Terrestrial Vertebrates of Pennsylvania

A Complete Guide to Species of Conservation Concern

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Critical and Emerging Issues in the Conservation of Terrestrial Vertebrates

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Introduction

Most of the issues contributing to species decline are part of an age-old assemblage of anthropogenic-related factors that have had a cumulative effect on vertebrates and other species over the past few centuries or more. Although the scientific and resource management communities are still trying to fully understand how these issues influence species decline, modern technology, greater public awareness of the value of biodiversity, and increased funding for research and management have all contributed significantly toward solutions to these historic conservation issues. Unfortunately, as progress is made on some of these long-standing problems, new ones are continually emerging—some result from recent and developing technologies, some because of rapid changes in the earth's climate, and some for which we don't even yet understand the proximate mechanisms. In this chapter, we review examples of a few critical ongoing and emerging issues related to the conservation of vertebrates in the eastern United States. Our goal here is not to provide a comprehensive overview but instead to focus on a few particularly vexing issues, some of which have only recently emerged within the region.

Wind Energy and Wildlife

Growing concerns over the environmental impact of carbon emissions resulting from using fossil fuels have led to increasing emphasis and investment in "cleaner" alternative energy sources. At the center of this movement, wind power, especially that produced from commercial-level turbines (>1.0 megawatt), is perceived as a hopeful solution and has become one of the fastest-growing areas in the energy industry. However, an increasing number of studies have now documented that wind turbines are responsible for high levels of bird and bat fatalities (Kunz et al. 2007a, 2007b, Arnett et al. 2008) and may especially affect bat populations throughout the eastern United States. The result is a growing controversy that has those committed to wind power at odds with conservation biologists, who maintain that the benefits accrued from wind energy in many locations may not outweigh the costs to our wildlife. This controversy though is not so easily resolved, as both the benefits of a cleaner power source and the costs to our wildlife require detailed study and analysis. The following is a brief synopsis of what we currently know about this problem and how it is being addressed.

Large numbers of bat, songbird, and raptor fatalities are reported from wind turbines in the United States. However, deciphering and understanding the relative effect on wildlife populations is difficult because of the many factors that influence assessment of such fatalities, including (1) the types of species most affected, (2) the accuracy of mortality estimates, (3) the causes of mortality, (4) the actual effect on bat and bird populations, and (5) the considerable variation in mortality across locations, types of turbines, and regions of the country (Kunz et al. 2007b, National Research Council 2007, Arnett et al. 2008).

Raptor mortality appears to be heaviest at wind farms in the western United States (National Research Council 2007), whereas songbirds and bats appear to be at greatest risk in the East, where wind farms are usually constructed on forested ridges (Kunz et al. 2007a). In Pennsylvania, for example, the majority of the seventy-five wind-energy facilities are located along ridge tops (Capouillez and Limbrandi-Mumma 2008). In a review of songbird mortality at wind facilities across the United States (excluding California), Erickson et al. (2001, cited in Kunz et al. 2007a) found that mortality of songbirds accounted for 78 percent of the carcasses recovered. Similar reviews of bat mortality in the eastern United States (reviewed by Kunz et al. 2007b) report mortality rates between 15.3 bats per megawatt (MW) per year, to 53 bats/MW/year. All such estimates, however, are likely to underestimate actual mortality rates because of biases in human detection (Arnett 2006) and the loss of carcasses to scavengers (Kunz et al. 2007b and references therein). The effect on bird and bat populations also varies with behavior, habitat, and season. Among the bats, mortality is most common for migratory, leaf, and tree-roosting species, whereas for birds, it is the nocturnal, migratory species that are most commonly lost by turbines (National Research Council 2007).

Certainly, many more detailed studies are needed to assess the effect of wind turbines on bat and bird populations, yet the research to date clearly indicates a potential threat to wildlife. Kunz et al. (2007b) and others (Kunz et al. 2007a, National Research Council 2007) detailed methodology that is required to understand both the effect and options for mitigation. They call for cooperation between the conservation community and the wind-energy industry and careful quantitative research conducted before construction, after forests are cleared and construction is complete, and after turbines are fully operational. As detailed by Kunz et al. (2007b), such risk assessment requires systematic monitoring methods (e.g., capture surveys, night vision surveys, radar or acoustic monitoring, infrared imaging, or radiotelemetry), both costly and time consuming but absolutely necessary if we are to understand the effect of turbines on wildlife. On the basis of the concerns raised to date, several scientific organizations, including the National Research Council, U.S. Fish and Wildlife Service, North American Society of Bat Research, American Society of Mammalogists, the Wildlife Society, and the Pennsylvania Biological Survey, have released formal reports, resolutions, or policy statements that independently call for careful monitoring studies and mitigation treatments to reduce the threat.

In the northeastern United States, many states are already taking appropriate action to deal with this conservation challenge. In Pennsylvania, for example, where seventy-five wind farms were either proposed or in operation by 2008, the Pennsylvania Game Commission (PGC) coordinated the Pennsylvania Game Commission–Wind Energy Cooperative Agreement (Capouillez and Limbrandi-Mumma 2008), a voluntary arrangement between the Pennsylvania Game Commission and twenty of the twenty-four wind-energy developers operating in the state known as the Pennsylvania Wind and Wildlife Cooperative (PAWWC). The agreement calls for both pre- and postconstruction monitoring of both bat and avian populations, as well as a risk assessment provided by the Pennsylvania Game Commission that is used to determine the site selection of wind facilities and the design and intensity of survey protocols. By 2008, preconstruction monitoring efforts coordinated by the PAWWC resulted in the discovery of the first maternal colony of the silver-haired bat (*Lasiurus noctivagans*) and the second largest maternity colony of the Indiana bat (*Myotis sodalis*); these and other preconstruction results also have guided site selection of wind facilities across the state (Capouillez and Limbrandi-Mumma 2008).

Amphibian Declines

In the late 1970s, biologists began to note the decline and disappearance of amphibians from habitats around the world (Vitt et al. 1990). Over the next two decades, the accumulating evidence of a severe global decline was irrefutable (Houlahan et al. 2000, Stuart et al. 2004). The scope of the decline is sobering. In 2008, the International Union for the Conservation of Nature (IUCN) estimated that at least 32 percent of the world's amphibian species were threatened or extinct, as many as 159 species were already extinct, and at least 42 percent of all amphibian species were declining in abundance (IUCN et al. 2008). Although the severest declines and majority of extinctions have occurred in the Tropics, amphibian declines have occurred throughout the world.

Although the causes are not completely understood, there is not a single universal cause to the many declining amphibian populations around the world. Collins and Storfer (2003) identified six leading hypotheses for the global decline in amphibian populations: (1) invasive species, (2) overexploitation, (3) land use change (i.e., habitat loss and degradation), (4) global change (e.g., increased ultraviolet radiation and global warming), (5) pesticides and other toxic chemicals (i.e., pollution), and (6) emerging infectious diseases. Habitat loss and degradation are by far the greatest present threat to amphibian populations. The IUCN estimates that nearly 4,000 species are affected. Pollution is considered to be the second greatest threat, affecting around 1,200 species. Although disease affects less than 500 species, its effects on those species can be devastating (IUCN et al. 2008). Several diseases are capable of causing widespread mortality in amphibian populations; however, the pathogenic chytrid fungus (*Batrachochytrium dendrobatidis*) has rapidly become the most threatening. By 2004, it had infected at least ninety-three species around the world (Speare and Berger 2004), often leading to massive declines or even extinction. One trademark of the chytrid fungus is that it often rapidly eliminates species from otherwise pristine habitats.

The status of amphibian populations in Pennsylvania is not as critical as in many parts of the world. The only known amphibian species extirpated from the state, the tiger salamander (*Ambystoma tigrinum*), occurred in the extreme southeast corner of the state and disappeared because of habitat loss. Five species of amphibians are presently listed as Threatened or Endangered in Pennsylvania; all five of these species are peripheral species whose ranges barely extend into the state. Many species of amphibians have declined in abundance in recent years, primarily due to habitat loss and degradation. However, most species have not yet reached levels at which their survival is threatened. This does not mean that all is well with amphibians in Pennsylvania. First, if the slow, gradual decline in many species is not eventually halted and reversed, abundant species will eventually become rare or extirpated. Second, several species in Pennsylvania have undergone substantial decline in recent years.

Populations of eastern hellbenders (*Cryptobranchus alleganiensis alleganiensis*) have declined substantially over the past several decades in many streams in Pennsylvania (A. Hulse, personal communication). The causes of this decline are fairly well understood and include stream siltation, acid mine drainage, water pollution, and habitat alteration due to construction of dams. Chytrid fungus may have played a role in the decline, as hellbenders in a stream in northern Pennsylvania have tested positive for *B. dendrobatidis*. However, the fungus is not fatal to all amphibian species, and it is not presently known what effects it has on hellbenders.

More problematic than the decline of the hellbender is the rapid disappearance of several anuran species within the tree frog (Hylidae) and true frog (Ranidae) families. Within the tree frogs, chorus frogs (*Pseudacris* spp.) and northern cricket frogs (*Acris crepitans*) have declined dramatically in recent years, as has the northern leopard frog (*Lithobates pipiens*) within the true frogs. Although declines in some areas are due to habitat loss and degradation and pollution, frogs also have disappeared from apparently pristine habitats. Adding to the mystery, closely related frogs within these same families are thriving. The cause of these declines must be identified and remedied. Because the chytrid fungus has already been identified in the state, a first step should be to test remaining populations, as well as closely related species from habitats where these species have recently disappeared, for the presence of the fungus. If the chytrid fungus is found to be present, then the susceptibility of these species to the fungus should be determined. Species, and even populations within the same species, appear to differ in their susceptibility to the fungus, which may explain why only some species are declining. If the chytrid fungus is found not to be the cause, other causal agents should be investigated. Quick action is necessary; otherwise, these species may soon disappear from the commonwealth.

Complex and Unpredictable Consequences of Climate Change: A Case Study

Although many factors contributing to the imperiled status of our wildlife are obvious (e.g., habitat loss, white-nose syndrome), others are more subtle (e.g., gradual changes in vegetation due to climate change), while still others are quite complicated as a result of numerous intersecting factors that may have completely unexpected consequences. Here we describe one such situation that illustrates how several factors interact to produce rather significant and grave consequences for one of our mammals of concern: the northern flying squirrel (*Glaucomys sabrinus*).

This species—elevated to Endangered status in Pennsylvania in 2007—has been the subject of considerable investigation in the state for more than a decade. Early records indicated relatively stable populations in the state perhaps well into the 1960s (Merritt 1987). Intensive trapping efforts and nest box surveys over the past several years, however, reveal that current populations are small, spatially fragmented, and concentrated primarily in the Pocono Plateau, where they are subject to increasing expansion of the human population (Steele et al. 2004). Such studies also indicate that in Pennsylvania, unlike in most other portions of the species' geographic range, wherever northern flying squirrels are found so are southern flying squirrels (*Glaucomys volans*), a major competitor of *G. sabrinus*.

These two species generally show nonoverlapping geographic ranges. The northern species occurs in boreal, coniferous forests across Canada, the northern United States, and montane regions of the southern Appalachian, Rocky, and Cascade mountains, whereas the southern flying squirrel is typically found in oak-hickory or pine-oak associations in the eastern third of North America and as far south as Honduras.

Despite this dichotomy in habitat and geographic ranges, overlapping (sympatric) populations of the two species are reported from the southern Appalachians, Ontario, and now Pennsylvania (Steele et al. 2004). This sympatry, however, may be a recent occurrence, as rapid changes to the squirrels' habitat and environment may have brought the two together. In Ontario, for example, Bowman et al. (2005) recently documented the northward movement of southern flying squirrel populations, and a corresponding northward retraction in that of the northern flying squirrel, which they attribute to warming shifts in climate. Support from this hypothesis follows from the observation that in a single year of unusually low temperatures, the range of the southern flying squirrel appeared to contract more than 250 km (Bowman et al. 2005). In contrast, it appears that in Pennsylvania, habitat loss and habitat degradation are the key factors bringing the species together (Steele et al. 2004). Loss of mature conifer forests, especially those that include red spruce, appears to have resulted in considerable fragmentation and isolation of northern flying squirrel populations, with relic populations now isolated predominantly in hemlock stands. Such stands typically border riparian zones and are surrounded by hardwood forests where *G. volans* is often common. Moreover, the two species also tend to converge on hemlock patches for nest sites, and have even been recorded from the same nest structures during winter. But further concern follows from the condition of the state's hemlock forests, now subject to significant mortality from the invasive woolly adelgid (*Adelges tsugae*), which holds the potential for eliminating much of the squirrel's last remaining habitat in this region of the Appalachian Mountains (Orwig and Foster 1998).

The increasing association with southern flying squirrels raises yet other issues that may further contribute to the demise of *G. sabrinus* in Pennsylvania. Aside from competition for resources (e.g., nest structures), the southern flying squirrel is hypothesized to harbor a nematode parasite that is detrimental—possibly even lethal—to the northern flying squirrel (Weigl 1969). Indeed, this parasite-mediated competition between the two species may explain the nearly nonoverlapping ranges in these species and, as well, may have helped accelerate the formation of a reproductive barrier as these two species diverged (Price et al. 1988). Although strong experimental evidence for parasite-mediated competition is still lacking, recent preliminary parasite surveys in the Northeast, show that *Strongyloides robustus* is present in both species of flying squirrels in sympatric populations in Pennsylvania but is apparently absent from *G. sabrinus* in populations to the north in the Adirondack Mountains of New York where *G. volans* has always been absent, possibly until just recently (Krichbaum et al. 2010). Certainly, more information is needed on this interaction.

Finally, the close association between the two flying squirrels raises another situation only recently considered possible (Steele et al. 2004): hybridization between the two species. On the basis of extensive sampling and molecular analyses (nuclear and mitochondrial DNA), Garroway et al. (2009) demonstrate the presence of a hybrid zone in Pennsylvania and southern Ontario. Their results, which show evidence of backcrossing, but not extensive introgression, suggest that this is a recent phenomenon due possibly to both contemporary climate change and habitat degradation. Although detailed study is further needed to delineate this hybrid zone, this example illustrates how anthropogenic factors can influence interspecific hybridization and no doubt have important evolutionary and conservation consequences.

Invasive Species: A Vertebrate Example

As outlined in chapter 1, the spread of invasive species, from pathogens to vertebrates, poses a significant problem for native biodiversity (Pimentel et al. 2000). The lists of invasive species that now plague the Northeast, however, are too extensive and varied to discuss here. Several, such as the woolly adelgid, pose significant conservation threats to vertebrate habitat and are mentioned throughout this volume. Here, we discuss one example—an invasive vertebrate—the feral hog (*Sus scrofa*) that potentially can inflict serious harm to ecosystems of the Northeast (Sweeney et al. 2003).

Also known as wild hogs, wild boars, and feral pigs, the feral hog is the same species as the domesticated pig but wild. This feral strain was introduced to the United States from Asia and Europe initially by Spanish explorers and is now present in approximately twenty-five states, sixteen in which the species has recently colonized or is now deemed a significant problem in forested ecosystems (Sweeney et al. 2003, World Conservation Union 2007, Campbell and Long 2009). Recent increases in feral pig populations are attributed to the escape of domestic pigs followed by interbreeding with feral pigs, escape of feral pigs from shooting preserves, and the deliberate release of feral pigs by hunters (Sweeney et al. 2003). As confirmed by the U.S. Department of Agriculture Animal and Plant Health Inspection Service and reported by the Western Pennsylvania Conservancy (www.wpconline.org/assets/feral-swine.pdf), breeding populations in the state are confirmed in at least five western counties and suspected in as many as five others as far east as Wyoming County. Similar problems with this invasive pig are reported in neighboring states (Ohio, Maryland, and New York), which suggest a potential problem for the mid-Atlantic.

The effect of feral hogs includes significant destruction of wildlife and their habitats; damage to crops, including those managed by the forestry product industry; and the spread of disease to wildlife, domestic animals, and humans (Graves 1984, Sweitzer and Van Vuren 2002, Sweeney et al. 2003, Witmer et al. 2003, Hartin et al. 2007). Feral pigs exhibit a broad opportunistic diet of most plant and animal material they encounter (Graves 1984, Sweeney et al. 2003). Moreover, rooting and digging behavior by the species results in serious damage to a broad range of terrestrial habitats and negatively influences forest regeneration, while wallowing behavior in streams and wetlands degrades water quality (Sweeney et al. 2003, Campbell and Long 2009). The feral pig is also known to consume a substantial biomass of small vertebrates (e.g., mammals, amphibians, and reptiles) when such species occur in high numbers because of episodes of explosive breeding or migration (Jolley 2007, Wilcox and Van Vuren 2009). And, perhaps of greatest concern, feral hogs are important disease vectors; they are susceptible to as many as twenty viral and ten bacterial diseases, many of which pose a significant threat to both wildlife species and domestic livestock (Witmer et al. 2003).

In Pennsylvania, the Department of Agriculture (PDA) was the sole agency dealing with feral swine until about 2005 when they developed a Feral Swine Task Force, which included a number of organizations such as the Governor's Invasive Species Council and eventually the Pennsylvania Game Commission (www.wpconline.org/assets/feral-swine.pdf). By May 2006, the Pennsylvania Game Commission had removed the statewide ban on feral swine and now allows the systematic and controlled removal of this invasive species (www.pgc.state.pa.us/pgc/lib/pgc/wildlife/feral_swine/executive_letter.pdf). However, management and eradication of feral swine is not easily accomplished and in most situations, requires a comprehensive integrated strategy of various removal techniques, public education, and long-term monitoring (Campbell and Long 2009).

White-Nose syndrome

Bats have evolved a variety of physiological and behavioral mechanisms to survive and thrive in hypervariable environments, such as the highly seasonal temperate environment of Pennsylvania. In light of this, the emergence of what has been dubbed "white-nose syndrome" and its ensuing mortality and spread has caught wildlife biologists and pathologists by surprise. White-nose syndrome, now recognized as a disease in bats, was first noted in 2006 in New York state. It is named for the white fungus that grows on the muzzle and on the ears and wing membranes of hibernating bats (fig. 7.1). In its worst manifestation, white-nose syndrome has resulted in mortality rates that exceed 95 percent, most likely from starvation (United States Fish and Wildlife Service 2009). It is also associated with depleted fat reserves by midwinter, a potentially reduced ability to arouse from deep torpor, altered hibernation arousal patterns, changes in physiology, damage to wing membranes, and atypical behavior (e.g., "staging" near cave and mine entrances and emergence from the hibernacula) during the winter.

Since its first discovery (and as of the spring 2009 emergence from hibernation), white-nose syndrome has been identified in Canada, New York, Vermont, New Jersey, New Hampshire, Massachusetts, Connecticut, Pennsylvania, Virginia, and West Virginia (fig. 7.2). It has spread faster than expected and is predicted to continue to spread. White-nose syndrome was first noted in Pennsylvania in late December 2008, and by April 2009, at least ten affected hibernacula had been identified, including sites in Lackawanna, Luzerne, and Mifflin counties. White-nose syndrome affected hibernacula, including coal mines, limestone caves, and iron mines.

The characterization of the fungus associated with white-nose syndrome affected bats by Blehert et al. (2009) strongly suggests that this fungus (now identified as the newly described *Geomyces* spp.) may in fact be an emerging fungal pathogen. Experiments are under way to determine whether it is the causal agent and to examine the mechanisms by which this fungus is either directly or indirectly leading to bat death. Multiple laboratories as well as state and federal biologists are diligently collaborating to develop and test hypotheses related to white-nose syndrome (see Reeder and Turner 2008, United States Fish and Wildlife Service 2009) and to discuss mitigation and conservation strategies. Within Pennsylvania, white-nose syndrome work has included participation in regional efforts to monitor and conduct surveillance for white-nose syndrome, as well as partaking in studies examining the effects of white-nose syndrome on hibernation patterns and physiology and on summer survivorship and reproductive success.

From the emergence of this disease in 2006 through the winter of 2008-2009, it is estimated that more than 1 million bats have died from white-nose syndrome throughout the affected region. Thus far, white-nose syndrome has been identified in six species of cave-dwelling bats, including little brown *Myotis* (*Myotis lucifugus*), northern long-eared *Myotis* (*Myotis septentrionalis*), tri-colored bats (*Perimyotis subflavus* [also known as eastern pipistrelles]), big brown bats (*Eptesicus fuscus*), the threatened small-footed *Myotis* (*Myotis leibii*), and the endangered Indiana bat (*Myotis sodalis*). The number of affected sites and counties in Pennsylvania is likely an underestimate as many hibernacula are unknown or not able to be surveyed. In addition, to stop the potential anthropogenic spread of white-nose syndrome in Pennsylvania, some previously scheduled hibernacula surveys were suspended in the winter of 2008-2009, including sites within the known affected

Fig. 7.1. White-nose syndrome. Photo courtesy of Cal Butchkoski.

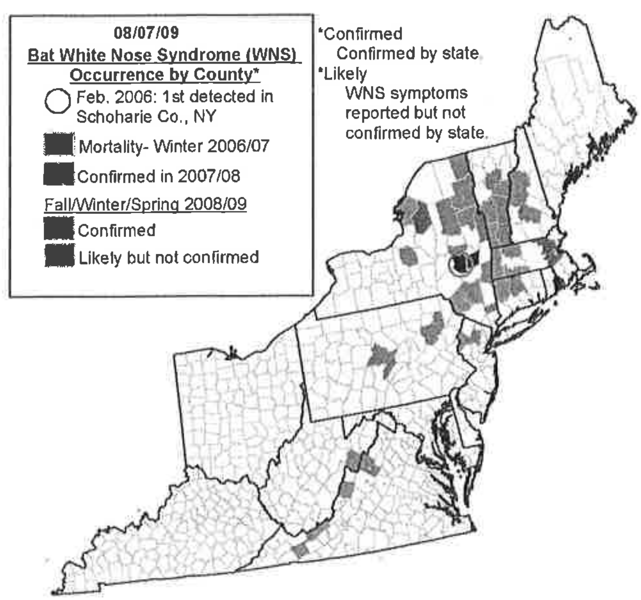

Fig. 7.2. Documented distribution of White-nose syndrome as of June 6, 2009. Map courtesy of Cal Butchkoski.

counties. Strict equipment and personal decontamination protocols have also been established (see the state white-nose syndrome updates and protocols available at www.pgc.state.pa.us).

Given the estimated millions of hibernating bats found throughout the affected region and in the projected path of the disease, white-nose syndrome represents a significant and unprecedented problem with likely dire consequences not only in Pennsylvania but also in continental North America as well. If the cold-loving *Geomyces* fungus is the disease-causing agent, other vertebrates that use daily or seasonal torpor may also be at risk.

The Complexity of Forest Fragmentation and Its Effect on Avian Communities

Habitat fragmentation is one of the most pervasive and problematic threats to wildlife in Pennsylvania, the Northeast, and worldwide. It occurs when large contiguous blocks of habitat are broken up into smaller patches of habitat by other land uses or when blocks of habitat are penetrated by roads, transmission lines, or other corridors. Although habitat fragmentation can occur in any habitat type and does affect a vast array of species, we know the most about how fragmentation of contiguous blocks of forest habitat affects forest-dwelling Neotropical migrants (Faaborg et al. 1995, Walters 1998, Brittingham and Goodrich 2010).

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 forest-dwelling birds. Perhaps more problematic is the resulting increase in forest edge habitat and decrease in forest interior (forest habitat away from an edge or opening). This change in amount of edge to interior is particularly detrimental to a group of birds known as area-sensitive or forest-interior songbirds. This group includes many of our migrant songbirds like warblers, thrushes, and tanagers that breed in Pennsylvania forests and winter in the Central and South America. For a variety of reasons, nest predators that feed on eggs and nestlings, and the brown-headed cowbird (*Molothrus ater*), an obligate brood parasite that lays its eggs in the nests of other species, tend to be more abundant close to edges and openings than within the forest interior. As a result, songbirds nesting near edges and openings are much less likely to successfully raise young than individuals that are able to nest away from edges and openings. As fragmentation increases, there is less forest interior and more forest edge. As a consequence more individuals nest near edges where nest success is low. Fewer young are produced, and eventually populations decline and disappear from the area.

When an area is fragmented, we see changes, or shifts, in the wildlife community as some species become more abundant while others decline. Species that tend to do well and increase in abundance are species that are habitat generalists, use a mix of habitat types, are tolerant of disturbance, and can easily coexist with people. This group includes birds, such as crows (*Corvus* spp.), blue jays (*Cyanocitta cristata*), and brown-headed cowbirds, and familiar backyard birds, such as chickadees (*Poecile* spp.) and cardinals (*Cardinalis cardinalis*). Species that tend to decline in number and eventually disappear from the area include habitat specialists, area-sensitive or forest-interior songbirds, and species such as the broad-winged hawk (*Buteo platypterus*) and northern goshawk (*Accipiter gentilis*) that are intolerant of disturbance. Many of our species of greatest conservation need are included in the group of species that decline in number as forests are fragmented. This is of great concern as we see an increase in abundance of wildlife species that are common throughout the state and a decline in abundance of rare species and species with regional and national significance.

The effects of fragmentation are complicated. They vary with the size of the opening (larger openings produce greater fragmentation effects), the type of opening (permanent openings are more detrimental than temporary openings), and the surrounding landscape. Fragmentation effects are most evident in landscapes that are around 45 percent to 55 percent forested (Thompson et al. 2002). With less forest, the entire landscape tends to be fragmented, and nest success is low throughout. In areas with >90 percent forest cover, the number of generalist nest predators and cowbirds are generally rare in the region, so they are initially less available to use the openings and edges.

In the past, agriculture was an important cause of fragmentation as forests were cleared for farms. Today, fragmentation is primarily due to suburban sprawl and the creation of permanent edges by roads and utility rights of way. Energy exploration and development also fragment habitats. Earlier in this chapter, we discussed the direct effects of wind-energy development on birds and bats, but there are also indirect effects through habitat fragmentation. In addition to habitat loss and fragmentation resulting from openings for the turbines, there are road networks and transmission line corridors that cause extensive fragmentation as they may extend for long distances, often traversing through extensive blocks of forest habitat. A new challenge to forest integrity is the accelerating pace of natural gas exploration and development in Pennsylvania. Much of the new drilling activity is targeted at natural gas found in the Marcellus Shale Formation. As with wind energy, fragmentation from the infrastructure of roads, and, in this case, pipelines, can be particularly detrimental. This is of particular concern because the Marcellus Shale Formation covers much of the Allegheny Plateau region, which encompasses the largest block of contiguous forest and is the stronghold for many forest-dwelling Neotropical migrants. It is also the location of much of the public lands that have played an important role in providing habitat for area-sensitive forest species.

From a regional and global perspective, Pennsylvania plays an important role in maintaining populations of area-sensitive songbirds and other forest habitat specialists. As we look to the future, we need to minimize future habitat fragmentation and maintain our remaining core forests and large blocks of contiguous forests to retain viable and abundant populations of the diversity of forest birds currently breeding within Pennsylvania forests.

The Ever-Growing Challenge of Road Mortality

A nearly century-old threat that continues to grow throughout the Northeast and will continue to affect vertebrate populations long into the future is road mortality. As discussed throughout this volume, road mortality is a significant threat to many vertebrates of greatest conservation need (Glista and DeVault 2008). Road mortality, however, is not random; it varies considerably with road type, traffic volume, and habitat type and often results in hot spots of mortality for certain species or species assemblages (Gibbs and Shriver 2002, Glista and DeVault 2008, Langen et al. 2009). Such clusters of mortality are invariably associated with wetlands. In New York state, for example, spatial patterns of mortality of reptiles and amphibians were highly clustered, remained constant over time, and were most often associated with roads within 100 m of a wetland, especially when the road dissected a wetland (Langen et al. 2009). By both fragmenting habitats and serving as a major source of mortality, roads can significantly contribute to local extinction, and when this occurs near biodiversity hot spots, the effects can be catastrophic.

Road mortality is inevitable, and it will most likely increase as more roads are developed and traffic volume increases. Although it cannot be eliminated, future efforts must be directed at studying and managing this growing problem so that we optimize road networks, traffic patterns, and road designs to accommodate movement and dispersal of species and minimize mortality.

Looking to the Future with a Lesson from the Past

Finally, we close the volume with a brief reference to a significant long-standing environmental concern that has contributed significantly to loss and degradation of habitat, one that often poses a significant threat to vertebrate populations throughout the Northeast: acid mine drainage. Historically, more than 50 percent of the wetlands that occurred in Pennsylvania before human settlement have been lost, an estimate that far exceeds both the national (14%) and regional (27%) averages (Tiner 1990). However, significant wetland degradation has also occurred as a result of acid mine drainage due to poor mining practices in both the northeastern and western portions of the state. Acid mine drainage, referenced repeatedly throughout this volume, has a significant long-term effect on water quality as a result of high levels of dissolved iron and sulfate and other pollutants, sedimentation, high levels of acidity, and physical disturbance to benthic substrates (see review by Bruns 2005). These effects significantly reduce macroinvertebrate richness, a primary component of the food webs in these systems (Bruns 2005) and, in turn, leave affected wetland systems virtually uninhabitable for many vertebrates.

Efforts to heal scarred lands from past mining practices have met with some success, but the repair will take many years and acid mine drainage problems will be around for decades before such lands are truly reclaimed. Indeed, such poignant lessons from the past must serve to guide future decision making.

We face numerous challenges in the conservation of biodiversity, and there is much to be done. Yet there are many reasons to be hopeful. Today, we understand many of the problems of rarity and species decline far better than we did a few decades ago. With more focused and comprehensive education, increased funding for research and conservation, growing public and government support, and the benefit of new technologies, we will continue to make the changes necessary to conserve Pennsylvania's biodiversity for generations to come.