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Chapter 15

Habitat Fragmentation: A Threat to Pennsylvania's Forest Birds

Margaret C. Brittingham[1] and Laurie J. Goodrich[2]
[1]The School of Forest Resources, The Pennsylvania State University, 409 Forest Resources Building, University Park, PA 16802
mxb21@psu.edu
[2]Acopian Center for Conservation Learning, Hawk Mountain Sanctuary, 410 Summer Valley Road, Orwigsburg, PA 17961

Habitat fragmentation occurs when large contiguous blocks of habitat are broken up into smaller patches of habitat by other land uses. In some cases, these habitat patches become islands separated from other like habitat patches. Fragmentation also occurs when contiguous blocks of habitat are penetrated by roads, transmission lines, or other corridors which do not necessarily isolate patches of habitat but do compromise the integrity of the habitat interior. Loss of habitat integrity may occur by increasing the amount of edge and introducing foreign or invasive species into the core. Habitat fragmentation can have negative effects on birds through direct habitat loss or indirectly through changes that occur as a result of the adjacent habitat type and the particular land use associated with it.

In this chapter, we review the causes and extent of fragmentation of Pennsylvania forests and the consequences to Pennsylvania's breeding birds. The chapter is divided into three broad sections. The first reviews what is known about the effects of habitat fragmentation on breeding forest birds with an emphasis on Pennsylvania and the Northeast. The second section focuses specifically on Pennsylvania forests and their status in terms of fragmentation and forest patch size. The third section looks at historic, current, and future impacts of habitat fragmentation on Pennsylvania's forest birds.

EFFECTS OF FOREST FRAGMENTATION

The effects of forest fragmentation on birds have been an issue of interest for over 30 years, and a number of reviews have been written on this topic (Faaborg et al. 1995, Walters 1998). Fragmentation results in both a quantitative and qualitative loss of habitat and can affect birds in a number of ways. As forests are converted to non-forest habitat, there is a direct loss of habitat for the birds which depend on that habitat type and the remaining habitat is often isolated from similar habitat patches. In addition, there is a decrease in forest interior (forest away from an edge or opening) and there is an increase in forest

habitat come in contact with forest-dwelling species. Fragmentation caused by roads or other openings within a forest matrix creates additional edge habitat.

Area-sensitive and Forest-interior Species

As forests are fragmented and patch or woodlot size becomes smaller and more isolated, a specific group of species decline in number or are absent from the forest tract (Ambuel and Temple 1983, Robbins et al. 1989). These species are often categorized as "area-sensitive" or "forest-interior" species. A species is considered sensitive to fragmentation if density or fitness of individuals within the remaining habitat patches changes as fragmentation of the surrounding landscape increases (Walters 1998). An area-sensitive species has lower abundance and/or lower reproductive success in small woodlots. Similarly, forest-interior species tend to be less abundant near edges or have lower reproductive success near edges. Because smaller habitat patches have relatively more edge than larger ones, the two terms "area-sensitive" and "forest-interior" have often been used interchangeably. It should be noted that those species associated with forest gaps or patches of early successional forest habitat can also be considered "area-sensitive" if they require large blocks of forest habitat in order to prosper.

Area-sensitive species tend to be neotropical migrants (Faaborg 1995). Most nest in open cup nests on or near the ground and generally raise one brood per year. These birds are often absent from small woodlots including ones that well exceed the size of their home range and provide apparently suitable habitat. These species appear to be negatively impacted by the increase in edge-to-interior ratio. The consequence is that the breeding bird community within large contiguous tracts of forest is very different from the breeding bird community within small woodlots of the same forest type. The bird community within large forested areas is dominated by neotropical migrants such as warblers, vireos, thrushes, and tanagers. Smaller woodlots are dominated by year-round residents and short-distance migrants. Typical species would include chickadees, white-breasted nuthatches (*Sitta carolinensis*), woodpeckers, common grackles (*Quiscalus quiscula*), and corvids like American crows (*Corvus brachyrhynchos*) and blue jays (*Cyanocitta cristata*). Below we review how habitat loss and an increase in edge-to-interior ratio result in these changes.

Habitat Loss

The most noticeable effect of forest fragmentation is the outright loss of habitat. Species negatively impacted include those such as northern goshawk (*Accipiter gentilis*) and broad-winged hawk (*Buteo platypterus*) that have large home ranges, avoid areas of human activities and require a mostly closed canopy for nesting (Goodrich et al. 1996, Squires and Reynolds 1997). Other species have smaller home ranges but may rely on a specific microhabitat that is no longer present in the remaining habitat patch.

For example, worm-eating warblers (*Helmitheros vermivorum*) are considered area-sensitive. These warblers have small home ranges, but they prefer moderate to steep hillsides for breeding. If this habitat is absent, they will generally not be present within the woodlot (Hanners and Patton 1998). Robbins et al. (1989) found the probability of nesting worm-eating warblers was reduced by 50% in mid-Atlantic region woodlots less than 150 ha. Other specialized forest birds may find their microhabitat hard to find even in large

Increase in Edge Habitat and Negative Edge Effects

Historically, edge habitat was considered to be beneficial for wildlife as many of our game species use a mosaic of habitat patches or reach their highest abundance near edges, and there is often a greater diversity of wildlife near edges (Leopold 1933, Yahner 1988). However, there is a downside to this increase in diversity as many species of mammalian and avian nest predators such as gray squirrels (*Sciurus carolinensis*), raccoons (*Procyon lotor*), blue jays, and common grackles are also more abundant near edges or concentrate their hunting near edges. These predators tend to be generalists that thrive in habitats close to human habitation. Thus edges created by agriculture and residential development are often associated with high numbers of nest predators and as a consequence, high levels of nest predation. Brown-headed cowbirds (*Molothrus ater*) are obligate brood parasites that lay their eggs in the nests of other species. Cowbirds feed in open habitat but will travel into the forest to search for host nests. Consequently, their abundance and rates of parasitism are often higher near forest edges where they are in close proximity to both feeding and nest searching habitat (Brittingham and Temple 1983, Hoover et al. 2006).

The consequence of high rates of nest predation and in some cases nest parasitism is that nest success tends to be lower near edges, in small woodlots, and in more fragmented forests (Yahner and Scott 1988, Donovan et al. 1995, Hoover et al. 1995). For example, in southeast Pennsylvania, Hoover et al. (1995) found that wood thrush nest success was related to forest patch size with success ranging from a low of 0.12 in a small woodlot to over 0.70 in large woodlots and contiguous forest (Figure 1). The primary cause of nest failure was predation, and activity by nest predators was greater in small forest patches and near edges than in large areas of contiguous forest (Hoover et al. 1995).

In small woodlots, reproductive success may not be high enough to balance expected mortality. To get a rough estimate of woodlot size needed in southeast Pennsylvania to support a viable population of wood thrush, we estimated the nest success rate that would be needed to balance expected mortality rates. We used an estimated annual adult survival rate of 0.60 and an estimated annual juvenile survival rate of 0.30 (Temple and Cary 1988). We measured nest success, number of young per successful nest, and the number of nests per season in the field. Using these values, we determined that a nest success rate of at least 0.54 was needed to balance mortality and that level of success occurred on woodlots that were at least 100 ha (256 acres) in size (Table 1). Although there are many estimated values in the equation, it suggests that the reproductive success of wood thrush in many woodlots is not high enough to balance mortality rates. Porneluzi et al. (1993) found that nesting success and density of ovenbirds (*Seiurus aurocapilla*) in Pennsylvania was significantly reduced in woodlots as large as 183 ha compared to continuous forest habitat suggesting that woodlots may need to be larger than 183 ha to provide suitable habitat for many birds. Robbins et al. (1989) has shown that effects of fragmentation on density and site occupancy varies across species.

Table 1. Demographic parameters[a] used to calculate woodlot size needed by nesting wood thrush to balance annual mortality rates, Berks County, PA, 1990–1991. (Data from Hoover et al. 1995).

Parameter	Value
Annual adult survival	60%
Annual juvenile survival	30%
Fledglings/successful nest	3.3
Nests/season	1.5
Nest success	0.2-0.8

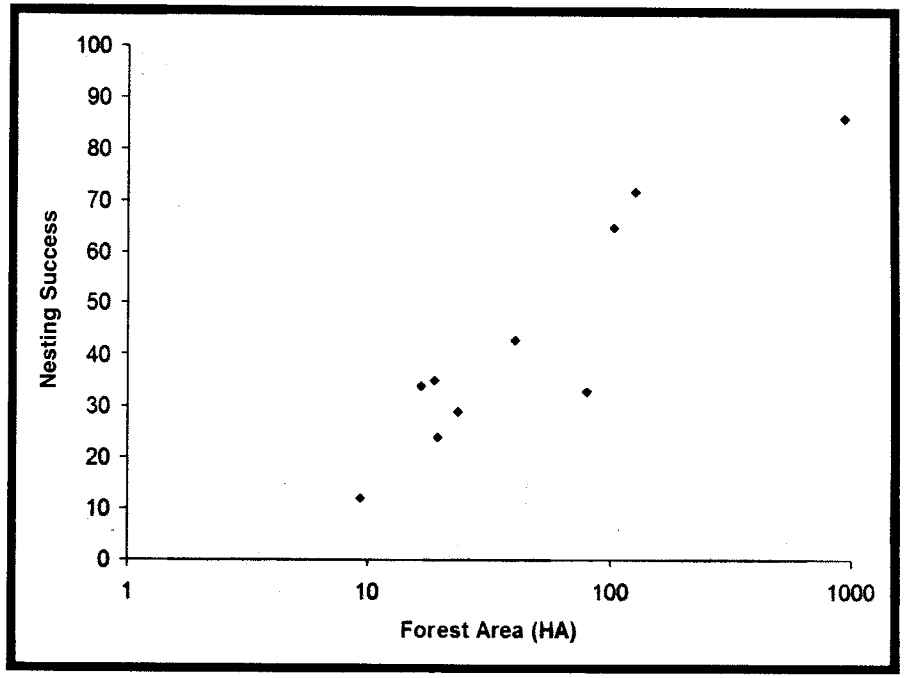

Figure 1: Nest success of wood thrush increases as forest patch size increases on 10 study sites in Berks County, Pennsylvania (1990–1991). (Figure from Hoover et al. 1995).

Types of Edges and Openings

As studies on fragmentation have progressed and occurred in a variety of habitat types, it has become evident that all edges and openings are not alike. The relative impact of fragmentation on an ecosystem depends on both the persistence of the change (e.g., how permanent or long-lasting) and the similarity of the disturbance to the native habitat (Marzluff and Ewing 2001). An urban area has high persistence and low similarity with the surrounding native cover and thus is expected to have the greatest fragmentation effects (Figure 2). Timber harvesting with adequate natural regeneration would have a much lower effect since persistence would be lower (e.g., the cut area will grow back to mature forest)

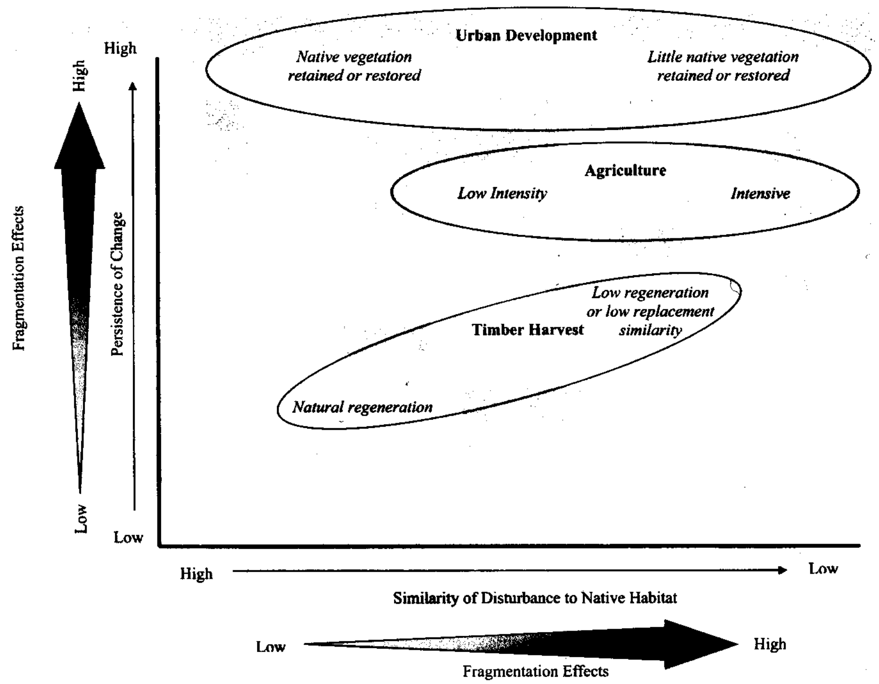

Figure 2: The relative impact of fragmentation on an ecosystem depends on both the persistence (e.g. how permanent) of the disturbance and the similarity to the native habitat being replaced. (Figure modified from Figure 1 Marzluff and Ewing 2001).

Rodewald and Yahner (2001) working in Central Pennsylvania looked at nest success within forested landscapes with openings created by either agricultural or silvicultural practices. Nest success was lower within forests disturbed by agriculture than by silviculture, and this difference was attributed to an increased abundance of avian and mammalian nest predators in the landscape disturbed by agriculture. Although studies have shown some negative edge effects associated with timber harvesting (e.g. King et al. 1996, Yahner and Mahan 1997), the general conclusion is that openings and edges created by timber harvesting do not create the extent of negative fragmentation effects typically associated with agricultural and residential development (Rudnicky and Hunter 1993, Hanski et al. 1996, Donovan et al. 1997).

The creation of permanent edges within large areas of contiguous forest by roads and utility rights-of-way is a potentially more serious problem (Askins 1994). These permanent openings introduce species associated with open habitat into the forest interior by serving as travel corridors for nest predators and cowbirds moving from the open habitat to the forest (Askins 1994). Researchers have found higher rates of predation in forest habitat adjacent to these corridors (Chasko and Gates 1982, Askins et al. 1987, Small and

Other Effects of Fragmentation

Some neotropical migrants have lower pairing success in small woodlots and near edges than in large contiguous forest habitat (Gibbs and Faaborg 1990, Villard et al. 1993, Porneluzi et al. 1993, Goodrich unpublished data). For ovenbirds, small woodlots tend to have a lower abundance of individuals and a lower abundance of mated males (Goodrich unpublished data). In addition to reduced reproductive success in small woodlots and near edges, changes in the microclimate may result in a lower quantity and quality of food making these areas less preferred by females (Burke and Nol 1998). Fragmentation also affects extraterritorial movements of birds within the forest and surrounding landscape (Belisle et al. 2001, Norris and Stutchbury 2001).

Model to Predict Regional Fragmentation Effects

Thompson et al. (2002) developed a hierarchical model to explain how fragmentation effects vary regionally. Effects appear to operate in a top-down manner with factors occurring at an upper level constraining effects at a lower level. At the top level is the biogeographical scale. Bird species abundance and distribution vary geographically and the relative abundance of potential nest predators and nest parasites will ultimately influence the effects that openings or edges might have on reproductive success. For example, brown-headed cowbirds are most abundant in the midsection of the country close to their historical range, and their abundance declines as one moves farther away from this area (Hoover and Brittingham 1993). Consequently, rates of parasitism and effects of habitat fragmentation are greater towards the center of the cowbird's range than at farther distances.

The biogeographical scale in turn constrains effects at the landscape scale. The landscape scale encompasses the predominant land use and land cover in an area. This scale appears to be the most important in determining fragmentation effects. The landscape matrix and forest patch size influence rates of predation and brood parasitism. It appears that edge effects associated with fragmentation are most pronounced in landscapes where forest cover makes up 45–55% of the landscape (Thompson et al. 2002). In this case, predation rates tend to be high near edges and decline as one moves into the forest interior. At this level of forest cover, the open habitat is providing feeding sites, and nest predators that are using those feeding areas are penetrating into the forest adjacent to those areas.

In landscapes where the forest is less than 15% forested, as occurs in much of southern Pennsylvania, predation rates tend to be high in both the edge and the interior of the habitat. In this situation there is so much habitat available for feeding that these nest predators are ubiquitous in the environment. At the other extreme are landscapes that are more than 90% forested. This would be similar to some areas in northern Pennsylvania. In this case, predation rates tend to be low in both forest interior and forest edge because there is so little feeding habitat available for generalist nest predators.

The next level influencing fragmentation effect is the local or habitat scale. This refers to the patch size where the bird is nesting, the structure of the vegetation, and the distance of the nest from the edge. By far the majority of studies on effects of fragmentation on

PENNSYLVANIA FORESTS – PATCH SIZE AND CORE AREAS

Historically, Pennsylvania and most of the northeastern United States were forested. During the eighteenth and nineteenth centuries massive deforestation occurred as a result of logging, agricultural development, and fires associated with expanding human population (e.g. MacCleery 1992). Since the early 1900's, the amount of forest cover in Pennsylvania and other eastern states has increased, but it is a different type of forest in both species composition and landscape pattern than what was here historically. Today Pennsylvania is over 60% forested, but most of that forest is fragmented or edge habitat with less than half of remaining forested land in "core" or interior forest habitat, away from edge (over 100 m from road or edge) (Goodrich et al. 2002). Forty-two percent of forest habitat in Pennsylvania is considered core habitat while 58% is considered edge (Figure 3). Of the core forest, 70% is found in patches of 5,000 acres (2,023 ha) or less, suggesting that large forests are increasingly rare statewide. Core forest varies regionally with the lowest proportion (less than 20%) in southeast and southwestern regions and the greatest amounts in the Ridge and Valley and Allegheny Plateau.

Southern Pennsylvania eco-regions and areas near the Great Lakes show less than 30% of remaining forest in core forest habitat for wildlife. Northern Pennsylvania show a higher proportion of core forest. In the Ridge and Valley eco-region and other southern eco-regions, the greatest amount of remaining core forest over 5,000 acres (2,023 ha) in size is on ridgetops (Goodrich et al. 2002).

CURRENT AND FUTURE CAUSES OF FRAGMENTATION

Today Pennsylvania is almost 60% forested but threats of fragmentation still continue. Below we review some of the causes of fragmentation with an emphasis on more recent threats.

Suburban Sprawl

In the past, agriculture was an important cause of fragmentation as forests were cleared for farms. Today, there is very little new land going into agricultural production. Instead, we see much of the agricultural land being converted to residential and suburban areas while the remaining farmland is being farmed more intensively. The loss of farmland and intensification of farming has detrimental effects on farmland wildlife while the conversion of farmland to suburban area has resulted in increasingly negative fragmentation effects (Figure 2). In general, urbanization causes more severe and long-lasting fragmentation effects because of the extent of changes to the vegetation, the persistence of those changes, and additional hazards associated with disturbance from people and pets (Marzluff and Ewing 2001).

The increase in sprawl development across the state has also encroached into forested habitats and reduced forest quality, particularly in eastern counties. For example, in Monroe county, the number of homes has grown by 23% since 1990 (US Census). Housing unit growth exceeded 15% from 1990 to 2000 in Butler, Chester, Juniata, Lancaster, Monroe, Centre, and York counties. State-wide the number of housing units has grown by 6.31% (Goodrich et al. 2002).

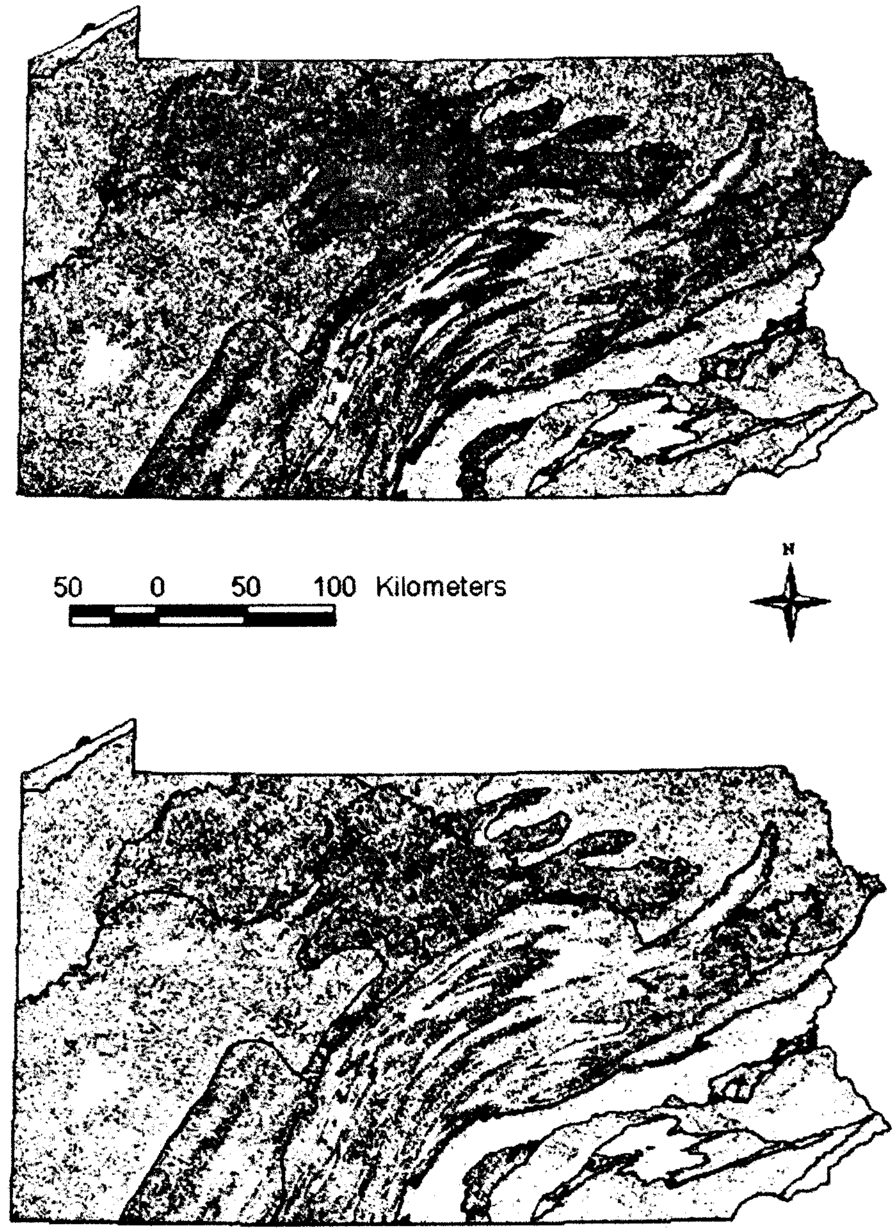

Figure 3: Pennsylvania images depicting 2001 forest cover as recorded by the LandSat satellite. The top image depicts total forest including both core forest and edge forest. The bottom

wildlife (D. Klem, this volume, Chapter 20). In addition, bird populations can be reduced by the increase in predators around human dwellings, e.g. cats and dogs.

Roads

Roads are associated with almost all human activity and can have a major impact on the quality of forest habitat particularly when introduced into formerly roadless areas. Road density varies across Pennsylvania with greatest concentrations in the urbanized Southeast and Southwest (Goodrich et al. 2002). Roads are associated with habitat loss and fragmentation, increase in mortality, changes in behavior and productivity, and chronic disturbance (Trombulak and Frissell 2000, Saunders et al. 2002).

When roads are built there is a direct loss of habitat, but the extent can be much greater when edge effects and fragmentation effects are taken into account. Edge effects resulting in reduced densities of birds may extend up to 600 m within the forest (Reijnen et al. 1995, Forman and Deblinger 2000). Studies in Oregon found that productivity of bald eagles (*Haliaeetus leucocephalus*) declined with proximity to roads and that eagles preferentially nested away from roads (Anthony and Issacs 1989). As with other fragmentation effects, the extent of the effect varies with the size of the disturbance, the species of interest, the landscape matrix, and region. For example, King and DeGraaf (2002) found no effect on ovenbird productivity of unsurfaced forest roads within an extensive forest area in New England.

Roads can also be a significant source of mortality for birds. For example, a 10-year study of road mortality in Cape May, New Jersey recorded 250 raptors of 12 species over 145 km (90 miles) of road (Loos and Kerlinger 1993). Owls were the most numerous making up 88% of the dead raptors collected. Raptors may be attracted to roadsides because of the grassy habitat that attracts rodents; unfortunately, the road-side habitat has heightened risks. Finally, roads facilitate the use of an area by humans which in itself brings higher levels of disturbance, introduction of invasive plants, higher predation levels, and other more subtle degradation to the overall habitat for nesting birds.

Wind Power

Wind energy provides a renewable energy source but may also have negative impacts on birds depending on the number, size, lighting, and in particular the location of the wind turbines. Most of the research on impacts of wind farms on wildlife have focused specifically on quantifying collision mortality (Kuvlesky et al 2007, T. Katzner, this volume), but habitat loss and fragmentation associated with wind farm development may be equally important. Habitat loss and fragmentation is a consequence of the total area impacted by construction of the wind farm and the ancillary infrastructure associated with it. In addition to the individual turbines, each of which directly impacts from 0.08 ha (0.2 acres) to 0.2 ha (0.5 acres) (Kuvlesky et al. 2007), there is also the construction of roads to allow access to the turbines and electrical transmission lines to transport electricity. Direct habitat loss and fragmentation will be a function of the number of turbines, but road networks and transmission line corridors also cause extensive fragmentation as they may extend for long distances often traversing through extensive blocks of forest habitat. Leddy et al. (1999) found that grassland bird densities were higher on grasslands without wind turbines

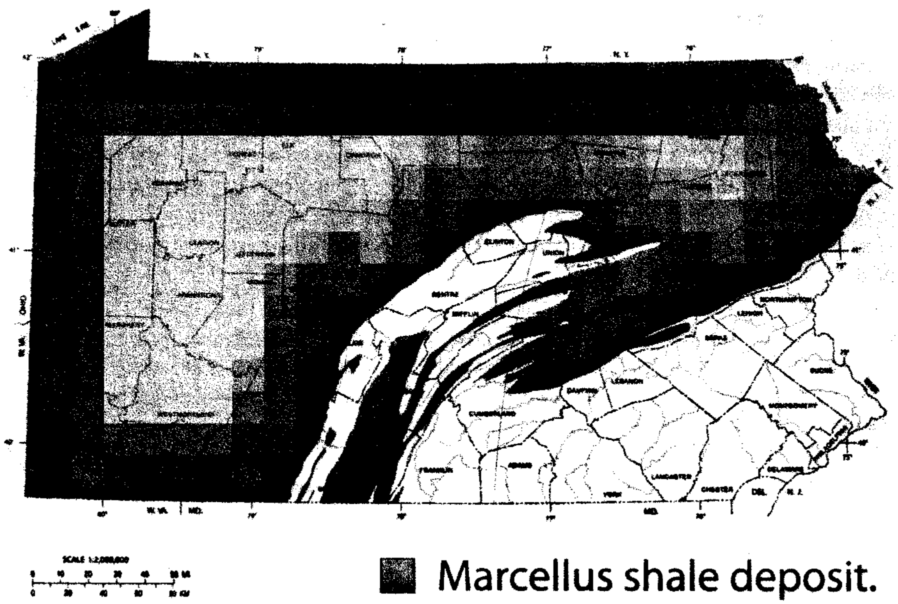

Figure 4: The shaded area depicts the Marcellus Shale deposit where natural gas exploration and development is targeted. (Original map prepared by Bureau of Topographic and Geological Survey, Third Edition, 1990. Modified by Penn State College of Agricultural Sciences, 2008).

the wind farms are placed on our forested ridges causing not only a direct hazard to migrants using the ridge (see Chapter 22) but also fragmenting the areas in Pennsylvania with the greatest extent of contiguous forest habitat (Goodrich et al. 2002).

Natural Gas Development

A new challenge to forest integrity is the accelerating pace of natural gas exploration and development in Pennsylvania. Higher energy prices and improving technology have made it easier and more attractive to drill for natural gas in Pennsylvania. Much of the new drilling activity is targeted at natural gas found in the Marcellus Shale Formation (Figure 4). In 2006, Pennsylvania natural gas producers drilled approximately 3,900 wells in the state, and that rate is not expected to decline in the foreseeable future. The footprint of an individual well site includes the well pad site (generally 1.2–2.0 ha [3–5 acres]) plus associated pipelines and roads to service the wells.

Habitat fragmentation concerns include direct loss of habitat but more importantly fragmentation resulting from the pipelines, roads, and openings associated with the well site. This is of particular concern because the Marcellus Shale Formation covers much of the Allegheny Plateau region which encompasses our largest block of contiguous forest and is the stronghold for many of our forest dwelling neotropical migrants. It is also the location

OUTLOOK FOR PENNSYLVANIA FOREST BIRDS

Pennsylvania currently has stewardship responsibility for many forest-interior and area-sensitive forest songbirds. Responsibility species are ones for which a large proportion of the species population resides within the state (Rosenberg and Wells 1995). For example, 17% of the world population of scarlet tanagers (*Piranga olivacea*), 10% of worm-eating warblers (*Helmitheros vermivorus*), and 9% of the wood thrush (*Hylocichla mustelina*) population breed within Pennsylvania forests (Rosenberg and Wells 1995). From a regional and global perspective, Pennsylvania plays an important role in maintaining populations of these and other forest dwelling species. We have provided an overview of how fragmentation changes the quantity and quality of forest habitat and the far-reaching effects it can have on forest birds. Although we have focused on birds, it should also be noted that fragmentation affects entire communities with no taxonomic group unaffected.

As we look towards the future, we need to minimize future habitat fragmentation and maintain our remaining core forests and large blocks of contiguous forests in order to retain viable and abundant populations of the diversity of forest birds currently breeding within Pennsylvania forests. In the southeastern and southwestern regions of the state where core forest habitat is rare, efforts should be made to reduce isolation among woodlots and to restore ecological function within woodlots to enhance their suitability for area-sensitive species (Marzluff and Ewing 2001).

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Chapter 16

The Status and Conservation of Farmland Birds in Pennsylvania

Andrew M. Wilson
School of Forest Resources
The Pennsylvania State University
University Park, Pennsylvania 16802
email: amw328@psu.edu

INTRODUCTION

Grassland-obligate bird populations have been in steady decline across North America for the past four decades or more (Vickery 2001, Sauer et al. 2008). The declines are of such magnitude that they have been predicted to become a "prominent wildlife conservation crisis of the 21st Century" (Brennan and Kuvlesky 2005). Declines have been particularly steep in the eastern United States, which due to bird distributional shifts following the large-scale destruction of native tall-grass prairies, supports significant populations of some grassland bird species (Sauer et al. 2008, Norment 2002). However, the declines in species often associated with grasslands are by no means restricted to native grassland habitats; in certain parts of their breeding range these species are largely dependent on agricultural grasslands and croplands. Further, these declines in farmland birds are not unique to North America: population decreases of similar timing and magnitude in a range of farmland bird species in Europe have received a great deal of attention from conservation biologists and policy makers alike (Donald et al. 2001, Gregory et al. 2005, Mattison and Norris 2005).

Changes in bird populations associated with farmland and grassland habitats are, of course, not new—the fortunes of these birds have long been inextricably linked with agriculture. Prior to European settlement, the birds that we now associate with these habitats in North America would have been abundant in the vast swathe of native grassland that stretched from Texas north into Canada, and from the Rockies east to The Mississippi. Some species quickly adapted to the new openings created by the agriculture of early settlers in the forested east of North America (Askins 1999). These were boom times for some species of open country, although at a continental scale this may have been very short-lived as by the mid 19th Century the vast tall-grass prairies were rapidly going under the plow. Within little more than a century, 99% of the tall grass prairie had disappeared (Noss et al. 1995).

In Pennsylvania, farmland birds would likely have been rare or absent prior to European settlement; in the words of Todd (1940) "There could have been few if any birds such as Bob-white, Prairie Horned Lark, Bobolink, Meadowlark, Vesper Sparrow, Savannah Spar-

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EDITED BY

SHYAMAL K. MAJUMDAR, Ph.D.
Kreider Professor Emeritus of Biology
Lafayette College
Easton, PA 18042

TERRY L. MASTER, Ph.D.
Professor of Biology
East Stroudsburg University of Pennsylvania
East Stroudsburg, PA 18301

MARGARET C. BRITTINGHAM, Ph.D.
Professor of Wildlife Resources
Penn State University
University Park, PA 16802

ROBERT M. ROSS, Ph.D.
Research Ecologist
Northern Appalachian Research Laboratory
United States Geological Survey (retired)
Wellsboro, PA 16901

ROBERT S. MULVIHILL, M.S.
Field Ornithologist
Carnegie Museum of Natural History, Powdermill Avian Research Center
Rector, PA 15677

JANE E. HUFFMAN, Ph.D.
Professor of Microbiology
East Stroudsburg University of Pennsylvania
East Stroudsburg, PA 18301

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