Potential Effects of Large-Scale Elimination of Oaks by Red Oak Borers on Breeding Neotropical Migrants in the Ozarks[1]

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Abstract

The Arkansas Ozarks are currently experiencing an outbreak of the red oak borer (*Enaphalodes rufulus*), a native insect that has previously not been considered an important forest pest species. As many as 50 percent of the trees in the Ozarks, which has the highest density of oaks in the United States, may be dead by the year 2006. The Ozarks are generally believed to be a source region for Neotropical migratory birds, compared to fragmented areas to the east and north, but that could change very rapidly with the elimination of oaks. The potential impact on migratory breeding birds was assessed, first, by reviewing the impact on birds of other tree species eliminations that have occurred in the eastern United States (American chestnut [*Castanea dentate*], American elm [*Ulmus americana*], American beech [*Fagus grandifolia*], and Frazer [*Abies fraseri*] and Eastern [*A. canadensis*] firs). Those results were incorporated into our studies on migratory breeding birds in the Arkansas Ozarks. Populations of 11 of 20 migratory species are predicted to decline, and some species, such as the Cerulean Warbler (*Dendroica cerula*), may be extirpated. Only five forest species are predicted to increase, but at least five early successional species (e.g. Indigo Bunting [*Passerina cyanea*], Yellow-breasted Chat [*Icteria virens*]), which are currently absent from upland hardwood forests, should increase with the development of a scrub layer as the canopy opens. Thus, the red oak borer infestation has the potential to greatly alter the composition of the avifauna of the Ozarks, which may have far-reaching implications for many species of neotropical migratory birds.

Key words: Arkansas, *Enaphalodes rufulus*, migratory birds, oaks, Ozark Mountains, red oak borer, upland hardwood forests.

Introduction

Bird populations and avian community structure can be influenced and changed by a wide variety of factors, ranging from relatively ephemeral dramatic increases in food supply, such as emergence of 13-year or 17-year periodical cicadas (*Magiciada* spp.) which last only a matter of weeks (e.g., Williams et al. 1993) to the subtle changes in vegetation structure which may take place over decades due to ecological succession (e.g., Holmes and Sherry 2001). Factors may be biotic or abiotic (e.g., Rotenberry et al. 1995), and their importance may differ between breeding and non-breeding seasons (e.g., Rappole and McDonald 1994).

Since the pioneering works by Fran James on quantification (James and Shugart 1970) and analysis of bird-habitat relationships (James 1971), it is generally agreed that structure of the vegetation is one of the most important factors influencing terrestrial breeding-bird community structure. Typically, it is the physiognomy, or structure, of vegetation that is important (James 1971), not individual tree species per se (but see Robinson and Holmes 1984). Although geographic variation in habitat selection exists in widely distributed species such as Wood Thrush (James et al. 1984; scientific names of birds are in tables), the vegetation associated with occurrence (or density) of a particular breeding species is usually predictable on a regional/local scale.

More fundamentally, most temperate passerines prefer to nest in live vegetation, and only a relatively few species nest in dead trees. Termed "secondary cavity nesters," they must rely on other birds ("primary cavity nesters" like woodpeckers) to excavate holes for them or wait for suitable cavities to appear from decay. Conversely, primary cavity nesters prefer to nest in deadwood; the only exception is Red-cockaded Woodpecker (*Picoides borealis*), which nests in live wood of pine trees.

Typically, live trees far outnumber dead trees in the deciduous forests of the eastern United States, and changes in physiognomy would be expected to be slow and occur over a long period of time (Holmes and Sherry 2001). Currently, however, the forests of the Ozark Mountains in Arkansas and Missouri are experiencing a remarkable outbreak of a native, normally endemic insect species, the red oak borer, *Enaphalodes rufulus* (Coleoptera: Cerambycidae). High levels of red oak (genus *Quercus*, subgenus *Erythrobalanus*) mortality were first observed on the

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Ozark National Forest in 1999, when a U.S. Department of Agriculture Forest Service (USFS) survey estimated that severe damage (>75 percent mortality/decline) existed on 7800 ha and moderate damage (50 to 75 percent mortality/decline) existed on another 9800 ha. By the end of 2001, the USFS estimated >400,000 ha of forest in the Ozark Mountains were being impacted. Extensive oak mortality is anticipated in these forests (Spencer 2001, Spencer and Sutton 2001), with as much as 50 percent of the deciduous trees dead by 2006. The impact of the red oak borer on Ozark forests has been so rapid that there is little research on the actual effects on the forest (Stephen et al. 2001, Heitzman 2003).

The Ozark Mountains and Oak/Hickory Forest Ecosystem

Braun (1950) first coined the term "Interior Highlands" in reference to the forested Ozark Plateau (hereafter, Ozarks) and Ouachita Mountains (*fig. 1*). Whereas the more southern Ouachita Mountains are primarily forested with pines, the Ozarks support the western edge of the eastern deciduous forest (Braun 1950), and have compositional affinities with similar forests stretching east through Ohio, Pennsylvania, and southern New England (Whitney 1994: *fig. 4.3*).

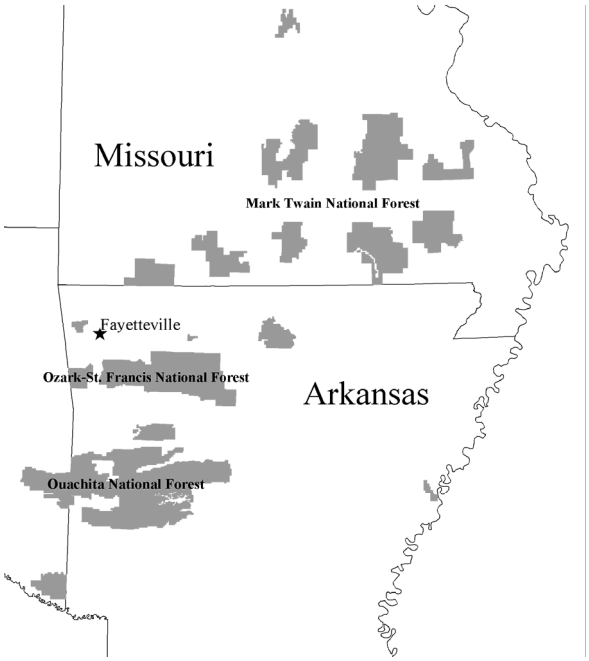

Figure 1— Map of the Interior Highlands in Missouri, Arkansas, and Oklahoma. The outline of the Mark Twain National Forest in Missouri and the Ozark-St. Francis National Forests approximates the Ozark Plateau, and the outline of the Ouachita National Forest approximates the Ouachita Mountains.

The pre-settlement forest of the Ozarks was nearly a monoculture of majestic white oaks (*Quercus alba*), with canopies barely touching, first branches 3 to 5 m from the ground, and a grass understory (see Braun 1950). However, the Ozarks were clear-cut in the period from 1880 to 1900, primarily for railroad ties for the western United States (reviewed in Smith and Petit 1988). The resulting forest today is a nearly even-aged mixture of oaks, hickories (*Carya* spp.), maples (*Acer* spp.), and other deciduous species with some pine (*Pinus* spp.) in the southern portions. Given the even-aged closed canopy, there generally is little or no shrub layer development and the ground cover is predominately poison ivy (*Rhus radicans*). Shelford (1963: 59) referred to the Missouri and Arkansas Ozarks as the largest forest of oak and hickory without pine in North America and, therefore, the world. The Ozarks currently have the highest density of oaks in the United States (McWilliams et al. 2002). Nonetheless, white oak is no longer a dominant feature of the forests, probably due to fire suppression since the mid-1920s and several other factors (see Abrams 2003). Sugar maples (*Acer saccharum*) and red maples (*A. rubrum*) may be replacing oaks as the climax forest in more mesic areas (Pallardy et al. 1988, Abrams 2003).

The Ozark National Forest (*fig. 1*) was established in 1908, and today it includes 14.2 million ha in northwestern Arkansas, north of the Arkansas River. According to the USFS Continuous Inventory of Stand Conditions (CISC) database, only 6 percent of the hardwood forests on the Ozark National Forest are currently <40 years old, while 72 percent are between the ages of 40 and 90 years old (prime mast-producing age), and 21 percent are >90 years old (age of significant decline) (S. Duzan, pers. comm.).

The Ozarks within Arkansas are about 98 percent forested today, and about 75 percent of the forest is composed of a variety of oak habitats (Smith et al. 1998). According to a USFS 1995 Forest Survey, red oaks (*Erythrobalanus*) comprise 46 percent of the live-tree volume, 42 percent of growing stock volume, and 35 percent of sawtimber volume of forested regions in Arkansas (Guldin et al. 2001). Thus, much of the Arkansas Ozarks is covered with oaks, and red oaks, the more numerous subgenus, are of great commercial value to the economy of the state. However, the densities of red oak borers currently being observed in the Ozarks render the timber commercially useless (J. Guldin, pers. comm.). Anticipated loss of trees and degradation of timber from red oak borer may exceed 2.4 million cu board ft. (G.E. Leeds, pers. comm.). On an 800 ha forest in northern Arkansas in summer 2002, Heitzman (2003) documented that the basal area of red oaks had been reduced to 20 percent of pre-outbreak levels and the number of red oak trees per ha was 17 percent of pre-outbreak levels.

Causes for the Current Crisis in the Ozark Mountains

The eruption of the red oak borer in the Ozarks would appear to be a classic example of a forest insect that has existed at endemic levels for a long period of time, but has become epidemic due to some density-independent factor(s), allowing population levels to cross some regulatory threshold (see Berryman 1982: *fig. 1*; Berryman 1987; Berryman et al. 1987: *fig. 5*). Various hypotheses have been suggested as explanations for the cause of the current oak mortality in the forests of the Ozark Mountains (Stephen et al. 2001). The USFS refers to "widespread and locally severe mortality and decline of red oaks…on the Ozark National Forest during the summer of 1999" (Starkey et al. 2000). A USFS fact sheet describes the situation as an "oak decline" event and suggests that there are a variety of causes (Oliveria et al. 2000).

In describing decline etiology concepts, Manion (1991) refers to *predisposing, inciting,* and *contributing* factors. In relation to oak decline in the Ozark Mountains, important *predisposing* factors are older tree age, prolonged drought, poor soils, and low site quality (Starkey et al. 2000). *Inciting* factors are suggested to be the acute, short-term drought stress that occurred in Arkansas through much of the late 1990s (Starkey et al. 2000). *Contributing* factors include defoliation from secondary insects; root diseases, e.g., *Armillaria mellea*, and stem cankers, e.g., *Hypoxylon* sp., both of which have appeared in the Ozarks within the last 10 years (J. Guldin, pers. comm.); and secondary species of borers such as two-lined chestnut borer, *Agrilis bilineatus* (Wargo et al. 1983) and red oak borer (Starkey et al. 2000).

Thus, factors involved with the current outbreak include advanced age of stands (70 to 100 years); xeric conditions associated with shallow rocky soils, exacerbated by three years of drought; and appearance of two fungi, one attacking roots and one attacking above ground, all of which weaken the trees' resistance to attack by red oak borers. Coincident with that opinion is the idea that the logging history of the region, which consisted of continuous high grading of the forests during the early 1900s, resulted in stands that are frequently dominated by red oaks of similar age structure (Ozark-St. Francis National Forests 1978). Non-industrial private forestlands are especially at risk, since red oaks comprise 50 percent of sawtimber volume and 74 percent of live-tree volume on timberland in the private sector (Guldin et al. 2001). Red oak trees also are dying now in Arkansas' urban areas, such as yards and city parks in major cities surrounding the national forest (e.g., Fayetteville, *fig. 1*).

Biology and Life History of the Red Oak Borer

Many forest insect species that have become significant disturbance factors in relatively unmanaged native forests are exotics. The red oak borer, however, is a native species in eastern North America (Donley and Acciavatti 1980) that attacks living oak trees, with preferred hosts being those in the red oak group, including southern red (*Q. falcata*), northern red (*Q. rubra*), black (*Q. velutina*), willow (*Q. phellos*), and Nuttall (*Q. nuttallii*) oaks. It also breeds in the white oak group (Donley and Acciavatti 1980), which includes white and post (*Q. stellata*) oaks in the Ozarks. Red oak borer attacks normally occur at sufficiently low densities that they seldom result in tree mortality (Hay 1972, Petit et al. 1988). Population levels of the epidemic magnitude currently being reported in the Ozark Mountains have never been witnessed within the range of this species (Stephen et al. 2001). Attacks and borer galleries are being seen in trees and limbs as small as 8 cm in diameter. Typically, red oak borer infestations have been local; red oak borers previously have been considered unimportant insect pests in oak forests (Oak 2002).

Throughout the central United States (including the Ozarks), there is a two-year life cycle during which synchronous emergence of adults occurs only in odd numbered years (Hay 1972, Donley and Acciavatti 1980). The main emergence period is about 3 weeks long. Adults do not feed on twigs or foliage, and average longevity of males and females is approximately 3 weeks (Hay 1972, Donley 1978, Solomon 1995). Oviposition continues for about 16 days, during which time females lay about 120 eggs, singly or in small groups, usually in bark crevices or under lichens (Donley 1978). Eggs hatch in 10 to 13 days (Solomon 1995). Larvae chew through the bark and begin gallery excavation in phloem tissue. The young larvae chew back out through the bark and open small oblong holes through which fine frass is ejected during feeding (Solomon 1995). Following their first winter, larvae continue to feed in phloem, then enter the sapwood in summer. They overwinter in sapwood in their second year, and then pupate there in May or June. Adult emergence begins in late May or June depending on latitude.

Petit et al. (1988) found that most infected trees contained a single larva. We (Stephen et al. 2001) conducted a preliminary study to compare population parameters from the current outbreak with historical data and found attack density averaged 244 (± 30.8 SE) per m^2 of tree trunk in fall 2001. Density of mature (2nd year) larvae averaged 21.4 (± 4.4) per m^2, and emerging adult density averaged 18.5 (± 4.3) per m^2. Based on preliminary analysis of data we collected during the emergence in summer 2003, it would appear that the number of emerging adults in 2003

was comparable to that of 2001 and that there definitely will be another large emergence in summer 2005.

Based upon the magnitude of this insect outbreak and the potential for losing upwards of 50 percent of the trees in the Ozarks forests, we examine here the potential impact on birds currently breeding in the forested Ozarks. Our focus is on migratory birds, although undoubtedly permanent resident species also are being impacted.

Methods

We conducted a literature search to determine what was known about bird predation on red oak borers and what effects the demise of dominant tree species from the eastern deciduous forest over the last century had on the breeding populations of neotropical migratory birds. This search focused on the American chestnut (*Castanea dentata*), which was eliminated as a canopy tree by the fungus *Cryphonectria* (= *Endothia*) *parasitica*, technically the "chestnut bark disease," but more popularly, the "chestnut blight"; the American elm (*Ulmus americana*) eliminated by the Dutch elm disease, caused by a fungus (*Certatocystis ulmi*) and carried by a native bark beetle (*Hylurgopinus rufipes*) and a European bark beetle (*Scolytus multistriatus*); the change in physiognomy of the American beech (*Fagus grandifolia*) by the beech bark disease, a fungus, *Nectria coccinea* var. *faginata*, spread by a scale, *Cyrptococcus fagi* and possibly also another scale *Xylococculus betulae*; and woolly adelgids causing the demise of Fraser fir (*Abies fraseri*) in the southern Appalachians by *Adelges piceae*, and to the north, Eastern hemlocks (*Tsuga canadensis*) by *Adelges tsugae*.

Based on our research on bird communities in the Ozarks of Arkansas (Rodewald and Smith 1998, Smith et al. 2004), we compiled a list of neotropical migratory birds that breed in upland hardwood forests. Based on that research and the literature review, we speculate on the impact of oak elimination on breeding neotropical migrants in the Ozarks.

Results

Previous Research on Red Oak Borers and Birds

Little published work exists on the predation of red oak borers by birds. All studies suggest that the only impact is from woodpeckers and that it occurs in winter. The entire immature life cycle is within the tree trunk, and when adults do emerge in summer, all their activity is at night (Solomon 1995). In Mississippi, Solomon (1969) most often found Red-bellied Woodpeckers (*Melenerpes carolinus*) on infested trees, and he less often observed Hairy (*Picoides villosus*), Downy (*P. pubescens*), Red-headed, and Pileated (*Dryocopus pileatus*) woodpeckers. In Ohio and Kentucky, Hay (1972, 1974) observed mostly Hairy and Downy woodpeckers at infested trees and, to a lesser degree, Red-headed and Red-bellied woodpeckers during overwintering dormant periods. He attributed 33 percent of the borer mortality to woodpeckers during the first winter, almost no predation during the first summer, and 3 percent (3 of 113) mortality in the second winter of original larvae, but 30 percent of those available (3 of 10). Some sites showing evidence of woodpecker drilling still produced adults. The only other bird study to mention red oak borers is Petit et al. (1988), who found about 10 percent mortality on larvae during the second winter due to woodpecker predation.

Comparisons with Other Massive Tree Losses within the Eastern Deciduous Forest

American chestnut

Once the major component of the hardwood forests of the eastern United States, American chestnut composed about 25 percent of the forest in central Appalachian forests (Liebhold et al. 1995), but some stands were closer to 85 percent chestnut. The fungus probably arrived in the late 1800s from China or Japan, and it destroyed large numbers of trees in and around New York City in 1904 and 1905 (Anagnostakis 1987, Moss 1973). Once out of New York City, the fungus spread at the rate of 37 km/ year, and within 50 years, trees on 3.6 million ha were dead or dying (Anagnostakis 1987). More recently, the fungus has eliminated chinquapin (*Castanea pumila*) from the Ozarks (Paillet 1993). There are only anecdotal references to the effect of elimination of the American chestnut on animal population dynamics, e.g., suggested increases in woodpecker populations due to availability of dead trees (e.g., Smith et al. 2000).

American beech

References in the nineteenth century spoke of the "great" beech forests in the northern and northeastern United States (e.g., Cogbill et al. 2002, Whitney 1994) and the impact that beech mast crops had on the population dynamics of seed-eating birds, e.g., Red-headed Woodpeckers (Smith et al. 2000). Introduced into Halifax, Nova Scotia about 1890, beech bark disease migrated south; the first outbreaks of the disease were documented about 30 years later in Maine. Most damage occurred in the 1930s and 1940s. Large numbers of mature and over-mature beeches were present because of the low regard for this species as a lumber tree. During the outbreak, large trees were killed or removed in fuelwood salvage cuts. Beech remains part of the forest in terms of numbers of trees and basal area, but today trees are much smaller and form thickets with little or no mast production (Houston 1975).

Apparently no research was conducted on the effects on breeding bird populations.

American elm

Dutch elm disease began killing elm trees in the eastern United States early in the twentieth century (Karnosky 1979). Impacts moved westward through Ohio (1940s) and Illinois (1950s), and reached the western edge of the distribution of elms in Iowa in the 1980s (Smith et al. 2000). Increases in breeding populations of Red-headed Woodpeckers followed closely behind the front, tracking the dead trees for decades (Smith et al. 2000).

Serendipitously, S. C. Kendeigh and colleagues had been studying bird populations from 1927 through 1976 at Trelease Woods, a 24-ha woodlot in southern Illinois. Kendeigh (1982) documented the demise of the American elms and the reaction of the bird community. The most dramatic increases were in four woodpecker populations and those of the European Starling (*Sturnus vulgaris*) while dead trees remained standing. Although not many migratory species occurred in Trelease Woods (*table 1*), shrub-nesting species, such as Northern Cardinals (*Cardinalis cardinalis*), Gray Catbird, Brown Thrasher, Common Yellowthroat, and Eastern Towhees, became much more numerous (*table 1*).

Fraser fir and hemlocks

Over the last 20 years, introduced adelgids (Homoptera: Adelgidae) have reduced conifer populations in the Appalachians. Rabenold et al. (1998) monitored bird populations at a site that experienced a 90 percent decline in Fraser fir over a 13-year period. Over a 16-year period, they documented that 9 of 11 canopy bird species declined and that singing males declined 50 percent. Species that foraged on the ground and those that foraged low in the foliage were less affected (*table 2*). An influx of species characteristic of open and disturbed forests, including some neotropical migrants like Chestnut-sided Warbler (*table 2*), began 10 years after arrival of adelgids.

More recently, Tingley et al. (2002) documented the impact of the elimination of Eastern hemlock in southern New England by adelgids on breeding birds by comparing intact stands with those where hemlocks had declined. Black-throated Green Warbler, Acadian Flycatcher, Blackburian Warbler, and Hermit Thrush were particularly sensitive to hemlock decline, but Hooded Warblers appeared to benefit from canopy mortality opening the understory.

Table 1— *Migratory birds reported by Kendeigh (1982) from his 50-year study of birds at Trelease Woods in southern Illinois. General trends in population levels following elimination of American elm in the late 1950s are given along with comments made by Kendeigh.*

Species	Scientific name	Trend	Comments
Yellow-billed Cuckoo	*Coccyzus americanus*	none	0 to 6 pairs – fluctuated annually
Ruby-throated Hummingbird	*Archilochus colubris*	none	1 pair almost every year
Eastern Wood-Pewee	*Contopus virens*	decreased	8 pairs early – 20 pairs in 1950s – back to 8 in 1970s
Great Crested Flycatcher	*Myiarchus crinitus*	none	3 to 8 pairs – fairly constant
Red-eyed Vireo	*Vireo olivaceus*	decreased	like Eastern Wood-Pewee
House Wren	*Troglodytes aedon*	none	increased in 1950s but not due to food or dead trees
Wood Thrush	*Hylocichla mustelina*	none	fairly constant – unaffected by tree death
American Robin	*Turdus migratorius*	increased	rare before opening of canopy
Gray Catbird	*Dumetella carolinensis*	increased	after canopy opening in late 1950s
Brown Thrasher	*Toxostoma rufum*	increased	after canopy opening in late 1950s
Common Yellowthroat	*Geothlypis trichas*	increased	doubled after canopy opening in late 1950s
Yellow-breasted Chat	*Icteria virens*	decreased(?)	1 pair 1944 through 1960
Eastern Towhee	*Pipilo erythrophthalmus*	increased	occurred after tree death
Indigo Bunting	*Passerina cyanea*	decreased(?)	peaked before tree death and then declined

Table 2— *Migratory birds reported by Rabenold et al. (1998) in their study of the decline of Frasier fir in the southern Appalachians. Data are from censuses in 1974 (pre-adelgid), 1986 (10 years post), and 1990 (14 years post), reported as number of males/20 ha, and occurrence based on a series of point counts performed at seven locations in 1993. Transient species were treated categorically as frequent, occasional, or rare.*

Species	Scientific name	1974 Pre-adelgid	1986 10-yr post	1990 14-yr post	1993 17-yr post
Breeding species					
Strongly affected:					
Solitary Vireo	*Vireo solitarius*	25	9	6	6/7
Black-throated Green Warbler	*Dendroica virens*	6	5	2	3/7
Increased:					
Chestnut-sided Warbler	*Dendroica pensylvanica*	0	1	9	7/7
Black-throated Blue Warbler	*Dendroica caerulescens*	0	0	6	2/7
Canada Warbler	*Wilsonia canadensis*	0	0	0	6/7
Other migratory species					
Veery	*Catharus fuscescens*	8	5	5	7/7
Hermit Thrush	*Catharus guttatus*	0	3	1	2/7
Magnolia Warbler	*Dendroica magnolia*	0	0	0	1/7
Transients					
Broad-winged Hawk	*Buteo platypterus*	rare	0	0	0/7
Chimney Swift	*Chaetura pelagica*	occasional	occasional	rare	3/7
Ruby-throated Hummingbird	*Archilocus colubris*	rare	0	0	0/7
Willow Flycatcher	*Empidonax traillii*	0	0	0	1/7
Blackburnian Warbler	*Dendroica fusca*	rare	rare	0	1/7
American Redstart	*Setophaga ruticilla*	0	0	0	1/7

Potential impact of loss of red oaks in the Ozarks

A greater number of migratory species breed in the Arkansas Ozarks (*table 3*) than in the other areas mentioned above. Of the eight common species, six are predicted to decrease with the elimination of red oaks, and three of the four uncommon species are predicted to decline. Two of the three rare species may increase and five species, currently absent from mature upland hardwoods, should increase as the canopy opens and a shrub layer develops. The only scrub-nesting species that occurs in undisturbed upland hardwood forests of the Ozarks is the Hooded Warbler (Smith et al. 2004).

Discussion

In a typical upland hardwood forest in the Arkansas Ozarks, most migratory species nest in the canopy (i.e., in trees) (*table 3*), a few species nest on the ground (e.g., Ovenbird, Black-and-white Warbler, Worm-eating Warbler), and only one species nests in shrubs (Hooded Warbler). Given the relatively even-age structure of those upland forests, the canopy is closed, and there is little development of a shrub layer. However, opening the canopy and allowing light to penetrate to the forest floor allows shrub development in 1 to 2 years (Rodewald and Smith 1998, Heitzman 2003). This layer can become an almost impenetrable thicket within 5 to 10 years.

Even relatively small openings may have an impact on forest birds, and development of the shrub layer may attract species (e.g., White-eyed Vireo, Blue Grosbeak, Indigo Bunting) not normally associated with forested habitats (Gram et al. 2003, Rodewald and Smith 1998). Opening of the forest canopy either immediately (Kendeigh 1982) or eventually (Rabenold et al. 1998) allowed early successional bird species to colonize new areas that previously were unsuitable habitats. Similarly, Gram et al. (2001) recently documented short-term changes in bird community structure in the Missouri Ozarks with an estimated reduction of 10 percent of the canopy structure. Fragmented forests in Missouri actually have more species than contiguous forests, but the number of Neotropical migrants is greatly decreased in the fragmented forests (Howell et al. 2000).

Table 3— *Migratory birds that breed in the Arkansas Ozarks, current status in mature upland hardwood forests, and predicted population trend if red oaks are eliminated from the Ozarks. Occurrence data and current status from Rodewald and Smith (1998), Smith (1977), Smith (unpubl. data), and Smith et al. 2004). Predicted trends based primarily on Rodewald and Smith (1998) and Smith et al. (2004).*

Species	Scientific name	Current status	Predicted trend
Yellow-billed Cuckoo		Uncommon	Decrease
Ruby-throated Hummingbird		Uncommon	???
Eastern Wood-Pewee		Common	Increase
Acadian Flycatcher	*Empidonax virescens*	Common	Decrease
Great Crested Flycatcher		Uncommon	???
White-eyed Vireo	*Vireo griseus*	Absent	Increase
Yellow-throated Vireo	*Vireo flavifrons*	Uncommon	Increase?
Red-eyed Vireo	*Vireo olivaceus*	Abundant	Decrease?
Blue-gray Gnatcatcher	*Polioptila caerulea*	Common	Increase
Wood Thrush		Common	Decrease
Blue-winged Warbler	*Vermivora pinus*	Absent	Increase
Chestnut-sided Warbler		Rare	Increase
Black-throated Green Warbler		Uncommon	Decrease
Cerulean Warbler	*Dendroica cerulea*	Uncommon	Decrease
Black-and-white Warbler	*Mniotilta varia*	Common	???
Worm-eating Warbler	*Helmitheros vermivorus*	Common	Decrease
Ovenbird	*Seiurus aurocapillus*	Common	Decrease
Louisiana Waterthrush	*Seiurus motacilla*	Rare	Decrease
Kentucky Warbler	*Oporornis formosus*	Uncommon	Increase
Hooded Warbler	*Wilsonia citrina*	Common	Decrease
Yellow-breasted Chat	*Icteria virens*	Absent	Increase
Summer Tanager	*Piranga rubra*	Uncommon	Increase?
Scarlet Tanager	*Piranga olivacea*	Common	Decrease?
Blue Grosbeak	*Guiraca caerulea*	Absent	Increase
Indigo Bunting		Absent	Increase

In most cases, canopy foraging species were negatively impacted by the elimination of live trees in the canopy, and ground and low-foraging species were not (Kendeigh 1982, Rabenold et al. 1998). Cerulean Warbler, a species of conservation concern, is currently a relatively common breeder in the Arkansas Ozarks (James et al. 2001), but it probably will be extirpated with the demise of large oak trees (see Rodewald and Smith 1998). Populations of Black-throated Green Warblers that recently colonized the Arkansas Ozarks (Rodewald 1997) also will be greatly reduced as will most wood-warblers (*table 3*), particularly those mentioned above that nest on the ground (Rodewald and Smith 1998). In the short-term, populations of Chestnut-sided Warblers, another new breeder in the Ozarks (Rodewald 1997), probably will increase (Rabenold et al. 1998).

As mentioned previously, Rabenold et al. (1998) found a decrease in canopy species following the elimination of Fraser fir. Similarly, Davis et al. (2000), in assessing change in community structure that had occurred on plots that had experienced 0 to 26 controlled burns over the last 31 years, found that as restoration proceeded there was a general decline in insectivores, particularly those that fed in the upper canopy, and a general increase in omnivores that fed on the ground and in the lower canopy. They also found that woodpeckers increased and were correlated with the increase in standing dead trees. Kendeigh (1982) also found that primary hole-nesters showed a positive response to the presence of dead trees, followed by a positive response by secondary-cavity nesters. However, unlike the other situations mentioned above where many dead trees were left standing, the trees in the Ozarks are so heavily damaged by borer drilling that they fall over in 1 to 2 years, precluding any increase in hole-nesting species.

In some respects, the effects of elimination of oaks in the Ozarks may be similar to those experienced in forests that have been defoliated by gypsy moth (*Lymantria dispar*) caterpillars. Defoliation allows more light penetration so that understory development increases, which leads to a dramatic increase in Hooded Warblers (Bell and Whitmore 2000). Most canopy nesting species are adversely affected, but shrub nesting species such as Eastern Towhee showed increases (DeGraaf 1987, Bell and Whitmore 1997). Nest predation rates increased with defoliation by gypsy moth caterpillars (Thurber et al. 1994), but Matsuoka et al. (2001), studying forests that

had been decimated by spruce beetles (*Dendroctonus rufipennis* [Kirby]) in Alaska, found that predation rates were not higher, due to concomitant decreases in the number of predators (primarily squirrels).

In general, the forested Ozarks are considered a source region for neotropical migrants compared to fragmented areas to the east and north that have become population sinks (Donovan et al. 1995, Howell et al. 2000, Robinson et al. 1995), and reproductive success among the more common Neotropical migratory species is relatively good (>50 percent; Li 1994). Elimination of oaks from the Ozarks could potentially reverse that situation rather quickly, such that the Ozarks also may become unsuitable for sustained reproductive success for many species.

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