblers, and prairie warblers require large openings more typical of clearcuts (Annand and Thompson, in press) (fig. 4).

Landscape level impacts

Unlike even-aged management, selection cutting maintains a mature tree component at all times and does not create a mosaic of different-aged stands. This may benefit forest-interior warblers because large tracts of forest with mature trees can be maintained. However, if edge effects occur around group selection openings, they could cause local populations to become sinks, because while small, these openings can be numerous and widely dispersed throughout the forest (Thompson 1993). Selection cutting will not provide habitat for species that require larger openings or stands of early successional forest, or a diversity of even-aged stands.

Edge effects

Research in southern Indiana compared reproductive success of Acadian flycatchers, wood thrushes, red-eyed vireos, and worm-eating warblers between the forest interior and 2 sites that contained several group selection openings (D. Whitehead, unpubl. data) (fig. 5). Across all species, there were no significant differences in parasitism levels. Parasitism levels were significantly higher for the worm-eating warbler at one of the managed sites. Across all species, the proportion of depredated nests was significantly higher at one of the managed sites, but there were no significant differences for individual species. Ongoing research in southern Illinois suggests that species reproductive success is not strongly affected by selective cutting, although parasitism levels were higher for some species in recent cuts. Potentially higher parasitism levels could be the result of changes in forest structure as opposed to edge effects or fragmentation resulting from group openings. Reproductive success of some gap-dependent species (e.g., hooded warbler and white-eyed vireo, but not indigo bunting) was very low (S. Robinson, unpubl. data).

Comparison of Landscape-Level Impacts of EAM and UEAM

The effects of even-aged and uneven-aged regeneration methods must be considered at a landscape level to assess their impact on bird populations. Thompson (1993) used simulation modeling to compare the effects of group selection and clearcutting on a forest-interior bird population. Simulated population size declined up to 40 percent in a forest managed by clearcutting on a 100-year rotation, but projected populations differed only slightly in models with and without edge effects (fig. 6). This suggests that most of the decline was due to the conversion of older stands to younger stands (a reduction in habitat suitability or carrying capacity) because even-aged management did not create enough edge to greatly affect production, and that forest interior bird populations may persist at reduced levels in managed forests even with deleterious edge effects (Thompson 1993). In simulations without edge effects, group selection cutting had little impact on the modeled population because the total area in group openings was small and it was assumed that carrying capacity of the surrounding forest was unaffected. However, if edges around group selection openings function as ecological traps, they could result in local extirpations or population sinks, because while small, these openings could be much more numerous and widely

dispersed than those created by clearcutting. If openings created by selection cutting do not function as ecological traps, then selectively cut forests could maintain higher populations of a mature-forest species than forests managed by clearcutting (fig. 6) (Thompson 1993).

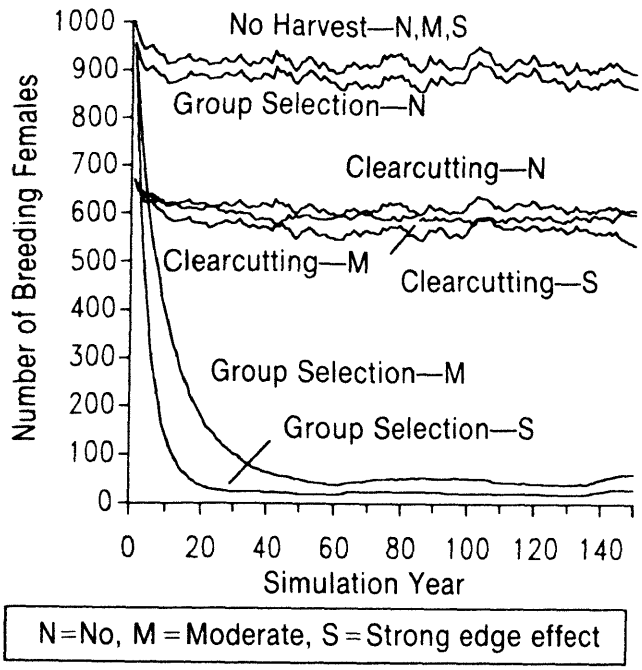


Figure 6.—*Simulated effects of clearcutting and selection cutting on a forest interior bird in a Central Hardwood forest (adapted from Thompson 1993).*

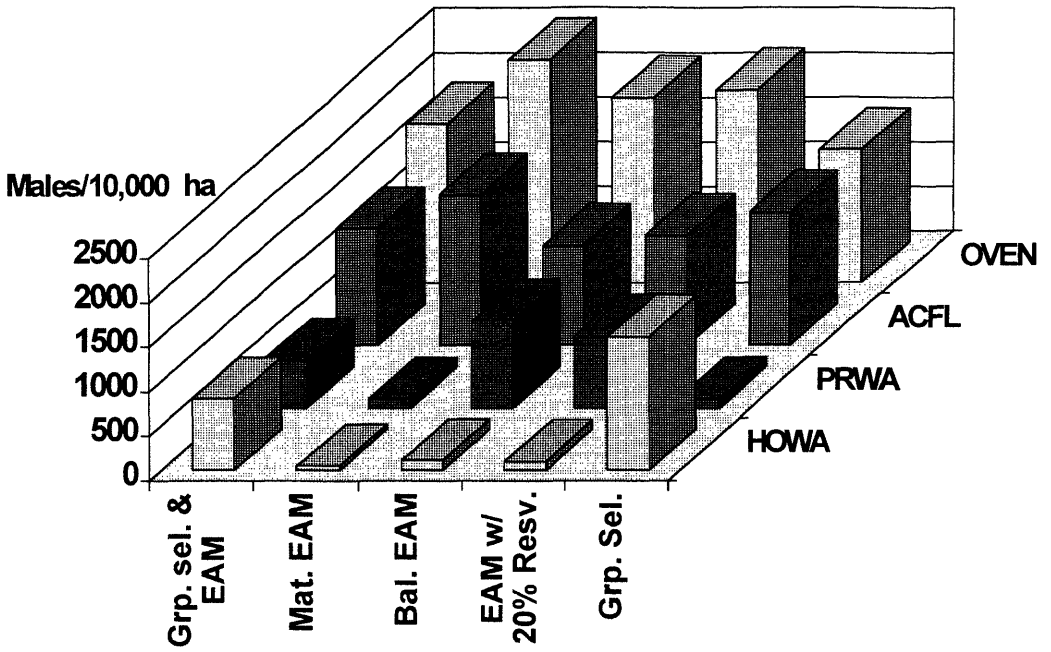
We used a simple model to compare the abundance of 4 species in Central Hardwood landscapes under 4 different management scenarios (fig. 7). We modeled abundance of a species that prefers small gaps (hooded warbler), a species that prefers large stands of young forest (prairie warbler), and two characteristic forest interior species that breed in mature forest (Acadian flycatcher and ovenbird). We used previously reported absolute and relative density estimates for these species in stands managed by silvicultural practices in the Missouri Ozarks (Thompson *et al.* 1992, Annand and Thompson 1997) to assign density values to different aged even-aged forest and to forest managed by a combination of group and single tree selection (fig. 7). We estimated the amount of each of these habitats in a 10,000-ha landscape to determine total population size. We modeled 5 management scenarios that represent realistic alternatives for public and private lands in the Central Hardwood Region. The mature even-aged management scenario was a landscape composed entirely of mature (>60-year-old) forest. The balanced even-aged management scenario was a landscape managed by the clearcut method with a 100-year rotation and balanced age class distribution (i.e., 10 percent 0- to 10-year-old forest, 10 percent 11- to 20-year-old forest, etc.). Even-aged management with 20 percent reserved was managed as the even-aged landscape except 20 percent of the area was reserved from harvest and was always mature forest. The group selection method was based on recommendations for Central Hardwood forests by Law and Lorimer (1989). The group selection and EAM option consisted of equal areas managed by the clearcut method and the selection method. The model was based on density data from managed forests and the area of each forest habitat in the modeled landscape; it accounts for edge effects on abundance and reproductive success only to the extent these effects were reflected in the original density estimates by Thompson *et al.* (1992) and Annand and Thompson (1997).

Species abundances under different management scenarios varied as a function of their habitat preferences (fig. 7). For instance, ovenbirds were most abundant in the Mature EAM landscape because they are most abundant in mature even-aged forest. Prairie warblers were most abundant in the Balanced EAM landscape because they prefer young forest stands. More importantly the model allows comparison of densities among species and management options. From this perspective, the only option that maintains moderate to high densities of all 4 species is a mix of EAM and group selection. While this model represented a single landscape, it is not important (or necessarily always desirable) that this mix be provided within one landscape; it could also occur among a group of landscapes.

Forest-Wildlife Openings

Forest wildlife openings are small openings created in the forest for a variety of objectives, including habitat for some wildlife and plants as well as recreational opportunities including hunting and wildlife observation. These openings are managed in various ways, including planting them to cereal grains, grass and

Bird abundances in landscapes under different management scenarios



Bird abundance in habitats created by forest management

Species	Territories / 10 ha				
	Forest age (even-aged)				uneven-aged
	0-10	10-20	20-40	>40	(group selection)
HOWA	0.3	0.3	0.1	0.1	1.5
PRWA	5.5	3.5	0.1	0.1	0.1
ACFL	0.0	0.1	0.5	1.7	1.5
OVEN	0.3	1.5	2.0	2.5	1.5

Figure 7.—*Simulated bird abundance in central hardwood landscapes under different management scenarios.*

forbs, or maintaining them in a grass or shrub stage of succession by disking, mowing, or fire. They provide habitat for some resident songbirds and NTMB's such as indigo buntings but often are too small for early successional NTMB's such as yellow-breasted chats, blue-winged warblers, and prairie warblers.

Because of their small size, these openings do not result in the loss of significant amounts of mature forest. Of greater potential concern are possible impacts of edge effects on mature-forest birds in adjacent forest stands. In southern Indiana, Whitehead *et al.* (unpubl. data) found higher parasitism levels across all species, and individually for the wood thrush, red-eyed vireo, and indigo bunting, in sites with forest openings compared to forest interior sites. Similarly the proportion of depredated nests was greater for all species combined, and individually for the wood thrush, at sites with openings (fig. 5).

Fire and Neotropical Migratory Birds

Recognition of the need for periodic disturbance has led to increased use of prescribed fire as a management and restoration practice in oak-dominated ecosystems, but its effect of this trend in restoration on forest birds is not fully understood. Clearly, an effort as potentially influential as savanna restoration will strongly effect certain species. As with other forest management practices, certain species of neotropical migrants likely will benefit from fire and savanna restoration and others will be adversely affected (fig. 4).

In addition to the forest birds associated with savannas that are identified in figure 4, the following species also have significant habitat associations with savannas: black-billed cuckoo, whip-poor-will, ruby-throated hummingbird, least flycatcher, purple martin, barn swallow, northern rough-winged swallow, cliff swallow, bank swallow, warbling vireo, dickcissel, and the orchard and northern oriole (J. Brawn, unpubl. data). Most of these species are declining in the region (Appendix 2). This list reflects a broad definition of a savanna as an area with 20- to 70-percent-canopy closure and a permanent herbaceous groundlayer (note that definitions differ widely among states and various agencies). Our criteria on inclusion on the list was that a species have an important habitat association with savannas and open woodlands during the breeding season. Certain species also have important associations with other habitats and ecosystems such as grasslands, shrublands, or forest (fig. 4). Importantly, many other species of permanent residents and short-distance migrants also are associated with midwestern savannas (Brawn 1994). The list of long-distance migrants is diverse in taxonomy and ecology and includes species as different as whip-poor-wills and summer tanagers. One life history trait common to many of these species is that they forage on the wing and catch insects in the air. Obviously, the ability of birds to forage this way is favored by an open canopy.

The majority of species associated with savannas are significantly declining within the region (Appendix 2). Very few have significantly increased. Therefore, the conservation status of these birds as a group is worrisome. Fire and restoration will provide more habitat for the subset (a majority) of these species that are not equally abundant in non-disturbed areas. We don't know what effects fire will have on ecological factors that affect reproductive success; specifically, rates of cowbird parasitism and nest predation. Preliminary evidence from the fragmented landscapes of Illinois suggests that fire does not significantly affect productivity, but reproductive success is so low in these landscapes that effects would be difficult to demonstrate (J. Brawn, unpubl. data). Savanna restoration in heavily forested landscapes may yield more positive results because of the effects of forest fragmentation on reproductive success (Donovan *et al.* 1995a, Robinson *et al.* 1995). The influence of changes in habitat due to fire will depend on the landscape context of restoration efforts. A large burn unit surrounded by large holdings of prairie or closed-canopy forests likely will be more beneficial to most birds than a similar burn in a landscape dominated by agriculture.

Other considerations for prescribed fire pertain to factors under the control of local managers. When and how often to burn are important questions and no single prescription will be valid for all areas. While restoration efforts are underway, burning will be relatively frequent. Once savanna-like conditions are established with respect to canopy closure and a herbaceous groundlayer, burning may become less frequent. Importantly, burning is only one element of savanna or oak woodland restoration. Other techniques such as planting and mechanical manipulation of vegetation may also be required (see Botts *et al.* 1994 for a full discussion of restoration techniques and considerations).

Finally, although we view prescribed fire as an important management option for the Central Hardwoods, we do not believe that sound conservation will be served by burning "everywhere." Species that nest in dense understory or shrubs, such as the wood thrush and the hooded warbler, will not benefit from fire (Brawn, unpubl. data). Close attention should be given to the types of areas that burned naturally and those that did not burn. An effective approach to this problem is the concept of "landscape burns," whereby burns are allowed to proceed where they may, but are not forced into areas (e.g., ravines) that are too mesic to have burned naturally.

Another use of prescribed fire is the management of edges. Historically, savannas often were juxtaposed between prairies and wooded habitats. Thus, there may have been a gradual transition between non-wooded and wooded habitat. In modern midwestern landscapes, sharp transitions between agriculture and forest may create edges that are highly unfavorable for neotropical migrants (Suarez *et al.*, in press). Fire may soften the transition and create edges that are more hospitable as breeding habitat.

CONSERVATION STRATEGIES

Management Issues for the Conservation of Forest Birds In the Central Hardwood Region

We believe two dominant issues concern conservation of migrant birds in the Central Hardwood Region:

1. Land use patterns have resulted in great variation in the amount of forest cover. We have strong evidence that NTMB populations are structured as sources and sinks, but we do not know how populations are linked by dispersal. This question is important because land management actions in one population can affect other populations. For example, fragmentation of source habitat could lead to extinction of sink populations, or abundant sink habitat could drain source populations (Donovan *et al.* 1995b). Conservation planning must recognize the spatial structure of populations in the Midwest and emphasize enhancement and preservation of regional source populations.

2. Conservation of NTMB's is competing with other land uses for a limited land base. There may be conflicts with commodity production, recreation, wilderness management, and wildlife management; among NTMB species; or between species and ecosystem management. Nevertheless, we have assessed costs and benefits of these practices for NTMBs but acknowledge compromises will be required for multi-resource planning.

Address Landscape-Level Fragmentation at a Regional Scale

The Central Hardwood Region consists of a mix of source and sink populations whose status is linked to landscape-scale fragmentation of forest. The population status of forest-dwelling migratory birds is related to the amount of source and sink habitat in the region. Given the current concern for migratory birds and observed declines in some species, the first step should be to ensure that sufficient source populations exist in the region. Only a few large, heavily forested landscapes remain in the Central Hardwood Region (fig. 2). We believe a prudent conservation strategy for the region is to maintain a high percentage of forest cover in these landscapes, to maintain the largest forest tracts in the region, and to take advantage of any opportunities to restore and recreate larger forest tracts in more fragmented landscapes (the "macrosite" approach mentioned in Robinson *et al.* 1995). Most land in the Central Hardwood Region is privately owned. Extensively forested land, however, is disproportionately owned by Federal and State agencies (fig. 2). The relationship of public lands to the distribution of forest cover greatly enhances the value of public land to forest bird conservation. It is not coincidental that the core of nearly all the large tracts of forest in the Central Hardwood Region are National and State Forests. Federal and State agencies have long protected, conserved, and in some cases reforested these lands; continued forest conservation by the agencies is critical to forest breeding migratory birds. Maintaining a balance of birds in source and sink habitat may be crucial to the long-term survival of regional populations (Urban and Shugart 1986, Temple and Cary 1988, Donovan *et al.* 1995b).

Provide Appropriate Habitats and Landscape Pattern

In addition to protecting extensively forested landscapes, appropriate forest habitats must be provided within these landscapes. Within Central Hardwood landscapes migratory birds breed within a wide range of forested and semi-forested habitats. Even when we reviewed habitat use by a reduced set of priority species, those species still spanned a wide range of habitats. Conservation planning is further complicated when we acknowledge that many of these lands are managed for multiple use, including recreation and forest products.

Plan forest management activities to meet habitat needs

Priority species, and forest birds in general, require a variety of forest habitats. Land

management planning should provide these habitats across the region. Land managers and the public must recognize that this means that the management of any particular landscape will benefit some species but will have negative effects on others, but that across landscapes the needs of all species will be met. We believe a mix of even- and uneven-aged silvicultural practices, designated reserve areas, and use of prescribed fire will be required within the Central Hardwood Region to meet bird conservation objectives and other objectives for forest lands. We used a simple model based on landscape composition to demonstrate that almost any mix of regulated, sustainable forest management practices likely will sustain most species across a landscape; densities, however, differed greatly among alternatives. Land management objectives for other resources also will influence the balance of managed forest lands and reserved areas. Ultimately, conservation planning for migratory birds should develop minimum habitat requirements and plan the distribution of these within a region. This approach is currently being pursued by the Partners in Flight program.

Reduce internal edge and disturbance where appropriate

Reducing the amount of non-forest habitat in a landscape, and the edges it creates, should benefit forest breeding birds by creating more breeding habitat and reducing nest depredation rates and brood parasitism. These habitats include cropland, grassland, pasture, mowed rights-of-way, and suburban, urban, or commercial developments. These habitats likely increase the number of predators and cowbirds in the landscape. Reforestation, or even less drastic modifications of land-use, on small non-forested inholdings in large forest tracts could have disproportionate benefits to forest breeding birds.

We had difficulty developing recommendations concerning disturbances and edges resulting from forest management. Some priority species within the Central Hardwood Region require disturbance-dependent communities, such as young forest, glades, barrens, or savannas. The significance of deleterious edge effects associated with forest management differs among species and sites. The only evidence of population impacts is from simulation modeling, which suggests edge effects can result in population declines and even extirpations (Temple and Cary 1988, Thompson 1993), but that potential edge effects from regulated forest management are tolerable (Thompson 1993). We recommend reducing disturbance and edges from forest management practices where late-successional, forest-interior species are a priority, while acknowledging that edge is a necessary byproduct of desirable management practices where early successional species or other forest management objectives require disturbance. Where possible, promote gradual, shrubby edges rather than abrupt edges, and keep intensive recreation development out of the core of some large forest tracts. Depending on forest ownership, legal mandates, historical landscape composition, and management objectives, practices that create early successional habitats or produce forest products will be appropriate. The challenge in these circumstances is to meet habitat or commodity objectives while not creating unnecessary edge effects. Again, as mentioned in the previous section, a mix of managed forest lands and reserved areas within an adequate forest landbase will accommodate the needs of Central Hardwood NTMBs.

Plan comprehensively across ownerships

Land management planning for the conservation of forest-dwelling NTMB's must occur across public and private lands. An example of comprehensive planning across ownerships with voluntary participation by private landowners is the Coordinated Resource Management Program in Missouri (Missouri Department of Conservation). Because conservation agencies have more direct control over public lands, and within the Central Hardwood Region they form the core of most heavily forested landscapes, they have unique value. NTMB populations should benefit if public lands are managed to complement private lands and to provide disproportionate amounts of high-quality, rare ecosystems such as savannas and glades, old-growth forest, and large heavily forested landscapes. In landscapes in which private lands provide abundant early-successional habitat, manage for disproportionate amounts of mature forest on public lands or the use of uneven-aged management instead of even-aged management. Alternatively, where private land provides too little early-successional habitat, or unsuitable early-successional habitat (such as from partial-cut methods as high-grading), public lands may need to provide shrublands and clearcuts in heavily forested

landscapes where reproductive success is likely to be high. Opportunities for restoration of natural communities, such as savannas, will most likely be greatest on public lands.

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Appendix 1.—*Migrant landbirds that breed in Illinois, Indiana, Missouri, and Ohio. Species fillowed by 'A' are long-distance migrants and winter south of the United States. Species followed by 'B' winter primarily in the Unites States, but part of the population winters south of the United States. List developed by the Partners in Flight program in cooperation with Colorado Bird Observatory and State conservation agencies.*

Turkey vulture	B	Purple martin	A	Prothonotary warbler	A
Osprey (supp.)	B	Tree swallow	B	Worm-eating warbler	A
American swallow-tailed kite	A	Northern rough-winged swallow	A	Swainson's warbler	A
Mississippi kite	A	Bank swallow	A	Ovenbird	A
Northern harrier	B	Cliff swallow	A	Northern waterthrush	A
Sharp-shinned hawk	B	Barn swallow	A	Louisiana waterthrush	A
Cooper's hawk	B	Brown creeper	B	Kentucky warbler	A
Red-shouldered hawk	B	House wren	A	Mourning warbler	A
Broad-winged hawk	A	Sedge wren	B	Common yellowthroat	A
Swainson's hawk	A	Marsh wren	B	Hooded warbler	A
Red-tailed hawk	B	Golden-crowned kinglet (supp.)	B	Canada warbler	A
American kestrel	B	Blue-gray gnatcatcher	A	Yellow-breasted chat	A
Peregrine falcon	A	Eastern bluebird	B	Summer tanager	A
Killdeer	B	Veery	A	Scarlet tanager	A
Upland sandpiper	A	Hermit thrush	B	Rose-breasted grosbeak	A
Mourning dove	B	Wood thrush	A	Blue grosbeak	A
Black-billed cuckoo	A	American robin	B	Indigo bunting	A
Yellow-billed cuckoo	A	Gray catbird	A	Painted bunting	A
Burrowing owl	A	Northern mockingbird	B	Dickcissel	A
Long-eared owl	B	Cedar waxwing	B	Rufous-sided towhee	B
Short-eared owl	B	Loggerhead shrike	B	Chipping sparrow	A
Common nighthawk	A	White-eyed vireo	A	Clay-colored sparrow	A
Chuck-will's-widow	A	Bell's vireo	A	Vesper sparrow	B
Whip-poor-will	A	Solitary vireo	A	Lark sparrow	A
Chimney swift	A	Yellow-throated vireo	A	Lark bunting	A
Ruby-throated hummingbird	A	Warbling vireo	A	Savannah sparrow	B
Belted kingfisher	B	Red-eyed vireo	A	Grasshopper sparrow	A
Yellow-bellied sapsucker	B	Bachman's warbler	A	Song sparrow	B
Red-naped sapsucker	B	Blue-winged warbler	A	Swamp sparrow	B
Northern flicker	B	Golden-winged warbler	A	Bobolink	A
Eastern wood-pewee	A	Northern parula	A	Red-winged blackbird	B
Acadian flycatcher	A	Yellow warbler	A	Eastern meadowlark	B
Alder flycatcher	A	Chestnut-sided warbler	A	Western meadowlark	B
Willow flycatcher	A	Magnolia warbler	A	Yellow-headed blackbird	A
Least flycatcher	A	Black-throated blue warbler	A	Brewer's blackbird	B
Eastern phoebe	B	Black-throated green warbler	A	Brown-headed cowbird	B
Great crested flycatcher	A	Blackburnian warbler	A	Orchard oriole	A
Western kingbird	A	Yellow-throated warbler	A	Northern oriole	A
Eastern kingbird	A	Prairie warbler	A	Purple finch	B
Gray kingbird	D	Cerulean warbler	A	Pine siskin	B
Scissor-tailed flycatcher	A	Black-and-white warbler	A	American goldfinch	B
Horned lark	B	American redstart	A		

Appendix 2.—*Trends in abundance of forest birds, based on the Breeding Bird Survey for years 1966-1994*[1], *for four states in the Central Hardwood Region.*

Species	ILLINOIS			INDIANA			MISSOURI			OHIO		
	Trend[2]	# Rts[3]	No/Rt[4]	Trend	# Rts	No/Rt	Trend	# Rts	No/Rt	Trend	# Rts	No/Rt
Turkey vulture	1.5	22	0.37	2.2	28	1.63	4.8***	40	2.18	4.70**	56	2.41
Wild turkey							11.5	24	0.49			
Cooper's hawk										3.2	21	0.06
Red-tailed hawk	7.7**	65	0.70	8.5***	39	0.76	-1.0	45	1.08	3.1	57	0.71
Mourning dove	-0.2	80	33.42	-0.1	44	46.82	-2.7***	45	38.91	0.6	69	36.63
Black-billed cuckoo	-2.1	33	0.24	-2.6	23	0.22				-6.7*	32	0.26
Yellow-billed cuckoo	-3.4***	73	3.74	-2.8**	41	2.92	-0.4	45	10.15	-3.0***	53	1.09
Great horned owl	7.7	33	0.15	9.0*	18	0.15	-1.4	25	0.45			
Barred owl	-5.0	14	0.08				4.7	18	0.12			
Chuck-will's-widow							0.7	25	1.23			
Whip-poor-will	-16.1**	16	0.25				-0.8	32	1.40			
Chimney swift	-1.7***	77	14.52	-1.6*	43	12.72	-0.9	45	9.30	-0.4	68	15.24
Ruby-throated hummingbird	-2.0	28	0.25	0.5	26	0.50	-5.7	29	0.51	2.5	42	0.38
Red-headed woodpecker	-1.4*	75	5.25	-2.8***	42	3.24	-0.3	44	6.04	-5.3***	49	1.10
Red-bellied woodpecker	1.4	69	3.88	-0.2	43	5.00	-0.7	44	7.14	0.8	61	2.44
Downy woodpecker	1.0	64	1.47	-0.8	43	2.34	0.6	45	2.54	0.4	64	1.79
Hairy woodpecker	2.6	32	0.17	-0.3	25	0.25	-2.8	35	0.41	-6.5*	33	0.15
Northern flicker	-2.8***	77	3.26	-2.2***	44	4.10	-1.3*	45	3.33	-3.2***	66	3.17
Pileated woodpecker	7.2*	15	0.22	1.8	16	0.65	-1.0	27	0.91	2.3*	30	0.61
Eastern wood-pewee	-0.7	75	2.46	-0.6	40	5.17	-1.8	44	6.13	-1.8***	66	3.76
Acadian flycatcher	-2.9	24	0.52	-1.5	26	1.83	2.4	21	0.37	-1.4	42	2.11
Eastern phoebe	4.8***	59	0.64	2.7**	30	0.88	3.2**	44	3.45	-0.3	53	1.77
Great crested flycatcher	-1.4**	70	1.95	-0.3	41	2.33	-1.0	45	4.94	-2.8***	64	1.65
Blue jay	-0.9	80	9.75	-0.2	44	9.44	-0.5	45	17.02	0.8	69	8.92
Black-capped chickadee	3.1***	39	1.20				0.0	26	2.96	3.8***	14	1.37
Carolina chickadee	-0.5	22	0.79	0.0	33	2.15	-0.7	22	3.91	1.8***	45	2.13
Tufted titmouse	1.6*	68	4.12	1.7**	44	8.60	-0.8	45	11.30	-1.2*	69	8.71
White-breasted nuthatch	5.0***	51	0.89	0.8	42	1.84	3.1***	39	2.87	2.8	63	1.21

Appendix 2. Continued.

Species	ILLINOIS			INDIANA			MISSOURI			OHIO		
	Trend	# Rts	No/Rt	Trend	# Rts	No/Rt	Trend	# Rts	No/Rt	Trend	# Rts	No/Rt
Carolina wren	5.1*	42	1.77	6.7***	34	2.78	0.6	36	2.15	-1.0	56	2.51
Bewick's wren							-2.5	23	1.04			
House wren	1.6**	72	6.24	2.8***	42	7.08	-2.0***	42	4.91	2.9***	67	9.62
Blue-gray gnatcatcher	5.9	34	0.80	0.7	26	1.24	-0.2	36	3.85	-0.5	44	1.79
Wood thrush	-1.5	50	0.93	-1.5**	42	3.37	-1.5	29	1.38	1.4*	63	5.96
American robin	3.2***	80	51.61	3.0***	44	59.85	2.3***	45	32.58	3.6***	69	60.51
Gray catbird	1.5**	74	3.53	1.2**	44	6.26	-2.2**	45	2.94	1.4***	69	7.11
Northern mockingbird	-3.4***	61	4.48	1.8	37	4.44	-3.0***	45	10.39	0.9	47	3.17
Brown thrasher	-0.7*	80	6.16	-0.7	44	4.51	-1.6***	45	8.94	-1.4*	64	2.64
Cedar waxwing	14.3***	55	1.46	7.8***	40	3.00				2.1	58	3.99
White-eyed vireo	-0.9	24	0.96	0.6	25	1.29	0.5	26	1.68	2.8**	40	1.71
Bell's vireo	-3.7	22	0.16				-3.2	22	0.58			
Yellow-throated vireo	4.2	27	0.27	0.7	27	0.99	-2.1	27	0.37	0.00	49	1.03
Warbling vireo	1.2	68	2.01	0.6	43	3.95	1.0	38	1.41	-3.00**	58	1.81
Red-eyed vireo	-2.7**	53	0.61	0.2	39	3.81	2.4	34	3.20	1.2**	66	6.43
Blue-winged warbler										-0.8	32	0.94
Northern parula	6.7**	16	0.19				0.3	33	1.24			
Yellow warbler	6.1***	49	0.54	2.4**	39	2.09				0.2	64	5.16
Yellow-throated warbler				4.8***	14	0.48				-1.5	17	0.30
Prairie warbler							-6.3	14	0.97	-1.2	24	3.15
Cerulean warbler										-4.8***	30	0.47
Black-&-white warbler							2.6	18	0.15			
American redstart										-3.6*	23	0.73
Ovenbird										0.2	25	1.84
Louisiana waterthrush							3.8	14	0.12			
Prothonotary warbler	1.2	14	0.09									
Kentucky warbler	-2.8	14	0.29	1.1	14	1.56	3.6**	29	0.95	0.00	23	0.97
Common yellowthroat	-0.4	77	9.75	-0.6	43	14.72	-0.7	45	9.89	1.4**	69	10.94

Appendix 2. Continued.

Species	ILLINOIS			INDIANA			MISSOURI			OHIO		
	Trend	# Rts	No/Rt	Trend	# Rts	No/Rt	Trend	# Rts	No/Rt	Trend	# Rts	No/Rt
Hooded warbler										3.7	20	0.74
Yellow-breasted chat	-4.1***	44	1.65	-1.9**	33	3.54	-0.8	39	4.69	-2.8***	45	3.68
Summer tanager	-3.5	15	0.34	-2.1*	15	0.91	0.2	37	3.02	0.4	20	0.34
Scarlet tanager	-1.5	30	0.22	2.7**	33	1.31	8.5	20	0.33	1.2	50	1.87
Northern cardinal	1.0	80	18.83	0.1	44	24.43	-1.1**	45	29.05	1.2**	69	22.53
Rose-breasted grosbeak	3.3***	53	1.53	1.9	21	0.44	0.4	24	1.63	-1.6	26	0.73
Blue grosbeak	1.6	16	0.33				1.0	40	3.59			
Indigo bunting	-0.8*	80	21.96	-1.6***	44	34.20	-0.1	45	25.24	1.1***	69	19.06
Rufous-sided towhee	-0.8	60	1.53	0.4	38	3.24	-2.0*	42	4.84	-1.4**	62	3.97
Chipping sparrow	0.4***	75	5.04	2.8**	44	10.45	-0.5	41	3.66	1.8**	69	11.95
Brown-headed cowbird	2.1**	80	13.27	0.3	44	12.49	0.2	45	24.92	-2.1***	69	9.62
Orchard oriole	-8.9	48	0.97	-0.1	36	1.69	-0.6	44	2.92	0.8	41	0.45
Northern oriole	1.1	74	2.97	1.8*	43	2.96	0.1	41	3.57	1.2	64	2.61

[1]Provided by Bruce G. Peterjohn, National Biological Service, Patuxent Environmental Science Center, Laurel, Maryland

[2]Percent annual change. Asterisk indicate statistical significance; ***,0.01; **, 0.05; *, 0.1.

[3]Sample size for trend analysis.

[4]Mean number of birds per BBS route