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Breeding Birds and Forest Management: the Hardwood Ecosystem Experiment and the Central Hardwoods Region

Forestry has always focused on multiple objectives, including recreation, watershed health, fire protection, and wildlife habitat improvement. However, these objectives have often been secondary to economic goals. As a result, sustainable forestry initially focused mostly on the maintenance of a continuous supply of wood products.

Now, however, the focus of forest science is increasingly shifting to the management of forests as complex systems rather than as simple agricultural landscapes—with a much greater appreciation for interactive ecosystem processes. In addition, now for many forest landowners the ecological value of their land is at least as important as the economic return. It is, therefore, vital to understand how forest management affects not only timber production, but also the overall function of forested ecosystems.

This publication summarizes the effects of forest management on bird species in the Midwest based on data collected as part of the Hardwood Ecosystem Experiment (HEE) in southern Indiana and other studies. We hope this summary provides a basis for understanding interactions between forest management and forest birds as well as guidelines for bird-friendly forest management in Indiana.

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Forest Management

Forest management can have multiple objectives that are generally achieved by manipulating two main forest attributes: composition and structure. *Composition* is the relative proportion of different tree species in an area. Forest *structure*, which is more complicated, is the distribution of components of the forest (Oliver and Larson 1996), including the total number, general size, and description of the spread of trees across the landscape (Figure 1). Other components of structure include the number and distribution of standing dead trees (snags), decomposing wood on the forest floor, and distribution of foliage layers between the forest floor and the treetops.

It takes foresters many years of training to understand and predict the long-term impacts of forest management decisions (including decisions not to manage forests) on structure and composition. Forest structure changes when timber harvesting removes trees, reducing the total number and leaving trees that are, on average, smaller than those harvested. At the same time, the preference to harvest or regenerate certain tree species directly affects composition and influences long-term forest development (Box 1).

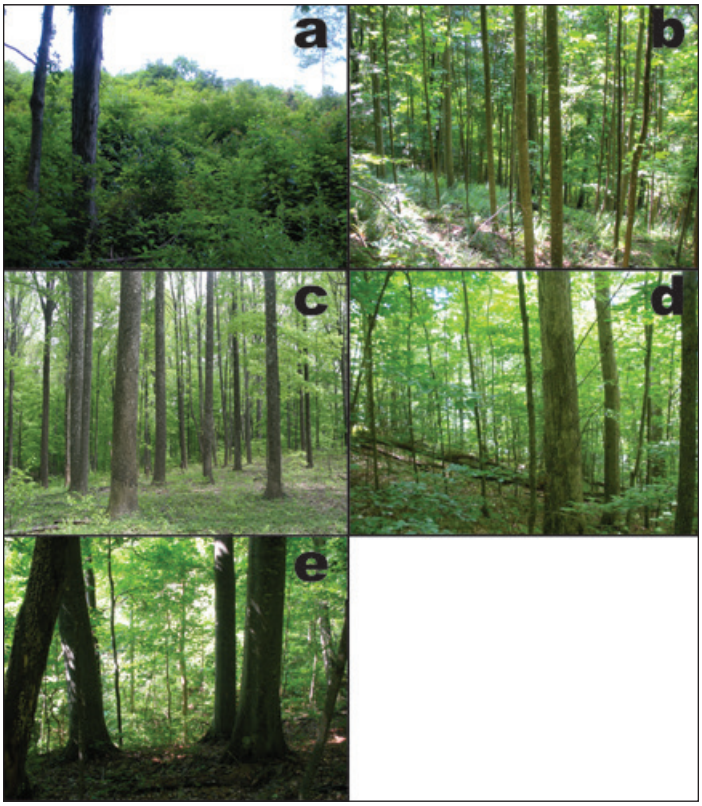


Figure 1. Structural characteristics of forests at different stages of development. The pictures represent a general progression from very young forest (**a**) to mature forest structure (**e**). Images **a-c** show structure characteristic of even-aged forests as they regenerate following a major disturbance, while images **d-e** show the multiple canopy layers characteristic of older even-aged forests and uneven-aged forests (including forests without timber harvesting).

Forest Structure and Composition in Indiana and the Midwest

Indiana's forests are part of the Central Hardwoods Forest Region (hereafter "Central Hardwoods"), an area where a large majority of forests are dominated by oak and hickory. Most of these forests originated from land previously cleared in the late 19th and early 20th century, making the forests approximately 80–120 years old. These forests have dense canopies 70 or more feet in the air that limit the amount of sunlight that reaches the forest floor. However, since growing oak and hickory seedlings need more sunlight than is available under these Indiana forest canopies (Figure 2), the historically dominant species cannot regenerate. Ultimately, the forest composition will shift and become dominated by species that can regenerate in the shade—like American beech, sugar maple, and red maple.

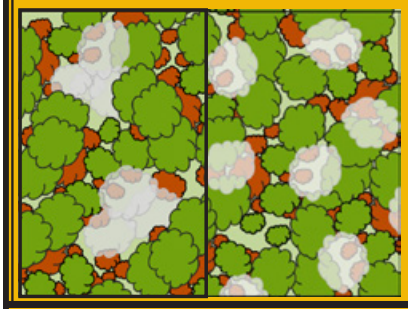
Figure 2. The structure of the forest canopy influences which tree species are most likely to grow. In **2a**, the canopy has been partially removed to promote oak seedlings. In **2b**, an intact canopy has allowed American beech to become established in the understory.

Uneven-aged Management

Uneven-aged forests are characterized by trees of many different sizes and ages. Sun-loving trees initially dominate the forest canopy, while mainly shade-tolerant trees survive in the understory. As time passes, shade tolerant begin to replace the sun-loving trees in the canopy.

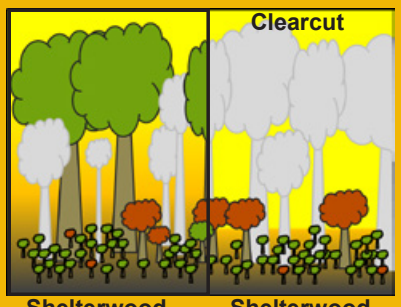
Uneven-aged forest management involves the removal of individual trees or small groups of trees dispersed across a wide area. Only a moderate amount of sunlight is created, so mainly shade-tolerant tree species regenerate, though oaks and hickories do sometimes grow in larger openings.

Group Selection/ Patch Cut | **Single-tree Selection**

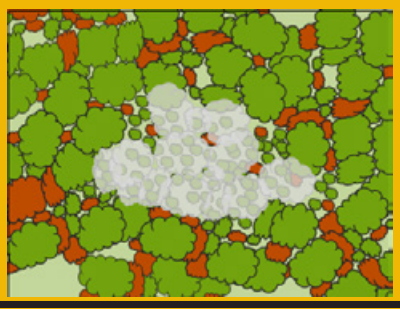


Even-aged Management

Even-aged forests have many large trees in a uniform canopy layer with a smaller number of trees growing beneath. These trees all originated at roughly the same time, within about a decade of each other, and so are roughly the same age.

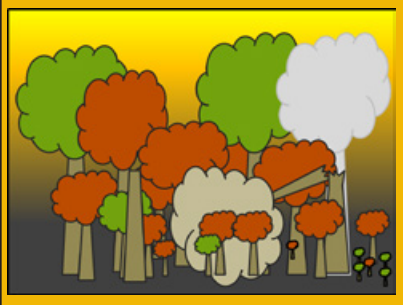


Even-aged forest management involves the removal of all of the large canopy trees and most of the small trees in an area that is often a few acres in size. This creates a substantial amount of sunlight on the forest floor, which allows sun-loving species to regenerate and grow rapidly.

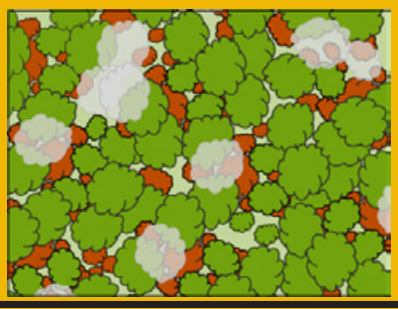


No Harvesting

Unharvested forests are still subject to disturbances such as wind, insect pests and pathogens. Single-trees or large groups of trees may be killed at one time. These disturbances favor shade tolerant tree species, since the amount of new sunlight is often not enough for oaks and hickories to grow.



Over many decades, the species composition in these unmanaged forests will also change as oak and hickory trees in the canopy are replaced by shade tolerant species. The smaller openings that occur in unmanaged forests also provide very little early successional wildlife habitat. However, these forest also have multiple layers of foliage.



Box 1. Common forest management approaches and their impacts on forest structure and composition. The specific treatments used in the Hardwood Ecosystem Experiment are also described here.

Disturbances, especially fire, probably were much more common and extensive in the Central Hardwoods prior to 1900 than today, and these disturbances created structural conditions that allowed oak seedlings and saplings to establish and survive in the forest understory. Windstorms frequently created small openings (< 0.5 acres) in the canopy and occasionally created much larger openings (> 1 acre) that allowed the established oak saplings to grow into full-sized trees. At the beginning of the 20th century, widespread and heavy forest clearing associated with European settlement probably contributed to the establishment of the trees that we see in Indiana's forests today.

Disturbance in the forest canopy is very important for allowing new trees to grow, especially species that cannot survive in a shady understory. Following canopy disturbance, a proliferation of sunlight causes young forests to regenerate rapidly, with dense thickets of shrubs, vines, and regenerating trees (Figure 1a). For up to a decade following the creation of young forest patches (often called early successional habitat), these areas provide substantial cover and foraging opportunities for wildlife, as productivity of vegetation, insects, and soft mast (berries) increases greatly.

However, shrubby young forest habitat does not last for long. As tree seedlings grow above the shrubs and begin to create shade, the young forest patches come to be dominated by thousands of small trees competing vigorously for sunlight (Figure 1b). For a century or more following the disturbance, the total number of trees slowly decreases as trees die from heavy competition (Figure 1c).

As forests age, they take on unique structural and compositional characteristics (Figures 1d and 1e). These characteristics develop as the most dominant trees in the canopy die, forming gaps that let in more sunlight and allow seedlings and saplings already established in the shade on the forest floor to grow more rapidly. As more trees die in the canopy of an older forest, the structure becomes more complex, with a broad mix of tall canopy trees interspersed with small gaps that are filled with smaller, younger trees. Forest composition, however, tends to become simpler, because only tree seedlings that survive in dense shade can survive until a gap forms.

Bird Habitat Management

Wildlife management originated in Europe when royalty employed individuals to manage game species such as grouse and partridge to provide enjoyable hunting experiences for the privileged. In the United States, this history continued with the addition of management of land for nongame species, including rare and declining birds. Over the years, most management for bird species followed the "If you build it, they will come" theme from the movie *Field of Dreams*. In the movie, the main character was told that if he built the right habitat (a baseball field in the corn fields), baseball players would come. Similarly, bird management has stressed the production of suitable habitat, with the assumption that the birds would find their way to it.

What is suitable bird habitat? Providing suitable habitat means creating suitable composition and structure.

Even the earliest studies of avian community ecology showed that structure was more important than composition for most birds. While there are some examples of bird species that require a specific plant type for nesting or foraging, much more often birds require habitat with a certain structure. For instance, most woodpeckers need dead or decaying wood in large tree trunks and branches, large enough to excavate a properly sized cavity. The species of tree matters less than its condition. Relatively few native woodpeckers dig their nest holes in a single species of tree, except where one tree species is most likely to develop to the necessary size or to develop dead or rotten limbs or stems that the birds can excavate.

Another general point is that habitat needs can vary seasonally. Many references define "suitable habitat" for individual bird species by emphasizing habitat used in the nesting season. Different kinds of habitat may be critical in seasons other than the nesting season. Many species of long-distance migrants, for instance, require dense vegetation (both for protected resting areas and to explore for food) during the spring and fall migration periods, regardless of what kind of habitat they use in the summer. These patches are called "stopover habitat." Another example comes from the late summer: many birds that breed in mature forest move to younger, more open habitats when their young have left the nest, but still depend on their parents for food and protection. Young stands of shrubs and trees provide lots of cover for the young fledglings and food in the form of insects and berries that is often easy for the parents to gather. Thus, even "mature forest birds" may be found in other habitats during important parts of their annual cycle.

Some general principles have developed from the decades of avian research on habitat use by birds and the effect of management practices on different species. The main principle is that many species prefer habitat with a particular structure, and, therefore, land covered by one particular type of habitat (with one structure) is likely to support only the few species that prefer that habitat. For example, few bird species are found in corn or soybean fields, which are structurally very simple. Similarly, a forest patch composed entirely of trees of one species that are about the same age will support fewer birds than a forest with a diversity of tree species, ages, and conditions.

Structural components such as dead snags, woody debris on the ground, and a diversity of tree heights and densities can be important in attracting some bird species. The number and arrangement of foliage layers is also important. A forest with

many layers supports a wider array of small habitat niches that can be used by different species of birds, while a forest with few layers may provide adequate habitat for only a few species. Forest habitats that contain a diverse array of these structural components will support a wider diversity of birds.

At the broadest scale (across landscapes) some habitat types or conditions may be quite rare, while others are common (see Box 2). In this situation, management aimed at increasing a rare habitat type or condition on one property may add diversity at the largest scale, even if the property itself is not very diverse. For instance, much of the Central Hardwoods today has a very small amount of very old forest (>150 years old), but many landscapes in the region also have little area composed of young forest (< 20 years old). Management that increases either of these relatively rare conditions will add to habitat diversity across the region. In other words, it is not necessary to provide for all species by creating all possible habitat conditions within a single property; sometimes the most appropriate goal is to provide what is rarest in the region.

Grouping Birds into Habitat Guilds

Many birds can be grouped into guilds (Table 1) based on their relative preference for older forest (*mature forest guild*) versus young forest (*early successional guild*) habitat. These groupings can be useful in the assessment of bird responses to management.

If leaders of a forestry operation want to maintain or improve bird habitat, monitoring birds within these guilds can provide valuable information regarding habitat characteristics of the forest important for the species of interest. Forest management activities can then be targeted to develop these characteristics. However, as with most things in the natural world, birds rarely fit neatly into groups. For example, in most studies reviewed in Table 2, the Kentucky warbler is classified as a mature forest bird. Two studies, though, classify it as an early successional bird. Kentucky warblers are generally associated with large tracts of intact forest, but are most successful in forest tracts that include small canopy openings with a dense shrub layer, conditions that can be created by

When considering the possibility of creating forest openings to increase landscape-level habitat diversity, it is important to also consider the landscape context in which the forest occurs. The images to the right show an area including HEE unit 2 in southern Indiana (top) and a typical small woodlot in northern Indiana (bottom). The grey cross-hatched box indicates a theoretical 5-acre opening in the forest. The small black square indicates 40 acres, and the large dotted square indicates 160 acres. Because the area in the top image is 100% forested, a 5-acre opening would only reduce the total area of mature forest by about 12.5% in the 40-acre block and by only a little more than 3% in the 160-acre block. However, in the bottom image, the total forested area (including the harvested area) in the 40-acre block is about 17 acres: a 5-acre opening would remove close to 30% of the mature forest. For the 160-acre block, this leads to a reduction from a little more than 29 forested acres to slightly more than 24, leaving only 15% of the landscape in mature forest.

An additional effect in the small woodlot is the reduction of interior forest habitat, which is habitat far enough from the forest edge to remove the influence of the edge. Some mature forest birds tend to be restricted to areas with interior forest habitat; which may be 200 feet or more from the forest edge. In the upper figure, the total area of interior forest was reduced by about 10% from 160 acres to about 144 acres. In the lower figure, forest interior area is already very low; only about 4.4 acres (or about 2.75% of the 160-acre patch). Creation of a 5-acre opening in the area would further reduce the total forest interior area to about 1.8 acres, or slightly more than 1% of the landscape. If the objective in an isolated woodlot is to increase the amount of young forest habitat that is available, other methods would probably be advisable. It should also be noted that the interior forest estimates in these images are based on the assumption of a 200-foot edge effect; some studies have shown impacts much deeper in the forests.

Box 2. Assessing the impact of forest management in the context of the landscape.

Table 1. Species most commonly designated as early successional or mature forest birds in studies reviewed in the sections on *Breeding Birds and Forest Management*. Species of interest in the HEE study are shown in bold text.

Early successional	Mature forest
American goldfinch (*Spinus tristis*)	**Acadian flycatcher** (*Empidonax virescens*)
Blue-winged warbler (*Vermivora cyanoptera*)	Black-and-white warbler (*Mniotilta varia*)
Brown-headed cowbird[1] (*Molothrus ater*)	**Cerulean warbler** (*Setophaga cerulea*)
Carolina wren (*Thryothorus ludovicianus*)	Kentucky warbler[3] (*Geothlypis formosa*)
Common yellowthroat (*Geothlypis trichis*)	**Ovenbird** (*Seiurus aurocapilla*)
Eastern towhee (*Pipilo erythrophthalmus*)	Pine warbler (*Setophaga pinus*)
Field sparrow (*Spizella pusilla*)	**Red-eyed vireo** (*Vireo olivaceus*)
Gray catbird (*Dumetella carolinensis*)	Scarlet tanager (*Piranga olivacea*)
Hooded warbler[2] (*Setophaga citrina*)	**Wood thrush** (*Hylocichla mustelina*)
Indigo bunting (*Passerina cyanea*)	**Worm-eating warbler** (*Helmitheros vermivorum*)
Mourning dove (*Zenaida macroura*)	
Northern cardinal (*Cardinalis cardinalis*)	
Prairie warbler (*Setophaga discolor*)	
White-eyed vireo (*Vireo griseus*)	
Yellow-breasted chat (*Icteria virens*)	

[1] Various studies classified brown-headed cowbirds only as nest parasites.
[2] Stoleson (2013) classified hooded warbler as a species associated with mature forest.
[3] Two of the studies classified Kentucky warbler with other early successional bird species.

Table 2. A summary of bird responses to forest management in the Central Hardwoods Forest Region.

Study Location	Treatments	Guild	General Findings	Unique Findings
Southern Indiana (HEE)[1]	*Uneven-aged:* single-tree selection, patch cuts *Even-aged:* shelterwood, clearcut	Mature forest	Species responses were variable. Some species were significantly more abundant in harvested units; others were more abundant in controls. An overall increase in detections for all species regardless of treatment was also observed.	Both cerulean and worm-eating warblers were more common in uneven-aged and even-aged units than controls. Acadian flycatcher was most abundant in controls.
		Early successional	Significant increases in numbers of most early successional species up to 3 years following both even-aged and uneven-aged harvests, in comparison to controls.	Populations of brown-headed cowbirds, a species that is associated with nest parasitism, did not increase.
Ouachita Mountains and Missouri Ozarks[2]	*Uneven-aged:* single-tree selection, group selection *Even-aged:* shelterwood, clearcut	Mature forest	Mature forest species were found in abundance on control sites, and responded positively to uneven-aged treatments as well. Responses of mature forest species to even-aged management varied: some increased in density, some decreased, and others stayed at similar levels.	Several of the studies support past observations of mature forest species inhabiting even-aged treatment stands.
		Early successional	Early successional species could be found in both even and uneven-aged stands, although they were most abundant in even-aged stands. Species' densities peaked about 5 to 8 years post-harvest.	In one study, time since harvesting was an important factor in determining how species responded to various treatment techniques.
Southern Illinois[3]	*Uneven-aged:* single-tree selection, group selection	Mature forest	Most mature forest species were not significantly less common in harvested areas.	Red-eyed vireos and ovenbirds were the only two mature forest species that were significantly more numerous in areas that were not harvested.
		Early successional	Early successional species' densities peaked dramatically after about 2 to 3 years of cutting, but dropped back to pre-harvest levels between 5 and 10 years post-harvest.	No unique findings for early successional species.
North-Central Pennsylvania[4]	*Even-aged:* clearcut	Mature forest	About 7 of the 10 bird species captured in mature forests were mature forest species, and half of the species captured in clearcuts were mature forest species.	This study supports past observations of mature forest species inhabiting even-aged treatment stands.
		Early successional	Half of the early successional species caught were captured exclusively in clearcuts, and not in the forest interior.	No unique findings for early successional species.

[1]Malloy 2012; Malloy and Dunning (2013)
[2]Thompson et al. 1992; Annand and Thompson 1997; Clawson et al. 2002; Morris et al. 2013; Perry and Thill 2013
[3]Robinson and Robinson 1999
[4]Stoleson 2013

group-selection harvesting (see Box 1 for a brief description of this management technique). Thus, classification of the Kentucky warbler into a guild depends on the scale under consideration. If we consider the scale of the entire forest, the Kentucky warbler is a classic mature forest bird. However, if we consider the scale of the forest opening, the fact that Kentucky warblers benefit from the shrubby habitat in that opening could lead to its classification an early successional bird. As described more fully in Box 2, the value of promoting specific habitat characteristics on a property depends in part on the context of the surrounding landscape—maintaining a higher proportion of forested land in intact forest will have a greater conservation impact if your property is surrounded by farm fields than if your property is located in a largely forested landscape.

The Hardwood Ecosystem Experiment

The Hardwood Ecosystem Experiment and Wildlife Habitat

The Hardwood Ecosystem Experiment (HEE), a project started in 2006 and scheduled to last for 100 years, was developed to help researchers understand how forest management in southern Indiana impacts different parts of the ecosystem, including plants, wildlife, and human communities.

Forest management is one of the most common human-caused disturbances in Indiana forests, and can have both positive and negative impacts on bird habitat. Forest managers can prescribe actions that mimic the effects of the natural disturbances (such as windstorms) that have historically shaped a forest community, knowing that the native plants and wildlife in the community have adapted to forest disturbance. Because birds respond more strongly to forest structure than to composition and because forest management directly impacts structure, forest management also directly affects bird habitat. By better understanding the impacts of forest management on bird habitat structure, we can better adapt forest management practices to maximize the quality of bird habitat.

The project covers a large landscape. It was established on nine research cores spread across more than 2,500 acres of Morgan-Monroe and Yellowwood State Forests, as well as one research core in Brown County State Park (Figure 3). A brief description of the forest management approach on the HEE is provided below.

For a more thorough description of the project and the timber harvesting treatments, please see *The Hardwood Ecosystem Experiment: a framework for studying response to forest management* (Swihart et al. 2013), a publication of the US Forest Service freely available online at http://www.nrs.fs.fed.us/pubs/42882 and *The Hardwood Ecosystem Experiment: Indiana Forestry and Wildlife*, FNR-500-W, (Meier 2015), a Purdue University Extension publication also available online at https://mdc.itap.purdue.edu/item.asp?item_number=FNR-500-W

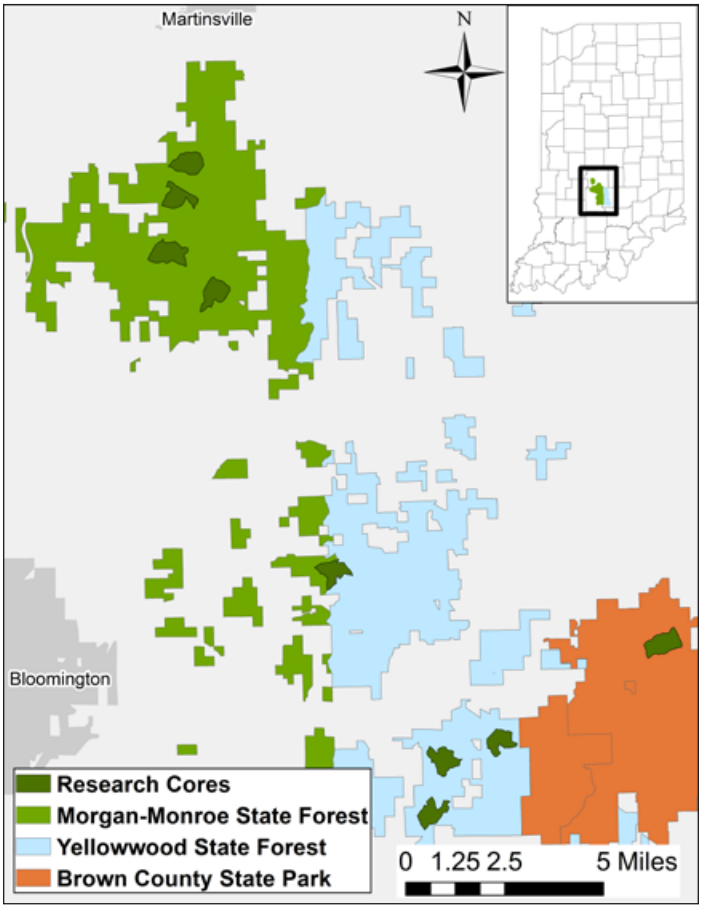


Figure 3. Location of the HEE research cores in southern Indiana. Reprinted from Figure 1 in Kalb and Mycroft (2013).

Forest Management on the HEE

In 2006, the HEE research cores were divided into three different treatment types, corresponding to widely used forest management approaches:

- uneven-aged management,
- even-aged management,
- no timber harvesting (control).

Each of these approaches represents different management intensities and objectives, which are described in Box 1. Each management approach also produces unique habitat structures (Figure 1). HEE forest management treatments include single-tree selection and patch cutting (1–5 ac. openings) in the uneven-aged research cores and shelterwood and clearcut harvests (both approximately 10 ac. openings) in the even-aged cores. Shelterwood harvests involve the

removal of the forest canopy in multiple stages (Box 1). Currently on the HEE sites, only trees below the main canopy have been removed in the shelterwoods; the final stage of shelterwood removal has not yet been completed.

Surveys of forest composition and structure done prior to implementing the harvest treatments showed that there were no significant differences between units in terms of forest structure or composition and that the structure and composition was reflective of forests in the wider Central Hardwood region. All of the current research areas had been managed for more than 50 years as part of the overall state forest management program and all had undergone some level of timber harvesting until they were designated as HEE research cores in 2006.

Breeding Birds and Forest Management: the HEE

To assess the impacts of different forest management approaches on birds, researchers on the Hardwood Ecosystem Experiment are monitoring the responses of selected species of mature-forest and early successional breeding birds to the experimental treatments described above (Malloy 2012, Malloy and Dunning 2013). Since the initiation of the surveys, there has been an overall increase in the total number of birds detected, regardless of harvesting treatment or species guild (Figure 4).

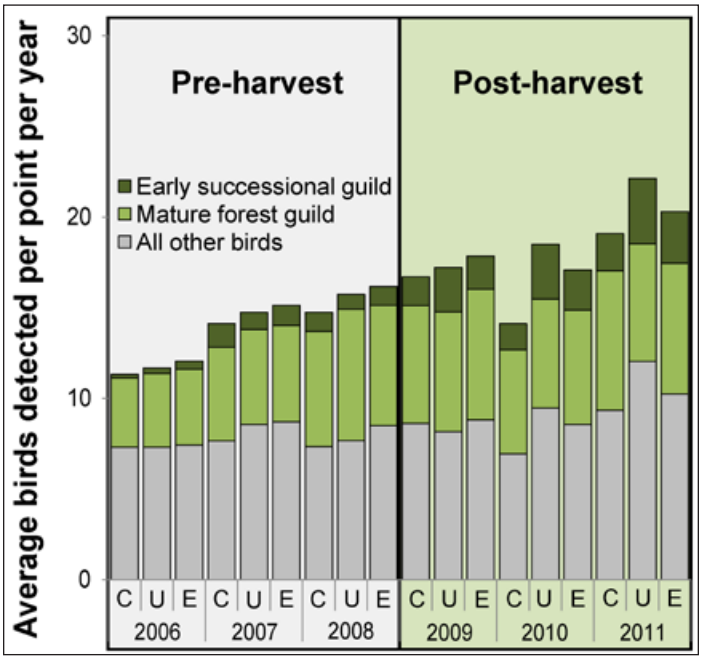


Figure 4. Average number of birds detected at each survey point per year for each management type (**C**: control, **U**: uneven-aged, **E**: even-aged). The years 2006–2008 were prior to harvesting and 2009–2011 followed timber harvesting. The control points include points in Brown County State Park (BCSP), though BCSP was not surveyed in 2006 or 2007.

The average number of species detected at each point for all birds (also known as species richness) was highest in the proximity of harvest areas (Figure 5). Most members of the early successional guild responded positively to timber harvests (Figure 4, Figure 6, and Figure 7). Both the indigo bunting (Figure 8, Figure 9, see Table 1 for the scientific names for the birds listed in this publication) and eastern towhee (Figure 10, Figure 11) were rarely detected prior to harvesting; however, following harvesting, detections of both species increased, mainly within harvested areas. Though indigo buntings were detected in most harvest areas, eastern towhees used only some of the openings, particularly larger harvest areas.

The main exception to the response of the early successional guild is an interesting one. The brown-headed cowbird is considered an early successional species because it requires open, disturbed ground in which to forage. Cowbirds are nest parasites; they do not build their own nests but instead lay their eggs in the nests of other species. The parent birds that end up with the cowbird eggs (called hosts) are often forest species, which then usually do very poorly in raising their own young. Increased cowbird parasitism of the nests of mature forest bird species is often cited as a problem associated with creating large openings in forested areas even though cowbirds frequently parasitize host species from both the early successional and mature forest guilds. It was noteworthy, therefore, that numbers of brown-headed cowbirds did not increase across the HEE treatments and that large cowbird numbers were not associated with clearcuts or patch cuts in particular. The data collected on the HEE project prior to the harvests showed that cowbirds were already common throughout the forests that were sampled. It is important to emphasize that cowbird use of forest openings is dependent on the character of the surrounding landscape; edges associated with small

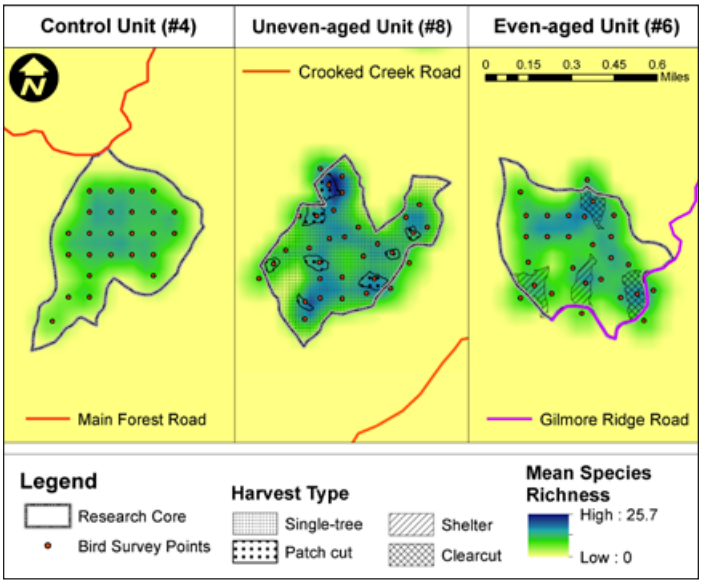


Figure 5. Average number of bird species (species richness) observed per point in relation to HEE harvest areas.

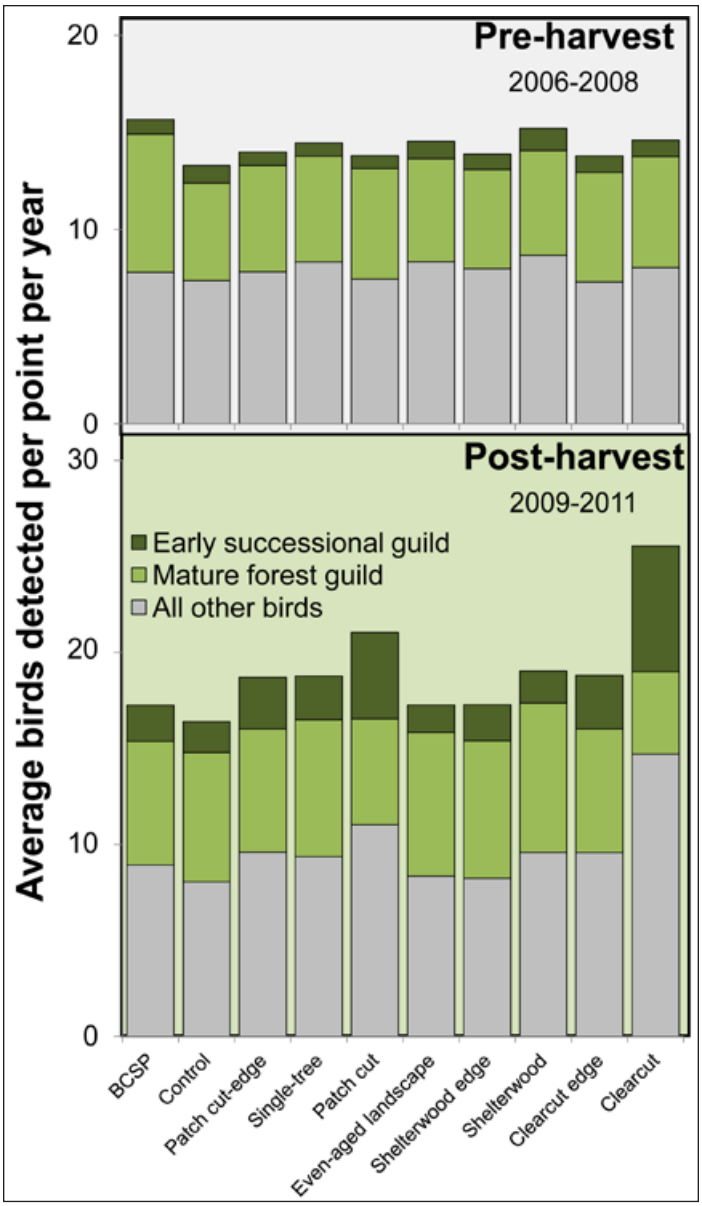


Figure 6. Average number of birds detected at each survey point per year for each landscape condition. Management intensity generally increases from left to right. Edge points are located within 100 yards of a forest management opening, either a clearcut or a patch cut. The even-aged landscapes are unharvested points between clearcuts and shelterwoods in the even-aged units. BCSP represents Brown County State Park; it is important to note that BCSP was not surveyed in 2006 or 2007.

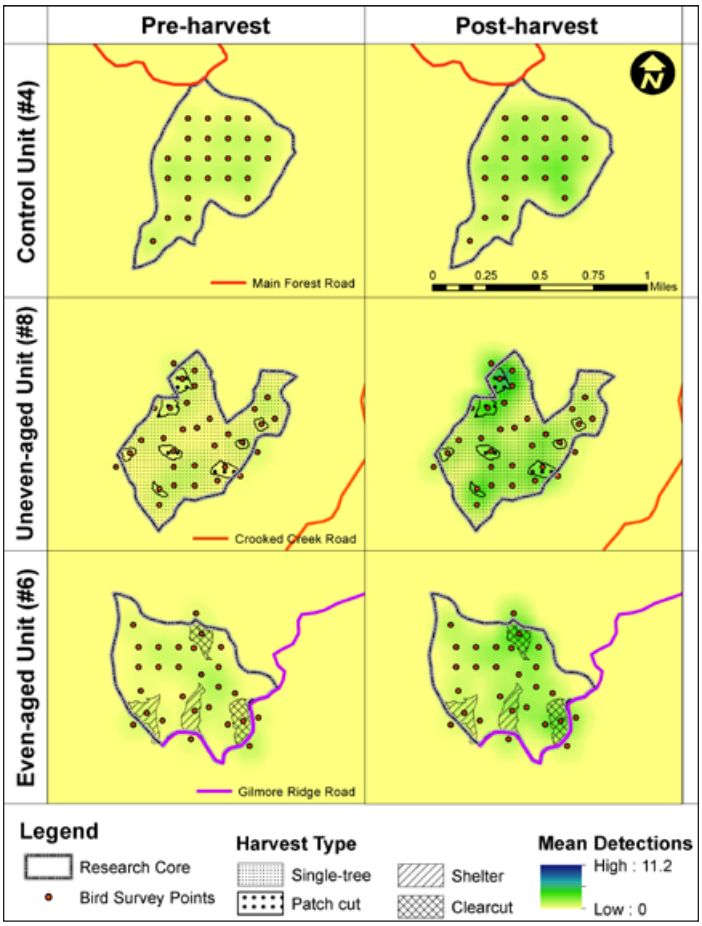


Figure 7. Average number of birds detected in the early successional guild for each visit to a survey point in relation to different HEE harvests.

Figure 8. Male indigo bunting.

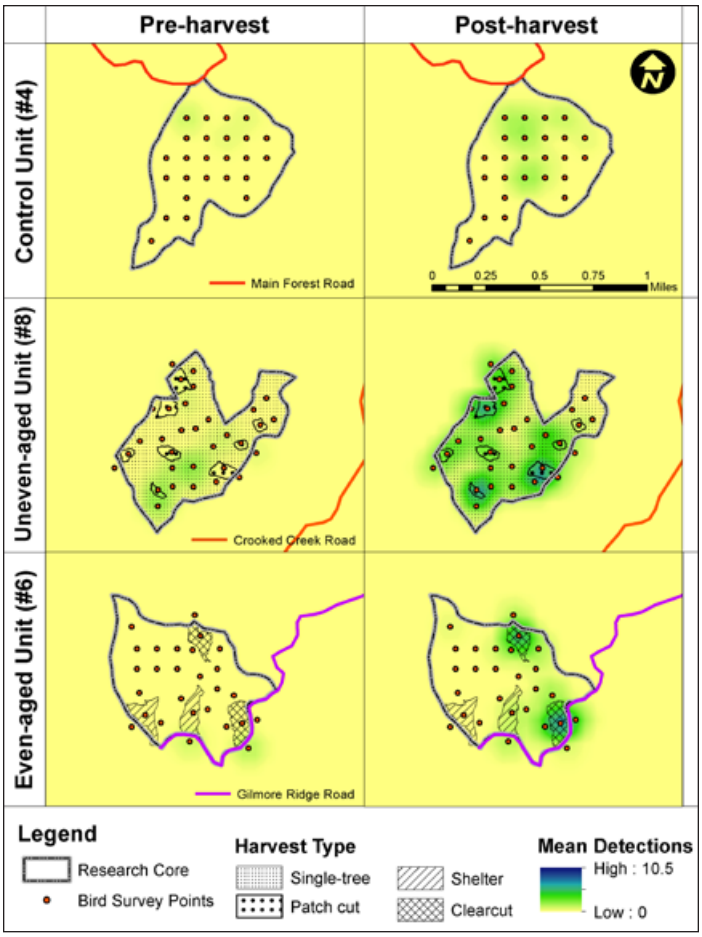


Figure 9. Average number of indigo buntings detected for each visit to a survey point in relation to different HEE harvests.

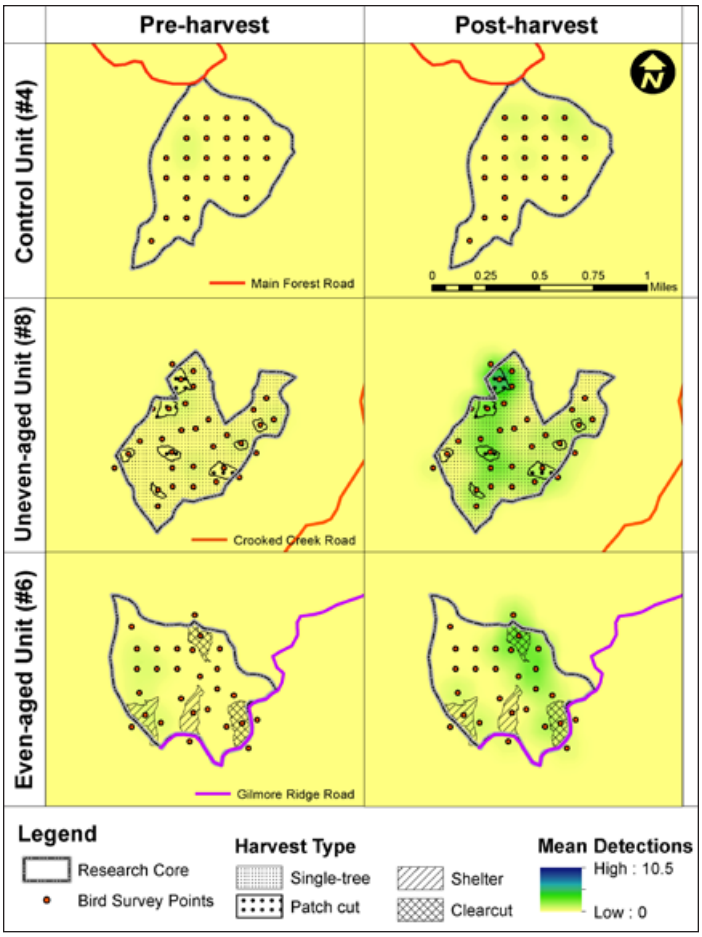


Figure 11. Average number of eastern towhees detected for each visit to a survey point in relation to different HEE harvests.

Figure 10. Male eastern towhee in winter.

forest patches in a largely agricultural landscape tend to have more cowbirds than do edges and openings in contiguous forested landscapes.

Bird species that nest in mature forest showed a more variable response to the harvest treatments (Figure 4 and Figure 6). Some species such as the ovenbird declined in some treatment areas while other species such as the cerulean warbler and Acadian flycatcher increased in some areas, but not others. Detections of mature forest birds in the even-aged and uneven-aged units appeared to be more concentrated in particular areas after the harvests (Figure 12), which may suggest that some species may be more densely packed into remaining mature forest habitat after the harvests (called the "crowding effect" by other researchers). Alternatively, the high concentrations found near or even in openings could suggest that mature forest birds were not avoiding the open habitats created by the timber harvest. Patterns of red-eyed vireo (Figure 13 and Figure 14) detections were similar to the general pattern for mature forest species (Figure 12), with a lower relative density in large openings, but with an overall increase in detections. Wood thrush (Figure 15) detections

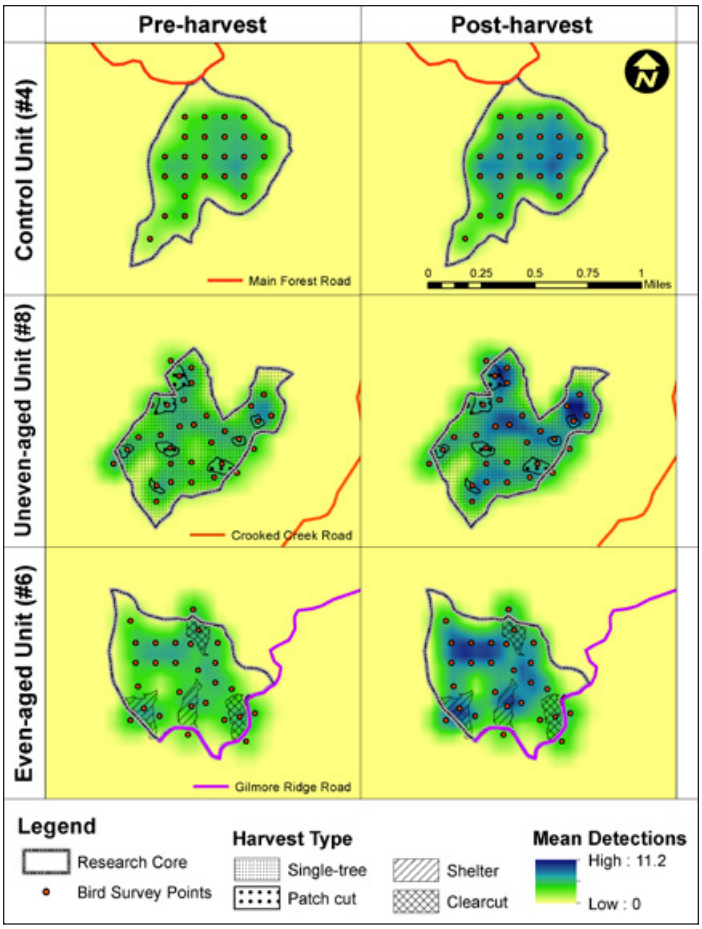


Figure 12. Average number of birds detected in the mature forest guild for each visit to a survey point in relation to different HEE harvests.

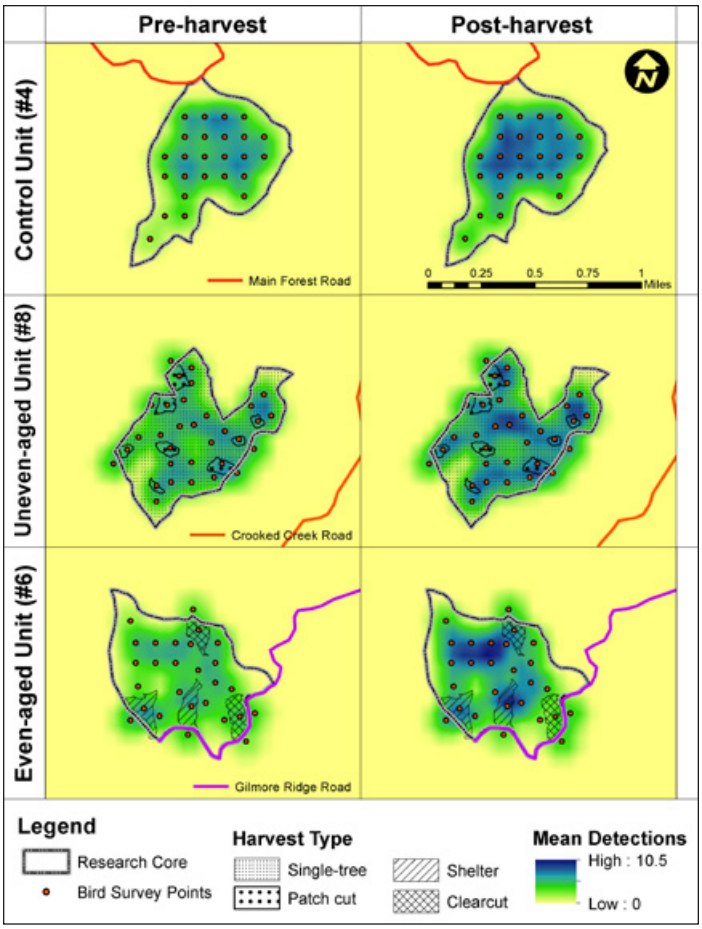


Figure 14. Average number of red-eyed vireos detected for each visit to a survey point in relation to different HEE harvests.

Figure 13. Nesting red-eyed vireo.

Figure 15. Adult wood thrush. *(Photo by Jameson Pierce)*

varied somewhat from other mature forest species. The average number of detections decreased, with fewer wood thrush detections in clearcuts as well as a slight shift towards the edges of patch cuts. However, utilization of some single-tree selection areas did increase slightly (Figure 16).

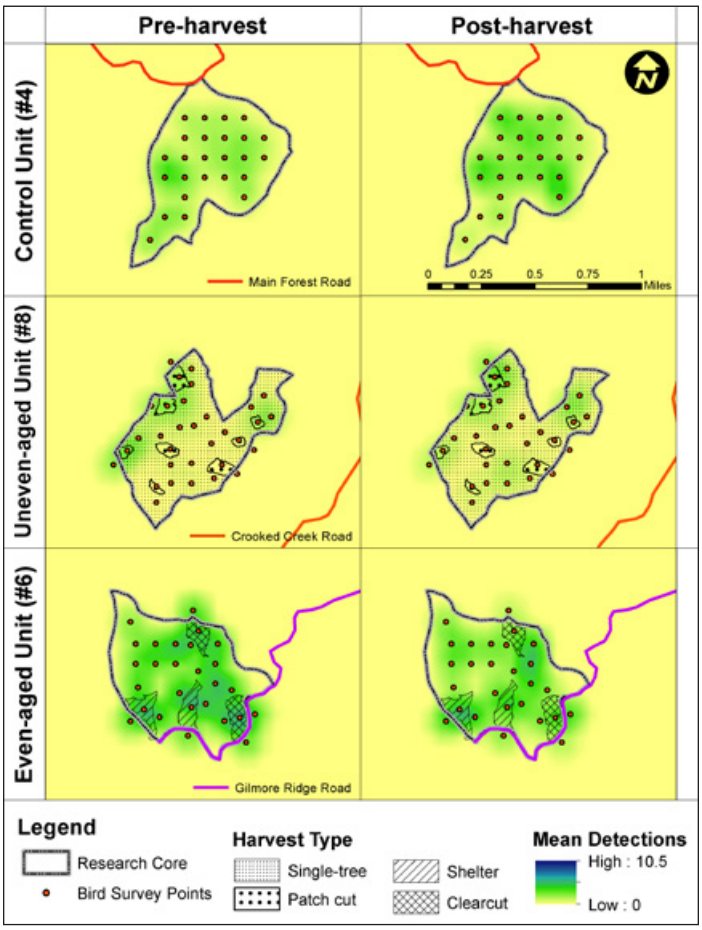


Figure 16. Average number of wood thrushes detected for each visit to a survey point in relation to different HEE harvests.

Breeding Birds and Forest Management: the Central Hardwoods

Although the effects of various forest management techniques on bird populations have been widely studied, long-term data collected across large areas, like those from the HEE breeding bird survey, are limited for the Central Hardwoods. One other experiment—the Missouri Ozark Forest Ecosystem Project—provides the most comprehensive comparison to the HEE, while several other studies across the Central Hardwoods provide a wide geographic basis for a summary of bird responses to forest management in the region. The results of these studies are summarized in Table 2.

From all of these case studies, it is evident that there is no single response of all forest bird species to forest management. Early successional guild species, however, generally respond much as do other species in the guild (Malloy 2012). These birds depend on young forests for nesting and foraging habitat and, where little such habitat exists, early successional birds are rare or absent. The creation of large patches of early successional habitat through forest management in all of these studies provided this habitat, and the abundance of early successional birds increased substantially in response. Some species that hadn't been present in the landscape prior to management appeared in the harvested areas in the following years. However, early successional habitats are ephemeral; most studies indicated that after 5 or 10 years of forest regrowth, the harvested patches no longer provided the structure needed for early successional birds. Abundance of these species subsequently began to decline.

Responses of mature forest guild birds to forest management were much more variable. In general, relative to unharvested areas, populations of mature forest birds were not negatively impacted by uneven-aged management such as single-tree or group selection, and some species responded positively. In landscapes that included even-aged harvests, some mature forest species increased in abundance during the breeding season, others decreased, and others stayed the same. Though many species appeared to strictly use mature forest habitat for nesting, a few studies noted that a large proportion of mature forest species also utilize harvested areas, especially uneven-aged treatment areas. However, due to the variability among mature forest bird species, generalizing responses for the entire mature forest guild is less informative than for the early successional guild (Malloy 2012). Therefore, the responses of individual species of interest should be considered when assessing the impacts of management.

An important caveat to note here is that most surveys of bird populations occur during the nesting season (generally May–June). As mentioned earlier, bird habitat requirements differ substantially depending on the season, and many birds considered to be mature-forest birds actually utilize early successional habitat later in the summer. The case study from north-central Pennsylvania (Table 2) provides an example of this shift in habitat use, and this study is consistent with studies done in other parts of North America. It is now understood that many birds that breed in mature forests bring their offspring into habitats dominated by shrubs and young trees shortly after the young leave the nest.

Summary

Research done on the HEE and throughout the Central Hardwoods indicates that different bird species respond differently to habitat change associated with forest management. No single management strategy will provide suitable conditions for all birds, or even for a single species at all times of the year. As the famed conservationist Aldo Leopold famously wrote in *A Sand County Almanac* (1970), "to keep every cog and wheel is the first precaution of intelligent tinkering." From a bird habitat management perspective, each type of habitat could be considered a "cog" or "wheel."

Forest management can be useful for restoring habitat types that are under-represented or missing from the landscape. In much of the Central Hardwoods, this certainly includes the maintenance and protection of areas of older forest. This also includes restoration of patches of young forest. Since many of Indiana's forests are naturally progressing to older forest conditions, landowners and land managers should also identify areas that can be managed for young forest habitat.

Management of forests for the birds in Indiana and the Central Hardwoods, as shown by results from the Hardwood Ecosystem Experiment and numerous other studies, should focus on the creation of a diverse array of habitats on individual properties and across the landscape. This provides for all the "cogs" and "wheels" that the native bird community needs. Landowners should seek to create habitat that is rare in their local area, thereby increasing the attractiveness of the landscape to birds that rely on that habitat. For everyone who loves to see birds, a diverse landscape is the Field of Dreams.

Management Recommendations

Some bird habitat management recommendations for private landowners and for public and industrial forests are shown in Box 3.

A few key principles that apply across all land ownership types:

- Diverse habitat structure attracts the most diverse bird population.
- Identify habitats that are uncommon in the area of interest and increase the representation of those habitats where possible.
- Management decisions made on a small scale (<10 acres) can be just as beneficial as those made on large landownerships, since habitat diversity is often more important than habitat patch size.
- Most birds in the early successional guild respond similarly to changes in habitat structure, but birds adapted to mature forests show more variability in their response.
- Management for individual bird species, particularly those of high conservation concern, can often be important, but treatments good for one species may not be good for others.
- The only way to know if management of bird habitat has the desired effects is to first know the birds already there; bird monitoring should be an important component of forest inventories. Private landowners can contact the local chapter of the Audubon society or DNR District Wildlife Biologists for help identifying birds on their property (Table 3).
- Birds may use different habitats at different times of the year. So, just because a bird species is uncommon in one habitat in June doesn't mean it won't be there in August.

Bird Habitat Management Strategies for Small Landowners

- First, seek assistance from an Indiana DNR (IDNR) district forester, IDNR wildlife biologist, consulting forester, or industrial forester (websites for these resources are shown in Table 3).
- Use different management techniques on your land and vary intensity of management across the property.
  - Use a mixture of single-tree and group selection with a few larger openings.
  - Refrain from harvesting in some areas.
  - Retain some areas as permanent early successional openings by mowing once a year or once every couple of years.
  - Look for opportunities to retain large live and dead trees with low economic value.
    - As these trees die and decay, they will provide important habitat niches for birds like woodpeckers, owls, and cavity –nesting songbirds.
- If you don't wish to use active forest management, you may choose instead to identify a few areas where you can maintain early successional forest filled with dense shrubs.
  - This is great habitat for species like gray catbird or hooded warbler.
  - This approach requires regular intervention to maintain the patches over the long-run.

Bird Habitat Management Strategies for Public and Industrial Landowners

- Mix harvesting techniques and vary harvesting intensity within stands rather than applying treatments uniformly.
  - In a stand with an uneven-aged management prescription, retain a higher residual basal area in certain parts of the stand to allow for the creation of large group selections (up to about 0.5 acre) or small patch cuts (up to about 3 or 4 acres) in other areas.
    - In this example, average basal area at the stand level can still meet the prescription target, though certain areas will have higher or lower residual basal area.
    - This approach can allow for the same average per acre volume of harvested timber as in the uniform application of a single-tree selection harvest, but with much greater habitat diversity.
  - Leave harvest residues (e.g., tops, low-quality logs) in the forest to increase the amount of coarse woody debris.
- Set aside a certain portion of the landscape to be managed for old forest habitat characteristics.
  - These areas can be allowed to develop old forest characteristics naturally over a period of many decades or even centuries.
  - The development of old forest structure (e.g., large trees and multiple canopy layers) can be accelerated through active application of small group selections, single-tree selection, and targeted crop-tree release.
  - Assign some portions of the landscape for early successional habitat to benefit a wide variety of birds.
    - Management for early successional habitat requires management at relatively short time intervals, since young forest openings lose value as habitat for early successional bird species by 10 years of age. It is important that new patches of young forest habitat are created on a regular basis.

Box 3. Some specific strategies for adapting forest management for bird habitat.

Table 3. Resources available to help private landowners manage their land.

Resource	Organization	Website
District Foresters	Indiana Department of Natural Resources	http://www.in.gov/dnr/forestry/4750.htm
District Wildlife Biologists	Indiana Department of Natural Resources	http://www.in.gov/dnr/fishwild/2716.htm
Consulting and Industry Foresters		http://www.findindianaforester.org/
Other Forest Landowners	Indiana Forestry and Woodland Owners Association	http://www.ifwoa.org
Local Birders	National Audubon Society Local Chapters, Indiana Audubon Society	http://www.audubon.org/chapters?state=IN http://www.indianaaudubon.org/
Wildlife and Forestry Extension Specialists	Purdue University	https://ag.purdue.edu/fnr/Extension/Pages/default.aspx

Other recommendations are based on the landscape:

- In a landscape dominated by agriculture or other non-forest land uses (like northern Indiana), it is probably more important to maintain forested patches as large as possible to protect interior forest habitat. Because such patches are relatively rare in these landscapes, removing them could severely limit habitat for mature forest birds (Box 2).

- Minimize the occurrence of abrupt edges between forest and non-forest land types, such as between high-canopy forest and open agricultural fields. These "hard edges" are associated with nest predators and parasites such as the brown-headed cowbird, which can negatively affect nesting forest birds, especially in landscapes that have low forest cover.

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