THREATS TO BREEDING NEOTROPICAL MIGRATORY BIRDS IN THE MIDWEST

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ABSTRACT.—Neotropical migrants face threats throughout their complex life cycles. This review focuses on threats to breeding neotropical migratory birds (NTMBs) with emphasis on studies conducted in the Midwest. The two primary threats appear to be habitat fragmentation and habitat loss, which are usually closely associated with each other. Midwestern studies have overwhelmingly shown that many NTMBs of forests and grasslands are area-sensitive and prone to reproductive failure in small, edge-dominated habitat patches. Cowbird parasitism is often identified as the chief cause of reproductive failure, but nest predation may be just as important. Fragmented landscapes appear to serve as population "sinks" for many species that are only being maintained by immigration from "source" populations in large, unfragmented habitat tracts. Direct evidence for source/sink metapopulations, however, is lacking. Habitat loss has been most acute for floodplain forest, grasslands, and savanna habitats, all of which should to be the focus of restoration efforts. Changes in habitat structure and composition resulting from a lack of natural disturbances may threaten some of the Midwest's highest-priority species. Other threats such as global warming, drought, loss of stopover and winter habitat, and decreasing food supply either have not yet been well documented or are largely outside the control of land managers in the Midwest.

An approach that potentially reduces most of the major threats to breeding NTMBs in primarily agricultural landscapes is to conserve and restore large tracts. When combined with effective management (e.g., edge reduction) of networks of smaller tracts, macrosites might help maintain regional populations of NTMBs by providing "source" habitat where reproductive success is high enough to produce a surplus. In primarily (>80 percent cover) forested or grassland landscapes, managers should be most concerned with maintaining a representative mix of habitat types.

INTRODUCTION

Neotropical migratory birds (NTMBs) have become the focus of the largest international conservation effort ever for nongame wildlife that is not yet endangered (Terborgh 1989, Hagan and Johnston 1992, Finch and Stangel 1993, Martin and Finch 1995). NTMBs are an extremely diverse group of more than 250 species that occupy virtually every terrestrial habitat in North America. In some forest communities, NTMBs form up to 90 percent of the breeding bird community (Terborgh 1989). The insects consumed by NTMBs may play a role in maintaining forest health (Marquis and Whelan 1994). Neotropical migrants are being used increasingly as indicators of ecosystem health and examples of the need to manage on a larger spatial scale than previously recognized (Maurer 1993, Villard and Maurer 1996). The "Partners in Flight" program (Finch and Stangel 1993) has become a model of the kinds of interagency cooperation and coordination that will be necessary to address ecosystem-level and global conservation issues.

Conservation of NTMBs, however, is a very complex task because their life cycle makes

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them vulnerable to loss of habitat on geographically widely separated breeding, wintering, and migratory stopover habitats (Martin and Finch 1995). Although there is a growing consensus that NTMBs face significant threats throughout the year (reviewed in Askins *et al.* 1990; Finch 1991; Sherry and Holmes 1993, 1995; Robinson 1993), some have argued that threats on the winter grounds are more likely to limit populations than those on the breeding grounds (e.g., Rappole and McDonald 1994, Rappole 1995). The American Midwest, however, has historically provided abundant evidence that loss and fragmentation of breeding habitat poses a severe threat to many species (see table 1). Indeed, many of the studies listed in table 1 formed part of the scientific platform on which the Partners in Flight program was based (Finch 1991). Since the publication of these studies, our knowledge has expanded greatly. A new generation of studies have been completed and we are increasingly able to offer more useful and scientifically rigorous management recommendations (Faaborg *et al.* 1993, 1995; various papers in Martin and Finch 1995 and Maurer and Villard 1996), which is the primary emphasis of most chapters in this book. As will become clear from this paper, however, we still have a great deal to learn about NTMBs and how best to conserve them. Managers must remember that our understanding of basic NTMB population biology is still in its infancy. Any recommendations we make now may have to be modified later as we obtain more data, conduct more experiments, and, above all, have had a chance to monitor impacts of management activities over the long run.

The purpose of this paper is to provide an overview of threats faced by NTMBs with a focus on those most relevant to the Midwest. I have divided these threats into three general categories, each of which has several related sub-issues. The first threat is habitat fragmentation, which I define as the disruption in the continuity of a habitat (Lord and Norton 1990). This definition includes the more extreme case of insularization of habitat patches by agricultural or residential land use and the subtler fragmentation that can occur when human activities such as logging create a mosaic of successional stages within a tract. The second general threat is habitat loss, which usually accompanies habitat fragmentation but is often targeted at specific habitats such as grasslands or floodplain forest. The third general threat is changes in habitat structure and composition, which can result in the loss of species that require particular microhabitats. There are other potential threats such as global climate change (Root and Schneider 1995, Rotenberry *et al.* 1995), but we currently know little about them and I mention them only briefly at the end of the paper. Additional threats posed by tropical deforestation may be very important for some species (e.g., cerulean warbler: Robbins *et al.* 1992; reviewed in Petit *et al.* 1993, Rappole and McDonald 1994, Rappole 1995), but are mostly beyond our ability to affect here in the Midwest (Faaborg *et al.* 1996). Throughout this paper I will cite mostly studies that were conducted in the American Midwest; for more geographically comprehensive reviews, see Askins *et al.* (1990), Askins (1993), Finch (1991), Faaborg *et al.* (1993), Robinson (1993), Robinson and Wilcove (1994), Wilcove and Robinson (1990), and Sherry and Holmes (1993, 1995).

THREATS RELATED TO HABITAT FRAGMENTATION

The Midwest has long provided some of the most robust data demonstrating the severe threat posed by habitat fragmentation (table 1). In this section, I review the major ways in which neotropical migrants are threatened by habitat fragmentation.

Area-sensitivity is the absence of a species from woodlots below a certain size even if suitable habitat is present. Area-sensitivity has been well documented in the Midwest, largely because of the abundance of discrete habitat "islands" in agricultural landscapes (e.g., Bond 1957; Howe 1979, 1984; Ambuel and Temple 1983; Kendeigh 1982; Hayden *et al.* 1985; Howe *et al.* 1985; Blake and Karr 1994, 1987; Herkert 1994a,b). Freemark and Collins (1992) found that area-sensitivity was more pronounced in Illinois than in the more extensive forests of Ontario. Nevertheless, small (10-100 ha) isolated forest tracts in central Illinois often contain many, if not most forest birds as long as there is at least one major ravine system present (Blake and Karr 1984, 1987; Robinson 1988, 1992). Even some forest raptors occupy small tracts in Illinois (Robinson 1991). Area-sensitivity is most pronounced when very small (<10 ha) woodlots are included in the analysis (e.g.,

Table 1.—*Selected Midwestern references relating to NTMBs in chronological order*

Paper (Year)	Summary
Bond (1957)	Area-sensitivity (see also Ambuel and Temple 1983) and habitat requirements of forest birds
Graber and Graber (1963)	Adaptability of many birds to early agricultural landscapes
Faaborg (1980)	Fallacy of managing for local diversity at the expense of regional diversity by promoting habitat heterogeneity (see also Robinson 1988, Reese and Ratti 1988)
Kendeigh (1982)	One of the longest-term censuses ever conducted (see also Brawn and Robinson 1996)
Brittingham and Temple (1983)	Edge effects on cowbird parasitism and link with declining neotropical migrants
Blake and Karr (1984, 1987)	Area-sensitivity in birds of forested islands, see also Hayden *et al.* (1985) and Howe (1984)
Temple and Cary (1988)	Edge effects on parasitism and predation; landscape model
Gibbs and Faaborg (1990)	First paper establishing a link between pairing success and fragmentation
Johnson and Temple (1990)	First paper showing that grassland fragmentation was similar to forest fragmentation in its effects on breeding birds
Robinson (1992)	Extreme effects of fragmentation on nesting success (see also Bollinger and Linder 1994)
Herkert *et al.* (1993)	First management manual for NTMBs of forests and grasslands
Thompson (1993)	Simulated potential impacts from edge effects and habitat composition resulting from timber harvest
Herkert (1994a,b)	Area-sensitivity and habitat requirements of grassland birds
Thompson (1994)	Movement and habitat use patterns of brown-headed cowbirds
Robinson *et al.* (1995a)	Landscape-level scale of fragmentation
Donovan *et al.* (1995a,b)	Modeled source-sink demography in Midwestern populations

Blake and Karr 1987). Area-sensitivity therefore appears to be more extreme in Missouri than it is in Illinois, perhaps a reflection of the lack of alternative larger tracts in Illinois. There are, however, relatively more residents and short-distance migrants in small woodlots (Blake 1983) and the NTMBs in small woodlots are a fairly consistent subset of those present in larger woodlots (Blake 1991). Area-sensitivity is only a threat if birds avoid small woodlots where they could breed successfully. If small woodlots are poor habitat, however, then avoiding small woodlots many be adaptive (see below).

Cowbird parasitism is perhaps the best-documented threat to breeding NTMBs in midwestern woodlots (Brittingham and Temple 1983; Robinson *et al.* 1995a, in press; Thompson *et al.*, in press). For many forest species in the Midwest, levels of parasitism are positively related to levels of forest fragmentation (fig. 1). Cowbird parasitism is related to fragmentation because cowbirds do not feed in most forest or natural grassland habitats (reviewed in Robinson *et al.* 1993, 1995b). Instead, they feed in pastures, row crops, and lawns and commute up to 7 km to areas where they search for nests to parasitize (Thompson 1994; Thompson and Dijak, in press). In Illinois, cowbirds feed in row crops as well as pastures (Thompson and Dijak, in press), which may explain why they are more abundant in some Illinois landscapes than in Missouri landscapes (Thompson 1994; Thompson *et al.*, in press). Landscapes fragmented by agricultural land uses in the Midwest therefore provide ideal conditions for cowbirds, and woodlots in the agricultural Midwest have some of the highest parasitism levels ever documented (Robinson 1992; Robinson *et al.* 1995a,b; Brawn and Robinson 1996; Thompson *et al.*, in press). The ratio of cowbird to host abundance in fixed-radius point counts has proven to be a good predictor of community-wide parasitism levels for forest songbirds in the Midwest (Robinson *et al.*, in press; Thompson *et al.*, in press). Management recommendations to reduce cowbird parasitism have been described in Robinson *et al.* (1993).

Nevertheless, cowbird parasitism is far from a universal problem in the Midwest. The large forest tracts of the Missouri Ozarks and northern Wisconsin have insignificant levels of parasitism (Robinson *et al.* 1995a; Thompson *et al.*, in press; Donovan *et al.* 1995a) and in south-central Indiana, only a few species (e.g., red-eyed vireo and hooded warbler) sustain the kinds of parasitism levels that are likely to create population-level problems for these species (Winslow *et al.*, in press; Thompson *et al.*, in press). Similarly, cowbird parasitism appears not to be much of a problem for grassland birds in Illinois (Kendeigh 1941; Robinson *et al.*, in press), although it may be a more severe problem in Kansas (Elliott 1978) and the northern Great Plains (Koford *et al.*, in press; Davis and Sealy, in press). Edge/second-growth species are also less heavily parasitized than forest species, at least in some areas (Robinson *et al.*, in press). Large-scale reduction of cowbird populations (a difficult task at best: Rothstein *et al.* 1987, Robinson *et al.* 1993) therefore may have little impact on populations of most NTMBs (see also Rothstein and Robinson 1994, Robinson *et al.* 1995b). Local cowbird trapping, however, may be desireable to enhance populations of endangered species (e.g., Kirtland's warbler: reviewed in Robinson *et al.* 1993, 1995b) and to increase productivity in "macrosites" (see below) in landscapes where it is impossible to preserve or restore tracts that are large enough to be free of intense cowbird parasitism (Robinson *et al.* 1995a).

Nest predation also appears to be most severe in fragmented forest landscapes, although the effect is not as pronounced as it is with parasitism (Robinson *et al.* 1995a) (fig. 1). As with parasitism, however, there is much interspecific and inter-habitat variation in levels of nest predation (Robinson *et al.* 1995a). The tremendous diversity of nest predators makes reducing nest predation a complex task (Reitsma *et al.* 1990). Studies of the behavior of key nest predators (e.g., black rat snakes *(Elaphe obsoleta)*: Durner and Gates 1993, Withgott 1995) and of the relative abundances of nest predators in tracts of different sizes will help managers determine how to reduce predation to "acceptable" levels (which have yet to be determined: Martin 1992).

Edge effects.—Studies in the Midwest have provided some of the most widely cited examples of negative effects of edge on nesting success. Levels of nest predation (e.g., Temple and Cary 1988, Johnson and Temple 1990, Burger *et al.* 1994) and cowbird parasitism (Brittingham and Temple 1983, Temple and Cary 1988, Johnson and Temple 1990) have

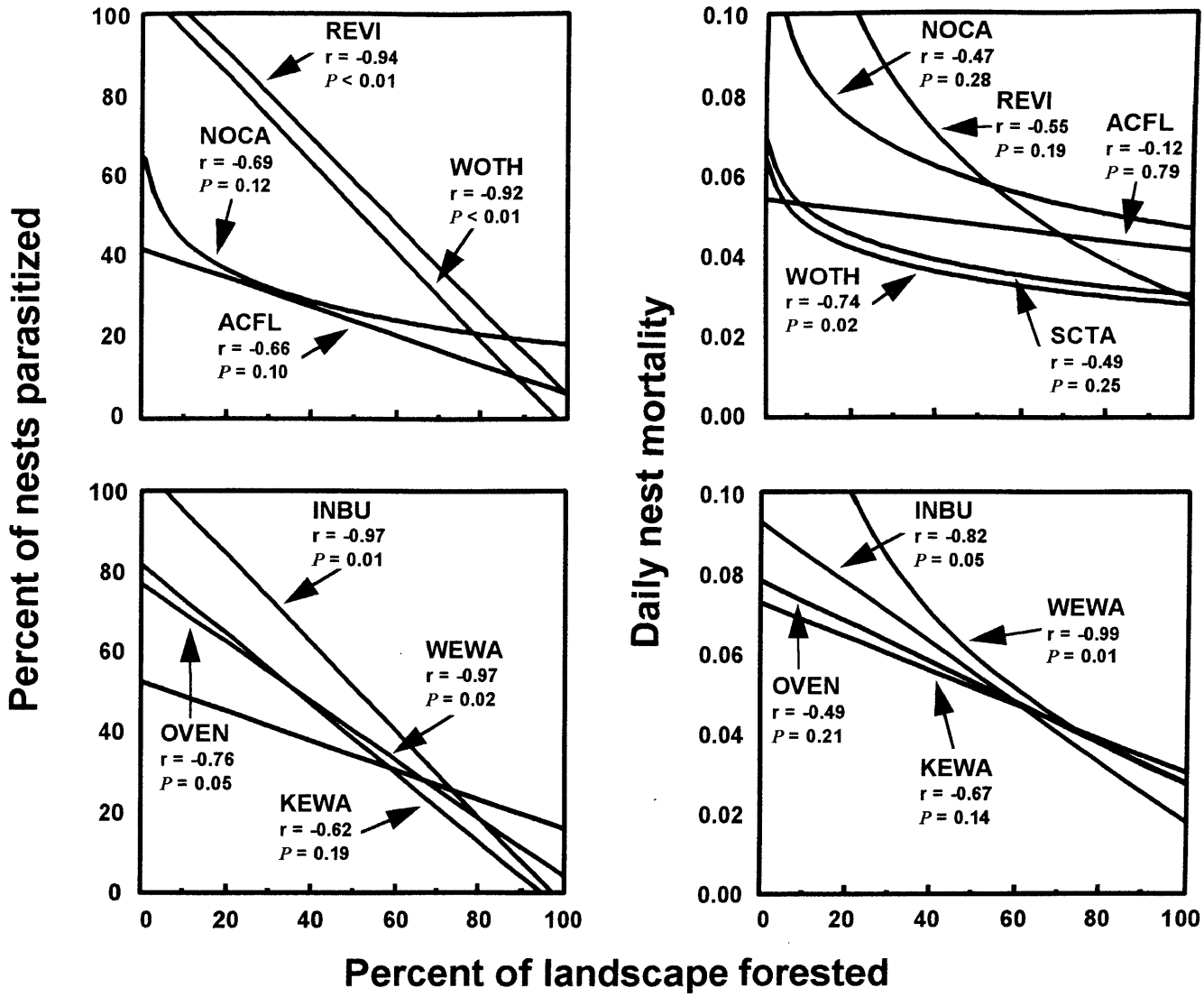

Figure 1.—*Correlations between levels of brood parasitism and nest predation with the percent of forest cover in nine Midwestern landscapes. Abbreviations are: ACFL, Acadian flycatcher; INBU, Indigo bunting; KEWA, Kentucky warbler; NOCA, Northern cardinal; OVEN, ovenbird; REVI, red-eyed vireo; SCTA, scarlet tanager; WEWA, worm-eating warbler; WOTH, wood thrush. Adapted from Robinson* et al. *(1995).*

been shown to be higher near edges. Cowbirds are also more abundant near clearcut edges in some landscapes (Thompson *et al.* 1992), but not in others (Winslow *et al.*, in press). Mating success of ovenbirds is also lower near edges (Gibbs and Faaborg 1990, Van Horn *et al.* 1995). Even trails may attract nest predators and parasites (Hickman 1990). Other studies that showed only weak or no edge effects were conducted in landscapes where nesting success is low everywhere and there may be no true habitat interiors (Robinson and Wilcove 1994; Thompson *et al.*, in press). In such habitats, cowbird and nest predator populations appear to saturate the available forests (Marini *et al.* 1995, Heske 1995). Even in severely fragmented forests, however, some edges (e.g., powerline corridors, campgrounds) are associated with increased levels of nest predation and parasitism (Robinson, unpubl. data). A particularly promising line of investigation will be to compare edge effects in different kinds of landscapes. Effects of edges created by logging, for example, may be most apparent in primarily forested rather than in mostly agricultural landscapes (Thompson *et al.* 1992; Winslow *et al.*, in press). Studies of the effects of different kinds of edges on birds would also be useful to managers (Ratti and Reese 1988). While edge-related declines in reproductive success have

been reported, no field studies have demonstrated their impact on populations (though they have simulated, Temple and Cary 1988, Thompson 1993).

Habitat heterogeneity.—The pronounced area-sensitivity of many NTMBs and other edge-related problems with nesting success have led some researchers to question the value of managing to promote habitat heterogeneity at the expense of large, contiguous tracts (Faaborg 1980, Reese and Ratti 1988, Robinson 1988). The kinds of management practices used to promote populations of some game animals may have detrimental effects on habitat specialists. Heterogeneity is needed at some (large) spatial scale, however, to meet the diverse habitat needs of NTMBs. Landscapes that consist of a mosaic of small (<5-ha) habitat patches are often dominated by habitat generalists and may lack habitat-interior specialists. A productive area for future research would be to develop management practices for areas managed for hunting that increase the value of these areas for NTMBs, without negatively affecting game populations (or perhaps even increasing them).

An important consideration for managers is that NTMBs have diverse habitat requirements. Even within a tract, what is productive habitat for one NTMB may be unproductive for another. Kentucky warblers for example appear to nest most successfully in older forests along streamsides and least successfully in evenage clearcuts and tree plantations (Morse 1996). Worm-eating warblers, on the other hand, nest equally successfully in older (>15-year) clearcuts as they do in older (>80-year) forests (Robinson, unpubl. data). Both species, however, respond well to selective logging (Robinson and Robinson, unpubl. data). On a regional spatial scale, managers need to ensure that a mixture of forest types and successional stages are available to maintain habitats for all NTMBs typical of that region. In mostly forested landscapes, this regional heterogeneity can be maintained by a mix of silvicultural practices (Thompson *et al.* 1996). In mostly agricultural landscapes where forest cover is limited, management practices should emphasize maintaining and enhancing forest cover rather than maximizing local habitat heterogeneity. In these landscapes, selective logging may be preferable to even-aged forest management (Thompson *et al.* 1995).

Metapopulation dynamics.—The "source-sink" metaphor (Pulliam 1988) for population dynamics appears particularly applicable to midwestern landscapes. Small, isolated woodlots in primarily agricultural landscapes appear to be ecological "traps" (sensu Gates and Gysel 1978) that attract birds, but fail to provide the conditions necessary for successful nesting as a result of high levels of parasitism and predation (Robinson 1992; Trine *et al.*, in press; Donovan *et al.* 1995a,b). Populations in these habitats may act as drains on regional populations and are maintained by immigrants from elsewhere (the "rescue effect" of Brown and Kodric-Brown 1977). A potentially disturbing aspect of the rescue effect is that populations in woodlots with extremely low nesting success can appear to be stable over the long term (Brawn and Robinson 1996). Problems with inferring local population health may be particularly severe for NTMBs in which young rarely return to breed in their natal area. This uncoupling of local reproductive success and population dynamics may be unique to fragmented landscapes. Holmes *et al.* (1988) and Sherry and Holmes (1992) found a strong correlation between reproductive success and population changes in subsequent years in the unfragmented forests of northern New England. Sink habitat, however, may not destabilize regional populations as long as adequate source habitat remains (Howe *et al.* 1991).

The results of Robinson *et al.* (1995a) suggest that a few key large forest tracts may be sustaining forest bird populations in most of the Midwest. Although we are a long way from being able to prove that this is the case, a prudent conservation strategy would be to preserve these large forest tracts. Because national forests form the core of most large tracts in the Midwest (see Thompson *et al.* 1996), any change in ownership could have a detrimental effect on regional populations if it results in increasing agricultural, residential, and recreational development.

Promising areas for future research include determining how much parasitism and predation key NTMBs can tolerate before source populations become sinks (the source-sink threshold of Pulliam 1988). Species may vary greatly in their vulnerability to cowbird parasitism (e.g., May and Robinson 1985). Donovan *et al.* (1996) provide examples of the kinds of data needed for source/sink analyses

(see also Donovan1995). As we obtain better demographic data, we will also be able to improve our estimates of the amount of source habitat necessary to balance sink habitats.

HABITAT LOSS

Most of the chapters in this book deal with the consequences of the loss of various key midwestern habitats. Virtually all native habitats in the Midwest have undergone drastic reductions since pre-settlement times. In the following section, I briefly review the key threats posed by habitat loss and refer the readers to the more detailed discussions in the following chapters.

Loss of floodplain forest has been particularly severe in the Midwest (Pashley and Barrow 1993, Knutson *et al.* 1996). To help reverse this trend, the Nature Conservancy, U.S. Fish and Wildlife Service, and Illinois Department of Natural Resources have formed a coalition to restore 60,000 acres of the Cache River wetlands in southern Illinois. Such projects may be necessary if we are to regain functioning floodplain forests of sufficient size to contain area-sensitive species and those that require natural disturbances (see below). Floodplain forest is especially important for Swainson's warbler (Eddleman 1978, Eddleman *et al.* 1980), Mississippi kites (Evans 1981), cerulean warblers (Robbins *et al.* 1992, Vanderah 1995), and red-shouldered hawks (Bednarz and Dinsmore 1981, Hands *et al.* 1989a), all of which are area-sensitive and at least locally endangered and a high regional priority (Thompson *et al.* 1993).

Central Hardwoods forests form the largest remaining tracts of native wildlife habitat remaining in the lower Midwest (Thompson *et al.* 1996). Their management is particularly crucial because of their economic importance. The Missouri Ozark Forest Ecosystem Project (Kurzejeski *et al.* 1994) promises to provide major insights into the effects of silvicultural practices on NTMBs (see also Thompson *et al.* 1995). Fragmentation by agricultural development is already known to pose a severe threat to NTMBs (Robinson *et al.* 1995a). Determining the extent to which silvicultural practices fragment the Central Hardwoods forest or provides needed habitat diversity remains a top research priority (Thompson 1993, Thompson *et al.* 1996, Annand and Thompson 1997). Because large, unfragmented tracts of Central Hardwoods forest already exist, the major threat to this ecosystem would be from changes in land ownership or management that might cause fragmentation of currently contiguous tracts.

Savanna/burned forests and barrens have also been reduced by a century of strict control of fires (Thompson *et al.* 1996). We know little about the dependence of NTMBs on burning except to say that many bird species of open, savanna-like habitats have also adapted well to human-modified habitats (Rotenberry *et al.* 1993, 1995; Robinson 1994; Brawn 1994). The Bachman's sparrow (not a NTMB) is perhaps the most notable exception because it appears to require large barrens and glades (Chambers 1994).

Grasslands have undergone perhaps the most severe reduction of any midwestern habitat (Herkert 1991, 1994a,b; Samson 1980; Johnson 1996; Herkert 1996). In addition, many surrogate grasslands such as hayfields and CRP fields are now being managed in such a way that successful nesting is often impossible (Bollinger and Gavin 1992; Herkert 1994a,b). Given their sensitivity to both area (Samson 1980; Herkert 1994a,b) and management practices, it is not surprising that grassland birds have declined dramatically (reviewed in Herkert 1991). Reversing these population declines is a top priority for the Midwest (even though many species are not NTMBs). Major restoration efforts such as the proposed Midewin Tallgrass Prairie near Chicago may be necessary to help grassland bird populations.

Northern Hardwood/Conifer Forests still exist in large tracts in the upper Midwest (Howe *et al.* 1996). As with Central Hardwoods ecosystems, the primary potential threats come from silvicultural practices and any changes in land ownership that might open up large, contiguous tracts to agricultural and residential development. The shift from late successional (spruce) to early successional (aspen-dominated) plant communities created by silvicultural activities likely has had a major impact on bird communities as well.

Agricultural landscapes formerly provided rich habitats for many species of NTMBs (Graber and Graber 1963), but are now being managed so intensively for row crops that they have little value for birds (Paruk 1990; Warner

1994; Rodenhouse *et al.* 1993, 1995; Koford and Best 1996). Creative use of government subsidies (e.g., using them to make larger habitat patches and delaying hay harvesting) may offer the best short-term hope for improving agricultural landscapes for NTMBs (Rodenhouse *et al.* 1992, Freemark *et al.* 1995). Agricultural practices may also expose birds to potentially hazardous pesticides and other environmental contaminants (Gard and Hooper 1995).

HABITAT STRUCTURE AND COMPOSITION

In addition to outright habitat loss described in the previous section, changes in habitat structure and composition pose significant threats to NTMBs. Below, I review some of the ways that changes in vegetation structure and composition can threaten populations of NTMBs.

Loss of oaks.—In the absence of fire, it is very likely that the relative importance of oaks will decline as they are replaced by late-successional, shade-tolerant species (Abrams 1992; Thompson *et al.* 1996). Although there are few data on use of particular tree species by NTMBs, a loss of oaks may negatively affect cerulean warblers (Robbins *et al.* 1992, Vanderah 1985) and result in a general deterioration of foraging conditions for some spring migrants (Graber and Graber 1983, Moore *et al.* 1993). Managing some areas to retain oak dominance (especially white oaks) seems like a prudent conservation strategy. Loss of oaks killed during impending gypsy moth invasions may add to the problems faced by oak-dependent wildlife. A productive area for future research is the potential role of birds in controlling levels of folivorous insects that might otherwise decrease forest health and change forest composition (Marquis and Whelan 1994, Whelan *et al.* 1989). Unfortunately, birds appear to have little impact on gypsy moth outbreaks (Smith 1985).

Loss of other tree species.—At least a few species appear to select nesting habitats based on particular tree species (Kahl *et al.* 1985, Mossman and Lange 1982, Robbins *et al.* 1992, Vanderah 1995). Continued loss of sycamores as a result of disease, for example, may negatively affect cerulean warblers (Vanderah 1985), northern parulas and yellow-throated warblers (Robinson, unpubl. data). Losses of dogwoods to anthracnose disease may reduce nesting substrate for species such as the wood thrush that routinely use them for nesting (S. Robinson, unpubl. data), and other species use their fruit during fall migration. More data are needed before we can make recommendations about how to manage tree species composition (Holmes and Schultz 1988).

Tree monocultures.—The replacement of diverse, mixed-species forests with planted monocultures (e.g., pines, walnuts, and sweetgum) has unpredictable effects on bird communities. Pine monocultures in Illinois and Indiana have greatly increased populations of pine and yellow-throated warblers in the state and provided nesting sites for Cooper's and sharp-shinned hawks in Missouri (Ehrlich and Drickamer 1993; Robinson, unpubl. data; Kritz 1989; D. Whitehead, pers. comm.). Pine plantations also contain significant populations of veeries, ovenbirds, hooded and Kentucky warblers, and summer tanagers in Illinois (Robinson, unpubl. data). White pine plantations in northern Illinois and Indiana have also been colonized by nesting populations of black-throated green warblers and brown creepers (Robinson, unpubl. data; D. Whitehead, pers. comm.). Pine plantations therefore appear to provide a surrogate habitat for many NTMBs. Cerulean warblers sometimes nest in black locust monocultures (Vanderah and Robinson, unpubl. data). There are few data, however, on nesting success of birds in plantations; Kentucky warblers suffer high parasitism and predation levels in a sweetgum plantation in southern Illinois (S. Morse, unpubl. data). Furthermore, it is possible that non-native plant communities may be ecological "traps" for extralimital breeders that ordinarily would nest further north or south. The use of plantations by NTMBs is clearly worth further study, especially in industrial forests.

Loss of understory.—Excess deer populations and (potentially) burning can result in a substantial reduction in the shrub layer (Thompson *et al.* 1996; Alverson *et al.* 1988). Species that require dense shrub layers such as Kentucky warblers (Wenny *et al.* 1993) may suffer increased nest predation as a result of reduced nest cover. Species preferring more open understories may benefit as a result (e.g., ovenbird: Wenny *et al.* 1993, Kahl *et al.* 1985).

Changes in plant species composition resulting from overbrowsing also may have longer-term negative consequences for canopy species. Deer management therefore may be critical to the long-term maintenance of NTMB populations.

Floodplain disturbance.—The scarcity of unconstrained, naturally meandering rivers in the Midwest may be creating long-term problems for several species. Natural disturbances along floodplains may have created the original habitat of many species (Zimmerman and Tatschl 1975, Rotenberry *et al.* 1993, Pashley and Barrow 1993), including cane-dependent Swainson's warblers (Eddleman *et al.* 1980) and Bachman's warblers (Remsen 1986, Hamel 1986). Cerulean warblers nest abundantly along natural levees in southern Illinois (Vanderah 1995) and prothonotary warblers show a strong preference for backwater habitats (J.P. Hoover, unpubl. data; Knutson *et al.* 1996). Red-shouldered hawks (Bednarz and Dinsmore 1981) and Mississippi kites (Evans 1981) also depend partly on openings in forest canopies created by large-scale disturbances. Managing for these species may require restoring natural floodplain dynamics (a difficult task) or mimicking natural disturbances (Rotenberry *et al.* 1993, 1995).

Shrubland/edge species.—Although many species that depend upon shrubland/edge habitats have benefited from human settlement of the Midwest (Johnston 1947, Karr 1968) some are now showing steep population declines (Askins 1993). Several species of special concern (listed in Thompson *et al.* 1993) in the Midwest (e.g., Bell's vireo: Hands *et al.* 1989b, golden-winged warbler: Hands *et al.* 1989b) depend on early successional habitats that are currently being created almost entirely by human land uses. Private, industrial forests and areas managed for game species may provide opportunities to manage for birds of early successional habitats that also require large tracts (e.g., prairie warbler: Nolan 1978, Annand and Thompson 1997). There also is a critical need for data on the effects of different *kinds* of edges on birds. Avoiding abrupt edges may increase nesting success of both forest birds (Ratti and Reese 1988) and edge-nesting birds (A. Suarez, K. Pfennig, and S.K. Robinson, submitted ms.). Similarly, natural, complex edges may provide better nesting habitat for some forest birds (e.g., Acadian flycatcher: L. Chapa and S.K. Robinson, unpubl. data).

Loss of old-growth forest.—Although the Midwest appears to lack an old-growth specialist such as the spotted owl, the cerulean warbler may depend in part on old-growth forests (Vanderah 1995). Pileated woodpeckers may also depend upon large trees (S. Robinson, pers. obs.) and the hooded warblers use treefall gaps in old-growth forests. A prudent conservation strategy in any managed landscape would be to maintain core areas of old-growth timber, especially in areas currently occupied by cerulean warblers. Natural disturbances characteristic of old-growth may also provide optimal nesting habitat for gap-dependent species (Noss 1991; Robinson, unpubl. data).

Exotic plant invasion.—The rapid encroachment of plants such as Japanese honeysuckle, buckthorn, and garlic mustard have as-yet undetermined effects on NTMBs. Certainly, many birds use these plant species for nest sites, but we do not yet know if nesting success is as high in non-native vegetation, or if foraging opportunities are as good.

Snag loss.—Any management activity that would reduce the density of snags could affect some NTMBs adversely, although only a few NTMBs nest in snags or use them as song perches. Snag management is made even more complicated because they are used frequently by cowbirds as perches, possibly to search for nests (Robinson *et al.* 1995b).

Mid-successional dynamics.—We know little about how bird community composition changes through the middle stages of succession. Even-aged forests of the White Mountains of New Hampshire appear to undergo a major peak of diversity and abundance in the 60-90 year range post-cutting (Holmes *et al.* 1986; R.T. Holmes, pers. comm.). If this proves to be a general result, then we may need a more complex mosaic of successional stages than previously assumed.

OTHER THREATS

Global climate change.—Climate change could have far-reaching consequences for midwestern birds, but we are not yet in a position to predict what they may be (Rotenberry *et al.* 1993, 1995; Root and Schneider 1995). The flexibility and broad geographic ranges of most breeding NTMBs, however, indicate that effects on breeding populations may be subtle.

Loss of stopover habitat.—The isolated woodlots of the agricultural Midwest and the coastal woodlots of the Great Lakes may be critical habitat for NTMBs during migration (Blake 1986; Moore and Simons 1992; Winker *et al.* 1992; Moore *et al.* 1993, 1995; Ewert and Hamas 1996). Maintenance of these habitat patches may be critical to more northerly breeding species (Moore *et al.* 1993). Acquisition of shoreline property on the Great Lakes is especially timely (D. Ewert, pers. comm.). Plant species composition of stopover sites is particularly likely to be a crucial management consideration (Graber and Graber 1983, Moore *et al.* 1993). Some stopover sites may fail to provide enough food for migrants to gain mass (Winker *et al.* 1992).

Loss of winter habitat.—Over the long run, some species may decline in the Midwest regardless of how well we manage our ecosystems (Terborgh 1989, Robbins *et al.* 1992, Petit *et al.* 1993, Faaborg *et al.* 1996). At present, however, we know too little about population regulation in any NTMBs to make the assumption that there is nothing we can do in the Midwest. Even the cerulean warbler, which is severely threatened on its eastern Andean wintering grounds (Robbins *et al.* 1992) is also threatened by forest fragmentation and cowbird parasitism on the breeding grounds (Robbins *et al.* 1992, Vanderah 1995).

Acid rain.—The extremely severe local population declines documented by the BBS may be at least partly caused by loss of spruce forests as a result of acid rain (James *et al.* 1996, James and McCulloch 1995). This problem is likely to be much less severe in the Midwest than in the East.

Food supply.—Conceivably, use of pesticides and fragmentation may be disrupting food supplies for many insectivorous birds (Gard *et al.* 1993, Gard and Hooper 1995). Preliminary data from Illinois fragments and other midwestern forests suggest that most nests that escape predation fledge most of the young that hatch, which indicates that food supplies may rarely be limiting (S. Robinson, unpubl. data; D. Whitehead, pers. comm.; J. Faaborg, pers. comm.). In contrast, in extensive forests in the Northeast, many species may be limited by food and some may even depend upon pulses of high productivity during outbreaks of defoliating caterpillars (Holmes *et al.* 1992). More studies over a greater range of geographical areas and climatic extremes would help determine the extent to which food supplies may be limiting.

Shiny Cowbirds.—Although it has not yet become abundant in the Midwest, the shiny cowbird may pose a new threat to many species (Robinson *et al.* 1995b). Shiny cowbirds regularly parasitize cavity-nesters, which could greatly expand the number of host species parasitized intensively.

Extreme Flooding.—The unprecedented 1993 midwestern floods killed many trees in the Mississippi floodplain but we know little about the effects on the bird communities. Additional flood events may further damage existing forests, but could also increase pressure to convert marginal farmland to wetland habitat that would be used extensively by NTMBs and other wildlife.

Drought.—There are several studies showing effects of drought on populations (e.g., Blake *et al.* 1992), productivity (DeSante *et al.* 1993), and community structure (Smith 1982). The drought of 1988 was associated with low population levels of forest birds in central Illinois (Robinson 1992), but we have no data on productivity during this period. Populations have largely recovered since the drought ended (Brawn and Robinson 1996), which suggests that effects of drought may be short-lived and therefore may not pose a long-term threat to NTMBs.

TRACT SIZE AND THE CONSERVATION OF MIGRANTS

Other papers in this symposium provide ecosystem-specific guidelines for conservation efforts in midwestern landscapes. One general approach to NTMB conservation that solves many, if not most of the problems identified in this review is to enlarge tract sizes and conserve existing large tracts (table 2). Very large habitat blocks (>25,000 acres) can meet the needs of all area-sensitive birds and are large enough to incorporate natural disturbances (Rotenberry *et al.* 1993). The intensive agricultural development in Illinois limits opportunities to conserve or restore tracts of this size, but several sites are reasonably large including the Cache River Bioreserve/Wetlands (60,000 acres) and the Prairie Parklands/Joliet Arsenal/Midewin Tallgrass Prairie site (43,500

Table 2.—*Threats reduced by emphasizing the management of large tracts ("macrosites").*

Threat	How the threat is reduced in large tracts
Cowbird parasitism	Fewer feeding opportunities, longer commuting distances, fewer edges
Nest predation	Reduced populations of some species subsidized by agricultural waste, fewer edges, more top predators to control medium-sized predators
Area sensitivity	Large enough to include all species, including raptors
Lack of natural disturbance	Large enough to manage for several kinds of disturbance simultaneously, possibly restore floodplain activities
Edge effects	Fewer edges, especially abrupt agricultural ones
Habitat heterogeneity	Opportunity to manage several large, contiguous habitat patches without too much local heterogeneity
Metapopulation collapse	Opportunity to create "source" habitat to recolonize nearby smaller tracts
Habitat loss	Opportunity to restore floodplain (e.g., Cache River Wetlands) and grassland (e.g., Prairie Parklands site)
Deer browse	Reduction of deer populations by natural predation, herd management, and distance from agricultural areas
Tree species composition	Opportunity to restore large areas of keystone plant species (e.g., white oaks)
Loss of old-growth	Opportunity to set aside "core" areas of old growth
Food supply	Isolation of core area from pesticides and other agrochemicals

acres). States such as Missouri, Indiana, Wisconsin, and Minnesota have the potential to preserve and restore much larger forest tracts.

How large tracts have to be to benefit NTMBs remains an open question. Robinson *et al.* (1995a) found substantial reductions in parasitism and predation levels in landscapes with an average tract size of 10,000-25,000 ha. Because forest cover covaried so closely with tract size, however, Robinson *et al.'s* (1995a) data cannot be used to identify tract sizes necessary to reduce parasitism and predation levels. Nor do we yet have firm targets for what levels of parasitism and predation are acceptable because of interspecific differences in tolerance of parasitism and predation (May and Robinson 1985, Martin 1992). As a general rule, daily nest predation rates of 4 percent or less and parasitism levels of 25 percent or less should give most NTMBs at least a chance of having self-sustaining populations (May and Robinson 1985; Donovan *et al.* 1995a,b; Trine *et al.*, in press). Clearly, however, we need better demographic data before we can set targets for minimum tract sizes. It is likely, however, that conservation strategies will have to be tailored to specific landscapes. What works best in agricultural landscapes may not be the best approach in mostly forested landscapes (Robinson *et al.* 1995). Enlarging tract size may be most crucial in agricultural landscapes. In contrast, managers in mostly forested landscapes should be

concerned primarily with maintaining a representative mix of forest types to meet the habitat requirements of all forest species native to the region.

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