# Ecological Effects of Fragmentation Related to Transmission Line Rights-of-Way: A Review of the State of the Science

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# Contents

# Chapter 1

## Introduction

For over 50 years, scientists have produced hundreds of studies on ecological effects of fragmentation related to transmission-line rights-of-way (ROWs)—the strips of land that a utility uses to construct, maintain, and repair a power line. Without a focused compilation of the research applicable to Wisconsin, the cumulative knowledge is relatively inaccessible, especially to the non-scientist. A systematic summary and critique is necessary to identify areas for further independent research and increase understanding beyond the current state of knowledge.

The purpose of this project was to synthesize existing research relevant to Wisconsin into a summary of what is and is not known, augmented by observations and commentary from scientists living and working in Wisconsin. The goal was to provide policy-makers, and other interested Wisconsin citizens, with an informed summary of the state of the science on ecosystem fragmentation and its effects, especially those involving species diversity and invasive species, in relation to transmission-line ROWs.

This report was written from an ecological perspective with conservation in mind. Humans are part of ecology and, more than any other species, have a profound impact on their environment. This has led society to place value, through the Endangered Species Act and similar legislation, on conserving and maintaining whole, functioning ecosystems. The effects of human development cannot be classified as negative or positive because the same effect may be beneficial for one species and detrimental for another. Also, the primary effect may have an impact on other species in a complex cascade of interactions, often with unpredicted positive and negative consequences.

This report is divided into six chapters: (1) Introduction, (2) Methodology, (3) Habitat Fragmentation, (4) ROW Corridors, (5) Summary and Conclusions, and (6) Gaps in the Research. The Methodology section discusses the selection criteria for the relevant literature and for the Wisconsin experts. The information gathered from the literature and interviews is integrated in Chapter 3: Habitat Fragmentation, which discusses the ecological effects of dividing an ecosystem, and Chapter 4: ROW Corridors, which discusses the ecological effects of introducing a corridor into an ecosystem. These two sections make up the bulk of the report. They are followed by a brief summary and conclusions and an overview of research gaps pertaining to fragmentation and corridors. Although the report focuses on the effects of fragmentation, a proper ecological perspective cannot be gained without discussing the impacts of corridors as well.

In Wisconsin, fragmentation of large blocks of forest by a ROW, particularly in the northern part of the state, may likely be of more ecological consequence than constructing a new ROW in the southern part, where there is more urban and developed land and fragmentation of primary plant and animal habitat is not a pressing issue. Overall, the potential for a negative effect of fragmentation is most critical for endangered species whose existence is in jeopardy, threatened species that are likely to become endangered, and species of special concern that have a suspected but not proven problem in population size or distribution.[i]

Rather than adding to the body of knowledge with additional field research, this effort provides the reader with an understanding of the significance of the research that has been conducted thus far and delineates key issues for future study from a conservation perspective. Such an undertaking is timely for Wisconsin because transmission-line routing is a growing concern for energy providers and consumers. With 11,500 circuit miles of transmission lines currently in place in Wisconsin, ROWs are present in many parts of the state. This report provides background information and a framework for understanding ROW-related fragmentation, and can serve as a critical resource for all parties involved with routing activities in Wisconsin. It should also serve as a guide for developing further research efforts that will add to the current knowledge of the ecological effects of transmission-line ROWs in Wisconsin.

[i] Rare plants and animals in Wisconsin are identified by the Wisconsin Department of Natural Resources (WI DNR) and classified, depending on their rarity and sensitivity as endangered, threatened, or of special concern. For a complete list of these species, please see the Natural Heritage Inventory Working List on the WI DNR's Web site: <http://www.dnr.state.wi.us/org/land/er/working_list/taxalists/>.

# Chapter 2

## Methodology

The primary literature search was carried out during February 2004 using the Biological Abstracts database with the following five key phrases—edge effect(s), fragmentation, corridor(s), neotropical migrant(s), invasive species—in combination with the keyword Wisconsin and with the key phrase transmission line(s).

| **Key Terms** | **Secondary Terms** |
|---|---|
| Wisconsin | edge effect(s) |
| transmission line(s) | fragmentation |
| | corridor(s) |
| | neotropical migrant(s) |
| | invasive species |

Additional terms similar to transmission line were used to ensure a comprehensive search. Of the citations identified in the literature search, only those pertinent to Wisconsin were selected for review. Final inclusion was determined according to the following criteria:

- Almost all international studies were eliminated, with the exception of Canadian studies that were conducted in locations with species similar to those that exist in Wisconsin.
- In most cases, studies conducted in locations (e.g., New Mexico) with very different species were eliminated.
- Some studies that did not appear in the primary literature search but were frequently cited in the articles reviewed were identified as particularly important and therefore were included. An example of such an article is "Nest predation in forest tracts and the decline of migratory songbirds" (Wilcove 1985), which was cited in many of the selected articles, but did not appear in the database searches because the abstract did not include any of the keyword combinations.

Noted Wisconsin scientists (Appendix A) provided information on their research efforts as well as a local perspective to the written literature. They were selected for their recognized expertise in the topics covered in the report and were interviewed by telephone or in person from February 24 to June 7, 2004. Interviewees were offered an opportunity to review the written analysis of the literature and provide feedback.

Wisconsin has a variety of ecological landscapes with unique combinations of physical and biological characteristics, such as climate, geology, soils, water, and vegetation that make up each ecosystem. They differ in composition, habitat suitability for wildlife, presence of rare species and natural communities, and in many other ways that affect land use and conservation management. Where possible, this report points out the relevant Wisconsin landscape, such as north central forest; however, not all studies cited in the report were conducted in the state. As with most ecological research, the findings of one study, especially one that is short-term and species-specific, represent only a snapshot of what is occurring in a particular location and cannot necessarily be extrapolated to other ecosystems or species. Several comparable studies in many similar locations are necessary to identify a trend and the reader is cautioned about extrapolating the findings reported in this document to a different location or species or applying trends for one ecosystem to others.

# Chapter 3

## Habitat Fragmentation: Ecological Effects

### Introduction

Human development activities can separate once-whole ecosystems. The result is habitat fragmentation, the ecological condition that occurs when a large area of contiguous plant and animal habitat is converted into smaller, divided remnants separated by dissimilar, often inhospitable habitat (Wilcove, McLellan, and Dobson 1986; Meffe, Nielsen, Knight, and Schenborn 2002).

A relatively well-researched form of habitat fragmentation is the small habitat patch that remains in a matrix of agricultural or otherwise-developed land (Rich, Dobkin, and Niles 1994). A lesser-recognized form of fragmentation results from the dissection of a contiguous area by a relatively narrow linear corridor, such as a transmission-line ROW, pipeline, highway, or railroad. This latter form of fragmentation does not appear to be as disruptive as the former (Meffe, Nielsen, Knight, and Schenborn 2002; Rich et al. 1994), nor do its effects appear to be the same as those exhibited by fragmentation caused by large-scale agricultural or development operations.

Regardless of its origin, the effects of habitat fragmentation are varied and complex. In addition to loss of existing habitat, a reduction in the overall area of a contiguous ecosystem can affect its resident populations. Many conservation biologists consider habitat fragmentation to be the "single greatest threat to biological diversity" (Noss 1991); however, habitat fragmentation formerly was practiced intentionally as a way to increase the local species diversity in a given patch of land, even though this increased diversity came at the expense of sensitive species being displaced by species that were more common in the larger surrounding areas (Noss 1991). Evan Weiher (2004), a biologist at the University of Wisconsin-Eau Claire, refers to this concept as the "homogenization of the globe," the increasing loss of local species, which can include rare plants and animals, to a suite of habitat generalists that are often dominant in many ecosystems.

This chapter begins with background on a scientific theory that underlies the study of habitat fragmentation, followed by a review of the characteristics of fragmented habitats that drive changes in species diversity. It examines three issues associated with fragmentation: (1) reduced habitat area, (2) species isolation, and (3) increased edge. Based on information available in the literature and gathered through interviews, these issues are then discussed in the context of habitat fragmentation related to transmission-line ROWs in Wisconsin.

The information in the chapter focuses on fragmentation of forests because it represents the most dramatic contrast in habitat and most well-studied scenario. Additionally, for other types of habitat such as prairies or barrens, a transmission line may not necessarily be seen as a source of fragmentation, particularly if vegetation in the ROW is managed to maintain the area as one contiguous ecosystem.

## Equilibrium Theory and Application to Habitat Fragmentation

The backbone of the concept that ties population dynamics to habitat fragmentation is found in MacArthur and Wilson's (1967) *Theory of Island Biogeography*. This theory has been used to explain how isolation and size of a particular habitat affect species diversity (Meffe, Nielsen, Knight, and Schenborn 2002). Although it was designed to predict the number of species present on oceanic islands of differing sizes and varying distances from the mainland population source, it is often applied to terrestrial habitat fragmentation.

The fundamentals of this theory rest on rates of immigration and extinction. Immigration is directly related to the extent of isolation: the closer an island is to the mainland, the higher the rate of immigration. On the other hand, extinction is directly related to the physical area of the island: the smaller the island, the higher the probability of a species becoming locally extinct. In theory, the number of species found on an island will be the equilibrium point between the rate of immigration and the rate of local extinction. The strongest effects are expressed on volcanic islands isolated by a barrier of sea.

In the case of terrestrial habitat fragmentation, the land dividing remnant patches does not provide as great a barrier as does the ocean (depending on the species). Consequently, isolation is less severe and immigration is more likely. Effects on specific species of plants and animals are subtle, yet still significant, with less disturbance of the landscape (Hanowski, Niemi, and Blake 1995; Askins 1994), such as that caused by creation of transmission-line ROWs. Thus, the degree to which the theory can be applied can only be considered on a case-by-case basis, because it depends on the surrounding landscape configuration and species' tolerance of other types of habitat.

Much of the habitat fragmentation in the Midwest results in the formation of remnant patches in a matrix of land allocated to use by humans. According to Terrence Yakich (2004), environmental project manager at American Transmission Company, double-width transmission-line ROWs through wooded areas typically create a distance between forest patches of approximately 100–300 feet. This distance maintains the patches in close enough proximity to allow for higher rates of immigration for most species than would be found with larger distances. Whereas this situation is less extreme than cases of oceanic islands described by the theory of island biogeography, some species may be affected by the ROW separation, which would result in the remnant patches acting as habitat "islands" (Albrecht, Hinkle, and Winship 1999), and the concept of decreasing diversity with decreasing patch size and increasing isolation would apply. The result would be further disturbance in, what is in Wisconsin, an already-fragmented landscape (Ades 1993).

## Effects of Reduced Habitat Area

In addition to the ecological impact of habitat loss associated with a newly developed ROW, there can be deleterious effects from a reduction in the size of the remnant patch. A reduction in patch size can result in the loss of species that are area sensitive, meaning they demonstrate significant decreases in probability of occurrence as habitat area decreases because they have certain minimum physical area requirements that are not met in smaller patches.

The term area sensitive previously encompassed any species that showed a direct relationship between patch area and probability of occurrence without taking into account the mechanism behind the relationship. Some researchers speculated that the mechanism had to do with changes in vegetation. For example, Robinson and Wilcove (1994) hypothesized that larger patches were more likely to have specialized habitat, or microhabitats, or that smaller forests may have different food availability than larger forests and that these factors may affect species composition. Ambuel and Temple (1983), however, were unable to identify any area-related changes in vegetation in a study of birds in different sizes of woodlots. They suggested that species-area relationships may be related to changes in biotic interactions, such as competition, predation, or brood parasitism.

A number of studies found a relationship between species abundance, community composition, and area (e.g., Robbins, Dawson, and Dowell 1989; Blake and Karr 1987), whereas other studies found that species abundance and community composition were more closely related to core/interior range (Temple and Cary 1988) or, similarly, perimeter-to-area ratio (Helzer and Jelinski 1999). These latter findings have led researchers to propose that some species previously considered area sensitive may actually be responding to pressure from the edges of a habitat patch.

As scientists have reached a better understanding of the mechanisms behind species-area relationships, the term area sensitivity has come to refer specifically to species that have large area requirements. For example, the pileated woodpecker (*Picidae dryocopu*) has a large home range and thus would not typically be found in small, isolated forest patches. On the other hand, the ovenbird (*Seiurus aurocapillus)*, although it does not require a large patch of forest to succeed, is sensitive to pressures from the edge. Because of this edge sensitivity, there is a relationship between patch area and probability of occurrence for the ovenbird, even though it is not an area-sensitive species per se. Taken as a group, species exhibiting a relationship between habitat area and probability of occurrence for any reason, could more accurately be called fragmentation sensitive, a broad descriptor encompassing both area sensitivity and edge sensitivity. Although there is still some confusion in the literature, the term area sensitive is used in this report to indicate response to actual patch size.

*Species Loss*. If a species perceives forest patches divided by a ROW as two separate areas and neither patch consists of an area large enough to provide sufficient home range, food sources, heterogeneity, or other ecological requirements, the loss of individuals or the local population can be expected. Whether that loss happens relatively quickly, over the course of an individual species' lifetime, or over several generations is dependent on a multitude of factors including the species in question, the patch area, and the degree of separation from the next suitable patch.

Some species simply are not found in forest patches smaller than a specific minimum area, a size that varies by species (Robbins, Dawson, and Dowell 1989). This genuine area sensitivity is often a characteristic of animals with a large body size, high placement on the food chain, or special ecological requirements (Temple 1996) that need large blocks of habitat to succeed. For example, Biedermann (2003) and Crooks (2002) observed terrestrial animals, including carnivores, and concluded that body size accounts for some of the variation in species' area sensitivity.

The mechanisms underlying species-area relationships are now relatively well understood. Overall, species diversity, composition, and abundance are most likely the result of a combination of factors, each case specific and dependent on the landscape matrix, the species examined, and the location of the sampled area.

*Minimum Viable Population.* A forest patch cannot support the number of individuals or the number of species that the same area could support in a contiguous forested block (Cox 1997). Absolute threshold area numbers are hard to come by so scientists prefer to use probabilities. For example, in a 100-acre forest patch, there may be a 50 percent chance of finding a certain species of bird. In a larger forest patch of 500 acres, the probability of seeing that same species may be closer to 90 percent. In some situations, a small, area-sensitive population may remain in a forest patch in the short term, but face long-term local extinction if the population is isolated and not able to immigrate to a more suitable area. Consequently, conservation biologists often suggest trying to conserve enough area to maintain at least a minimum viable population of a particular species in isolated habitat patches. A minimum viable population is described as the number of individuals necessary to ensure with some degree of probability that the isolated population persists over time (Soulé 1987), although how to determine minimum viable population is a source of contention in the conservation community. For example, a few pairs of prairie chickens (*Tympanuchus cupido*), a threatened species in Wisconsin, nesting in a given prairie remnant do not ensure the persistence of the population—the fewer the number of individuals, the greater the chance of extinction of the population (Krebs 1994). And, as can be expected in the complex framework of factors affecting species survival, the number of individuals necessary to ensure persistence of any given population depends on the species and the overall landscape mosaic.

## Effects of Reduced Habitat Area in Wisconsin

In Wisconsin, fragmentation of the landscape must be a major consideration in constructing transmission-line ROWs. Eric Epstein (2004), Bureau of Endangered Resources, Wisconsin Department of Natural Resources (WI DNR), said that when planning land management, "The permanent breaking up of large contiguous patches into smaller disconnected patches has got to be the number one ecological issue to consider." Unfortunately, few studies address whether area-sensitive species perceive transmission-line ROWs as a source of fragmentation, that is, whether area-sensitive species are unable or unwilling to use habitat on both sides of the ROW.

One species that appears to be sensitive to fragmentation is the American marten (*Martes americana*), which is endangered in Wisconsin. Hagris, Bissonetter, and Turner (1999) examined distribution of the American marten in Utah in a forest with areas that were clear cut and concluded that "fragmentation can affect organisms long before the original habitat is reduced to remnant patches." They found decreasing capture rates with increasing amount of open area and increasing proximity to open area, demonstrating that American martens seemed to respond to low levels of landscape fragmentation. The authors speculated that several factors could have influenced their findings, among these the fact that the clear cut areas, given their harsh conditions, provided no habitat for the martens. Although these findings are provocative, whether fragmentation caused by transmission-line ROWs affects marten populations in Wisconsin is not known.

Another example of an area-sensitive species in Wisconsin is the pileated woodpecker (Robbins, Dawson, and Dowell 1989; Howe 2004). These birds are found only in the largest forests; however, like many strictly area-sensitive species, they are quite mobile, which means that the effects of area reduction due to ROWs may be limited. Detailed information on area-sensitive species in Wisconsin is given in Appendix C.

### Limitations of the Research

True area sensitivity is a complex concept. Not only is information limited on which species are area sensitive, but the issue becomes more complicated when discussing area-sensitive species and transmission lines because little information exists about species' perception of fragmentation. The gap between two areas of habitat separated by a transmission line is not large. Many species considered area sensitive may not necessarily perceive those two patches of habitat as separate entities; because they continue to use both sides, the area of their habitat is only reduced by the amount lost to the ROW. Intuitively, a gap such as a ROW should not affect the overall habitat area for wide-ranging, mobile species such as the pileated woodpecker or the timber wolf (*Canis lupis*), a threatened species in Wisconsin. However, for smaller terrestrial mammals or insects, a ROW may define the edge of a habitat patch. This concept will be discussed further in the section on edge effects.

## Effects of Species Isolation

As a result of habitat fragmentation, plants and animals in the remnant forest patches can become isolated. The effect of isolation, like the effect of reduced habitat area, is largely species dependent, especially in the case of isolation caused by a transmission-line ROW. The reaction of any particular species to creation of a ROW differs and it is likely that many species, especially those that are fairly mobile, are tolerant of small habitat gaps and do not perceive a single ROW as a source of fragmentation or isolation. The absence of more than one study for any species—with the exception of deer and a few birds—makes it difficult to identify behavioral patterns. Nevertheless, for species that do become isolated, the consequences can be seen in both long- and short-term effects.

Sensitive plants or animals may already have reduced numbers that are particularly vulnerable to catastrophic events in the short term. If something unfavorable, such as flooding or high predation occurs one year, it could wipe out a population, causing a local extinction. "As the population is split into parts and each consists of fewer individuals, just through chance those populations are going to change over time. For example, a newly isolated and smaller subpopulation may experience pressure from outside forces or genetic changes that larger, connected populations may be better able to tolerate. The probability that the isolated population will recover could be significantly less," said Epstein (2004).

Populations that are unable to exchange genetic information with other groups of their species will suffer genetic isolation. These populations, over time, will exhibit decreased genetic diversity, which means they will be less able to adapt to changing conditions.

Plants and animals disperse in many different ways and what may constitute a barrier for one species may not pose an obstacle for another. A transmission-line ROW is a modest barrier relative to an ocean or a four-lane highway, yet this gap may be an isolating factor for a specific and limited group of species for two reasons: either the species has a behavioral aversion to crossing, or its ecological requirements prevent it from doing so.

Depending on local circumstances, individuals or entire species may modify their behavior to avoid the ROW and thus become confined to one side. For example, some species habituated to traveling in the forest may be unwilling to cross a ROW and risk being exposed to the real or perceived danger that exists in the open. Alternatively, a ROW may represent an inhospitable environment, making a species unable to cross the gap. For other species the ROW acts as a filter, not completely blocking movement, but limiting crossings (Harris and Reed 2002).

For most species, only especially wide or particularly inhospitable barriers result in a significant lack of crossover. Nevertheless, a true lack of crossover may produce dire consequences. Populations that become isolated, both physically and genetically, face an increased risk of extinction (MacArthur and Wilson 1967). If a habitat patch loses its population of a certain species, physical isolation may prevent new individuals from immigrating to colonize the patch and the species will become locally extinct.

As well as preventing animals and plants from moving between habitat patches, isolation can also prevent the flow of ecological processes across the landscape. A ROW may not present a significant barrier to mobile animals tolerant of different habitats, but plants may be affected by loss or isolation of more sensitive pollinators and seed dispersers. The following section focuses on Wisconsin-relevant examples of species isolation.

## Effects of Species Isolation in Wisconsin

*Genetic Isolation.* Matthysen, Lens, Van Dongen, Verheyen, Wauters, Adriaensen, and Dhondi (1995) examined gene flow in several animal species, including birds, squirrels, and moths, by comparing small forest fragments (approximately 3–100 acres) to continuous forest (approximately 250–3,700 acres). Some species seemed to have reduced genetic flow while others were unaffected. They concluded that the effects of forest fragmentation "can be a complex mixture of changes in habitat quality and changes in dispersal patterns." Noel Cutright (2004), an ecologist at WE Energies, agreed that the issue is complex, saying that if a population becomes isolated, "That is always taken as a negative. I do not think we know enough about the effects of isolation to understand its significance to an overall population."

Despite evidence for decreased gene flow, genetic isolation and reduced dispersal capability are not always the rule when discussing fragmented landscapes. In a study that examined genetic makeup of sugar maples (*Acer saccharum*) (Wisconsin's state tree) pre- and post-fragmentation, Foré, Hickey, Vankat, Guttman, and Schaefer (1992) found that gene flow post-fragmentation was higher than pre-fragmentation, evidently due to increased wind resulting from more open area and the sugar maple's ability for longer-distance wind dispersal in the modified landscape.

*Birds.* Two similar studies carried out in Canada used mobbing calls to lure black-capped chickadees (*Poecile atricapillus*), a resident species in Wisconsin, from one location to another. Belisle and Desrochers (2002) measured the birds' gap-crossing decisions and found that, of the species studied, "birds prefer to travel under forest cover rather than cross open areas, even when the forested detour conveyed a substantially longer route than the short cut in the open" unless presented with an especially long detour.

Similarly, St. Clair, Belisle, Desrochers, and Hannon (1998) examined gap crossing and found that black-capped chickadees were less likely to cross gaps as the gap-distance increased. Chickadees limited their distance from the forest edge and did not cross gaps larger than 165 feet when there were forested alternatives. However chickadees, despite their unwillingness, had been observed crossing gaps of up to 650 feet when no forested alternative existed (St. Clair et al. 1998). The results from these two studies appear to imply that, for many species of birds, forest gaps, including ROWs, may function more as a movement filter rather than an absolute barrier.

A third study by Belisle, Desrochers, and Fortin (2001) found that black-throated blue warblers (*Dendroica caerulescens*), a species of special concern in Wisconsin, ovenbirds (neotropical migrants found in Wisconsin), and black-capped chickadees that were translocated in fragmented landscapes took more time and were less likely to return to their home territories than their counterparts in contiguous forest.

Howe (1984) compared the composition and dynamics of local bird assemblages in Australia and Wisconsin. He found that disruption of continuous forest tracts affected species occurring near the edge as well as forest interior species. Differences between species assemblages in small isolated forest patches and equivalent control plots near the edge of a large continuous forest were most pronounced in Wisconsin. There were fewer forest-interior and forest-edge species in Wisconsin forest islands than in corresponding control plots.

*Small Mammals.* In the first of two published small-mammal studies, Graves and Schreiber (1977) looked at movement of displaced white-footed mice (*Peromyscus leucopus*) and short-tailed shrews (*Blarina sp.*) (both found in Wisconsin) across two transmission-line ROWs in Tennessee, one 160 feet wide and one 340 feet. The study found that mice and shrews will cross both widths of ROW, but "shrews are less successful in their returns and take somewhat longer before recapture in the home area."

The second study, by Doucet and Brown (1997), examined snowshoe hare (*Lepus americanus*) and red and gray squirrel (*Tamiasciurus hudsonicus, Sciurus carolinensis*) (also Wisconsin mammals) activity on a 100-foot-wide transmission-line ROW in Quebec during two winters. The first winter there was no vegetation emerging from the snow and there were no crossings by hares; however, hares began to cross the ROW the second winter when vegetation was thicker. Squirrels did cross the ROW, yet in general, activity for both hares and squirrels was greater in the forest than in the ROW. The results of this study suggest that ROWs may contribute to temporary isolation of both squirrels and hares during the winter. Further evidence for this isolation was noted when hare activity on one side of the ROW ceased, leading the authors to speculate that disease or competition may have wiped out the population on one side of the ROW but left the other side unaffected, at least temporarily.

*Large Mammals.* The majority of the large-mammal studies are relevant to Wisconsin because they focused on white-tailed deer (*Odocoileus virginianus*), a common species in the state. Studies conducted in Vermont, New York, and Quebec found that deer activity was reduced in ROWs and proposed two reasons: lack of cover (Doucet, Stewart, and Morrison 1979) and deep snow in the winter (Willey and Marion 1980). On the other hand, Doucet and Garant (1997) argued that neither lack of cover nor deep snow acts as an impermeable barrier because deer trails have been observed crossing open sections of ROW in more than three feet of snow. One form of isolation mitigation that three studies (Doucet and Garant 1997; Willey and Marion 1980; Dominske 1997) addressed was the use of softwood travel lanes. These are areas where forested strips across a ROW are established or conserved during construction in order to maintain a connection between the habitat on either side. The lanes provide cover and additional browse, and prevent snow build-up. Willey and Marion (1980) found that these travel lanes are used by deer to cross ROWs in the winter and Doucet and Garant (1997) reported that they "are favorable habitat (not necessarily preferred sites) for deer to cross wide ROWs."

One large-mammal study examined moose (*Alces alces*) activity in and adjacent to a transmission-line ROW. Joyal, Lamothe, and Fournier (1984) found that moose make much less use of a ROW than the surrounding forest and cross ROWs 295 feet wide more frequently than those 460 feet wide. Although Wisconsin boasts an overabundance of deer, moose are rare and the WI DNR lists the species as critically imperiled in the state. Many factors are involved in the decimation of the moose population and ROWs probably have very little effect on the species. However, moose have a shared range with white-tailed deer, the normal host for the meningeal worm (*Parelaphostrongylus tenuis*), a parasite that does not harm deer, but is fatal in moose. ROWs, among other landscape changes, can have a positive effect on deer populations by providing more browse. This increase in deer is thought to negatively affect moose populations because of the spread of the meningeal worm. For many reasons, including the spread of parasites, the enhancement of deer populations in Wisconsin is not desirable from a conservation biologist's perspective.

*Plants, Insects, Reptiles, and Amphibians.* Although little research has been done on the effects of habitat fragmentation on plants, insects, reptiles, and amphibians, scientists have identified these groups as potential candidates for ROW-induced isolation. Several of the Wisconsin experts who were interviewed speculated that some insects may be averse to crossing the open ROW. This can be especially damaging when these species happen to be pollinators or important contributors to seed dispersal. Donald Waller (2004), a botanist at the University of Wisconsin-Madison, noted that some plants, such as wild ginger (*Asarum canadense L.*), disperse with the help of forest ants. A ROW, he added, could be a mechanism for isolation because forest ants may be unwilling to cross open ground. Additionally, an open corridor could potentially bring in open-area ants that are less effective as seed dispersers and may compete with the forest ants for resources. Waller (2004) and Thomas Rooney (2004), a conservation biologist at the University of Wisconsin-Madison, also identified trillium (*Trillium sp.*), with one species threatened and one of special concern in Wisconsin, and Braun's holly fern (*Polystichum braunii*), a state-threatened species, as plants that may become isolated by transmission-line ROWs.

Gary Fewless (2004), a botanist at the University of Wisconsin-Green Bay, offered another example of a plant with limited dispersal. Little goblin moonwort or the goblin fern (*Botrychium mormo*), endangered in Wisconsin, has particularly large spores and limited dispersal capabilities. "This means," said Fewless, "if a population is isolated and has only a few individuals, normal population variance could push them towards local extinction due to their inability to disperse." The patch may not be re-colonized and, if a species has low numbers to begin with, each population cluster lost is extremely detrimental. Epstein (2004) agreed, saying "Another secondary impact will result for plants that depend on insects or some other animal vector for either pollination or seed dispersal. If the vectors shy away from a corridor, one can certainly envision scenarios where there will be local extirpations of the plant populations. And, assuming the fragmentation was something that continued, the effects regionally could be fairly serious."

### Limitations of the Research

While it is apparent that many species are affected by transmission-line ROWs, the relatively narrow gap of a ROW does not seem to present an absolute barrier to any species studied so far and, given the evidence for edge effects discussed in the following section, species isolation is probably not the most significant effect of transmission-line ROWs on native plants and animals. There is a dearth of literature examining isolation sensitivity in general and even less information on the ability or willingness of many species to cross transmission-line ROW forest gaps. Crossovers on the ROW depend on the width of the gap, the species in question, and the habitat provided by the ROW, among other factors. Overall, species isolated by transmission-line ROWs are likely few in number.

## Edge Effects

Edges occur naturally between terrestrial ecosystems; however, unlike natural edges, the edge between a ROW and a forest is usually abruptly delineated.[ii] Abrupt edges create dramatic changes in an ecological community that extend anywhere from ten to several hundred feet into the forest (Reese and Ratti 1988). The area and shape of a remnant patch are important considerations in assessing edge effects.[iii] For example, a circular-shaped patch may retain a particular amount of forest interior; if the same area were stretched into an oval, the total area would remain the same but more of the forest interior would become edge habitat. If a patch is small, edge effects could extend through the entire area, thereby leaving it unsuitable for forest-interior species.

As well as being sensitive to patch area, some species may be sensitive to edges and vulnerable to edge-associated pressures. Creation of edge induces variations in microclimate, transformations in vegetation and animal life, and changes in biotic interactions such as predation, parasitism, competition, herbivory and seed dispersal (Watkins, Chen, Pickens, and Brosofske 2003; Brisson, Fortin, and Bouchard 1997; Chasko and Gates 1982; Murcia 1995; Waller 2004). The microclimate along a new edge exhibits variations in solar radiation, light and wind intensity, temperature, and humidity of both the soil and the air (Meffe, Nielsen, Knight, and Schenborn 2002; Murcia 1995) and these variations lead to changes in vegetation and animal life depending on each species' physiology (Murcia 1995). These direct effects lead to even more variation through indirect effects such as brood parasitism and predation (Murcia 1995) and the degree of those effects is linked to the contrast between the two habitats—the greater the contrast, the greater the effects (Anderson 2004). Epstein (2004) emphasized that the effects of transmission-line ROWs could be more severe than some other types of edges because ROWs cover long distances and are more permanent than edges resulting from more temporary openings, such as clear cuts. Fragmentation produced by ROWs is likely to have a negative impact on the greatest number of species as a result of edge effects.

## Ecological Effects of Increased Edge

*Direct Effects.* The transitional zone between a ROW and a forest is characterized by species, habitat, and microclimate that are different than that of either the forest or the ROW. The width of this transitional zone or habitat edge can only be defined in relation to a specific effect because some direct effects will be relatively shallow while others will penetrate deeper into the habitat patch.

One example of a direct, though minimal, edge effect was illustrated by Brothers and Spingarn (1992), who found that dandelions (*Taraxacum officinale*) did not advance beyond a certain distance into an old-growth forest in Indiana. Dandelions need relatively high levels of light; at a distance of eight feet from the physical forest edge light-intensity decreased and only four percent of the study sites contained dandelions. This situation is considered a shallow edge effect (Wilcove, McLellan, and Dobson 1986).

A common example of a deep edge effect can be seen in the browsing behavior of white-tailed deer. Edges are composed of a mixture of open and forested habitat that deer prefer and they increase deer density by providing more browse. Because deer are highly mobile, they can have profound effects on vegetation extending for several hundred feet into the forest patch (Alverson, Waller, and Solheim 1988). Greater mobility and tolerance for many different habitats, at least for short periods of time, may explain why some animal-related edge effects often extend deeper into the forest than plant-related edge effects (Wilcove, McLellan, and Dobson 1986).

The complexity of vegetation along the edge of a transmission-line ROW attracts not only forest species, but also open-habitat and mixed-habitat species. There is ample documentation of the association between edge habitat and an increase in species diversity and abundance (Kroodsma 1982; Reese and Ratti 1988, Fleming and Schmiegelow 2002; MacArthur and MacArthur 1961). An increase in species richness is not always positive because edge-related climatic and vegetational variations often favor habitat generalists (e.g., white-tailed deer, house wren (*Troglodytes aedon*)), which are already abundant in the landscape, and exclude relatively uncommon habitat specialists that rely on large tracts of undisturbed landscape (Robbins, Dawson, and Dowell 1989; Ambuel and Temple 1983; Harris 1984). Researchers now believe edge-related increases in species richness may come at the expense of some forest-interior species, especially long-distance avian migrants.

The North American Breeding Bird Survey, a program that monitors the status of breeding birds, shows that about one-third of neotropical migrants, a group of birds that breeds in the temperate regions of North America and winters in the tropics of Central and South America and the Caribbean, have been demonstrating complex patterns of declining abundance in some areas of the country for the past 30 years (Temple 1998a). There has been much speculation about the cause of the neotropical migrant population decline and many scientists believe that decreasing abundance can be linked to fragmentation or, more specifically, edge effects. Many studies have found that some species exhibit species-area relationships yet do not have large home ranges. This has led to the theory that, rather than being related to area per se, abundance of these species is related to edge effects, which increase with decreasing area. The increase in edge increases brood parasitism and predation pressures associated with the edge, consequently making some small forest patches unsuitable habitat (Niemuth and Boyce 1997; Terborgh 1989).

A related theory holds that forest edge may function as an ecological sink, where mortality exceeds reproduction.[iv] Birds may be attracted to edges by the complexity of the vegetation and, in fact, abundant evidence exists in support of the idea that forest birds are often found in high densities along edges (Evans and Gates 1997; Kroodsma 1982; Morneau, Doucet, Giguere, and Laperle 1999; Kroodsma 1987; MacArthur and MacArthur 1961); however, increased parasitism and predation may lead to mortality rates that surpass reproduction (Gates and Gysel 1978; Temple 1998b; Robinson, Thompsoni, Donovan, Whitehead, and Faaborg 1995). Although forest edge may be functioning as an ecological sink, local extinction is not always a predetermined outcome in a sink area, because in some cases, colonists from areas called sources, where populations are experiencing growth, continue to immigrate to the sink area, thereby maintaining the population (Robinson, et al. 1995). Though extinction is not always imminent, the situation of having many sinks and few sources usually results in population declines. In the case of neotropical migrants, the declines are thought to be related to brood parasitism and nest predation in addition to overall habitat loss and fragmentation.

*Indirect Effects.* Parasitism and predation are indirect effects that are by-products of habitat fragmentation. The introduction of invasive species, another indirect effect, will be addressed in the next chapter.

<u>Parasitism</u>—The most problematic invasive animal associated with edges throughout the Midwest and the East is the brown-headed cowbird (*Molothrus ater*), which has been identified as a cause of declining populations of neotropical migrants (e.g., Brittingham and Temple 1983). Cowbirds are brood parasites; they lay their eggs in the nests of their hosts and leave their young for the host species to raise. The cowbird population increased more than fourfold in the last century because of an increase in open habitat and agricultural land. An increase in habitat fragmentation has presented more opportunities for cowbirds to access host nests. The cowbird provides an example of how dramatic changes in the landscape can allow a species to surpass its former natural population threshold and spread so quickly that other species cannot adapt. Historically cowbirds parasitized relatively few species; they now lay their eggs in the nests of numerous species, many of which have not evolved sufficient defense mechanisms to cope with the newly introduced threat.

<u>Predation</u>—Another factor associated with increased edge is increased predation, especially nest predation. Nests situated along forest edges are subject to higher predation rates than those found in the forest interior (Robinson, Thompsoni, Donovan, Whitehead, and Faaborg 1995; Chalfoun, Ratnaswamy, and Thompson 2002; Flaspohler, Temple, and Rosenfield 2001; Manolis, Andersen, and Cuthbert

2002). Although many species potentially are subject to higher rates of predation along transmission-line ROW edges, the association between nest predation and edge has proven particularly detrimental for neotropical migrant birds. It has been suggested that, in addition to brood parasitism, nest predation associated with small woodlots, fragmented landscapes, and edge, is a major factor in declining populations of neotropical migrants. The birds in this group are especially susceptible to predation because they tend to produce only one brood (Whitcomb, Robbins, Lynch, Whitcomb, Klimkiewicz, and Bystrak 1981), their open-cup and ground nests are more vulnerable, and their small size means they are less able to drive away predators (Wilcove 1985; Terborgh 1989).

Many omnivorous mammals, such as raccoons *(Procyon lotor*), squirrels, housecats (*Felis cattus*), opossums (*Didelphis virginiana*), blue jays (*Cyanocitta cristata*), grackles (*Quiscalus quiscula*), skunks (*Mephitis mephitis*), and dogs (*Canis canis*), have been identified as nest predators (Terborgh 1989; Wilcove 1985; Pasitschniak-Arts and Messier 1996; Zastrow 2004) and the presence of these medium-sized generalist predators has been associated with the habitat diversity found along edges and in fragmented landscapes (Oehler and Litvaitis 1996). They are able to maintain sizeable populations, especially in areas, such as human-dominated (often fragmented) landscapes, where large predators are generally absent and food sources associated with humans are readily available. These predators travel along edges or use edges as places to enter the forest looking for prey. This is especially detrimental when a previously intact block of mature forest is fragmented, allowing edge predators greater access to forest birds and other species that were previously inaccessible.

## Edge Effects and Species Diversity

Wildlife managers originally employed techniques to increase edge habitat in order to increase local species diversity and attract edge-generalist game species (Eaton and Gates 1979; Morneau, Doucet, Giguere, and Laperle 1999; Small and Hunter 1989; Reese and Ratti 1988; Wilcove, McLellan, and Dobson 1986). This increase in local diversity along edges is predicted by the intermediate disturbance hypothesis, which states that species diversity will be greatest in areas that have had a moderate frequency of disturbance and will be lower in areas that have had very low or very high frequency of disturbance (Connell 1978). The idea is that intermediate levels of disturbance maximize local species diversity because competitively dominant species exclude subordinate species at low disturbance, but too much disturbance leads to local extinctions. Although commonly practiced in the past, increasing edge habitat is now considered an outdated management strategy contrary to the goals of conservation biology (Harris 1984). Yahner (1988) stated that “Managing for edge habitat in order to maximize wildlife diversity raises aesthetic, moral, and scientific issues because we now recognize that maximum diversity may not always be a desirable objective; for example,” he continued, “it further endangers species that are dependent on extensive stands of undisturbed habitat.”

The local benefits gained by increased edge have been weighed against the potential detrimental regional effects for sensitive species. “A distinction must be made,” stated Robbins, Dawson, and Dowell (1989), “between managing for diversity and managing for conservation of an ecosystem.” Although more edge may boost species diversity and richness overall, it may also make small forest patches unsuitable habitat for native species and result in the local extinction of plants and animals that rely on ever-scarcer undisturbed or mature habitat (Hansson 1983). Consequently, species diversity, typically viewed as being important to maintain or augment if possible, cannot be used as the sole metric by which to gauge ecosystem health. An absolute measure of species diversity in a region does not express any information about the composition of species in the community; for example, if the addition of a number of invasive species into an ecosystem causes the local extinction of an endangered species, species diversity will increase, but at the expense of a rare or sensitive species. Noss (1991) summarizes this idea, saying, "…enhancement of species richness at a local scale can mean loss of species richness at a global scale as sensitive endemics are lost and weeds prosper."

## Edge Effects in Wisconsin

Forests once covered approximately 66 percent of Wisconsin. Much of this forested area has been cleared in the southern half of the state but in the northern section conservation management has protected and enhanced forest land. In order to build a transmission line through a forest, trees and brush must be cleared to provide a ROW. One mile of 100-foot wide ROW through a forest results in the loss of about 12 acres of trees. This loss of forested habitat increases the number of edge plants and animals and reduces the number of forest-interior species (Public Service Commission of Wisconsin 1998).

*Deer*. An often-overlooked impact of increased edge that many experts identified as significant in Wisconsin is increased deer density. This is attributed to an increase in habitat that includes a mixture of forest and open areas, such as that provided by ROWs. The white-tailed deer is currently over-abundant, with the estimated deer population at 1,109,000, 58 percent above the state-wide goal of 702,300. Deer densities after the 2003 hunting season ranged from 12 to 73 deer per square mile (deer/mi$^2$), with an average of 32 deer/mi$^2$. The highest densities were seen throughout the southern part of the state, where the 2003 deer population was 113 percent higher than the WI DNR's goal. The central forest of Wisconsin, the smallest region with the fewest deer, was still four percent above the preceding year's population and 23 percent above the WI DNR-determined population goal (Rolley 2003). "The point is that deer populations are extraordinarily high. There is nothing detrimental about the deer in particular; adverse effects are seen because deer have never existed in such high numbers," said Fewless (2004). A recent study by Rooney, Weigmann, Rogers, and Waller (2004) identified over-abundant deer as a key driver of ecological change in Wisconsin.

Edges promote higher deer utilization by providing a greater amount of available browse; however, Nancy Mathews (2004), a wildlife ecologist at the University of Wisconsin-Madison, explained, deer do not "flock" to an edge. A newly created edge will only affect the social groups (primarily females and their young offspring) that already exist in the area. Females do not often venture beyond a specific home range, so the browsing effects of any one social group may be geographically limited. Nevertheless, said Mathews, the impacts on native plant diversity are all negative. The increasing pressure on local vegetation with increasing deer densities may even lead to an increase in non-native plants, she added.

Rooney and Waller (2003) studied the effect of deer browse on hemlock (*Tsuga canadensis*) and white-cedar (*Thuja occidentalis*) (key species in increasingly rare ecosystems (Hardin 2004)), on red oak (*Quercus rubra*) and yellow birch (*Betula alleghaneinsis*) (deciduous species), and on forest herbaceous communities in Wisconsin. They found clear evidence that as browsing pressure increases, regeneration of hemlock and white cedar declines; however, this relationship was less clear in red oak and yellow birch. For forest understory plants, they reported that, "as local deer browsing increases in mixed coniferous-deciduous stands, understory herb community diversity declines, while ferns, grasses, sedges, and rushes become increasingly dominant."

In addition to the tree species studied by Rooney and Waller (2003), Fewless (2004) added that the American yew (*Taxus canadensis*) seems to be particularly affected by increased browsing pressure. "It was extremely common and now has been reduced to a tiny fraction of its former population apparently due to overbrowsing." And Davis, Sugita, Calcote, Ferrari, and Frelich (1994) have documented the pervasive conversion of primary forests with strong conifer components to secondary forests dominated by sugar maples and other deciduous species in the Upper Peninsula of Michigan. Cutright (2004) stated that "herbivory is changing the entire successional pattern of Wisconsin forests. Deer grazing has an effect on how gaps are filled." It should be noted that many factors contribute to the prevalence of deer in the landscape; increased edge due to transmission-line ROWs is just one of those factors.

*Cowbirds.* The brown-headed cowbird is a particularly serious problem in many states that are heavily cultivated, such as Wisconsin. It is especially prevalent in areas with ample agricultural land and small forest patches—the landscape composition that is found in much of the southern part of Wisconsin. Given the cowbird's association with edge and its need for open habitat in which to forage, Brittingham and Temple (1983) hypothesized that the rate of parasitism by cowbirds increases with increased edge or open habitat and that this has led to declining populations of neotropical migrants. Although other factors are involved, they found that increased cowbird abundance and fragmented habitat led to increased parasitism by cowbirds, which has helped maintain and possibly accelerate the decline of Wisconsin's forest songbirds. This increase in cowbird parasitism near open habitat or habitat edges has been well-documented (Evans and Gates 1997; Brittingham and Temple 1983; Robinson and Robinson 2001; Robinson and Wilcove 1994; Chalfoun, Ratnaswamy, and Thompson 2002; Gates and Evans 1998); however, some experts believe that distance to edge may not be the most important factor involved in determining parasitism rates (e.g., Mathews 2004; Paulios 2004).

Mathews (2004) stated that only regions containing a large proportion of forest, such as the Chequamegon-Nicolet National Forest in Wisconsin, appear to be virtually impenetrable to cowbirds. Other landscapes may be more sensitive to overall cowbird densities in the area, which, at least in southern Wisconsin, are already high, added Mathews. Andy Paulios (2004), a wildlife biologist at the WI DNR, agreed and commented that, in the eastern US, the theory that parasitism is related to edge may be over-rated. He does not see cowbirds as a driving force in the northern forests because their densities are low. Stanley Temple (2004), a wildlife ecologist at the University of Wisconsin-Madison, also sees a relationship between cowbird density and nest parasitism. Like Mathews and Paulios, he noted that "cowbird parasitism is a much larger problem in the southern part of the state where the remaining patches of forest are basically islands in a sea of cowbird habitat. It is a much greater problem than in northern Wisconsin, where the matrix is largely forest and cowbirds are restricted to patches of habitat within that matrix."

In a comprehensive study across five states in the Midwest, including Wisconsin, Robinson, Thompsoni, Donovan, Whitehead, and Faaborg (1995) found that increasing incidence of cowbird parasitism was strongly related to decreasing percent forest cover, percent forest interior, and average forest patch size. A large difference in parasitism rates suggested that source-sink dynamics may be applicable in this region.

A few studies have specifically examined the relationship between cowbird abundance and transmission-line ROWs in areas similar to Wisconsin. A ROW facilitates cowbird movement and increases abundance by providing more open area and corridors that can act as direct linkages between forested habitat, important for breeding, and agricultural land, important for foraging. Gates and Evans (1998) carried out a spatial study in Maryland measuring breeding and roosting ranges for the brown-headed cowbird and reported that ranges are "often elongated, with the long axis paralleling a linear canopy opening, such as a road, power line, or stream edge," and also advised that mown ROWs may promote higher densities of cowbirds than shrubby ROWs because mown areas can act as feeding grounds. A study by Rich, Dobkin, and Niles (1994) in New Jersey found a "surprisingly high" number of cowbirds on narrow forest-dividing corridors combined with reduced relative abundances of neotropical migrants on the corridor edge (for corridors approximately 52 and 75 feet wide).[v] Temple (2004) added that transmission-line ROWs provide an opportunity for parasitism to occur but how that opportunity is used is dependent on local cowbird densities.

Although there is ample circumstantial evidence that the brown-headed cowbird is responsible for declining populations of neotropical migrants, Terborgh (1989) and Cutright (2004) note that absolute causal evidence has yet to be obtained for any species with the exception of Kirtland's warbler (*Dendroica kirtlandii*), a federally endangered and protected species and one that is considered critically imperiled on a global scale. The list of neotropical migrants identified in Robbins, Dawson, and Dowell (1989) includes such species as the Acadian flycatcher (*Empidonax virescens*), black-throated blue warbler (*Dendroica caerulescens*), cerulean warbler (*Dendroica cerulea*), worm-eating warbler (*Helmitheros vermivorus*), and the Kentucky warbler (*Oporornis formosus*), all of which were identified by Sumner Matteson (2004), an avian ecologist at the WI DNR, as Wisconsin species with special ecological requirements (see Appendix C).

A study by Bielefeldt and Rosenfield (1997), found conflicting evidence to that reported in the majority of the literature. They examined Acadian flycatchers in Kettle Moraine State Forest in Wisconsin and found low rates of parasitism (7–12 percent). They also re-examined the much-cited Brittingham and Temple (1983) study and found no correlation between nest parasitism and proximity to a non-forest opening when Acadian flycatchers were examined separately from the rest of the host species. Additionally, the separation of the Acadian flycatchers from the other species caused the relationship between proximity to edge and parasitism for the other 12 species to become non-significant. Temple (2004) suggested that the reduction in sample size may have contributed to the differences in the results and commented that Bielefeldt and Rosenfield's findings do not mean there is no biological effect of parasitism.

Similarly, Gustafson, Knutson, Niemi, and Friberg (2002) also found lower than expected rates of parasitism (approximately 7–12 percent) in Minnesota, Iowa, and the driftless area of southwestern Wisconsin. Although they did find a relationship between proximity to edge and parasitism on a local scale, parasitism on a landscape scale seemed to increase with increasing forest cover and decreasing fragmentation. However, the authors cautioned that cowbird parasitism patterns can be unpredictable.

Overall, the research points to three conclusions relevant to Wisconsin landscapes: (1) increasing abundance of the brown-headed cowbird is a result of increased feeding ground and access to host species; (2) increased fragmentation and creation of edge, including that resulting from transmission-line ROW construction, contribute to the accessibility of host species; and (3) brood parasitism by cowbirds has most likely contributed to the decline of many species of birds, including some forest-interior neotropical migrants. That said, parasitism patterns are highly variable depending on fragmentation of the landscape, local cowbird densities, amount of edge, and suitable breeding and foraging habitat in close proximity.

*Predation.* Edges have also been associated with increased rates of predation, both of nests and in a more general way. "Predators show numerical and functional responses to their prey." Simply put, "where there is more prey, there are more predators" said Temple (2004). Edges contain not only species from both of the adjacent habitats, but also edge species. Temple called this the "classic definition of edge effect: an increased density and diversity of species that live in edges." According to Temple, this means that "predators end up being attracted to edge." This phenomenon is becoming increasingly important in many parts of the state, especially in northern Wisconsin, where populations of medium-sized predators such as raccoons, opossums, jays, and grackles are increasing along with human development (Paulios 2004).

Alverson, Waller, and Solheim (1988) suggested that another factor related to higher rates of nest predation may be the increased abundance of deer in fragmented and edge-heavy landscapes. Increased deer browse associated with edge may reduce nest cover and increase rates of predation (Robinson and Wilcove 1994).

A frequently cited study used to corroborate the association between edge and high rates of predation was conducted in Maryland and Tennessee, but is applicable to Wisconsin. Wilcove (1985) measured predation using artificial nests filled with quail eggs and found that predation was greater along edges in suburban areas versus isolated woodlots and also greater for open-cup nests placed on the ground, versus open-cup nests placed higher up or cavity nests. On the other hand, Haskell (1995) questioned the validity of quail-egg predation experiments because many neotropical migrants produce eggs that are much smaller than those produced by quail. He found evidence that small rodents (e.g., chipmunks) cannot prey on quail eggs because the eggs are too large. He concluded, "Quail-egg experiments should not be accepted as reflecting the true differences in relative rates of predation on the nests of neotropical migrant birds living in fragmented landscapes."

The study conducted by Robinson, Thompsoni, Donovan, Whitehead, and Faaborg (1995) in Wisconsin and four other Midwestern states found that nest predation rates, like parasitism rates, were correlated with percentage of forest cover. Predation rates were especially high for some species that nested on or near the ground.

Flaspohler, Temple, and Rosenfield (2001) recently carried out a comprehensive study in northern Wisconsin examining natural nests for eight species of birds to determine whether a relationship exists between nesting success and proximity to edge. They found that for the two ground-nesting species, the hermit thrush (*Catharus guttatus*) and ovenbird, there was a relationship between nest failure and distance to edge, though only during the nestling stage, not during incubation. They also observed that nest density seemed to be higher along forest edges and, given the lower nesting success of ground-nesting birds near the edge, speculated that the forest edge may present an ecological sink.

As with parasitism, very few pertinent studies have been conducted specifically addressing predation rates along transmission-line ROWs. Fleming and Schmiegelow (2002) reported that artificial nest predation in Alberta, Canada, was greater along the edge of a wider ROW, but the width of the ROW did not affect the penetration depth of the predation into the forest.

## Limitations of the Research

One edge effect that is not often studied is the influence of humans (Meffe, Nielsen, Knight, and Schenborn 2002). Poachers, hunters, nature enthusiasts, birdwatchers, mountain bikers, and users of all-terrain vehicles find most transmission-line ROWs in Wisconsin readily accessible, especially where the ROW bisects a road. The low-growing vegetation typically encountered makes it a desirable transit route and allows humans access to areas that might otherwise have been relatively inaccessible.

In addition to human use, there is a paucity of research on the relationship between edge and non-avian species, non-forest habitats, and ecological processes other than predation and parasitism. Only a handful of studies exists and the results tell us almost nothing about ecological trends for species such as reptiles, amphibians, mammals, and insects or for wetlands and other habitats. It is assumed that edges experience higher rates of predation in general, not only nest predation, but there is little published evidence.

Edge effects are highly variable. Whether an effect exists, and if it does, determining the strength of that effect and whether it is beneficial or detrimental, is almost wholly dependent on the species in question. Nevertheless, edge effects are possibly the most significant outcome of fragmentation related to transmission-line ROWs discussed in this chapter.

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[ii] Although man-made edges usually start out abruptly defined, it is important to note that, in the case of transmission-line ROWs, only the area directly under the wire needs to be maintained as low-growing vegetation. The edges of the ROW can be allowed to return to somewhat taller vegetation (e.g., tall shrubs). In cross section, this type of vegetation scheme would form a cup shape with the lowest vegetation directly in the wire zone (Yakich 2004).

[iii] The term "edge effects" was originally used to discuss the increase in species diversity where two habitats meet, with either natural or man-made edges (Leopold 1933).
[iv] Small habitat patches can also function as ecological sinks and, although there is little concrete evidence, it is believed that northern Wisconsin may serve as a source for many species of birds typically associated with larger forests. These species also may be found in small patches that act as sinks and may be continually replaced by immigrants from the north woods (Temple and Cary 1988).
[v] The 75-foot wide corridor was a transmission-line ROW.

# Chapter 4

## ROW Corridors: Early Successional Habitat and Species Movement

### Introduction

An ecological corridor[vi] is a linear strip of vegetation connecting two similar patches of land. It is characterized by vegetation contrasting to that of the surrounding area, thus creating new habitat in both the corridor and the area directly adjacent to the corridor (Bennett 1999). New habitat will bring different species into the area, those species that would not have resided in the original, but are well-supported in the new. When corridors connect similar habitats, they also may serve as movement corridors by providing plants and animals with a dispersal route. Corridors increase connectivity[vii] between habitat patches and affect the surrounding landscape in both positive and negative ways, facilitating movement of rare or sensitive plants and animals in some cases, but also providing for the spread of unfavorable invasive species.

Corridors in Wisconsin exhibit many forms, including remnant strips of vegetation and man-made linear facilities such as fencerows and transmission-line ROWs. The land set aside for electric transmission lines creates long ribbons of low-growing vegetation, often in contrast to the landscapes through which they pass. As a result, transmission lines produce ecological corridors—used by some species as habitat and by some for movement.

This chapter presents two issues associated with the ecological role of corridors: (1) the formation of new early successional habitat, and (2) the function of connectivity and movement—both benefits and adverse effects. Based on information available in the literature and gathered through interviews, these issues are then discussed in the context of ecological corridors related to transmission lines in Wisconsin.

### Effects of Early Successional Habitat

Transmission-line ROW corridors can create new early successional habitat (Askins 1994; Geibert 1980; Meehan and Haas 1997; Kroodsma 1982; King and Byers 2002), as can old fields, over-grown farmsteads, abandoned orchards, regenerating forests, and floodplain areas. The vegetation structure and wildlife composition of early successional habitat is very different from that of older, mature habitat. Transmission-line ROWs provide benefits to the plant and animal species that thrive in early successional habitat—characterized by the mixture of grasses, flowering plants, shrubs, and saplings found in these areas (Askins 1994; King and Byers 2002). Examples of these beneficiaries include birds (Confer and Pascoe 2003; Askins 1994), a variety of butterflies (Lanham and Nichols 2002), rare plants (Sheridan and Penick 2002), and amphibians (Yahner, Bramble, and Byrnes 2001).

The species that use ROWs as habitat and the extent of the advantages or disadvantages found in a particular ROW depend on the vegetation and land management practices in the corridor and in the surrounding habitat, as discussed in the previous chapter on fragmentation. Increased habitat area typically leads to increased species diversity and improved population viability (MacArthur and Wilson 1967; Tewksbury, et al. 2002[viii]) for early successional species inhabiting the corridor.

Few adverse effects have been attributed specifically to the addition of early successional habitat. One documented concern is the possibility of creating habitat that functions as an ecological sink. As discussed in Chapter 3, these habitats may appear to provide an ideal environment, but new populations that enter after construction may not be sufficiently adapted to respond to the threats they encounter (Soulé 1991). In this way ROW habitat, like many small habitat patches, may suffer from a net loss of individuals for select species.

Additional negative effects generally are associated with habitat loss and fragmentation, which also were discussed in the preceding chapter. Like forest edges, habitat corridors, such as those created by transmission-line ROWs, are not immune to edge effects of predation or brood parasitism. As the surrounding landscape is influenced by the corridor, so is the corridor influenced by the surrounding landscape (Soulé 1991; Bennett 1999).

## Effects of Early Successional Habitat in Wisconsin

Open areas in Wisconsin, such as prairies, barrens, grasslands, and savannahs, are declining. The decline in these disturbance-dependent open areas is due mainly to a proliferation of trees that are able to invade because of the lack of sufficient disturbance, such as fire. The amount of early successional habitat is also declining—from post-settlement levels that were artificially elevated by development and logging—and now more accurately reflects the amount of early successional habitat that existed pre-settlement (Temple 2004). In this context, ROWs provide habitat for species that may face population reductions following habitat loss.

*Butterflies.* One documented benefit of ROW corridors in Wisconsin is the provision of abundant habitat for the federally endangered Karner blue butterfly (*Lycaeides melissa samuelis*) (Lowell and Lounsberry 2002). The Karner blue butterfly, a key Wisconsin species, is sensitive to habitat and land management practices. It relies on blue lupine (*Lupinus perennis*), an early successional plant, as a food source during its larval stage and on certain species of ants that tend the larvae. Blue lupine grows best in areas where it has relatively little competition (Lentz 2004) and high light intensity (Smallidge, Leopold and Allen 1995; 1996)—conditions often provided by ROWs. Management practices on ROWs can promote the growth of blue lupine and thus provide habitat for the Karner. Although the Karner is relatively abundant in Wisconsin because it has several areas of high-quality habitat, it is rare across the rest of the US, making Wisconsin a particularly important stronghold for the species (Lentz 2004).

Swengel (1996) conducted a study in central Wisconsin observing the frosted elfin (*Incisalia irus*), a state-threatened butterfly also dependent on blue lupine. She found that ROWs under a limited-mowing management plan were favorable habitat for this species.

*Reptiles and Amphibians*. ROWs and adjacent areas may also provide habitat for some amphibians. Robert Hay (2004), a herpetologist at the WI DNR, examined ephemeral ponds adjacent to a transmission-line ROW just west of Stevens Point, Wisconsin. He found four-toed salamanders (*Hemidactylium scutatum*), blue-spotted salamanders (*Ambystoma laterale*), tiger salamanders (*Ambystoma tigrinum tigrinum*), and wood frogs (*Rana sylvatica*) breeding in these ponds. "It may have been advantageous for them to have an open canopy because it would warm up the water more quickly and speed transformation," said Hay, adding that the transmission-line ROW may provide a unique opportunity for these species. This example demonstrates, explained Hay, that although the loss of original forest habitat may produce deleterious consequences for some reptiles and amphibians, other species will be able to take advantage of the new habitat.

*Birds.* The positive effect of new early successional habitat on specific bird populations in Wisconsin has been well-documented (Hanowski, Niemi, and Blake 1995). Cutright (2004) reported that, after grassland species, the birds that prefer early successional habitat are those that are facing the largest declines in Wisconsin, making ROWs potentially important areas for conservation of these avian species.

The chestnut-sided warbler (*Dendroica pensylvanica*) is one example of a bird that has benefited from habitat found on ROWs. Although not declining in Wisconsin, chestnut-sided warblers are facing declines in other parts of the US and appear to find ROWs suitable habitat. A study by Hanowski, Niemi and Blake (1995) conducted along a ROW in northern Wisconsin found that the chestnut-sided warbler and the mourning warbler (*Oporornis philadelphia*) preferred early successional habitat and were more abundant along the edge of the ROW than in the surrounding forest. Some researchers have expressed concern that ROWs may be sink habitats for chestnut-sided warblers; however, a study conducted by King and Byers (2002) in Massachusetts found that not only are ROWs source habitats for this species, but nest survival rates observed in this study were similar to those found in extensive remote patches of early successional habitat.

### Limitations of the Research

The research conducted on new early successional habitat in ROWs is limited. Results typically identify only the presence or abundance of a species and often do not examine population trends. David Mladenoff (2004), of the Forest Ecology and Management Department at the University of Wisconsin-Madison, stressed the importance of conducting field studies that examine not only whether a species inhabits or uses a ROW, but how the corridor affects their population over time. "Just because a given species is found in a corridor does not necessarily indicate that the particular habitat is producing an overall positive effect for the population."

## Connectivity and Species Movement—Benefits

Creating ecological corridors for the movement of animals and, indirectly, plants, between remnant habitat patches has been endorsed as a means of mitigating landscape fragmentation (Noss 1991). Increased connectivity facilitates immigration between habitat patches (Temple 1996) and dispersal through disturbed or otherwise unsuitable landscapes. It has been suggested, though not wholly accepted, that transmission-line ROWs, which traverse long distances and cross many different types of habitat, can benefit a few specific species by providing dispersal routes (Schaefer 2002). Ecological processes contributing to the spread and viability of plants can be affected by enhanced movement of organisms acting as pollinators or seed dispersers (Tewksbury, et al. 2002[ix]). The increased movement is thought to promote genetic exchange and enhance population viability (Temple 1996; Simberloff and Cox 1987) in plants and animals, thereby evading or reversing local extinction. This concept is known as the rescue effect, a phrase coined by Brown and Kodric-Brown (1977). It implies that populations can be rescued from the brink of local extinction by immigrants from other populations. Greater connectivity is often associated with augmenting conservation or wildlife enhancement efforts by allowing populations to avoid the problems associated with isolation and to colonize new habitat (Temple 1996; Beier and Noss 1998).

A number of field studies have been conducted on movement corridors, a handful of which specifically examine transmission-line ROW corridors functioning in this capacity. The weight of evidence suggests that some benefit is gained by their role in increasing connectivity of the landscape (Soulé and Giplin 1991; Haddad and Baum 1999; Gilbert, Gonzalez and Evans 1998; Coffman, Nichols and Pollock 2001); however, increased connectivity gained by new corridors is always at the expense of further fragmentation and habitat loss. Connectivity could also have a negative effect on the local ecology by facilitating the spread of invasive species.

## Benefits of Connectivity and Species Movement in Wisconsin

Wisconsin's highly fragmented landscape has created a myriad of isolated habitat patches. Many noted scientists consider transmission lines to be a potentially beneficial tool for mitigating effects of that isolation and maintaining connectivity in some Wisconsin landscapes. Temple (2004) said, "Utility corridors, roads, and other types of linear corridors may function to reconnect otherwise isolated patches." "In general," added Temple, "ecosystems that are physically and vegetatively similar to utility corridors, such as open grassland habitat, are among those most likely to benefit." In one article, he suggested that properly designed utility ROWs "could make a significant contribution to preserving threatened elements of the state's biodiversity" (Temple 1996).

The majority of the research literature, supported by anecdotal evidence, argues that ROW corridors have the potential, depending on their placement, to facilitate movement (Bennett 1999; Simberloff and Cox 1987; Lentz 2004). This is especially true for smaller species that have limited dispersal relative to the mobility of larger, wide-ranging animals (Mladenoff 2004; Temple 2004). On the other hand, scientists differ on whether these movement corridors play an important role in maintaining connectivity across Wisconsin's landscapes. Even among those who agree on this point, there remains controversy about whether this form of connectivity is a benefit or detriment to wildlife and conservation interests. According to some, movement corridors enhance conservation efforts (Bennett 1999; Simberloff and Cox 1987) by facilitating dispersal and enhancing the viability of populations through immigration and genetic exchange; however, several sources discussing movement corridors called ROWs "disturbance corridors" and suggested that they have limited potential for positively affecting the landscape (Bennett 1999; Barrett and Bohlen 1991).

Given the habitat provided by ROWs and the landscape composition of Wisconsin, the areas most likely to be positively affected by ROW connectivity are pine barrens, oak savannahs, and prairies, which typically exist in the state as small, disconnected patches in a larger matrix of dissimilar habitat, usually woodland. These habitats are diminishing in abundance and quality in Wisconsin with changes in fire and land-use patterns. Because they often support small populations of rare or sensitive species, conservation benefits could be gained by connecting the patches. These areas are mostly concentrated in the northwest, northeast, and central sands regions of Wisconsin (Epstein 2004).

*Karner Blue Butterfly.* The most convincing evidence that corridors facilitate beneficial movement comes from studies of butterflies, especially the Karner blue in Wisconsin. This evidence shows positive results in specific areas where historically the habitat was barrens and savannah-type communities and has since become overgrown with forest, leaving patches of open habitat in a matrix of wooded land (Hay 2004).

Research conducted by Jim Hardin (2004) and his students in the wildlife program at the University of Wisconsin-Stevens Point College of Natural Resources, found that the Karner blue butterfly will avoid dispersing through “perfectly open” pine plantations, preferring to use corridors. According to Hardin, Karners will use open corridors, such as transmission-line ROWs, even if blue lupine is not part of the vegetational composition. As long as there is an abundance of other flowering plants, Karners will use corridors as a means to move from one lupine patch to another or to colonize unoccupied patches (Hardin 2004). Dave Lentz (2004), the Karner blue butterfly habitat conservation plan implementation coordinator at the WI DNR, agrees that Karners do use ROWs both as habitat and to move between sites. Because Karners have limited dispersal abilities, effective sites must be relatively close together.

A study by King (1998) in Wisconsin’s Necedah National Wildlife Refuge observed that Karner blue butterflies dispersed approximately three-quarters of a mile, although they did not use corridors that were provided by road edges in his study to do so. King did stress that the study site was atypical, consisting of mostly open-canopy uplands, and that ROW corridors might aid the butterfly’s dispersal through closed-canopy forests.

*Reptiles and Amphibians.* Hay (2004) stated that ROWs could provide connectivity for some open-area reptiles in northwestern Wisconsin in an area of habitat currently and historically similar to that of the Karner blue butterfly. Transmission-line ROWs, assuming they connected these patches, could provide easy access between open areas that snakes and lizards might use. Butler’s garter snake (*Thamnophis butleri*), a state-threatened species, is one reptile that might especially benefit from ROW-connected patches. Based on some of the WI DNR’s survey work, Hay observed, “There’s a likelihood that those transmission-line corridors could be important for genetic exchange for this particular species.”

*Large Mammals.* Researchers have considered whether large animals, such as elk, would use transmission-line corridors as travel lanes (Turner 2004; Anderson 2004; Hardin 2004). Monica Turner (2004), a zoology professor at the University of Wisconsin-Madison, reported on a current study examining movement of elk that were reintroduced in Wisconsin in 1995. The site of reintroduction was deemed suitable habitat for browsing because it is located near a matrix of openings consisting of two federally owned facilities and adjacent transmission-line ROWs in northern Wisconsin (Anderson 1999). Turner believes the data will show that elk are using these corridors as travel lanes and Eric Anderson (2004), a wildlife ecologist at the University of Wisconsin-Stevens Point, agreed.

*ROW Management*. The majority of the experts interviewed felt that ROWs, if properly managed and thoughtfully sited, could provide important movement corridors for Karners and perhaps other species as well. As an example, Temple (1996) discussed using ROWs to promote dispersal of sharp-tailed grouse, an isolation-sensitive species with a behavioral aversion to passing through wooded habitat. Referring to pine barrens, he concluded that if the option exists "to keep important elements of biological diversity interconnected rather than fragmented . . . a perceptive utility industry could become part of the solution rather than part of the problem" (Temple 1996). Epstein (2004) commented, "I think it has been hoped that there would be some ability through the placement and management of corridors to link such patches and allow organisms to move back and forth and it may be happening. Connecting patches via corridors is a more attractive prospect than having to conduct translocations of individuals." However, William Fannucchi (2004) of the Electric Division at the Wisconsin Public Service Commission stressed that these benefits are secondary effects and should be recognized as such. He stated that the positive effects are limited and should always be considered retrospectively and not in advance of a project.

Further, species movement along ROWs cannot always overcome the challenge that large gaps between habitat patches pose to those with limited dispersal ability. In the case of transmission-line corridors, land use and ROW management are key factors in their ecological function. Much of the land in ROWs is privately owned and managed. A transmission-line easement crossing agricultural land will most likely continue to be cultivated. The likelihood of any transmission-line ROW maintaining long distances of similar contiguous vegetation is low and therefore, for some species, such variation in land use will affect the functioning of ROWs as efficient movement corridors (Yakich 2004).

## Limitations of the Research

Evidence in support of the benefits of connectivity is limited, species-specific, and incomplete. For some ecologists and conservation biologists, sufficiently convincing data are lacking and they consider the effectiveness of ROWs as movement corridors an optimistic possibility at best. Cutright (2004) believes that travel lanes and travel corridors are talked about more than they are understood. "I think the hope is that they could be very valuable," he said, but added that we have very little understanding of the importance or documentation of the effects.

"It is natural to want to generalize the effect of corridors but it simply cannot be done," said Mladenoff (2004). The merits of a transmission-line ROW as a movement corridor must be evaluated on a case-by-case basis because some ROWs may facilitate beneficial movement while others may not. As with most natural systems, the function of a ROW corridor will depend on a number of factors such as management, width of the ROW, habitat types being connected, and species factors such as composition and local population densities. To take variable results from species-specific studies and make generalizations about the effectiveness of transmission-line ROWs as beneficial dispersal-facilitating corridors overall, is not worthwhile. More field studies are needed on these linear habitats before definitive patterns can be established.

An additional problem is the difficulty involved in separating the effects of connectivity from the effects of increased habitat, both of which provide for increased species diversity and population viability (Tewksbury, et al. 2002[x]). Rosenberg, Noon, and Meslow (1997) find the ambiguous use of the term corridor to be a potential source of contention within the scientific community. Controversy over whether, as a general rule, corridors can be considered effective promoters of animal and plant dispersal is difficult to rectify because each corridor must be evaluated in the context of the particular species and habitat under observation. "Indeed, there is no general answer to the question 'Do corridors provide connectivity?'" stated Beier and Noss (1998), because specifics regarding species and habitat are necessary. A final problem with regard to the literature that examines connectivity and species movement is that the vast majority of the studies focus on either animals or plants, and do not address complex plant-animal interactions, such as pollination and seed dispersal (Tewksbury, et al. 2002).

## Connectivity and Species Movement—Adverse Effects

The previous section discussed benefits associated with increased movement; however, there is evidence that not all movement is positive. Scientists caution that the most detrimental consequence of corridors is the facilitated spread of invasive[xi] and undesirable species into previously pristine areas (Csuti 1991; Zink, Allen, Heindl-Tenhunen, and Allen 1995; Panetta and Hopkins 1991; Wilcox 1989). Invasive plants, also referred to in the literature as exotics, aliens, non-natives, or simply weeds (Westbrooks 1998), share characteristics that make them detrimental to native landscapes, including faster growth rates, efficient dispersal mechanisms, and tolerance of a wide range of conditions (Hoffman and Kearns 1997). These plants are also at an advantage because they typically exist in the absence of natural enemies that would serve to limit their populations.

When utility ROWs are "heavily disturbed but minimally maintained," they can serve as ideal sites for invasive plants to become established and spread (Westbrooks 1998). A poor restoration and management effort can lead to the establishment of exotics in the corridor and their spread into the surrounding landscape (Zink, Allen, Heindl-Tenhunen, and Allen 1995).

The large edge-to-area ratio and construction and maintenance disturbances associated with ROWs create an ideal situation for the establishment of invasive plants. The aggressive and opportunistic nature of invasives may endanger native plant and animal populations (Rubino and Williams 2002). Invasive species and their ability, in many cases, to out-compete native plants often create largely homogeneous areas with few other species. Zink, Allen, Heindl-Tenhunen, and Allen (1995) contrasted the vegetation in a pipeline corridor to that of an ecological reserve nearby and found the corridor to consist of a homogeneous community dominated by exotics, highly dissimilar to the surrounding vegetation.

Physically, corridors make easily accessible entrances into otherwise undisturbed areas. Animals following ROWs can act as seed carriers, either on their body or in their gut, as can the wind (Panetta and Hopkins 1991). Human influences also can affect the landscape directly through hunting and poaching, or indirectly by transporting seeds on clothing, unwashed recreational vehicles or utility equipment from existing infested areas through which the corridor passes.

## Adverse Effects of Connectivity and Species Movement in Wisconsin

Evidence suggests that ROWs do contribute to the spread of invasive species in Wisconsin (Howe 2004; Fannucchi 2004; Fewless 2004; Waller 2004; Rooney 2004, Kearns 2004). These corridors provide linkages between infested and uninfested areas and sufficient disturbance to promote invasive plant establishment. This phenomenon concerns Mathews (2004), "The tradeoff suggested is that corridors have more negative impacts on native biodiversity due to the entrance of exotics."

*Invasive Plants*. Wisconsin scientists interviewed cited invasive species as a serious concern in the state and noted that transmission-line ROWs contribute to the spread of invasive plants that directly threaten native plants and indirectly threaten animals through degradation of habitat (Panetta and Hopkins 1991).

Prairie and Open Areas—Fewless (2004), Howe (2004), and Kearns (2004) all expressed concern over the progression of invasives. Howe is most troubled about impacts on prairies, barrens, and other open habitats, including semi-native grasslands. Because comparable ecological conditions are found in both open areas and ROWs, Howe reasons that many invasive plants that would be found in ROWs may cause problems in prairies and other open areas because their spread would be limited only by the size of the patch of similar habitat. John Harrington (2004), Landscape Ecology Department, University of Wisconsin-Madison, agreed that this could be a problem. Kelly Kearns (2004), the plant conservation program manager at the WI DNR, listed leafy spurge (*Euphorbia esula)* and spotted knapweed *(Centaurea biebersteinii)* as the two most important invasive species affecting prairies, in addition to cut-leaved and common teasel (*Dipsacus laciniatus* and *Dipsacus sylvestris),* sweet clovers (*Melilotus alba* and *Melilotus officinalis)* and tansy (*Tanacetum vulgare).* Harrington added wild parsnip (*Pastinaca sativa*), quack grass (*Elytrigia repens*), reed canary grass (*Phalaris arundinacea*), smooth brome (*Bromus inermis*), and even some opportunistic native shrubs (e.g., prickly ash, gray dogwood) to the list of potential prairie-invaders.

Although conducted in habitat not found in Wisconsin, the Zink, Allen, Heindl-Tenhunen, and Allen (1995) study in California lends support to Howe's theory that prairies and other open areas are more susceptible to invasion. The authors observed that invasion of exotic plants appeared to be from a disturbance corridor into undisturbed native communities, especially those communities with a more open canopy. Another study, conducted by Tyser and Worley (1992) in Glacier National Park, corroborates Howe's concern about exotic invasion of grasslands. According to the authors, exotics use road corridors as foci of invasion into the surrounding grasslands. In particular, they found that fescue grassland in this region was vulnerable to invasion by exotics, even with low levels of disturbance.

Forests—Wisconsin experts interviewed identified honeysuckle (*Lonicera sp.*), buckthorn (*Rhamnus cathartica* and *Rhanmnus frangula*), autumn olive (*Elaeagnus umbellata*), multiflora rose (*Rosa multiflora*), dame's rocket (*Hesperis matronalis)* and garlic mustard (*Alliaria petiolata*) as invasive species in Wisconsin with habitat requirements that would allow them to invade forests from a transmission-line ROW. Fewless (2004) expressed a particular concern about invasives spreading through transmission corridors in northern Wisconsin forests, many of which are still free of invasive plants.

Wetlands—Kearns (2004) identified reed canary grass *(Phalaris arundinacea)* as the most important wetland invasive species. Phragmites (*Phragmites australis)*, wild parsnip (*Pastinaca sativa)*, crown vetch (*Coronilla varia)*, and bird's foot trefoil (*Lotus corniculatus)* can also invade wetlands. If introduced, purple loosestrife (*Lythrum salicaria*) is adept at colonizing these areas as well (Howe 2004; Braker 2004; Waller 2004; Rooney 2004).

Transmission of Invasives—According to Yakich (2004), at times, recreational use of ROWs in Wisconsin can be so extensive that it can be difficult to maintain vegetative cover. Rooney (2004) and Waller (2004) identified construction, maintenance, and recreational vehicles as possibly the most significant means of transmission of invasive plants along ROW corridors. The mud found on their tires can harbor and transport seeds of invasive plants from another part of the ROW or from another area altogether. In addition to vehicular traffic, movement of humans and animals is a catalyst for the spread of invasive plant seeds. Many invasive plants have seeds with mechanisms for sticking to fur, feathers, or clothing or they are ingested and eliminated in another location, often along the corridor or corridor edge, a preferred perching place for birds (Howell 2004; Fewless 2004). Further, it is common in Wisconsin to see evidence of invasive plants entering a transmission-line corridor from an infested road edge where the two intersect (Yakich 2004).

*Disease and Other Disruptions*. Studies warn that corridors could have adverse effects such as facilitating the spread of fires and transmitting contagious disease (Simberloff and Cox 1987). Mathews expressed concern that ROWs could facilitate the spread of chronic wasting disease, which is already present in deer populations in Wisconsin and in numerous states in the West.

Hess (1994) lends support to the theory that corridors can facilitate disease movement by using a model to contrast predictions of the spread of a contagious disease throughout a landscape connected by corridors with landscape patches that are unconnected. Hess' (1994) results show that connected patches generally suffer fewer animal extinctions than unconnected patches, "yet, for a small number of combinations of population growth rate and disease-induced mortality, the extinction rate in a connected landscape increases dramatically, surpassing the extinction rate in a landscape of isolated patches." This happens, wrote Hess, when a population of infected individuals survives long enough to allow for transmission of the disease between connected patches. Hess cautioned, "While connecting reserves with corridors may generally be beneficial, unanticipated consequences of these connections may decimate populations of the very organisms they were designed to protect."

## Limitations of the Research

A few studies looking into the severity of the concerns about species movement contradict the general agreement about invasive species among the Wisconsin experts. Rubino and Williams (2002) examined transmission-line corridors in Pennsylvania and found that invasive species were abundant in the corridor, but largely absent from the surrounding riparian forest. Cameron, Leopold, and Raynal (1997) concluded that the presence of invasives on ROWs should not be considered a major concern because, although ROWs are susceptible to non-native colonization, the overall coverage of exotic plants in a ROW is relatively small, and even smaller in the adjacent forest. They found that management-related disturbance did not in fact result in invasion of aggressive species that would cause a decline in species richness.

Two caveats must be made about these studies: (1) ROWs are open areas, and as such, will always have higher densities (and more flowering) of most exotics, and (2) most ROWs are relatively new (i.e., only decades old), meaning that their long-term impacts cannot yet be judged. Invasions often have a lag phase that can last a few decades before a species rapidly increases. In addition, early stages of any invasion may not appear to be serious if only a few plants are involved; however, these can eventually grow rapidly when the population reaches a certain threshold (Waller 2004).

The number of studies addressing the relationship between ROW corridors and disease transmission is limited, and most scientists offer a precautionary note in lieu of research data. Although there is little evidence that corridors contribute to extinction through spreading disease, some scientists continue to view disease transmission as a concern (Hess 1994). "[The lack of evidence] does not mean these issues should be dismissed; rather, empirical studies and monitoring of existing linkages are required to evaluate these concerns," said Bennett (1999).

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[vi] This report uses the term "ecological corridor" to mean that which may be referred to in the literature as a "wildlife corridor," "landscape linkage," "dispersal corridor," "green belt," or "greenway" (Bennett 1999).

[vii] "Connectivity…involves linkages of habitat, species, communities, and ecological processes at multiple spatial and temporal scales" (Noss 1991).

[viii] Tewksbury, Levey, Haddad, Sargent, Orrock, Weldon, Danielson, Brinkerhoff, Damschen, and Townsend

[ix] Tewksbury, Levey, Haddad, Sargent, Orrock, Weldon, Danielson, Brinkerhoff, Damschen, and Townsend

[x] Tewksbury, Levey, Haddad, Sargent, Orrock, Weldon, Danielson, Brinkerhoff, Damschen, and Townsend

[xi] For a list of all invasive species found in Wisconsin, please see the WI DNR Web site: <http://www.dnr.state.wi.us/org/caer/ce/invasives/listing.htm>.

# Chapter 5

## Summary and Conclusions

### Summary

The literature on the ecological effects of fragmentation focuses on reduced habitat area, species isolation, and increased habitat edge. Although very little has been written specifically about transmission-line ROWs, it is possible to summarize some key points related to fragmentation in general.

Plants and animals that are area sensitive, isolation sensitive, or edge sensitive will be negatively affected by fragmentation; however, plants and animals that are not sensitive to fragmentation may be unaffected or even positively affected by the separation if it results in an increase in habitat or favorable conditions for these species. There is some confusion in the literature regarding the term area sensitive because it is clear that not all species referred to as area sensitive in the literature are responding to a physical reduction in area. Some species, for instance those that are edge sensitive, do not require large blocks of habitat; hence, they may demonstrate a species-area relationship that is a result of edge-related pressure, not area per se.

Increased edge enhances local species diversity and has a positive effect on some individual species, typically those that are habitat generalists and are already relatively common in the landscape. However, increased edge also facilitates brood parasitism and predation, which have a negative effect on many species that are already rare. As a result, increased local diversity often comes at the expense of global species diversity, as rare plants and animals are replaced by common ones and habitat specialists are replaced by habitat generalists. This phenomenon causes ecosystems to lose complexity.

The literature on corridors formed by fragmentation focuses on early successional habitat, connectivity, and movement, especially movement of invasive species. A corridor may enhance local species diversity in an area because it provides new habitat for species that thrive in early successional forests. On the other hand, a corridor can be a challenge for species that are not adapted to new threats introduced by the change in landscape. Corridors can help some species overcome isolation by connecting populations living in rare, irregularly distributed ecosystems but they also allow for movement of invasive species. The effects of corridors are not only species specific, but are positive for some and negative for others.

Although it is difficult to generalize the ecological effects of fragmentation and corridors to the specific situation created by transmission-line ROWs, the conclusion offered by a review of the literature is that attention must be paid to maximizing the beneficial effects of ROWs while minimizing the detrimental effects for rare and endangered species in order to provide for the greatest global biodiversity.

## Conclusions

Transmission-line ROWs do not appear to have a broad ecological effect on groups of plants and animals in Wisconsin. On the contrary, the effects seem to be species-specific and localized; a particular species may experience a limited effect, but that effect cannot be extrapolated to other species in other locations throughout the state. ROWs have a relatively narrow width, and therefore are more likely to filter movement of animals, rather than completely block movement. Consequently, few species will be isolated or will perceive a reduction of their habitat area due to a ROW, although there may be substantial effects of increased edge.

In general, the literature presents three significant ecological effects of fragmentation that are relevant to transmission-line ROWs in Wisconsin: (1) creation of increased forest-edge habitat, (2) formation of early successional landscapes, and (3) spread of invasive species. Information gleaned from the interviews of Wisconsin scientists helps to form a perspective on some key applications of conclusions from the literature to ROWs in Wisconsin.

*Increased edge habitat.* Long linear breaks in the landscape, such as those produced by ROWs, create increased edge habitat. In fact, a distinguishing characteristic of a transmission-line ROW is that the percent of new edge habitat is high relative to the overall area of the ROW. This new edge habitat is a benefit to species that live in or use the early successional habitat that exists in ROWs, such as deer, which profit from the browsing potential created by increased edge. In Wisconsin, where deer are abundant, this is not considered to be a positive outcome, particularly for the state's native plants already suffering from heavy deer browsing. Increased edge has also been associated with a decrease in forest songbirds in Wisconsin as a consequence of increased brood parasitism from brown-headed cowbirds and predation of songbird nests.

*Early successional habitat.* The creation of open and early successional habitat in a ROW is beneficial to species that thrive in this type of landscape. In Wisconsin, ROWs have a positive effect on the federally endangered Karner blue butterfly. This species has increased in open areas, such as managed ROWs, where blue lupine, a plant vital to the butterfly's survival, is increasing in abundance. The Karner blue butterfly thus serves as an example of a positive outcome of ROW corridors.

*Invasive species.* A negative result of the increased connectivity and movement afforded by a ROW corridor is the potential for introduction of invasive species. For example, movement by animals along a ROW or human movement for management or recreational purposes can facilitate the spread of invasive species into previously inaccessible areas. This increased movement provides for the spread of damaging plants that monopolize ecosystems and compete with native vegetation, negatively affecting animals dependent on those habitats. It is evident from the interviews that the spread of invasive species is an issue of great concern to Wisconsin scientists.

# Chapter 6

## Gaps in the Research

### Introduction

The published scientific literature on the ecological effects of fragmentation tends to be scattered and suffers from a number of identifiable research gaps. These become even more apparent when information provided by the interviews of Wisconsin scientists is combined with findings from the literature. Because some ecological effects of ROWs are more consequential than others, the three areas of study that emerge as most important for an understanding of the ways in which transmission-line routing in Wisconsin can affect the local ecology are increased edge, early successional habitat, and invasive species.

### Increased Edge

The changes associated with construction of transmission-line ROWs include effects that vary in both magnitude and importance. In terms of overall impact relative to more intrusive landscape changes, ROWs cannot be considered major factors in reduced habitat area or increased species isolation for a majority of plants and animals; however, they have a significant impact on increased habitat edge. Without a doubt, edge effects are the most significant ecological outcome of fragmentation resulting from ROW development. There are a number of possible topics for future investigation of the effects of increased edge habitat.

- ROW width and management: How do ROW width and vegetation management in the ROW affect rates of cowbird parasitism and predation? Are there ROW widths or management techniques that could minimize the negative impacts associated with edge and maximize positive habitat- or connectivity-related benefits for Wisconsin's endangered species, threatened species, and species of special concern? How do these outcomes associated with ROWs differ from other forms of landscape fragmentation?
- Predation rates: To what degree are different species affected by predation across the state? Does predation affect non-avian species? How does management of the ROW edge facilitate or inhibit predator movement?
- Cowbirds: Causal evidence between cowbird parasitism and declining avian populations is lacking for most species. Which population declines are predominantly related to high rates of parasitism? What are the geographical patterns of cowbird parasitism in Wisconsin? How are amount of edge, regional cowbird densities, amount of forest interior, landscape configuration, and proximity to edge and cowbird feeding grounds related to parasitism rates?
- Source-sink dynamics: Are animals avoiding edge? Attracted to edge? Experiencing lower reproductive success along the edge? How do these patterns differ across the state? Where are species succeeding and which areas are sinks?

- Non-forest habitat: How are non-forest landscapes, such as wetlands, open areas, barrens, and prairies, affected by ROW edge?
- Human activity: How do edge-related human activities influence ecosystems?
- Movement: Does the density of vegetation typically found along the edges act as a barrier to movement for any species?

## Early Successional Habitat

Although the early successional habitat created by transmission-line ROW corridors is generally viewed as beneficial for some plants and animals in Wisconsin, there are limited data on the species that inhabit ROWs, especially those that are endangered, threatened, or of special concern, and whether or how they profit from this type of habitat.

- ROW species: What are the species that inhabit ROWs? Breed in ROWs?
- Source-sink dynamics: Does the narrow width of the ROW habitat make early successional species more susceptible to edge effects from the surrounding landscape? Do ROWs negatively affect some species by acting as ecological sinks?
- Management: How does management of a ROW affect which species reside there? Does ROW width affect a population's fitness or movement capabilities in ROW habitat?

## Invasive Species

The relationship of ROW corridors to connectivity and movement of invasive species in Wisconsin is not well-documented. Much of the concern regarding invasive species is a result of observations and anecdotal evidence.

- Construction and management of ROWs: Can ROWs be constructed and managed to maximize benefits and minimize adverse effects, particularly to species that are endangered, threatened, or of special concern in Wisconsin? What are the effects of vegetative composition and management (e.g., mowing, herbicide use) on facilitating or impeding movement of invasive species?
- Life history: How do invasive species differ in their ability to spread and colonize habitats?
- Human activity: What is the role of humans in the spread of invasive species along ROWs and can the spread be mitigated by management of access for leisure activities or best construction practices?

## Other Gaps

The three preceding categories deserve attention because they are the most significant ecological effects of transmission-line ROWs. However, there are gaps in the research pertaining to the other sections discussed in the report that merit consideration as well.

- Perception of fragmented habitat: What is the gap width at which key species lose their ability or willingness to cross?
- Connectivity and movement: Which species respond positively to connectivity? What ROW width or management practices are necessary to ensure that ROWs

are used as movement corridors for species that are endangered, threatened, or of special concern? What is the risk of ROWs facilitating disease transmission and how can this risk be mitigated through management practices?

- Isolation: Which species, if any, are susceptible to isolation resulting from ROW-induced fragmentation? How can that isolation be mitigated through management or construction practices? How are isolated populations affected? Genetically? Minimum patch size?

## Common Themes

Two general research gaps overlie all of the others. First, ecologists do not have enough information about the distribution, abundance, reproductive and habitat requirements, and interactions of plants and animals to determine what development activities will affect particular populations. For example, some groups, particularly plants and insects, may be significantly affected by ROW-induced isolation; however, a lack of general ecological knowledge makes it difficult to identify the affected groups or individual species. Field work on actual ROWs in Wisconsin on exotic plants, grassland birds, and the Karner blue butterfly would be invaluable.

Second, many studies discussed in this report and almost all the studies specific to ROWs are short-term and/or species-specific. In order to determine the effects of fragmentation related to ROWs, scientists need to have an understanding of the baseline—the assemblage of species that existed in an area prior to construction disturbance—before they can conduct meaningful research that could establish a causal relationship. General trends can only be identified when studies examine a number of species over time. The most useful studies would measure the abundance and distribution of a variety of species in a site before construction of a transmission-line ROW and for a period of time after construction. ROW-induced fragmentation may result in effects that are not perceived because they occur a long time after construction or they affect species that are not studied because they are deemed unimportant in relation to economic activity or conservation in the state.

## Conclusion

In order for ROW management practices to be effective, information must be available to enable managers to balance positive and negative outcomes of fragmentation with the needs and values of the citizens of Wisconsin, including:

- Human access for recreation
- Conservation, preservation, and restoration
- Economic development
- Quality of life

In reviewing the gaps in the research relevant to the ecological effects of fragmentation related to transmission-line ROWs in Wisconsin, it is clear that future research needs to be part of an overall framework of investigation with defined goals. Determination of next steps should be made with the elements presented in this report in mind.

**Appendix A**

# Interviews

All interviews were conducted by Cassandra Willyard from **February 24 to June 7, 2004**. Interviews were conducted by telephone and in person.

**University of Wisconsin-Madison**
John Harrington, Department of Landscape Architecture
Evelyn Howell, Department of Landscape Architecture
Robert Jeanne, Department of Entomology
Nancy Mathews, Department of Wildlife Ecology
Thomas Rooney, Department of Botany
Stanley Temple, Department of Wildlife Ecology
Monica Turner, Department of Zoology
Donald Waller, Department of Botany

**University of Wisconsin-Green Bay**
Gary Fewless, Department of Biology
Robert Howe, Department of Biology

**University of Wisconsin-Eau Claire**
Evan Weiher, Department of Biology

**University of Wisconsin-Stevens Point**
Eric Anderson, College of Natural Resources Wildlife Program
Alan Haney, College of Natural Resources Forestry Program
Jim Hardin, College of Natural Resources Wildlife Program

**State Government of Wisconsin**
Eric Epstein, Department of Natural Resources, Bureau of Endangered Resources
William Fannuchhi, Wisconsin Public Service Comission
Robert Hay, Department of Natural Resources, Bureau of Endangered Resources
Darrell Zastrow, Department of Natural Resources, Forestry Department

**Other**
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Noel Cutright, WE Energies

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**Appendix B**

# References

This list includes all references cited in the report as well as those providing background information but not cited. Abstracts are included for studies carried out in Wisconsin.

Ades WE. 1993. Do transmission lines fragment Wisconsin's forested natural areas? [M.S. thesis]. Madison (WI): University of Wisconsin-Madison. 64 p.

This Master's thesis examines whether transmission lines fragment Wisconsin's forests by looking at where transmission lines cross state natural areas and private preserves based on information from the Wisconsin Department of Natural Resources and the Nature Conservancy and information on transmission line routes from the Wisconsin Public Service Commission, Wisconsin Power and Light, and Dairyland Power Cooperative. Using this information, Ades located 54 transections and estimated their impacts on forest interior birds, by dividing the transections into low impact (with almost no forest interior), intermediate impact, and significant impact. Out of 54 natural areas transected by ROWs, 17 were significantly impacted. ROW transections in private forested areas were not taken into account.

(Abstract written by Resource Strategies, Inc. staff.)

Albrecht S, Hinkle R, Winship K. 1999. Habitat fragmentation resulting from the construction of linear projects: literature review—phase I. Chicago: Gas Technology Institute [previously Gas Research Institute (GRI)]. GRI-99/0034.

Alverson WS, Waller DM, Solheim SL. 1988. Forests too deer: edge effects in northern Wisconsin. *Conservation Biology* 2:348–58.

White-tailed deer densities can have profound effects on native herbaceous and woody plant populations such as Canada yew, eastern hemlock, and white cedar, evidenced by exclosure studies and populations surveys. Current deer densities in northern Wisconsin are far above what existed pre-settlement due to heavy logging during the nineteenth century and creation of "wildlife openings" to produce more easily accessible forage. Deer are highly mobile and their browsing activities penetrate deep into the forests. This increase in edge and early successional habitat has created and continues to create artificially high deer densities that threaten native fauna. The authors believe that some of this threat could be mitigated by providing for extensive unfragmented blocks of forest and increasing hunting.

(Abstract written by Resource Strategies, Inc. staff.)

Ambuel B, Temple SA. 1983. Area-dependent changes in the bird communities and vegetation of southern Wisconsin forests. *Ecology* 64:1057–68.

We studied avian biogeography and habitat selection in forests of southern Wisconsin ranging in area from 3 to > 500 ha. Bird diversity in these woodlots increases with area, due primarily to an increase in the number of forest-dwelling, long-distance migrants. We consider two possible explanations for this pattern: (1) area-dependent changes in forest vegetation, or (2) area-dependent change in interactions with competitors, predators, or brood parasites. We first describe vegetation structure and composition, then show that this description comprises important habitat features of forest birds. Bird habitat is characterized in three ways: (1)

vegetational structure within bird territories is compared with that at random locations in the same woodlots, (2) structural characteristics of territories of different species are compared, and (3) factors related to species' abundance in different woodlots are analyzed. We found no area-dependent trends in vegetation structure or composition that seem likely to influence the bird community. However, forest-edge and farmland species increase in density as woodlot area decreases. We suggest that forest-edge and farmland species increase in density as woodlot area decreases. We suggest that forest-edge and farmland species exclude certain forest-dwelling, long distance migrants from small woodlots, and that this exclusion influences the bird community more than area-dependent changes in habitat or the degree of woodlot isolation.
(Abstract reproduced with permission from the publisher.)

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We investigated the incidence of parasitism by brown-headed cowbirds (*Molothrus ater*) on the nests of Acadian flycatchers (*Empidonax virescens*) in relation to distance of hosts' nests to non-

forest openings in the Kettle Moraine State Forest (KMSF) in southeastern Wisconsin during 1991-94. We also reexamined the results of this relation in these (and other) species of songbirds in an oft-cited paper by Brittingham and Temple (1983), who reported a significant increase of parasitism with the proximity of host nests to non-forest opening on another southern Wisconsin study area. Parasitism in the KMSF was calculated at 7-12% of 69 flycatcher nests; we found no correlation (P > 0.05) between parasitism and nests' nearness to non-forest openings. Extraction of Acadian flycatcher nests from the composite data for 13 host species of songbirds in Brittingham and Temple (1983) eliminated the significant relation between parasitism rates and non-forest proximity for the combined nests of the 12 remaining hosts (P = 0.18), and for the flycatcher evaluated separately (P = 0.16). The Wisconsin data reported and reexamined here do not support the proposition that the rate of cowbird parasitism on forest-interior birds diminishes with increasing distance from forest edges and openings over distances of 300 m for openings greater than or equal to 0.2 ha in size.
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Brittingham MC, Temple SA. 1983. Have cowbirds caused forest songbirds to decline? *BioScience* 33:31–5.
Brown-headed cowbird populations and their rate of brood parasitism on forest songbirds in eastern North America have increased since 1900. Brood parasitism of forest songbirds is highest near open habitat. High brood parasitism rates within isolated fragments of forest habitat reduce reproductive success of certain forest songbirds and may be responsible for their recent declines.
(Abstract reproduced with permission from the publisher. Copyright, American Institute of Biological Science.)

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Using natural nests of eight bird species, we provide one of the first multispecies tests for edge effects on reproductive success in a forested landscape. Our primary objective was to assess whether distance to the edge of recent clearcuts was related to nesting success in intact northern hardwood forests. Estimated nest success was generally lower for the two ground-nesting species than for the six canopy-nesting species. Brood parasitism was <3% for species which typically accept eggs of the Brown-headed Cowbird (*Molothrus ater*), and nest predation was the most common cause of nest failure. Probability of nest failure was influenced by distance to forest edge for the ground-nesting Hermit Thrush (*Catharus guttatus*) and Ovenbird (*Seiurus aurocapillus*), but not for six canopy-nesting species. For the Hermit Thrush and Ovenbird, nest success relative to decreasing distance to the edge was reduced during the nestling stage, but not the incubation stage. Nest density appeared to be higher in forest zones near the clearcut edge for ground-nesting and for several canopy-nesting species. Our data suggest that the effect of proximity to edge on nest success for ground-nesting species may penetrate 300 m into intact forest, while the effect of proximity to edge on nest density may penetrate farther. These data suggest that the creation of openings in forested landscapes reduces nest success and increases nest density for some species of migratory birds in a zone adjacent to the opening. This pattern supports the notion that “ecological traps” may exist for ground-nesting birds in areas near recently created forest openings. Because areas of contiguous forest (e.g., publicly owned forest) in the Upper Great Lakes remain relatively intact, they may serve as source habitat for regional songbird metapopulations.
(Abstract reproduced with permission from the publisher.)

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We constructed alternative spatial models at two scales to predict Brown-headed Cowbird (*Molothrus ater*) parasitism rates from land cover maps. The local-scale models tested competing hypotheses about the relationship between cowbird parasitism and distance of host nests from a forest edge (forest–nonforest boundary). The landscape models tested competing hypotheses about how landscape features (e.g., forests, agricultural fields) interact to determine rates of cowbird parasitism. The models incorporate spatial neighborhoods with a radius of 2.5 km in their formulation, reflecting the scale of the majority of cowbird commuting activity. Field data on parasitism by cowbirds (parasitism rate and number of cowbird eggs per nest) were collected at 28 sites in the Driftless Area Ecoregion of Wisconsin, Minnesota, and Iowa and were compared to the predictions of the alternative models. At the local scale, there was a significant positive relationship between cowbird parasitism and mean distance of nest sites from the forest edge. At the landscape scale, the best fitting models were the forest-dependent and forest-fragmentation-dependent models, in which more heavily forested and less fragmented landscapes had higher parasitism rates. However, much of the explanatory power of these models results from the inclusion of the local-scale relationship in these models. We found lower rates of

cowbird parasitism than did most Midwestern studies, and we identified landscape patterns of cowbird parasitism that are opposite to those reported in several other studies of Midwestern songbirds. We caution that cowbird parasitism patterns can be unpredictable, depending upon ecoregional location and the spatial extent, and that our models should be tested in other ecoregions before they are applied there. Our study confirms that cowbird biology has a strong spatial component, and that improved spatial models applied at multiple spatial scales will be required to predict the effects of landscape and forest management on cowbird parasitism of forest birds.
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A four-year study was undertaken in order to assess the effects of edge habitat on species residing in an adjacent forest. Counts were conducted in Wisconsin two times a year—breeding and migration seasons, in two sites—edge and forest reference, from 1986 to 1989. Results revealed no differences in numbers of individuals or species between the reference and edge study areas; however among forest bird species that prefer edges, they were found to be more abundant there, in breeding season (Chestnut-sided Warbler and Mourning Warbler) or in both seasons (Black-and-white Warbler). The results of analyses of transects in this study suggest that the effects of the ROW edge extend to a depth of at least 200 meters into the forest.
(Abstract written by Resource Strategies, Inc. staff.)

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Small isolated forest patches (0.1–7 ha) in eastern New South Wales and southern Wisconsin were surveyed regularly for at least 1 yr between 1977 and 1981. Forests and woodlands in both regions have been cleared extensively during the past century. This analysis examines how fragmentation of forest habitat has affected composition and dynamics of local bird assemblages. Species in forests islands are compared with those in equivalent "control plots" near the edge of a large, continuous forest. Disruption of continuous tracts apparently affects not only birds of the forest interior, but also those occurring along or near the edge. Birds in New South Wales and Wisconsin show common patterns of distribution among forest islands, despite considerable differences in taxonomic relationships, seasonality, and habitat. (1) Area was the best predictor of species richness in islands and control plots. Other habitat variables (except isolation) were relatively uniform among sites and did not contribute consistently to variation in numbers of species. (2) Species common in forest islands also tended to be common in large nearby forests, but bird assemblages in forest islands were statistically different from those in forest control plots. (3) Species assemblages in forest islands generally were more predictable over space and time than were local assemblages in larger forests. Although transients or regular visitors commonly were observed in forest islands, nonresident species occurred even more frequently in control plots. Apparently habitat fragmentation alters the spatial and temporal dynamics of native forest bird communities. This, in turn, may favor some species and leave others at a disadvantage. Differences between species assemblages of forest islands and control plots were most pronounced in Wisconsin. Numbers of forest or forest edge species were much lower in Wisconsin forest islands than in corresponding control plots. Isolation of forest islands was associated negatively with species richness only in Wisconsin. Long-term effects of forest fragmentation in New South Wales might not yet be realized, because relatively large areas of forest remain near existing habitat islands.
(Abstract reproduced with permission from the publisher.)

Howe RW, Temple SA, Mossman MJ. 1992. Forest management and birds in northern Wisconsin. *The Passenger Pigeon* 54(4):297–305.
Northern Wisconsin is home to many species of birds, some endangered and threatened. In order to properly manage these populations and ensure that they persist, it is important to know their habitat requirements, the threats they face, and what management strategies should be implemented to conserve these populations. While habitat information is available for many species found in northern Wisconsin, management strategies have not been clearly identified. For this reason, the US Forest Service convened a Scientific Roundtable of experts to identify strategies for managing for biological diversity in the Nicolet and Chequamegon national forests. This article presents the recommendations of a sub-group that focused on the impacts of forest management on native bird species. Birds were divided into five categories, (1) source/core species, which appear to be more abundant, widespread, or productive in Wisconsin than in other areas, (2) isolation-sensitive species, (3) edge-sensitive species, (4) area-sensitive species, and (5) species with special needs. The authors discuss and give examples for each category. Averting declines in bird populations in northern Wisconsin means managing for vulnerable species or protecting large enough areas of habitat so that ecological processes continue to function, making specific management actions unnecessary, say the authors.
(Abstract written by Resource Strategies, Inc. staff.)

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Mark-release-recapture research was conducted to determine dispersal ability and patterns of the Karner blue butterfly (*Lycaeides melissa samuelis Nabokov*). Karner blue butterflies were marked during the first and second flights of the 1995 field season. Two hundred and three individuals were marked during the first flight, and 1,236 were marked during the second flight. The mean distance traveled by males between locations was 4569 m and 214.7 m during the first and second flights, respectively. The mean distance traveled by females between locations was 69.8 m during the first flight and 359.2 m during the second flight. Inter-site dispersers (those individuals dispersing 1,150 m to new sites) represented 7.4% and 11.2% of the recaptures during the first and second flights respectively. Only one individual (0.07%) was located on a road corridor between suitable habitat patches. The percentage of individuals making inter-site

dispersals was markedly different between sexes and among individual sites. Wind direction had no detectable effect on emigration rates for any of the sites, although significant differences in immigration rates were detected among wind directions. The observed dispersal trends indicate that Karner blue butterflies were able to disperse substantial distances (> 1,150 m) frequently and that they rarely use corridors to do so.
(Abstract reproduced with permission from the Wisconsin Academy of Sciences, Arts and Letters.)

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As a condition of a SEP-II project, Lakehead Pipe Line Company has undertaken a project to monitor species on ten miles of right-of-way in Adams and Wood Counties in Wisconsin. The purpose of this project is to determine the success of a restoration effort of the habitat of the federally endangered Karner Blue Butterfly that was disturbed during pipeline construction in 1997 and 1998. Preliminary results of the monitoring and assessment of the frequency and density of Karner Blues and food sources such as the lupine and other nectar plants indicate that the restoration effort will indeed replace disturbed habitat and in fact is likely to, in the long term, enhance habitat for the Karner Blues.
(Abstract written by Resource Strategies, Inc. staff.)

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Predation of artificial nests in pine barrens savanna patches in northwestern Wisconsin was correlated significantly with proximity to edge ($P = 0.02$). Densities of blue jays (*Cyanocitta cristata*) and brown-headed cowbirds (*Molothrus ater*) were significantly greater along edge transects than savanna interior transects ($P < 0.001$ and $P = 0.001$). Land management practices in the pine barrens may influence edge-related nest loss.

(Abstract reproduced with permission from The Wildlife Society.)

Noss RF. 1991. Landscape connectivity: different functions at different scales. In: Hudson WE, editor. *Landscape linkages and biodiversity*. Washington (DC): Island Press. p 27–39. ISBN: 1-55963-109-0.

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Robinson SK, Thompsoni FR, Donovan TM, Whitehead DR, Faaborg J. 1995. Regional forest fragmentation and the nesting success of migratory birds. *Science* 267(5206):1987–90.
Forest fragmentation, the disruption in the continuity of forest habitat, is hypothesized to be a major cause of population decline for some species of forest birds because fragmentation reduces nesting (reproductive) success. Nest predation and parasitism by cowbirds increased with forest fragmentation in nine midwestern (United States) landscapes that varied from 6 to 95 percent forest cover within a 10-kilometer radius of the study areas. Observed reproductive rates were low enough for some species in the most fragmented landscapes to suggest that their populations are sinks that depend for perpetuation on immigration from reproductive source populations in landscapes with more extensive forest cover. Conservation strategies should consider preservation and restoration of large, unfragmented "core" areas in each region.
(Abstract reproduced with permission from the American Association for the Advancement of Science. Copyright 1995 AAAS.)

Robinson SK, Wilcove DS. 1994. Forest fragmentation in the temperate zone and its effects on migratory songbirds. *Bird Conservation International* 4(2-3):233–49.

Rolley RE. 2003. White-tailed deer population status . <http://dnr.wi.gov/org/land/wildlife/harvest/Reports/wtaildeerpop03.pdf>. Accessed June 2004.

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Rooney TP, Waller DM. 2003. Direct and indirect effects of white-tailed deer in forest ecosystems. *Forest Ecology and Management* 181:165–76.
Ungulates, including white-tailed deer, have the ability to profoundly alter native ecosystems, both structure and function, by limiting regeneration of those plants that the deer favor or that are especially susceptible through browsing activities. Deer play a keystone role in many ecosystems because changes in faunal composition cause a cascade of indirect effects that can change how an ecosystem functions. Habitat modification and extirpation of native predators have caused substantial increases in deer densities and these unnaturally high densities have, in turn, reduced regeneration of eastern hemlock and white cedar and possibly oak and birch as well. Although the effect of deer on herbaceous understory plants is harder to assess, evidence from 50 years previous seems to indicate that the communities are changing in a way that implicates deer, with a reduction in forest herbs and an increase in grasses, ferns, and sedges. Despite this evidence, many important questions related to the effects of deer on the surrounding landscape are still unanswered.
(Abstract written by Resource Strategies, Inc. staff.)

Rooney TP, Wiegmann SM, Rogers DA, Waller DM. 2004. Biotic impoverishment and homogenization in unfragmented forest understory communities. *Conservation Biology* 18(3):787–98.
By using baseline data from 50 years ago, the authors were able to develop a clear and accurate picture of how understory vegetation in northern Wisconsin has changed. The study sites exist in a landscape that remains relatively unfragmented, however, despite this, changes were significant. Native species density declined an average of 18.5 % and the ratio of exotic species to native species increased at 80% of the sites. There were fewer habitat specialists and more habitat generalists, which accounted for the documented 8.7% rise in similarity between the sites. The greatest declines in native species density were seen in areas where deer hunting is prohibited. The authors identify deer as a key driver of community change and caution that, without active efforts to protect diversity, these trends will continue.
(Abstract written by Resource Strategies, Inc. staff.)

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In surveys conducted during 1988–95, 164 individuals of the frosted elfin (*Incisalia irus*) were found, 139 of them during formal transects that totaled 92.9 hr and 179.4 km of survey effort during the frosted elfin flight period. Individuals were observed between 10 May and 14 June, with maximum flight spans in a single year of 27–31 days. Peak flight occurred just before or at the beginning of peak flowering of the larval host, wild lupine (*Lupinus perennis*), and the first spring adults of Karner blue (*Lycaeicles melissa samuelis*), also monophagous as larvae on wild lupine. Fourteen individuals exhibited oviposition behavior on young stalks of green lupine flower buds. 94% of individuals occurred in savannas, nearly evenly split between open (10%–24% canopy) and closed (25%–49% canopy) ones. Relative lupine abundance at both the microsite and landscape scales appeared more important as a habitat factor than actual size of the particular lupine patch occupied. Both long-term lack of site management and too frequent/intense management (forestry, rotational fire) appeared unfavorable. Recreational trailsides, areas burned by wildfire 4 years ago, and rights-of-way mowed annually or less often

were favorable habitat. All frosted elfin sites also supported Karner blues, but within these sites, correlation of frosted elfin abundance with that of Karner blues was rather weak, indicating a fair degree of niche segregation between these two species.
(Abstract reproduced with permission from The Great Lakes Entomologist.)

Temple SA. 2004. Department of Wildlife Ecology, University of Wisconsin-Madison. Interviewed on April 20.

Temple SA. 1996. Ecological principles, biodiversity, and the electric utility companies. *Environmental Management* 20(6):873–8.
The synthetic field of conservation biology uses principles derived from many different disciplines to address biodiversity issues. Many of these principles have come from ecology, and two simple ones that seem to relate to many issues involving the utility industry are: (1) "Everything is interconnected" (and should usually stay that way), and (2) "We can never do merely one thing." The first principle can be applied to both the biotic and physical environments that are impacted by industrial activities. Habitat fragmentation and the loss of physical and biotic connectedness that results are frequently associated with transmission rights-of-way. These problems can be reduced--or even turned into conservation benefits--by careful planning and creative management. The second principle applies to the utility industry's programs to deal with carbon released by burning fossil fuels. Ecological knowledge can allow these programs to contribute to the preservation of biodiversity in addition to addressing a pollution problem without careful ecological analyses, industry could easily create new problems while implementing solutions to old ones.
(Abstract reproduced with permission from the publisher.)

Temple SA. 1998a. Easing the travails of migratory birds. *Environment* 40:6–9+.

Temple SA. 1998b. Surviving where ecosystems meet: ecotonal animal communities of Midwestern oak savannas and woodlands. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters* 86:207–21.
The animal communities associated with Midwestern oak savannas and woodlands have a typical ecotonal character. They are relatively rich in species, but they are composed mostly of species that have the centers of their geographic ranges in either the deciduous forest biome to the east or the prairie biome to the west. Few species have ranges centered on the transition zone (or ecotone) between these major biomes. Within the ecotone, species show individualistic patterns of habitat selection, with most species associated with a particular habitat type within the ecotone's complex mosaic of patches, ranging from prairies, through savannas and woodlands, to forests. The characteristics of the landscape surrounding a remnant patch of oak savanna or woodland (its context) influence the composition of the animal community in the patch, in some cases even more strongly than the characteristics of the patch itself at a large biogeographical scale, most species in the ecotone are near the edges of their ranges, and it is likely that their fitness is lower than it is nearer the centers of their ranges. At a smaller landscape scale, the patchy mosaic of habitats in the ecotone produces ecological phenomena, such as edge effects, that can reduce fitness of some species. Populations of species near the edges of their ranges or in relatively small habitat patches are often sink populations that require subsidies of dispersing immigrants from source populations either nearer the center of the range or in larger patches of forest or prairie habitat to remain viable. The remnant patches of oak savanna and woodland in the Midwest are now small, degraded, isolated and out of context. Scale and context (both

regional and local) are, therefore, important predictors of the composition and viability of animal communities in these remnant patches. Current efforts to manage and restore remnant oak savannas and woodlands must address these needs of the animal community if they are to truly reproduce the characteristic diversity of species associated with the ecotone.
(Abstract reproduced with permission from the Wisconsin Academy of Sciences, Arts and Letters.)

Temple SA, Cary JR. 1988. Modeling dynamics of habitat-interior bird populations in fragmented landscapes. *Conservation Biology* 2340-7.
By using a stochastic computer model, the authors of this paper were able to examine the effects of habitat fragmentation on a hypothetical population of forest-interior birds. Fecundity, which varied with distance to edge, was found to have the greatest influence on population dynamics. The authors found that fecundity dropped as the landscape became more fragmented and edge increased. They speculated that this drop in reproduction was significant enough to cause population declines, similar to what has been seen in southern Wisconsin. Local extinction may result for avian populations living in fragmented landscapes if those populations are not replenished with recruits from more productive areas.
(Abstract written by Resource Strategies, Inc. staff.)

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**Appendix C**

# Wisconsin Species with Special Ecological Requirements

The following table lists Wisconsin species that are sensitive to fragmentation or have special habitat requirements that make them vulnerable to human development activities. Selection of species was based on information provided by the Wisconsin Department of Natural Resources and presented in Howe, Temple, and Mossman (1992). Data for this table were gathered from a variety of sources. Each source is identified by the superscript number that follows the entry and corresponds to the key at the end of the table. The list is by no means exhaustive and does not imply that all species included will necessarily be negatively affected by ROWs. For example, the sharp-tailed grouse may benefit from connectivity that could be provided by the ROW corridors. Without a specific location and transmission line in mind, it is difficult to say how a ROW will influence a species. For this reason, habitat information and management considerations are given for most of the species on the list to help identify areas where the species is likely to be found, threats to the populations, conservation strategies, and other relevant information.

| **Species** | **Habitat** | **Type of sensitivity** | **WI Status**[1] | **Management Considerations** |
|---|---|---|---|---|
| BIRDS | | | | |
| Acadian flycatcher<br><br>*(Empidonax virescens)* | Require large tracts of mature mesic forest, with semi-open understory, and prefer forested streamsides and ravines. Breed in mesic, dry-mesic, and wet-mesic forests, as well as in hemlock, yellow birch, and white pine relics. In Kettle Moraine State Forest in southeastern Wisconsin, they have been found nesting in over-mature conifer plantations, with nests in red pine, white pine, Norway spruce, black cherry, box elder, common buckthorn, American elm, red oak, and white mulberry.[1] | Habitat quality sensitive, edge sensitive[5] | Threatened | Competition with northern mesic forest bird species, especially the least flycatcher (*Empidonax minimus)*, may be one barrier to range extension. Their distribution in the state is limited and relatively small, and they require large blocks of forest as nesting habitat. Any activity that destroys, reduces, or fragments extensive tracts of forest limits habitat availability for the Acadian flycatcher. Preservation of the Baraboo Hills and protection against fragmentation and logging will continue to provide habitat suitable for this bird. The conifer plantations in southern Wisconsin provide suitable habitat as well. Management of these plantations, including thinning but not fragmenting, will provide potential habitat.[1] This species is at the northern edge of its range in Wisconsin.[5] |
| Barn owl<br><br>*(Tyto alba)* | Fields of dense grass, open and partly open country (grassland, marsh, lightly grazed pasture, hayfields)[2] | Habitat quality sensitive[5] | Endangered | Declines related to loss of grassy habitat due to development, lack of secure nest sites. Protection of grassland habitats and the installation of nest boxes in or adjacent to grassy habitats. The southern third of the state is the northern edge of its range.[1] |
| Black-backed woodpecker | Boreal and montane coniferous forests, especially in areas with | Habitat quality sensitive[5] | Special concern- | This species is at the southern edge of its range in Wisconsin.[5] Timber harvest, fire suppression, removal of fire-killed or insect-infested trees, |

| Species | Habitat | Type of sensitivity | WI Status[1] | Management Considerations |
|---|---|---|---|---|
| *(Picoides arcticus)* | standing dead trees such as burns, bogs, and windfalls; less frequently in mixed forest and rarely in winter in deciduous woodland[2] | | protected | and the conversion of mature and old-growth forests to young stands with few decayed trees pose significant threats to the species. This species is uncommon in the landscape and populations may be depressed regionally. Sustaining and restoring viable populations will require a landscape and regional scale approach to habitat management, restoring natural fire regimes, allowing for natural patterns of insect infestation and disease to occur across landscapes, and maintaining fire-killed trees at least up to six years post-fire or until wood-boring insects decline. Further research is needed to better understand interactions in the dynamic context of forest fire and insect cycles.[2] |
| Black-throated blue warbler<br><br>*(Dendroica caerulescens)* | Understory of deciduous and mixed woodland, second growth, and partially cleared forest[2] | Edge sensitive[4] | Special concern-protected | Management should include preservation of forest tracts that are large with minimal edge, maintenance of dense understory, and alleviation of overbrowsing by white-tailed deer.[2] |
| Boreal chickadee<br><br>*(Poecile hudsonica)* | Black spruce bog[4] | Isolation sensitive[4] | Special concern-protected | |
| Canada warbler<br><br>*(Wilsonia canadensis)* | Woodland undergrowth (especially aspen-poplar), bogs, tall shrubbery along streams or near swamps, and deciduous second growth[2] | Edge sensitive[4] | Not listed | Habitat loss is a primary concern. Brood parasitism by brown-headed cowbirds occurs, but its impacts have not been studied. There is little information available on predation, but the species' ground-nesting habit may increase risk of losses.[2] |
| Cape May warbler<br><br>*(Dendroica tigrina)* | Primarily in forests of spruce and/or fir with well developed crowns[2] | Habitat quality sensitive[5] | Special concern-protected | The continued loss of mature forest throughout the breeding range will undoubtedly contribute to long-term declines in this species.[2] Wisconsin is at the southern edge of this species' range.[5] |
| Cerulean warbler<br><br>*(Dendroica cerulea)* | Mature, mesic deciduous woodlands[1] | Habitat quality sensitive[5] | Threatened | Limiting factors include forest fragmentation, loss of tree species to disease, cowbird parasitism, and human disturbance. Protection of mature forest tracts will benefit this species.[1] |
| Connecticut warbler | Spruce and tamarack bogs, dry ridges, poplar and aspen woods, moist areas with low shrubby growth, thick | Habitat quality sensitive[5] | Special concern-protected | Much of the core of this species' range is in the western boreal forest, so is threatened by forest conversion to agriculture along the southern edges of the boreal zone. This is one of the least well-known birds in |

| Species | Habitat | Type of sensitivity | WI Status[1] | Management Considerations |
|---|---|---|---|---|
| *(Oporornis agilis)* | undergrowth, or sapling thickets[2] | | | North America. Any study of its general biology would be a valuable contribution; the highest priority is a thorough study of its biology on the breeding grounds.[2] This species is at the southern edge of its range in Wisconsin.[5] |
| Gray Jay *(Perisoreus Canadensis)* | Coniferous and mixed coniferous-deciduous forest (primarily spruce), including open and partly open woodland and around bogs[2] | Isolation sensitive[4] | Special concern-protected | |
| Great gray owl *(Strix nebulosa)* | Dense coniferous and hardwood forest, especially pine, spruce, paper birch, poplar; also second growth[2] | Habitat quality sensitive[5] | Special concern-protected | Wisconsin is the southern edge of this species' range.[5] In addition to the provision of suitable habitat, management needs include protection of nesting areas from excessive human activity during the nesting season.[2] |
| Greater prairie-chicken *(Tympanuchus cupido)* | Prairie-openings interspersed among oak woodland and oak savannah[1] | Area sensitive[5] | Threatened | Habitat improvement, manipulations of grazing pressure, control of burning, providing dense vegetation for protective cover. Reintroduction possibly necessary, but often unsuccessful.[1] |
| Hooded warbler *(Wilsonia citrina)* | Mature southern silver maple-elm forest and southern sugar maple-basswood forest, and in pine plantations in southeastern Wisconsin.[1] | Edge sensitive within its range, habitat quality sensitive in Wisconsin[5] | Threatened | Forest fragmentation reduces nesting habitat and may increase predation and brown-headed cowbird parasitism. Management of forest areas to promote a dense understory while preventing fragmentation is necessary to maintain the habitat of this neotropical migrant.[1] |
| Kentucky warbler *(Oporornis formosus)* | In Wisconsin, Kentucky warblers nest in shrubby woodlands on hillsides and in brush floodplains, especially near white oak swamps. They are found particularly in areas with a dense understory near the base of surrounding bluffs and occur along major rivers, such as the Mississippi, lower Chippewa, and Wisconsin, and in ravines and hillsides of streams that feed into these rivers.[1] | Edge sensitive within its range[5] | Threatened | This species was rare in Wisconsin in the nineteenth century. Nesting has not been reported from any eastern counties, and all eastern sightings have been considered nonresident. The necessity of a dense understory may limit the Kentucky warbler. This species builds its nest on or near the ground. Preservation of large continuous blocks of deciduous forests in the Baraboo Hills and along the major river valleys of southwestern Wisconsin will benefit the species,[1] which is at the northern edge of its range in Wisconsin.[5] |
| Leconte's sparrow *(Ammodramus* | Sedge meadow[4] | Area sensitive[4] | Special concern-protected | Land use changes have affected the extent and distribution of available habitats. Brood parasitism by brown-headed cowbirds has been reported, but it is not known how productivity is affected.[2] |

| Species | Habitat | Type of sensitivity | WI Status[1] | Management Considerations |
|---|---|---|---|---|
| *leconteii)* | | | | |
| Lincoln's sparrow<br><br>*(Melospiza lincolnii)* | Bogs, wet meadows, riparian thickets, shrubby forest edge, marshes, brushy fields, also jack pine plain barrens[2] | Area sensitive[4] | Not listed | |
| Northern goshawk<br><br>*(Accipiter gentilis)* | Summer–conifer and boreal forests of northern Wisconsin; winter–southern Wisconsin or further south to neighboring states.[1] | Area sensitive[4] | Special concern-protected | Threatened by timber harvest and logging operations, or any activity that removes large trees. Habitat patch connectivity is also important to consider. Ecological units need to include a wide variety of forest conditions, from regenerating stands to mature second-growth or old-growth stands.[2] |
| Northern harrier<br><br>*(Circus cyaneus)* | Marshes, meadows, grasslands, and cultivated fields[2] | Area sensitive, habitat quality sensitive[5] | Special concern-protected | The most significant threat is the continuing loss of open habitats.[2] |
| Palm warbler<br><br>*(Dendroica palmarum)* | Bogs, open boreal coniferous forest, partly open areas with scattered trees and heavy undergrowth, usually near water[2] | Area sensitive[4] | Not listed | |
| Pileated woodpecker<br><br>*(Dryocopus pileatus)* | Dense deciduous, coniferous, or mixed forest, open woodland, and second growth[2] | Area sensitive[4] | Not listed | The primary management concern is the provision of required forest habitats, including both deciduous and coniferous forests. The most important characteristics of the forests are that they are extensive, and that they include mature trees and snags, a more or less open forest floor littered with decaying wood, and a relatively humid environment that promotes fungal decay and the ant, termite, and beetle populations on which these birds feed.[2] |
| Red-shouldered hawk<br><br>*(Buteo lineatus)* | Bottomland hardwoods, mesic deciduous or mixed deciduous-conifer forests, and wooded margins of marshes[1] | Area sensitive[4] | Threatened | Protection of large blocks of forest habitat.[1] |
| Sharp-tailed grouse<br><br>*(Tympanuchus phasianellus)* | Open barrens[4] | Isolation sensitive[4] | Special concern-protected | Historic conversion of native habitat to private cultivation is cited as a major contributor to declines. Natural succession of grasslands and shrub lands to forests, accelerated or expanded geographically by artificial fire regimes, have influenced habitat quality and populations in several regions. Habitat and distribution is constrained in regions where fire suppression has reduced early and mid-successional |

| Species | Habitat | Type of sensitivity | WI Status[1] | Management Considerations |
|---|---|---|---|---|
| | | | | vegetation communities.[2] |
| Solitary vireo<br><br>(Vireo solitarius) | Mixed coniferous-deciduous woodland, humid montane forest[2] | Edge sensitive[4] | Not listed | |
| Spruce grouse<br><br>*(Falcipennis canadensis)* | Conifer swamp and jack pine forest[4] | Isolation sensitive, edge sensitive[4] | Threatened | Preservation of large tracts of coniferous forest will benefit this species.[1] |
| Swainson's thrush<br><br>*(Catharus ustulatus)* | Dense tall shrubs, coniferous woodland, aspen-poplar forest, second growth, willow and alder thickets[2] | Edge sensitive[4] | Special concern-protected | |
| Wood thrush<br><br>*(Hylocichla mustelina)* | Deciduous or mixed forests with a dense tree canopy and a fairly well-developed deciduous understory, especially where moist[2] | Edge sensitive[4] | Not listed | Habitat degradation and fragmentation are commonly cited as the biggest threats. With loss of habitat and increased conversion to agriculture and pine plantations, both brood parasitism and nest predation increase. The brown-headed cowbird is by far the most serious threat, causing significant population declines throughout much of the range. In some areas of the Midwest, for example, thrushes are producing more cowbirds than thrushes, and avian nest predators such as grackles and crows are a serious threat.[2] |
| Worm-eating warbler<br><br>*(Helmitheros vermivorus)* | Well-drained, steep sloped hillsides within ravines and large tracts of southern Wisconsin forest[1] | Edge sensitive within its range[5] | Endangered | This species is as rare in Wisconsin now as it probably was a century ago. Nests are usually located on the ground and are threatened by predation. The local distribution of breeding populations and the species' sensitivity to forest fragmentation are causes for rarity and concern. Preservation of large blocks of mature decidous forest in the Baraboo Hills and along the Mississippi and Wisconsin rivers will aid conservation efforts.[1] This species is at the northern edge of its range in Wisconsin.[5] |
| Yellow-throated warbler<br><br>*(Dendroica* | Southern silver maple-elm forests[1] | Edge sensitive within its range[5] | Endangered | Proof of breeding in Rock County led the Bureau of Endangered Resources to add this bird to the Wisconsin endangered species list. Within its range in Wisconsin, this specie's status has changed from "accidental" to "casual" to "rare." Preservation of large unfragmented |

| Species | Habitat | Type of sensitivity | WI Status[1] | Management Considerations |
|---|---|---|---|---|
| *dominica)* | | | | bottomland forests will benefit this neotropical migrant.[1] Wisconsin is the northern edge of this species' range.[5] |
| MAMMALS | | | | |
| American marten<br><br>*(Martes americana)* | Mature, dense conifer forests or mixed conifer-hardwood forests. They prefer woods with a mixture of conifers and deciduous trees including hemlock, white pine, yellow birch, maple, fir and spruce. Large limbs and fallen trees in the understory are especially critical. In the past, the cutting of large areas of mature conifer forests destroyed much marten habitat.[1] | Area sensitive[5] | Endangered (re-introduced) | American martens are not endangered in the US or Canada. In some parts of their range, however, martens have been extirpated or are endangered. In 1972, American martens were placed on the Wisconsin Endangered Species List. Only through recent efforts to introduce martens from other parts of North America has a small marten population been established in the northeast and northwest segments of Wisconsin's national forests. Although0 the Nicolet National Forest population is increasing, it is too early to determine the status of the newly reestablished Chequamegon population. Extensive tracts of habitat should be maintained, particularly mature conifer forests with live-cavity trees, snags, and windfalls.[1] |
| Moose<br><br>*(Alces alces)* | Spruce forests, swamps, aspen and willow thickets[3] | Sensitive to a parasite that also affects white-tailed deer[5] | Special concern-protected | Meningeal worm may limit moose populations in areas where white-tailed deer are common. Deer are not negatively affected by the meningeal worm, the larval stage of which is passed in deer feces. Snails, often inadvertently ingested by moose feeding on vegetation, are the intermediate host for the worm. Deer, through worm-mediated impacts, commonly are believed to exclude moose from areas where deer occur.[2] |
| Timber wolf<br><br>*(Canis lupus)* | Central and northern Wisconsin[1] | Sensitive to interactions with humans, area sensitive[5] | Threatened | Wolves were classified as threatened in Wisconsin in 1999 and the WI DNR approved a new wolf management plan for the state that set a state delisting goal at 250 and management goal at 350, outside of Indian tribal lands.[1] |
| Wisconsin puma<br><br>*(Felis concolor schorgeri)* | Forests, swamps[3] | Sensitive to interactions with humans, area sensitive[5] | Special concern-protected | This species is listed by the WI DNR as one that occurred historically in the state and is suspected to still exist. Its occurrence may not have been verified in the past 20 years.[1] |
| REPTILES | | | | |
| Black rat snake<br><br>*(Elaphe obsoleta)* | Wooded bluffs and valleys of the driftless area in southwestern Wisconsin, where it reaches the northern limit of its range[6] | Sensitive to specific habitat needs[5] | Special concern-protected | Wyalusing State Park, at the juncture of the Wisconsin and Mississippi rivers, has the most consistent sightings of this uncommon species, which is thought to be in decline. It is also found in the Baraboo Hills in Sauk County. Few data are available on its status in the state.[6] |
| Eastern massasauga rattlesnake | River bottom forests and nearby fields, mesic prairies and lowland places, such as along rivers, lakes, | Habitat quality sensitive, area sensitive, and | Endangered | The distribution and numbers of this critically endangered species have been drastically reduced from historic levels in Wisconsin. Populations have declined by 90% or more, and available information leads experts |

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| *(Sistrurus catenatus catenatus)* | and marshes[1] | sensitive to persecution by humans[5] | | to suggest that no viable populations remain. Declines are a result of habitat destruction and degradation, collecting for commercial trade, and wanton killing.[6] Without the protection of its wetland habitats, the massasauga has no chance for survival. There is a lack of information about this species' life history and more research is needed.[1] |
| Timber rattlesnake<br><br>*(Crotalus horridus)* | Wooded hills, meadows and dry hillside prairies[6] | Sensitive to specific habitat needs and persecution by humans,[5] isolation sensitive[2] | Special concern-regulated with open/closed seasons | The timber rattlesnake has experienced the most dramatic declines in the states that represent the northern portion of its range, such as Wisconsin. In many of these states, appropriate habitat is limited, and this habitat has experienced significant alteration from human activities. In Wisconsin, the Timber Rattlesnake historically occupied the bluff country of the driftless area. The species still occupies most of its historical range in the state, but it has experienced a dramatic reduction in both the number of active hibernation sites (dens) and the number of individual snakes. Recent population surveys by scientists from the Wisconsin Department of Natural Resources, the Milwaukee County Zoo, and the Milwaukee Public Museum, indicate that timber rattlesnake populations are very low, with most dens now having too few snakes to support a population over time. Timber rattlesnake populations continue to decline today from habitat loss and degradation, particularly at critical den sites, as well as from indiscriminate killing and over-harvest by sport and commercial hunters.[6] |
| BUTTERFLIES & MOTHS | | | | |
| Powesheik skipperling<br><br>*(Oarisma powesheik)* | Wet mesic prairie habitat with native grasses, sedges, and a significant component of plants in the sunflower family[1] | Sensitive to availability of habitat and isolation[1] | Endangered | Each of the few sites in the state must be managed as the only remaining habitat for the species. Populations appear to exhibit fluctuations in size and small populations any given year combined with extremes of weather, management, or unforeseen events could cause local extirpations; therefore efforts to expand habitat, create corridors between existing populations, and bolster population sizes are important for the long term survival of the species in Wisconsin. Burn management used to discourage woody plants and cool-season grasses in the open wet prairie community is best conducted with controlled infrequent burns affecting only a portion of the available habitat. Selective cutting and mowing may be better management tools for inhabited patches.[1] |
| Regal fritillary<br><br>*(Speyeria* | Large grassland areas with prairie remnants or lightly grazed pasture lands containing prairie vegetation | Sensitive to habitat quality and possibly | Endangered | Survival of regal fritillaries in Wisconsin will depend on protection and enhancement of large areas of suitable grassland habitat. Habitat fragmentation and loss of prairie communities to development and |

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| *idalia)* | where topography often includes hills and valleys[1] | area sensitive[1] | | intensive agriculture contribute to the decline of the species. Grassland management activities must be adjusted where regal fritillaries are established in order to maintain the populations. Sites that experience frequent controlled burns (less than 5–7 year rotation) exhibit reduced numbers of butterflies; therefore, burn management should be avoided on regal sites. Light grazing, infrequent mowing and/or localized brush cutting are positively associated with regal abundance on sites in Wisconsin. Regals are strong fliers and appear to require large areas to support a population though area size depends on availability of quality habitat that will vary according to local vegetation and management.[1] |
| INSECTS | | | | |
| Lake Huron locust *(Trimerotropis huroniana)* | Inhabits exposed, high quality open dunes as well as upper beach areas with very sparse grasses, forbs, and beach shrubs on the northern shores of the Great Lakes[1] | Sensitive to habitat availability and quality[1] | Endangered | The Lake Huron locust has narrow habitat preferences and is threatened by shoreline recreational development along the Great Lakes dunes area. Habitat conservation with minimized human use will benefit this species.[1] |
| Red-tailed prairie leafhopper *(Aflexia rubranura)* | Dry to wet-mesic prairies with the host plant, prairie dropseed. Appears to be absent from prairies in southwestern Wisconsin.[1] | | Endangered | The leafhoppers have been found to survive on burned sites in very low numbers and recovery is largely by migration from unburned areas. As a flightless insect, the leafhopper travels slowly from unburned areas and such refugia must include enough prairie dropseed to sustain the population. Grazing reduces prairie dropseed. Mowing seems to have little effect on leafhopper populations and can be useful to remove woody plants encroaching on the prairie but does not remove the thatch buildup that eventually reduces prairie dropseed.[1] |

1. Wisconsin Department of Natural Resources
2. NatureServe Explorer
3. Burt (1980)
4. Howe, Temple, and Mossman (1992)
5. Temple (2004)
6. Wisconsin Herpetological Atlas Project