

## Chapter 1

# Breeding Birds of Pennsylvania: Forest Communities

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### FOREST HABITATS IN PENNSYLVANIA

Pennsylvania is a forested state—the very name means “Penn’s woods”. Despite being the sixth most populous state in the country, forests are the dominant land-cover type in Pennsylvania. Today approximately 60% of the commonwealth is forested, and Pennsylvania leads the nation in hardwood growing stock volume (Widmann 1995).

Forests are not uniformly distributed across the state, however. The most extensive and contiguous forests occur across the Allegheny High Plateau in the north central part of the state. For example, in this region Cameron and Forest Counties have > 93% forest cover (Widmann 1995). The Pocono Highlands and upland portions of the Ridge and Valley physiographic regions also retain heavy forest cover. In contrast, forests in the heavily urbanized southeast, the southern Pittsburgh Plateau, and the Great Lakes floodplain regions are sparse and, where they occur, highly fragmented. Across the state, most (79%) forested land is privately owned, the majority as small (< 50 acres) tracts by over half a million non-industrial owners (USDA 2004). Public forestlands (state forests and state game lands, and Allegheny National Forest) are disproportionately concentrated in the Allegheny High Plateau region, where they comprise 41% of the landscape.

Almost all of Pennsylvania’s forests are classified as deciduous hardwoods or hardwoods mixed with conifers. Two major biomes intergrade here: the central hardwoods or oak-hickory type (47% of forested land), and the northern hardwoods type (38%) (Fike 1999). In addition to oaks (*Quercus* spp.) and hickories (*Carya* spp.), oak-hickory forests typically include tuliptree (*Liriodendron tulipifera*), blackgum (*Nyssa sylvatica*), and red maple (*Acer rubrum*). Northern hardwoods are dominated by American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), black and yellow birches (*Betula lenta* and *B. alleghaniensis*), and eastern hemlock (*Tsuga canadensis*). Much of the High Plateau supports Allegheny hardwoods, an anthropogenic subtype resulting from the combination of large-scale clearcutting and rapid increase in deer numbers a century ago, and is dominated by black cherry (*Prunus serotina*) and red maple (Marquis 1975). Conifer-dominated forests are sparse in the state. These include a few high-elevation areas in the Poconos with spruce-fir association (*Picea rubra* and *Abies balsamea*), several remnant old growth stands of hemlock, white pine (*Pinus strobus*), and beech such as at Cook Forest State Park, and plantations of red pine (*Pinus resinosa*) or spruce (*Picea* spp.). Penn-

sylvania's forests support a high diversity of trees—over 100 species—yet just four account for 40% of tree stems statewide: red maple, black birch, black cherry, and American beech (USDA 2004).

### *Historical Trends*

When the first European colonists arrived in what is now Pennsylvania, they encountered a landscape that was almost completely forested. Much of the original forests on the cooler, more mesic uplands were old growth beech-hemlock, while chestnut-oak dominated warmer and more xeric areas (Whitney 1990). William Penn prophetically recommended that "care be taken to leave one acre of trees for every five acres cleared." In fact, progressive clearing for agriculture and timber production through the 1700s and 1800s did reduce forest cover to about 20% by 1900 (USDA 2004). The subsequent regrowth of forests, coupled with the succession of abandoned farmland, has produced a gradual increase in forested land across the state (Askins 2000). The percentage of land in forest has stabilized at about 60% since the 1960s (McWilliams et al. 2004). Because of this history, much of the state's forests consist of relatively even-aged second-growth stands between 90 and 120 years old.

Concurrent with the extensive regrowth since 1900, many other factors have shaped the Pennsylvania forests we see today. One is the introduction of exotic pests and pathogens. The inadvertent spread of chestnut blight (*Cryphonectria parasitica*) and Dutch elm disease (*Ophiostoma* spp.) all but eliminated these once dominant trees. Additional diseases and insect pests are currently impacting American beech, butternut (*Juglans cinerea*), eastern hemlock, and ashes (*Fraxinus* spp.). This topic is explored further in Chapter 17. Changes in natural successional patterns due to fire suppression, reduction of beaver populations, and deer overabundance have altered forest structure and composition as well (Naiman, Johnston et al. 1988; Abrams and Ruffner 1995; Lorimer 2001; Horsley, Stout et al. 2003). Recent state-wide surveys indicate inadequate advance regeneration to be a statewide problem, particularly where alternate browse is unavailable (McWilliams et al. 2004). Suppression of wildfires has produced an increase in mesophytic species, particularly red maple and birches, in oak-hickory forests statewide, causing a marked loss in habitat value for bird communities. A study conducted in Centre County demonstrated that oak-dominated forests had greater diversity and abundance of birds in most seasons than otherwise similar maple-dominated forests (Rodewald and Abrams 2002).

The approximately 60% of Pennsylvania that currently is forested comprises almost 17 million acres (USDA 2004). Because our mature forests are dominated by even-aged trees > 80 yrs old, many of them are considered sufficiently mature to be harvested. The timber industry is now a \$5 billion industry in Pennsylvania, and the value of its timber resources has helped to keep land in forest. However, most of the state's timbered lands are privately owned, and so are not subject to the regulations that promote and enforce sustainable management on public lands. Landowners often unwittingly allow their timber to be harvested in unsustainable ways—essentially "mining" the resource—and, by doing so, reducing the vigor, stocking, and species diversity of the forest. How this might affect the long-term habitat value of privately owned forests for Pennsylvania's birdlife remains unclear.

## FOREST BIRD COMMUNITIES IN PENNSYLVANIA

Pennsylvania's extensive forests support a great abundance and diversity of forest birds, including many forest interior specialists that are of continental conservation concern (Rich et al. 2004). For some of these species, Pennsylvania is home to a disproportionately large fraction of the global breeding population. For example, population estimates based on BBS data suggest that about 15% of all scarlet tanagers (*Piranga olivacea*) breed within the state, despite the fact that Pennsylvania comprises only 4.5% of the total breeding range; similar statistics for wood thrush and Louisiana waterthrush are 8% (population) and < 5% (range in PA) (Table 1; data taken from Partners in Flight [PIF] estimated population database; Blancher et al. 2007). Additional species of conservation concern have a high proportion of their total population breeding within PA, albeit not out of proportion to their distribution (e.g., cerulean warbler *Dendroica cerulea*). For both groups of birds, Pennsylvania has a high stewardship responsibility according to Partners in Flight (Table 1; Rosenberg 2004).

In general, patterns of avian diversity (i.e., forest bird community structure) reflect the diversity of forest types and forest structure found across the state. The oak-hickory vs. northern hardwoods dichotomy represents one of the major forest habitat gradients in Pennsylvania. It approximates a south to north gradient, but it is also influenced by eleva-

**Table 1. Birds of mature forest and forest edge for which a disproportionate fraction (% total population within PA >10% greater than % total range within PA) or a high portion (>4%) of their North American population breeds within Pennsylvania. Calculated from population and range size estimates in Partners in Flight population estimates database (Blancher et al. 2007).**

Species	Estimated population within PA	% of N. American population within PA	% of N. American range within PA
Sharp-shinned hawk <i>Accipiter striatus</i>	14,000	2.33	1.12
Cooper's hawk <i>Accipiter cooperii</i>	12,000	2.40	1.44
Black-billed cuckoo <i>Coccyzus erythrophthalmus</i>	45,000	4.09	2.38
Ruby-throated hummingbird <i>Archilochus colubris</i>	240,000	3.43	2.39
Downy woodpecker <i>Picoides pubescens</i>	340,000	2.62	0.92
Northern flicker <i>Colaptes auratus</i>	150,000	1.00	0.84
Eastern wood-pewee <i>Contopus virens</i>	210,000	3.50	2.88
Acadian flycatcher <i>Empidonax vireescens</i>	200,000	4.26	4.77
Red-eyed vireo <i>Vireo olivaceus</i>	3,600,000	2.57	1.35
Black-capped chickadee <i>Poecile atricapillus</i>	840,000	2.47	1.34
White-breasted nuthatch <i>Sitta carolinensis</i>	270,000	2.97	1.50
Wood thrush <i>Hylocichla mustelina</i>	1,100,000	7.86	3.37
Cedar waxwing <i>Bombycilla cedrorum</i>	530,000	3.53	1.58
Cerulean warbler <i>Dendroica cerulea</i>	50,000	8.93	9.52
American redstart <i>Setophaga ruticilla</i>	550,000	2.20	1.77
Worm-eating warbler <i>Helminthos vermivorus</i>	50,000	7.14	6.70
Ovenbird <i>Seiurus aurocapillus</i>	610,000	2.54	2.26
Louisiana waterthrush <i>Seiurus motacilla</i>	20,000	7.69	4.87
Scarlet tanager <i>Piranga olivacea</i>	320,000	14.55	4.52
Baltimore oriole <i>Icterus galbula</i>	230,000	3.83	2.50

tion, aspect, and land use history. Our northern forests support a distinct suite of birds whose ranges lie primarily north of Pennsylvania. These birds tend to be common and widespread in the northern tier of counties and southward at higher elevations (> 500 m) in the mountains, but they are sparse or absent from lower elevations in the southern half of the state. Certain northern birds have particularly strong ties to conifers and are rarely found away from them. They reside in native white pine and hemlock (or spruce in the Poconos), but also are found in the numerous plantations of red pine and spruce across the state. Such birds include red-breasted nuthatch (*Sitta canadensis*), yellow-bellied flycatcher (*Empidonax flaviventris*), golden-crowned kinglet (*Regulus satrapa*), Swainson's thrush (*Catharus ustulatus*), magnolia and yellow-rumped warblers (*Dendroica magnolia*, *D. coronata*), and purple finch (*Carpodacus purpureus*).

On the High Plateau, however, many northern birds are abundant in hardwood stands as well, even those dominated by oak. These include yellow-bellied sapsucker (*Sphyrapicus varius*), least flycatcher (*Empidonax minimus*), blue-headed vireo (*Vireo solitarius*), hermit thrush (*Catharus guttatus*), black-throated green warbler (*Dendroica virens*), blackburnian warbler (*D. fusca*), Canada warbler (*Wilsonia canadensis*), dark-eyed junco (*Junco hyemalis*) and winter wren (*Troglodytes troglodytes*). Birds of more southern affinities that approach or reach the northern limits of their distribution within the state, occupy oak-hickory or bottomland riparian forests almost exclusively. They tend to be most abundant and widespread at lower elevations in the southeastern and southwestern parts of the state. Most are local, sparse or absent from the extensive forests of the Allegheny High Plateau, which has implications for their populations (see below). This suite includes red-bellied woodpecker (*Melanerpes carolinus*), Acadian flycatcher, (*Empidonax virescens*) Carolina chickadee (*Poecile carolinensis*), cerulean warbler, worm-eating warbler (*Helmitheros vermivorus*) and Kentucky warbler (*Oporornis formosus*), as well as specialists of early-successional forests such as white-eyed vireo (*Vireo griseus*), prairie warbler (*Dendroica discolor*), and yellow-breasted chat (*Icteria virens*). Many of these southerners have been expanding their ranges northward since the early part of the 20th Century, and now can be found at least occasionally beyond the New York state line.

Many forest birds actually eschew deep, closed-canopy forest interiors, preferring instead more open woodlands, riparian forests with edges, gaps, and even suburban woodlots or orchards. Such birds include yellow-billed cuckoo (*Coccyzus americanus*), eastern wood-pewee (*Contopus virens*), great crested flycatcher (*Myiarchus crinitus*), rose-breasted grosbeak (*Pheucticus ludovicianus*), and Baltimore oriole (*Icterus galbula*). In contrast, the closed canopies of extensive mature forests are the preferred haunts of blue-headed vireos, blackburnian warblers, black-throated green warblers, ovenbirds (*Seiurus aurocapillus*) and others. An associated gradient in understory density affects which forest birds are found in that stratum: for example, open forest floors associated with closed canopy forests are preferred by ovenbirds and hermit thrushes, while dense brushy understories associated with forest gaps and edges provide habitat for hooded warblers (*Wilsonia citrina*), American redstart (*Setophaga ruticilla*) and veery (*Catharus fuscescens*).

Naturally, avian community composition changes over time with successional changes in forests following fires, wind damage, timbering, and clearing. When regenerating stands reach 12–20 years old, avian communities experience almost complete species turnover from early successional specialists (see Carey, chapter 5) to true forest birds (Hagan et al.

1997, Keller et al. 2002). As stands mature, the bird species that breed in them will gradually shift over time, those that prefer younger stands, such as American redstarts (Hunt 1998) dropping out over time while others colonize that specialize on mature stands, such as brown creeper (*Certhia americana*) and cerulean warbler (Haney and Schaadt 1996, Holmes and Sherry 2001).

### **Forest Area**

Many forest birds respond to forest patch size and are considered to be area-sensitive. Fragmentation effects are discussed in depth in Brittingham, Chapter 15. Briefly, the density of many of the most common forest species, such as red-eyed vireo (*Vireo olivaceus*), scarlet tanager, wood thrush (*Hylocichla mustelina*), and ovenbird increase with patch size (Wilcove 1985, Askins 2000). Those breeding in forest interiors experience higher nest success than those near edges, primarily because there tends to be a greater abundance of cowbirds (*Molothrus ater*) and nest predators along edges (Brittingham and Temple 1983, Hoover and Brittingham 1993, Robinson et al. 1995, Porneluzi and Faaborg 1999, Askins 2000).

Pennsylvania's forests all are fragmented to varying degrees by roads, utility rights-of-way, agriculture, and urban sprawl, producing forest patches in a broad range of sizes. The largest, most extensive tracts of contiguous forest are found primarily on the Allegheny High Plateau, where public forests are concentrated. In contrast, forests become increasingly fragmented, and average patch size becomes smaller, towards the heavily populated southwestern and southeastern corners of the state. As a consequence, much of the large, high-quality forest tracts in the state are northern hardwoods and mixed woods, while the most heavily fragmented forests tend to be oak-hickory. This dichotomy in habitat quality between forest types has implications for the conservation of Pennsylvania's forest birds.

## **POPULATION TRENDS**

Data acquired from two sources can be used to draw general inferences regarding population trends of birds that breed in Pennsylvania forests: the North American Breeding Bird Survey and the Pennsylvania Breeding Bird Atlas. The North American Breeding Bird Survey (BBS), initiated in 1966, is a standardized road-based point count survey run annually along > 4000 routes distributed across the U.S. and southern Canada. BBS methods are potentially biased as they do not survey habitats away from roads and, therefore, may fail to accurately measure populations of species that have a comparatively low tolerance of roads or edges (Bystrak 1981). Additionally, since no habitat data are collected by the BBS, no direct inferences can be made regarding the long-term occurrence patterns of species with respect to changes in habitat conditions. Nonetheless, interpreted with caution, BBS data do provide useful information regarding overall long-term trends in abundance, and they figure prominently in the establishment of management priorities, such as Partners in Flight prioritization scheme (Rich et al. 2004).

Breeding bird atlases are comprehensive surveys usually conducted over five or more consecutive years and repeated at long intervals (usually every 20–25 years). The Pennsylvania Breeding Bird Atlas determines presence-absence of species in 4,937 blocks, each block equal to 1/6th of a standard USGS 7.5-minute series topographic map. Importantly, because they are not strictly road-based, atlases have the potential to assess populations of species poorly sampled by the BBS methods (Robbins et al. 1989). Data for 1st Pennsyl-

vania Breeding Bird Atlas was collected from 1983–1989 (Brauning 1992); data collection for the second began in 2004 and continued through 2008. The consistency in sampling unit and coverage between the 1st and 2nd Pennsylvania Breeding Bird Atlases provides an opportunity to examine patterns of species occupancy and spatial distribution across the span of approximately 20 years. Comparing range changes with various spatial datasets (e.g., land cover and habitat) may reveal or suggest causal relationships between landscape-scale factors and observed shifts in bird distributions.

Despite the considerable concern expressed in both the scientific and popular literature over declines in forest bird populations, the current situation is anything but clear-cut in Pennsylvania. Analyses of > 40 years of BBS data indicate that not all forest species are decreasing; indeed, many are increasing. Contrasting trends can be found even among closely related species, presumably because of subtle differences in their ecological requirements (e.g. hermit vs. wood thrush, cerulean vs. black-throated green warblers; Sauer et al. 2008). Many species show no significant trend.

Generally, populations of those forest birds associated with northern hardwoods tend to be stable or increasing within the state, while those found mostly in the more fragmented oak-hickory forests tend to be decreasing. We tested this tendency statistically by contrasting population trend directions within the state between birds of northern and southern affinities using the Fisher Exact Test, for the subset of forest birds considered to be species of concern in the state's Wildlife Action Plan (PAGC-PFBC 2004; see Table 2 for

Table 2. Population trends within Pennsylvania of forest birds designated as priority species in the state Wildlife Action Plan (PAGC-PFBC 2005) in relation to biogeographic affinities, based on BBS survey results from 1966–2007 (Sauer et al. 2008).

Species	Affinity <sup>1</sup>	Annual % change in PA	P
Red-shouldered hawk <i>Buteo lineatus</i>	S	-6.1	0.06
Whip-poor-will <i>Caprimulgus vociferus</i>	S	-5.7	0.24
Acadian flycatcher <i>Empidonax virescens</i>	S	-0.4	0.28
Cerulean warbler <i>Dendroica cerulea</i>	S	-2.9	0.03
Worm-eating warbler <i>Helminthos vermivorus</i>	S	-2.4	0.09
Louisiana waterthrush <i>Seiurus motacilla</i>	S	0.1	0.93
Kentucky warbler <i>Oporornis formosus</i>	S	-3.2	0.05
Sharp-shinned hawk <i>Accipiter striatus</i>	N	8.4	0.14
Black-billed cuckoo <i>Coccyzus erythrophthalmus</i>	N	-2.6	0.01
Blue-headed vireo <i>Vireo solitarius</i>	N	4.3	<0.01
Winter wren <i>Troglodytes troglodytes</i>	N	3.8	0.09
Swainson's thrush <i>Catharus ustulatus</i>	N	1.1	0.55
Black-throated blue warbler <i>Dendroica caerulescens</i>	N	3.4	0.02
Black-throated green warbler <i>Dendroica virens</i>	N	2.0	0.03
Blackburnian warbler <i>Dendroica fusca</i>	N	1.4	0.22
Canada warbler <i>Wilsonia canadensis</i>	N	1.4	0.40
Broad-winged hawk <i>Buteo platypterus</i>	G	-0.2	0.92
Yellow-throated vireo <i>Vireo flavifrons</i>	G	0.3	0.61
Wood thrush <i>Hylocichla mustelina</i>	G	-2.3	<0.00
Scarlet tanager <i>Piranga olivaceus</i>	G	-0.5	0.24

<sup>1</sup>S = birds of mostly southern affinities; N = birds of mostly northern affinities; G = birds of general or broad distribution across eastern North America.

trends, species and affinities). A significantly larger proportion of southern birds (66%) are decreasing than northern species (11%) (Fisher Exact Test  $P = 0.009$ ).

Of course, state- or region-wide trends can sometimes mask local trends. For example, the most recent trend estimates for the magnolia warbler (*Dendroica magnolia*) indicate a significant annual increase of 4.8% from 1966 to 2006 within Pennsylvania ( $P < 0.001$ ; Sauer et al. 2008). However, populations just within the Ridge and Valley portion of the state have actually declined at 3% annually ( $P = 0.008$ , Sauer et al. 2008). In contrast, although cerulean warblers in Pennsylvania as a whole have declined by 2.8% annually in the same period (Sauer et al. 2008), that trend is primarily driven by losses in the increasingly fragmented southwestern corner, the stronghold for the species in the state (McWilliams and Brauning 2000). In recent years ceruleans have expanded northward and westward at least locally across the state (Sauer et al. 2008). These contrasts suggest that to be most effective, management actions should be developed that can address local conditions and problems, even if overall Pennsylvania conservation priorities are based on information about broader state or regional status.

### CONSERVATION AND MANAGEMENT ISSUES

Many factors threaten the ecological integrity of Pennsylvania's forests, including non-sustainable timber harvesting, natural resource extraction, wind energy development, invasive forest pest species, acid deposition, and over-browsing by white-tailed deer. These factors ultimately can impact forest bird communities through habitat loss, degradation and fragmentation. While the direct effects of habitat loss on biodiversity are rather apparent and quantifiable, the effects of forest fragmentation are more indirect and not as easily discerned. Fragmentation threatens biodiversity by increasing extinction risk via isolation, reduction of genetic variability, modification of microhabitat features and increased risk of predation, nest parasitism, and establishment of invasive species (Brittingham and Temple 1986, Yahner et al. 1989, Opdam 1991, Saunders et al. 1991, Lockwood et al. 2007). Forest fragmentation effects on songbirds of eastern North America have been well documented (Parker et al. 2005)

The potential for large-scale habitat loss and fragmentation through widespread timber harvesting is of particular concern for avian communities inhabiting Pennsylvania forests. Due to maturation of largely even-aged stands, much of the 16.6 million acres of forest in the Commonwealth currently contains large, merchantable trees. The potential for widespread, unchecked timber harvest on a scale not unlike that of a century ago is magnified by the fact that almost 70% of Pennsylvania's forests are privately owned. This means that the collective stewardship decisions of many private landowners will have a significant influence on the future fate of forest habitats and their associated bird communities in Pennsylvania.

As energy demands increase, forest loss and fragmentation resulting from resource extraction activities (i.e., oil, gas, and coal) and wind energy development will likely also increase. Pennsylvania is one of the leading coal producing states due to an estimated bituminous coal reserve that totals 23 billion tons (US DOI Office of Surface Mining 2004). While most coal is now extracted by underground mining, surface mining methods are also utilized; in 2006, surface mines in Pennsylvania produced approximately 10.6 million tons of bituminous coal. Frequently, following extraction of timber and coal resources, struc-

turally and botanically diverse forests are reclaimed to grasslands dominated by exotic grasses and forbs (Larkin et al. 2008). Further, these sites often persist in a state of arrested succession due to poor growing conditions, i.e., resulting from topsoil removal and surface compaction (Graves 1999).

Approximately, 34,000 acres were disturbed by surface mining in Pennsylvania between 2004 and 2007 (R. Agnew, PA Department of Environmental Protection). Moreover, since 1998 nearly 55,000 acres were reclaimed and approved for Stage II bond release (R. Agnew, PA Department of Environmental Protection). While mature forest dependant songbirds are negatively impacted by the conversion of forest habitat to reclaimed mineland, species that require earlier successional stages of forest regeneration appear to benefit. For example, golden-winged warbler (*Vermivora chrysoptera*), a shrubland nesting species of conservation concern, breeds on reclaimed surface mines in several Appalachian states (Patton et al. 2004, J. Larkin pers. obs.).

Increased energy demand is also creating a boom in oil and gas development in Pennsylvania. Pennsylvania's oil and gas fields are largely concentrated to the area west and north of the Allegheny Front (Pennsylvania Department of Environmental Protection 2007). This region of the state is also where some of the Commonwealth's most extensive forests are located. There are currently about 40,000 active gas wells in Pennsylvania (Swistock 2008). In 2007 alone, more than 4,000 oil and gas wells were drilled in Pennsylvania ([www.dep.state.pa.us/dep/deputate/minres/oilgas/RIG07.htm](http://www.dep.state.pa.us/dep/deputate/minres/oilgas/RIG07.htm)). While the footprint of a single well site is generally small (< 6 acres) relative to a surface mine, the potential for cumulative negative impacts to forest biodiversity clearly is considerable. This is particularly true in forested areas where multiple well sites are constructed, where the extent of fragmentation that occurs from construction of well sites and their associated road and pipeline infrastructure can be tremendous (Swistock 2008). In areas of Warren and McKean counties, new well sites are often installed in grids at the maximum legal density of < 300 meters apart (S.H. Stoleson, pers. obs.). Nonetheless, the extent to which oil and gas development impacts avian communities in Pennsylvania's forests remains unknown. Due to recent discoveries of new gas reserves and advances in extraction technologies, the number of gas wells is expected to increase considerably over the next decade (Swistock 2008). Clearly, research that examines the effects of gas and oil development on Pennsylvania's wildlife should be a research priority.

Because of its potential to provide clean renewable energy, compared to the burning of fossil fuels, wind energy is the fastest growing energy sector in the United States (McLeish 2002, Reynolds 2006). According to the American Wind Energy Association, a total of 177 wind turbines have been installed across Pennsylvania ([www.awea.org](http://www.awea.org)). These turbines are distributed among ten wind farms having from two to 43 turbines each. Additionally, there are 60 turbines under construction at two new wind farms ([www.awea.org](http://www.awea.org)) and more wind turbines are planned for construction. Although wind power is a clean method of energy generation, the potential for avian mortalities via collisions with turbine blades has been recognized for decades (Schmidt et al. 2003). While mortalities resulting from birds (especially raptors) colliding with turbines is a conservation concern in some western states (Schmidt et al 2003), research and monitoring to date indicate that such mortalities may be much less common in eastern states. Bat mortality, however, has emerged as a major concern with regard to wind energy development in the mid-Appalachians. Howev-

er, as with oil and gas development, the greatest threats to avian communities in Pennsylvania from wind energy development will be habitat loss and fragmentation of some of the state's last remaining large tracts of unbroken forests. For example, a 40-turbine wind farm located along the Allegheny Ridge in Cambria and Blair counties was placed on one of the few remaining forested ridges that connect the forests in northern Pennsylvania with those in southern portions of the state and West Virginia. In order to ensure that continued growth of the wind industry in Pennsylvania has minimal negative impacts on avian communities, monitoring protocols (including short-term mortality studies and long-term productivity and survivorship studies) should be developed that help track avian community response to disturbances associated with wind development.

Last but not least, overabundant white-tailed deer populations throughout portions of Pennsylvania also pose a threat to forest songbird communities. Ungulates, such as white-tailed deer (*Odocoileus virginianus*), serve many ecological roles that include influencing the rates of successional processes and the creation of spatial heterogeneity (Hobbs 1996). Ungulates have direct and indirect effects on a variety of fundamental ecosystem processes such as succession, nutrient cycling, fire regimes, and primary production (McNaughton 1992, Pastor et al. 2006, Hobbs 1996, Frank 1998). Effects of deer herbivory and trampling on plant species composition and structure have been well documented (Harper 1969, Pastor and Naiman 1992, Fleischner 1994, Augustine and McNaughton 1998, Dieni et al. 2000).

Forested areas with high white-tailed deer densities are often characterized by having minimal regeneration and a lack of diverse forest structure (Healy 1987, Tilghman 1989, Alverson and Waller 1997). Such modifications to forest structure can impact bird species through changes in food supply, loss of nest-sites, increased vulnerability to nest predation, or loss of roosting cover (Gill and Fuller 2007). Ultimately, the effects of over-browsing by white-tailed deer can result in the local extinction of animals and plant species and shifts in the species composition of a community (deCalesta 1994, Tilghman 1989, McCullough 1997, McShea and Rappole 1997). In Virginia, white-tailed deer browsing impacted the abundance and diversity of forest birds by reducing structural complexity (McShea and Rappole 2000).

In an enclosure experiment, species richness and abundance of mid-canopy nesting songbirds declined at moderate to high deer densities in northwestern Pennsylvania ( $> 7.9$  deer/km<sup>2</sup>; deCalesta 1994). A study in Massachusetts concluded that densities between 10–17 deer/km<sup>2</sup>, deer prevented forest regeneration, with the result that oak stands were converted to open, park-like systems with poorly developed understory and midstory layers (Healy 1997). Anderson and Katz (1993) suggested that forests subjected to prolonged, high levels of browsing may require 70 years after alleviation of browsing pressure to recover a size class distribution of shade-tolerant, browse-sensitive tree species characteristic of eastern forests.

While the negative impacts of high deer densities on forest songbirds has been very well demonstrated (deCalesta 1994, McShea and Rappole 2000), deer may also play an important role in the maintenance of structurally heterogeneous forests that meet the habitat needs of a greater number of forest bird species. In fact, forests with low deer densities may be similar to those with high deer densities in that they fail to meet the structural requirements of a more diverse avian community. When deer herds are maintained below carrying capacity, herbivory may be beneficial to forested ecosystems (Starkey and Happe

1995). Herbivory by cervids increased plant species diversity in an old-growth forest, thereby increasing available niches for birds (Starkey and Happe 1995). It is important that future studies attempt to quantify the effects of deer herbivory on forest structure and regeneration relative to other system drivers (i.e., climate change, acid deposition, and invasive species), and to determine the range of deer densities beneficial for, or at least not detrimental to, Pennsylvania's forest bird communities.

## **FUTURE PROSPECTS FOR PENN'S WOODS AND ITS FOREST BIRDS**

Conservation efforts must consider future as well as current issues affecting Pennsylvania's forests and their associated bird communities: these will include population growth and associated urban sprawl, and global climate change. As in much of the Northeast, Pennsylvania has experienced considerable urban sprawl in recent decades, and that pattern is projected to continue. Based on current patterns and rates of population expansion, Pennsylvania is predicted to lose 6,348 km<sup>2</sup>, or 8.8%, of its forest lands to urban growth by 2050 (Nowak and Walton 2005). However, most of that growth is expected to radiate out from existing urban centers; the Allegheny High Plateau will probably remain rural and heavily forested, so its value as a refugium for forest bird populations will likely increase.

Current population levels and trends may be overwhelmed in the foreseeable future by large-scale environmental phenomena, especially global climate change. While there is disagreement as to the time frame and severity of climatic changes expected and their resulting effects on biodiversity, most experts agree that significant changes will occur in the next century in the distribution of species in temperate zones. Most climate change models predict a northward shift of forest types, such that little or no northern hardwoods will remain within Pennsylvania as they are replaced by oak-hickory and oak-pine over the next centuries (Hansen et al. 2001, McKenney et al. 2007).

The effects of such large-scale shifts in forest communities in Pennsylvania are likely to have concomitant effects on the state's breeding bird communities. Ornithologists have already detected northward shifts in the breeding distributions of migratory birds by about 2.35 km/yr (Hitch and Leberg 2007), as well as earlier arrival times and later departure times from breeding areas (Butler 2003, Jonzén et al. 2006). Various experts have predicted a decoupling of migration arrival times and the phenology of ripening fruits and prey insect emergences, with potentially very negative effects on bird survival and reproduction (Strode 2003, Both et al. 2006, but see Marra et al. 2005).

Matthews et al. (2004) predicted shifts in the potential ranges of birds based on current vegetation and environmental correlates of their current ranges, assuming shifts in those factors under a range of climate change scenarios. Ironically, some of the species of highest conservation concern within the state currently (those of southern and oak affinities) are predicted to increase in both range and abundance. In contrast, many of those currently doing very well within the Commonwealth may decline or disappear; these are primarily northern and montane species. For example, hermit thrushes are currently widespread in the northern and mountainous parts of the state with populations growing at approximately 3.2% annually ( $P < 0.01$ ; McWilliams and Brauning 2000, Sauer et al. 2008). Yet the models by Matthews et al. (2004) suggest that the species will all but disappear from the state by the end of the 21st Century. Conversely, the Kentucky warbler now occurs primarily in remaining forests in the Southwest and Piedmont regions of the state, and,

although it has spread northward locally in recent years, statewide populations have declined at 3.0% annually based on BBS surveys (McWilliams and Brauning 2000, Sauer et al 2008). Climate change models predict Kentucky warblers will spread across the entire state and increase in abundance (Matthews et al. 2004). These models, however, do not take into account the predicted loss and fragmentation of forests due to urban sprawl. Thus, the short-term and long-term prospects for individual species within Pennsylvania will often vary depending on the interplay of many factors. Clearly, forest bird conservation in Pennsylvania will present many challenges and opportunities for students and researchers, natural resource managers and agencies, and private businesses and landowners moving forward into the 21st Century.

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# **Avian Ecology and Conservation: A Pennsylvania Focus with National Implications**

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