CONSERVATION IMPLICATIONS FOR NEOTROPICAL MIGRATORY AND GAME BIRDS IN OAK-HARDWOOD STANDS MANAGED WITH SHELTERWOOD HARVESTS AND PRESCRIBED FIRE

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Abstract.—Prescribed fire in conjunction with shelterwood cutting is a novel way to regenerate oak-dominated stands on certain upland sites while minimizing the intrusion of hardwoods. We describe three options (complete or partial canopy retention, postharvest prescribed burning, and complete canopy removal) within a shelterwood-prescribed fire regime that will create two-age stands that are likely to harbor a diverse mixture of mature forest and early successional birds; parklike woodlands with open woodland species; or early successional habitats with shrubland species. This system is a viable option for managing both avian and timber resources where oak-dominated stands on upland sites are the desired goal.

INTRODUCTION

In Eastern North America, shelterwood silviculture is a common technique for managing oak-dominated stands on upland sites (Sander et al. 1983). Partial harvests reduce the dense shade that suppresses root development of existing oak regeneration (Loftis 1990) and helps retard the rapid height growth of less-desirable species such as yellow poplar (*Liriodendron tulipifera* L.) and red maple (*Acer rubrum* L.). Additionally, soil disturbance from the harvesting operations prepares seedbeds for acorns produced by the retention stand, thereby encouraging oak seedling establishment (Cook et al. 1998).

On some upland sites, preharvest treatments such as herbicide application (Loftis 1990; Lorimer et al. 1994), low-intensity burning (Barnes and Van Lear 1998; McGill et al. 1999), tree sheltering (Potter 1988), and implantation of high-quality nursery stock (Bowersox 1993; Gordon et al. 1995; Schlarbaum et al. 1997) may precede the initial shelterwood harvest to encourage oak regeneration. However, these preharvest treatments are expensive and often ineffective and must precede the initial shelterwood cut by 5 to 15 years to allow sufficient root development of the oak regeneration.

The constraints of time and money that often affect private owners of small- to medium acreage require a more efficient means of regenerating oaks in shelterwood systems. Keyser et al. (1996) burned two oak-dominated shelterwood stands after an initial harvest and found that regeneration of yellow-poplar, red maple, and sweetgum (*Liquidambar styraciflua* L.) was reduced by as much as 90 percent while oak reproduction was reduced only by 11 percent. Followup investigations of fire effects in oak-dominated shelterwood stands reported similar results in high fire resistance among oak and low tolerance for burning among less desirable hardwood competitors. This illustrates the vital role of postharvest burning coupled with growing-season burns in creating an oak-dominated seedling cohort (Brose and Van Lear 1998a,b; Brose et al. 1999; Brose and Van Lear 1999; Van Lear and Brose 1999).

We suggest that this technique may be applicable elsewhere in upland oak-dominated stands (oak-hickory) of Eastern North America (Ward and Gluck 1999). Application of this technique (Fig. 1a-h) entails three-steps. First, an initial harvest leaves 50 to 60 dominant oaks per ha (11 to 12 m^2 of basal area/ha). The remnant stand should contain the best oak stock to encourage a vigorous regeneration cohort. The stand is then left undisturbed for 3 to 5 years to allow the development of a regeneration layer. After 3 to 5 years, a hot (flame length > 1.0 m) growing-season fire is applied to the stand, resulting in an oak-dominated regeneration cohort.

Although this technique was originally implemented to improve the viability of oak regeneration and the

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production of hardwood timber in uplands, the conservation of biodiversity also is a goal of many forest management activities. Birds comprise significant ecological components of eastern forest systems. Songbird population declines in many forests of the Eastern United States have focused attention on the effects of various silvicultural practices on conservation efforts. Such efforts have been particularly focused on many species of neotropical migrants (Askins et al. 1990). Game birds have long been a focus of forest management because of their economic and recreational importance. While numerous investigators have reported the effects of various silvicultural treatments on game and nongame birds, there is a dearth of information addressing the effects (real or potential) of prescribed fire on avifauna in hardwood systems. We discuss how various management options implemented in oak- shelterwood burn systems can influence the composition of avian communities. These potential influences are related to the vegetative structure and composition that result from the three oak-shelterwood burn options *and* from inferences drawn from other bird habitat studies conducted in other hardwood or pine- hardwood systems where silvicultural treatments have created habitat conditions similar to those expected in oak-shelterwood burns. To emphasize the potential importance of these treatments from a bird conservation perspective, we have used Bird Conservation Region (BCR) breeding scores (RCS-b) from Region 24 – Central Hardwoods, Region 28 – Appalachian Mountains, and Region 29 – Piedmont (Partners in Flight Species Assessment database: ww.rmbo.org/pif/scores/scores.html) as indicators of management priority.

Conservation Implications for Avian Communities

Canopy Retention

Canopy retention treatments provide two-aged stands twice during the shelterwood burn regime: 1) when “undesirable” hardwoods dominate the advance-regeneration cohort, and 2) after a satisfactory cohort of vigorous, advance oak- regeneration is achieved when a portion or all of the residual overstory trees may be retained for at least half of the next rotation.

A widely observed trend of bird -habitat relationship studies is the positive association between floristic structural diversity and bird-species diversity. Retention of some overstory during shelterwood treatments may provide sufficient canopy habitat and vertical structure for some mature forest canopy bird species to use partially harvested stands (Dickson et al. 1995). Relative to the composition of a mature forest songbird community, canopy retention treatments would be the least intensive and probably most similar to an uneven-aged mature forest. Dickson et al. (1995) concluded that the retention of a residual canopy (less than 50 percent) for several years after an initial harvest can provide habitats for some mature forest birds that otherwise would not inhabit stands managed using traditional even-age management techniques.

Wood and Nichols (1995) found that two-aged stands in West Virginia contained a greater density, richness, evenness, and overall diversity of breeding birds than early successional or mature stands. The total density for all neotropical migrants also was highest in the two-aged stands. Densities of forest-interior species did not differ statistically among clearcut, mature, and two-aged stands. The two-aged stands had densities of interior-edge species equal to or greater than the other two treatments. The co-occurrence of mature forest and early successional species within the same areas indicated that two-aged stands provided habitats for both mature and early successional species. Mature forest species reported in The Wood and Nichols study included veery (scientific names for all neotropical migrant and game bird species are in Table 1), American redstart, and scarlet tanager. Early successional species recorded in the same stands included chestnut-sided warbler, indigo bunting, and eastern towhee.

In the Missouri Ozarks, Annard and Thompson (1997) reported higher species richness for breeding birds in stands treated by the shelterwood method than in clearcuts, group selection, single-tree selection, or uncut stands. Species richness was higher in shelterwoods than in unharvested or uneven-aged stands. As in the Wood and Nichols study, these differences were attributed to the presence of both early seral stage and mature forest

Table 1.—Oak shelterwood burn occupancy potential of select neotropical migrant and game bird species[a]

Species	Option 1	Option 2	Option 3
wild turkey (*Meleagris gallopavo*)	X	X	X
northern bobwhite (*Colinus virginianus*)		X	X
ruffed grouse (*Bonassa umbellus*)	X	X	X
yellow-billed cuckoo (*Coccyzus americanus*)	X		
black-billed cuckoo (*C. erythropthalmus*)		X	
whip-poor-will (*Caprimulgus vociferus*)			X
Chuck-will's-widow (*C. carolinensis*)	X		
ruby-thr. hummingbird (*Archilocus colubris*)	X		X
Acadian flycatcher (*Empidonax virescens*)	X		
least flycatcher (*E. minimus*)		X	
willow flycatcher (*E.alnorum*)			
eastern kingbird (*Tyrannus tyrannus*)			X
great-crested flycatcher (*Myiarchus crinitus*)		X	
eastern wood-pewee (*Contupus virens*)		X	
gray catbird (*Dumatella carolinensis*)	X		X
wood thrush (*Hylocichla mustelina*)	X		
veery (*Catharus fuscescens*)	X		
blue-gray gnatcatcher (*Pilioptila caerulea*)	X		
red-eyed vireo (*Vireo olivaceous*)	X		
yellow-throated vireo (*V. flavifrons*		X	
warbling vireo (*V. gilvus*)		X	
white-eyed vireo (*Vireo griseus*)	X		
Blackburnian warbler (*Dendroica fusca*)	X		
black-throated blue warbler (*D. caerulescens*)	X		
black-throated green warbler (*D. virens*)		X	
cerulean warbler (*D. cerulea*)	X	X	
chestnut-sided warbler (*D. pensylvanica*)		X	X
yellow-throated warbler (*D. dominica*)			X
prairie warbler (*D. discolor*)			X
yellow-warbler (*D.petichia*)			X
blue-winged warbler (*Vermivora pinus*)	X		X
golden-winged warbler (*V. chrysoptera*)	X		X
American redstart (*Setophaga ruticilla*)	X		
black-and-white warbler (*Mniotilta varia*)	X	X	
common yellowthroat (*Geothlypis trichas*)			X
hooded warbler (*Wilsonia citrina*)	X		
Kentucky warbler (*Oporonis formosus*)	X		
northern parula (*Parula americana*)	X		
ovenbird (*Seiurus aurocapillus*)	X		

Continued

Table 1.—Continued.

Species	Option 1	Option 2	Option 3
Louisiana waterthrush (*S. motacilla*)	X		
worm-eating warbler (*Helmitheros vermivorus*)	X		
yellow-breasted chat (*Icteria virens*)			X
orchard oriole (*Icterus spurius*)	X	X	
Baltimore oriole (*I. galbula*)	X	X	
scarlet tanager (*Piranga olivacea)*	X		
summer tanager (*P. rubra*)		X	
indigo bunting (*Passerina cyanea*)	X	X	X
blue grosbeak (*Guiraca caerulea*)		X	X

[a]Bird habitat associations are inferred from associations in similar types and conditions of habitat that would be created by the options described in this paper. Bird habitat associations are derived from Hamel et al. (1982) and denote associations with seral stages in oak-hickory habitats as follows: Option 1 = sapling poletimber-sawtimber; Option 2 = grass-forb, sawtimber; Option 3 = seedling-sapling.

birds, including blue-winged warbler, prairie warbler, red-eyed vireo, worm-eating warbler, and Acadian flycatcher.

Nesting success must be considered in conjunction with measures of density and diversity of breeding birds. Wood and Nichols (1995) reported no differences in nest success among treatments in West Virginia. Nest parasitism by brown-headed cowbirds (*Molothrus ater*) was not a major factor in their study; only 8 of 246 nests were parasitized and there were no differences in the number of cowbirds among treatments. Annard and Thompson (1997) and Welsh and Healy (1993) reported similar results in Missouri and New Hampshire, respectively. However, one must remain aware, that patterns of predation and parasitism may vary depending on the landscape context. Overall, the impact of cowbirds and predators in extensively forested systems tends to be lower than that in agricultural and suburban landscapes (Wilcove 1985)

The findings of all of these studies are consistent with an earlier study by Crawford et al. (1981). Although they did not study shelterwood systems, the findings of Crawford et al. nonetheless are relevant because they concluded that timber management strategies altered bird communities in relationship to the degree of stand disturbance. They predicted that partial harvests would provide sufficient canopy cover to buffer complete species turnover from mature forest to early successional species observed in clearcut forests. They further surmised that partial cuts would return more quickly to site conditions conducive to mature bird species than even-age treatments. These findings have been corroborated by other studies that have shown that although populations of some forest-interior songbirds may be reduced relative to an undisturbed stand due to habitat alteration, increased nest predation, and parasitism (Webb et al. 1977; Wood and Nichols 1995), these species generally are not eliminated entirely and population recovery may occur rapidly as the new forest matures (Conner and Adkisson 1975; Askins and Philbrick 1987).

Canopy disturbance may benefit forest-interior bird species that have declined in some regions. Some birds that use early-successional gaps within mature forests may decline in areas where disturbances do not produce the regenerating ground-layer and shrub vegetation they prefer (Franzreb and Rosenberg 1997). Shelterwood harvesting would stimulate the growth of low vegetative cover. In West Virginia, Wood and Nichols (1995) found that Kentucky warblers, wood thrushes, American redstarts, and black-and-white warblers were 2 to 3 times more abundant in two-aged stands than in uncut controls. The abundance of these species in the shrubbier two-age stands lends credence to the shelterwood-shrub layer hypothesis.

The retention of the best, 11 to 12 m^2 of oak basal area/ha (50 to 60 dominant oaks/ha) in shelterwood stands also provides reliable acorn sources (Healy 1997). Acorns are one of the most important wildlife foods as they are eaten by more than 200 wildlife species throughout North America (Martin et al. 1951). Among these are a multitude of avian species (Martin et. al 1951; Beck 1993). Corvids, e.g., blue jays (*Cyanocitta cristata*) and American crows (*Corvus brachyrhynchos*), are voracious acorn predators and bear a large responsibility for the regeneration of oak stands through their caching activity. Although not a neotropical migrant or game species, red-headed woodpeckers (*Melanerpes erythrocephalus*) are short-distance migrants that are likely to benefit from overstory retention management activities. They also receive attention as species of regional importance from Partners in Flight (Panjabi et al. 2005). Several species of upland game birds including wild turkeys and ruffed grouse consume acorns (Martin et al. 1951; Dickson 2001), making canopy retention stands potentially important foraging habitat for both species.

On the basis of the floristic structure of stands expected after canopy retention treatments, Table 1 lists the diverse array of neotropical migratory and game bird species that are likely to occur in the diverse two-age structure of these areas. Conservation priority scores and management priorities for species occurring under this option are shown in Table 2. Note that the cerulean warbler, a species likely to benefit from the mature canopy retained in this silvicultural scenario (in mesic types), is characterized as a species with "Immediate Management" conservation priorities in both the Central Hardwoods and Appalachian Mountain Bird Conservation Regions BCR (Panjabi et al. 2005). Illustrating the diverse avian conservation potential for this scenario, golden-winged warblers and ruffed grouse also are Immediate Management priorities (Panjabi et al. 2005). In the Piedmont, conservation priorities are even higher as ruffed grouse are characterized as a species in need of "Critical Recovery". Ruffed grouse might occupy the complex woody/herbaceous understory resulting from the overstory retention option in the Central Hardwoods, Appalachian, and Piedmont BCR while golden-winged warblers should occupy similar habitats in the Appalachian mountains.

Understory Suppression Using Prescribed Burning

The second option in the oak-shelterwood burn scheme is the use of periodic prescribed fire in shelterwood stands. Among the three options discussed here, this method is likely to be intermediate in its effects on the songbird community. Ultimately, the shift in species composition will vary depending on the vegetative structure resulting from the season, intensity, and frequency of the prescribed fire. Dormant-season (winter) burns will produce low-growing, sprouting regeneration of shrub and trees and stimulate the production of soft mast (Stransky and Roese 1984). These responses may provide forage, cover and arthropod prey for many game and nongame birds (Dickson 1981, 2001).

Repeat dormant-season burning promotes an increased abundance of oak regeneration. Oak regeneration is limited with additional fires and released at intervals by withholding burning treatments, creating patchy stands in different successional stages. Dickson (1981) surmised that in southern pine and pine-hardwood forests, a patchwork of different successional stages within a stand (or across a landscape) could enhance bird diversity and abundance. This patchwork obviously would be dependent not only on the frequency and intensity of fires but also on the size, topography, and site capability of the area burned. In stands managed with dormant-season fires that allow the proliferation of hardwood shrubs and trees underneath an open canopy, bird communities are likely to consist of a large proportion of shrub nesting, e.g., white-eyed vireo, and midstory species, e.g., wood thrush, along with species more characteristic of open canopy forests, eg., yellow-billed cuckoo and blue-gray gnatcatcher. More so than other burning treatments, dormant-season fires in oak-shelterwoods are likely to produce bird communities more similar to two-aged canopy retention stands.

Annual or biennial prescribed burning during the growing season should create open hardwood woodlands

Table 2.—Conservation scores and management priorities[a] for selected avian species of regional importance potentially occupying oak-shelterwood burn habitats in central hardwoods (CH), Appalachian mountain (AM), and piedmont (PM) bird conservation regions.

Species	CH	AM	PM
northern bobwhite	16 MA	***15 IM***	***16 IM***
ruffed grouse	***15 IM***	***16 IM***	***14 CR***
yellow-billed cuckoo	15 MA		14 MA
black-billed cuckoo		17 MA	14 MA
whip-poor-will	17 MA	16 MA	18 MA
Chuck-will's-widow		14 MA	15 MA
Acadian flycatcher	16 PR	17 MA	
willow flycatcher	12 PR	11 PR	9 PR
eastern kingbird	15 MA		14 MA
eastern wood-pewee	15 MA	15 MA	15 MA
wood thrush	16 MA	16MA	16 MA
blue-gray gnatcatcher	14 MA		
yellow-throated vireo	16 PR	17 MA	14 PR
white-eyed vireo	15 MA		
Blackburnian warbler		14 MA	
cerulean warbler	***19 IM***	***21 IM***	16 MA
prairie warbler	18 MA	18 MA	18 MA
yellow-throated warbler	15 PR	16 PR	
blue-winged warbler	19 MA	17 PR	16 MA
golden-winged warbler		***21 IM***	
black-and-white warbler		16 MA	
hooded warbler		15 PR	
Kentucky warbler	18 MA	19 MA	15 PR
Louisiana waterthrush	15 PR	18 MA	
worm-eating warbler	18 MA	18 MA	13 PR
yellow-breasted chat	16 MA	15 MA	
orchard oriole	17 MA		
Baltimore oriole			14 MA
scarlet tanager		14 PR	
summer tanager	6 PR	16 MA	
indigo bunting	14 PR	14 PR	12 PR
blue grosbeak			14 PR
Average conservation score	18.22	16.24	14.6
Critical recovery	0	0	1
Immediate management	2	4	1

[a]Management actions in decreasing priority: CR= Critical Recovery; IM = Immediate Management; MA = Management Attention; PR = Planning and Responsibility (Panjabi et al. 2005)

and savannas by gradually eliminating much hardwood shrub and tree regeneration while stimulating production of ground-level herbaceous vegetation (Thor and Nichols 1973). Oak woodland and savanna habitats were described as common landscape features by early explorers and settlers who observed the extensive use of fire by indigenous Americans (Pyne 1982; Buckner 1983; Van Lear and Waldrop 1989). However, over time oak savannas and woodlands and some of the wildlife species associated with them have become rare. The restoration of hardwood savannas and open woodlands probably would shift bird guilds from mature forest-interior species to canopy and midstory dwelling, open woodland and grove species, e.g., great-crested flycatcher, eastern wood-pewee, orchard oriole and summer tanager. Here, even more so than in overstory retention stands, the red-headed woodpecker is likely to benefit from this management option. Such open habitats may also likely to attractive to wild turkey for a number of life requisites including foraging, resting, and brood rearing.

Although growing-season fires might benefit some bird species, others could be negatively impacted by burns initiated so late that nesting and other breeding activities are disrupted. Therefore, spring burning should be prescribed judiciously as early as possible in the season to minimize direct impacts on nesting or breeding birds.

Fire intensity (hot versus cool) also affects vegetative structure and, therefore, avian community composition. Studying the effects of fire intensity on bird communities in Alabama Piedmont pine-hardwoods, Stribling and Barron (1995) found a greater abundance and diversity of birds in less intensively burned stands with canopy, shrub, and cavity nesters the most abundant. Canopy, shrub, and bark-feeding species also were more abundant in cool burn sites than in untreated stands. These differences were attributed to the patchiness of the vegetative structure in these areas. This same study reported a higher abundance of ground-foraging and ground-nesting songbirds in stands burned with a hot, growing-season fire than in those burned by cooler growing-season fires. They surmised that the observed responses of terrestrially associated species could have occurred because of litter removal that may have provided better foraging and nesting habitat.

Some residual canopy trees such as maples (*Acer spp*.) and tulip-poplars and those with slash accumulations at their bases are susceptible to fire-kill or damage (Brose and Van Lear 1999a). These snags are important foraging sites for woodpeckers and other bark-gleaning species. Snags also provide perching/hawking sites and roosting/nesting habitats. Larger snags provide nesting habitats for both primary cavity excavators (woodpeckers) and secondary cavity nesters, including neotropical migrants such as the great-crested flycatcher (Lanham and Guynn 1996). In addition to the valuable function provided by snags, downed logs and other coarse woody debris, e.g., treetops, fallen limbs, provide habitat for forest floor-dwelling arthropods, herpetofauna, and small mammals (Hanula 1996; Loeb 1996, Whiles and Grubaugh 1996). These provide food resources for songbirds and larger bird species, e.g., raptors, wild turkey. Larger logs remaining on the forest floor also may provide drumming substrate for ruffed grouse (Dickson 2001). Because the effects of fire in forested stands can have such varied effects, a variety of bird species is possible based on fire frequency and intensity and various site characteristics. Because most natural resource mangers and private landowners are primarily concerned with the production of open, oak-dominated woodland, Table 1 lists species likely to occur in understory (growing-season) burned treatments that result in park-like, oak woodlands. Conservation priority scores for species occurring under this option are shown in Table 2. Of note within the context of an option producing woodland species, highest conservation scores and management priorities are listed for the cerulean warbler, which may benefit from the park-like conditions should they be implemented in mesic oak/hardwoods preferred by the species in the Central Hardwoods and Appalachian Mountain BCR. Ruffed Grouse retain an Immediate Management priority for this option in Central Hardwoods and Appalachian mountain habitats. In the Piedmont, this priority increases to Critical Recovery status

Overstory Removal

The third option of harvesting all of the residual overstory trees creates early successional hardwood habitats. These stands will undergo a dramatic turnover in avian composition with species such as indigo buntings and field sparrows occurring in regenerating hardwood stands during the grass-forb and seedling-sapling stages (Evans 1978). In subsequent years, as vertical structure within a regenerating stand changes with the growth of shrubs and saplings, avian diversity and abundance may surpass those of mature stands (Conner and Adkisson 1975; Thompson and Fritzell 1990; Thompson et al. 1992). In many eastern uplands, regenerating seedling-sapling hardwood habitats are preferred by shrub-scrub species such as prairie warblers, yellow-breasted chats, and chestnut-sided warblers. At this juncture in succession, northern bobwhite quail may use woody or brushy hardwood habitats that are interspersed with other cover types, e.g., pine forests, fallow fields, as escape, resting, and roosting cover in the nonbreeding season (Dickson 2001). Early successional hardwood stands may be used by wild turkey for nesting and brood-rearing habitat (Speake et al.1975). Ruffed grouse are especially dependent on dense thickets of hardwoods for drumming and brood rearing. Even-age systems including shelterwood regimes are cited by Dickson (2001) as a preferred method for creating suitable habitat for the species.

As regenerating stands mature to form closed canopy sapling-poletimber stands, species richness and abundance frequently decrease to levels below younger shrubland and older mature forest habitats (Conner and Adkisson 1975). However, some forest-interior songbirds such as black-and-white warblers and wood thrushes will begin using pole stands at this stage (Conner and Adkisson 1975; Mauer et al. 1981; Askins and Philbrick 1987). These stands continue to hold high suitability for ruffed grouse. (Gullion 1984). Table 1 lists bird species typical of regenerating, early successional hardwood stands. Conservation priority scores for species occurring under this option are shown in Table 2. Given the early successional conditions that are reproduced in this option, highest conservation priorities are given to the ruffed grouse (Central Hardwoods, Appalachian Mountains, Piedmont), northern bobwhite (Appalachian Mountains, Piedmont), and golden winged warbler (Appalachian Mountains).

DISCUSSION

The hardwood forests of Eastern North America are one of the largest, broad-leaved, deciduous ecosystems in the world (Hicks 1997). Numerous wildlife species, including a diverse assemblage of birds, inhabit oak-dominated forests. The songbird communities that depend on oak-dominated forests in the Southeast include a large number of neotropical migrants (Hamel et al. 1982; Thompson and Fritzell 1990). Since many of these species are declining, the management of their habitats has become a conservation priority. Although the prevailing songbird conservation paradigm in many eastern hardwood-dominated forests (especially large blocks of public forests) has been to limit harvests to single/group-tree selection or eliminate it entirely, thousands of acres of oak-dominated forests occur on private lands where wildlife conservation goals may be secondary to timber management priorities.

Game bird species also use oak stands in various stages of succession. The cultural and economic importance of maintaining harvestable populations of these species is a priority for many state agencies as well as private landowners. Prescribed fire in oak-shelterwood systems, when properly implemented, can provide the habitat diversity across the landscape that fosters healthy populations of game and nongame birds. The novel techniques suggested here provide an innovative management option that can satisfy the multiple goals of avian conservation and sustainable quality hardwood timber production.

Burning as a silvicultural technique in many forests traditionally has been associated with pine production. Conversely, it has been regarded as a force to keep out of hardwood forest management. The technique described here is an effective method for regenerating oak-dominated stands in the Southeastern Piedmont (Van Lear and Brose 1999). The steps involved in the process (partial harvest, burning, complete harvest) will create two-aged, open woodland, or shrubland habitats. Therefore, stands managed in different stages of the shelterwood-burn process across a landscape would offer habitats to forest-interior, edge-interior, open-woodland, and early-successional shrubland species. We believe that this technique has application beyond the Southeast to many other eastern forest uplands where oak is the desired dominant or codominant. The successful application of oak-shelterwood burn techniques may be especially critical in areas such as the Southern Appalachian Mountains where a number of species require critical recovery or immediate management efforts.

CAVEATS AND CONCLUSIONS

Where landscape context and logistics allow, managing upland oak-hardwood stands using some of the options outlined here can potentially produce a variety of habitats that favor various game and nongame birds while effectively producing quality hardwood timber. Management and conservation priorities for birds will vary regionally. The silvicultural regime suggested here offers alternatives that can accommodate a variety of different regional and management contexts.

We have offered baseline information on the conservation scoring and management priorities for neotropical migrants and gamebirds using Partners in Flight rankings and our best inference as to the habitat occupancy of the silvicultural options described herein. While these scores provide a basis for understanding the relative importance of a particular management option for various species and suites of species, they should not be used as stand-alone prescriptions for management. Researchers and natural resource managers must take regional and site specific contexts into account. We suggest that the use of conservation value indexing (Twedt 2004; Nuttle et al 2003; Bryce et al. 2002), which incorporates abundance estimates and other demographic factors, may provide a more quantitatively rigorous assessment of habitat "value" that can be used to build robust scenarios for planning and management.

While wildlife and timber production goals frequently are in opposition, the ability to reliably reproduce oak-dominated stands using a less intensive form of even-age management like the technique described here and associated options might be an effective tool for both wildlife conservation and sustainable timber production. As the demand for quality hardwood products increases, compromises regarding timber management and wildlife conservation in upland hardwood forests must be reached. While the oak-shelterwood burn system offers novel solutions for managing avifauna, the manager must always remember that he or she cannot manage every acre for every species. Rather, a knowledge of the landscape context and specific management objectives, supported by an adaptive management plan, offers opportunities for both the sustainable management of quality timber and diverse avian communities in eastern oak-dominated upland forests.

LITERATURE CITED

Annard, E.M.; Thompson, F.R. 1997. **Forest bird responses to regeneration practices in central hardwood forests.** Journal of Wildlife Management: 159-171.

Askins, R.A.; Lynch, J.F.: Greenberg, R. 1990. **Population declines in migratory birds in eastern North America.** Current Ornithology. 7: 1-57.

Askins, R.A.; Philbrick, M.J. 1987. **Effect of changes in regional forest abundance on the decline and recovery of a forest bird community.** Wilson Bulletin. 99: 7-21.

Barnes, T.A.; Van Lear, D.H. 1998. **Prescribed fire effects on advanced regeneration in mixed hardwood stands.** Southern Journal of Applied Forestry. 22(3): 138-142.

Beck, D.E. 1993. **Acorns and oak regeneration.** In*:* Loftis D.; McGee, C., eds. Oak regeneration: serious problems, practical recommendations; 1992 September 8-10; Knoxville,TN. Gen. Tech. Rep. SE-84. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 96-104.

Bowersox, T.W. 1993. **Artificial regeneration of upland oaks.** In: Loftis D.; McGee, C., eds. Oak regeneration: serious problems, practical recommendations; 1992 September 8-10; Knoxville,TN. Gen. Tech. Rep. SE-84. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 250-263.

Brose, P.H.; Van Lear, D.H. 1998a. **Responses of hardwood advance regeneration to seasonal prescribed fires in oak-dominated shelterwood**

stands. Canadian Journal of Forest Research. 28: 331-339.

Brose, P.H.; Van Lear, D.H. 1998b. **A shelterwood-burn technique for regenerating productive upland oak sites.** In*:* Meyer, D., ed. Proceedings, 26th hardwood symposium; 1998 May 6-9; Cashiers, NC. Cahsiers, NC: National Hardwood Lumber Association: 151-167.

Brose, P.H.; Van Lear, D.H. 1999a. **Effects of seasonal prescribed fires on residual overstory trees in oak-dominated shelterwood stands.** Southern Journal of Applied Forestry. 23: 88-93.

Brose, P.H.; Van Lear, D.H. 1999b. **A shelterwood-burn technique for regenerating oak stands on productive upland sites in the Piedmont region.** Southern Journal of Applied Forestry. 23: 88-93.

Brose, P.H.; Van Lear, D.H.; Cooper, R. 1999. **Using shelterwood harvests and prescribed fire to regenerate oak stands on productive upland sites.** Forest Ecology and Management. 113: 125-141.

Bryce, S.H.; Hughes, R.M.; Kaufman, P.R. 2002. **Development of a bird integrity index: using bird assemblages as indicators of riparian condition.** Environmental Management. 30(2): 294-310.

Buckner, E. 1983. **Archaeological and historical basis for forest succession in eastern North America.** In: Proceedings of the 1982 Society of American Foresters convention; 1982 November 10-14; Cincinnati, OH. SAF Publ. 83-04. Washington, DC: Society of American Foresters: 183-187.

Conner, R.N.; Adkisson, C.S. 1975. **Effects of clearcutting on the diversity of breeding birds.** Journal of Forestry. 73: 781-785.

Cook, J.E.; Sharik, T.L.; Smith, D.W. 1998. **Oak regeneration in the southern Appalachians: Potential, problems, and possible solutions.** Southern Journal of Applied Forestry. 22(l): 11-18.

Crawford, H.S.; Hooper, R.G.; Titterington, R.W. 1981. **Songbird population responses to silvicultural practices in central Appalachian forests.** Journal of Wildlife Management. 45: 680-692.

Dickson, J.G. 1981. **Effects of forest burning on songbirds.** In: Wood, G., ed. Prescribed fire and wildlife in southern forests; 1981 April 6-8; Georgetown, SC. Clemson, SC: Clemson University: 67-72.

Dickson, JG. 2001. **Wildlife of southern forests: habitat and management.** Blaine, WA: Hancock House Publishers. 480 p.

Dickson, J.G.; Thompson, F.R., III; Conner, R.N.; Franzreb, K.E. 1995. **Effects of silviculture on Neotropical migratory birds in central and southeastern oak pine forests.** In: Martin, T.E.; Finch, D.M., eds. Ecology and management of neotropical migratory birds: a synthesis and review of critical issues. New York: Oxford University Press: 245-266.

Evans, K.E. 1978. **Oak-pine and oak-hickory forest bird communities and management options.** In: Management of southern forests for nongame birds. Gen. Tech. Rep. SE-14. Asheville, NC.: U.S. Deparement of Agriculture, Forest Service, Southeastern Forest Experiment Station: 76-89.

Franzreb, K.E.; Rosenberg, K.V. 1997. **Are forest songbirds declining? Status assessment from the southern Appalachians and northeastern forests.** In: Wadsworth, K.; McCabe, R., eds. Transactions of the 62nd North American Wildlife and Natural Resources Conference: 264-279.

Gordon, A.M.; Simpson, J.A.; Williams, P.A. 1995. **Six-year response of red oak seedlings planted under a shelterwood in central Ontario.** Canadian Journal of Forest Research. 25: 603-613.

Gullion, G.W. 1984. **Managing northern forests for wildlife.** The Ruffed Grouse Society. 72 p.

Hamel, P.B.; LeGrand, H.E. Jr.; Lennartz, M; R.; Gauthreaux, S.A., Jr. 1982. **Bird habitat relationships on southeastern forest lands.** Gen. Tech. Rep. SE-22. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station.

Hanula, J.L. 1996. **Relationship of wood-eating insects and coarse woody debris.** In: McMinn, J.W.; Crossley, D.A., eds. Biodiversity and coarse woody debris in southern forests; 1993 October 18-20; Athens, GA. Gen. Tech. Rep. SE-94. Asheville, NC: U.S. Departent of Agriculture, Forest Service, Southeastern Forest Experiment Station: 55-81.

Healy, W.M. 1997. **Thinning New England oak stands to enhance acorn production.** Northern Journal of Applied Forestry. 14(3): 152-156.

Hicks, R. 1997. **A resource at the crossroads: A history of the central hardwoods.** In: Pallardy, S.; Cecich, R.; Garrett, E.; Johnson, P., eds. Proceedings 11th central hardwoods conference; 1997 March 23-26; Columbia, MO. Gen. Tech. Rep. NC-188. U.S. Department of Agriculture, Forest Service, North Central Research Station: 1-21.

Keyser, P.D.; Brose, P.H.; Van Lear, D.H.; Burtner, K.M. 1996. **Enhancing oak regeneration with fire in shelterwood stands: preliminary trials.** In: Wadsworth, K.; McCabe, R., eds. Transactions of the 61st North American Wildlife and Natural Resources Conference: 215-219.

Lanham, J.D.; Guynn, D.C. 1996. **Influences of coarse woody debris on birds in southern forests.** In: McMinn, J.W.; Crossley, D.A., eds. Biodiversity and coarse woody debris in southern forests; 1993 October 18-20; Athens, GA. Gen. Tech. Rep. SE-94. U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 101-107.

Loeb, S.C. 1996. **The role of coarse woody debris in the ecology of southeastern mammals.** In: McMinn, J.W.; Crossley, D.A., eds. Biodiversity and coarse woody debris in southern forests; 1993 October 18-20; Athens, GA. Gen. Tech. Rep. SE-94. U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 108-118.

Loftis, D.L. 1990. **A shelterwood method for regenerating red oak in the Southern Appalachians.** Forest Science. 36: 917-929.

Lorimer, C.G.; Chapman, J.W.; Lambert, D.W. 1994. **Tall understory vegetation as a factor in the poor development of oak seedlings beneath mature stands.** Journal of Ecology. 82: 227-237.

Martin, A.H.; Zim, H.S.; Nelson, A.J. 1951. **American wildlife and plants: a guide to wildlife food habits.** New York: McGraw-Hill.

Maurer, B.A.; McArthur, L.B.; R.C. Whitmore, R.C. 1981. **Effects of logging on guild structure of a forest bird community in West Virginia.** American Birds. 35: 11-13.

McGill, D.W., Bride, E.T., Hudson, J.B. 1999. **Understory fire effects on pin cherry seed germination.** In: Stringer, J.; Loftis, D., eds. Proceedings, 12th central hardwoods conference; 1999 March 1-3; Lexington, KY. Gen. Tech. Rep. SRS-24. U.S. Department of Agriculture, Forest Service, Southern Research Station: 282-287.

Nuttle, T.; Leidolf, A.; Burger, L., Jr. 2003. **Assessing conservation value of bird communities with Partners in Flight-based ranks.** Auk. 120(1): 541-549.

Panjabi, A.O.; Dunn, E.H.; Blancher, P.J.; Hunter, W.C.; Altman, B.; Bart, J.; Beardmore, C.J.; Berlanga, H.; Butcher, G.S.; Davis, S.K.; Demarest, D.W.; Dettmers, R.; Easton, W.; Gomez de Silva Garza, H.; Inigo-Elias, E.E.; Pashley, D.N.; Ralph, C.J.; Rich, T.D.; Rosenberg, K.V.; Rustay, C.M.; Ruth, J.M.; Wendt, J.S.; Will, T.C. 2005. **The Partners in Flight handbook on species assessment.** Version 2005. Partners in Flight Tech. Ser. 3. Rocky Mountain Bird Observatory. http://www.rmbo.org/pubs/downloads/Handbook2005.pdf.

Potter, M.J. 1988. **Tree shelters improve survival and increase early growth rates.** Journal of Forestry. 86: 39-41.

Pyne, S. 1982. **Fire in America.** Princeton, NJ: Princeton University Press.

Sander, L.; McGee, C.E.; Day, K.G.; Willard, R.E. 1983. **Oak-hickory.** In: Burns, R.M., Honkala, B.H.; tech. coords. Silvicultural systems of the major forest types of the United States. Agric. Handb. 445.Washington, DC: U.S. Department of Agriculture: 116-120.

Schlarbaum, S.E.; Kormanik, P.P.; Tibbs, T.; Barber, L.R. 1997. **Oak seedlings: quality improved available now - Genetically improved available soon.** In: Meyer, D., ed. Proceedings, 25th hardwood symposium; 1997 May 7-10; Cashiers, NC. Cashiers, NC: National Hardwood Lumber Association: 123-130.

Speake, D.W.; Lynch, T.E.; Fleming, W.J.; Wright, G.A.; Hamrick, W.J. 1975. **Habitat use and seasonal movements of wild turkeys in the Southeast.** Proceedings of the national wild turkey symposium. 3: 122-130.

Stransky, J.J.; Roese, J.H. 1984. **Promoting soft mast for wildlife in intensely managed forests.** Wildlife Society Bulletin. 12: 234-240.

Stribling, H.L.; Barron, M.G. 1995. **Short-term effects of cool and hot prescribed burning on breeding songbird populations in the Alabama Piedmont.** Southern Journal of Applied Forestry. 19(l): 18-22.

Thor, E.; Nichols, G.M. 1973. **Some effects of fires on litter, soil, and hardwood regeneration.** In: Komarek, E.V., ed. Proceedings of the 13th Tall Timbers fire ecology conference; 1973 March 22-23; Tallahassee, FL. Tallahassee, FL: Tall Timbers Research Station: 317-329.

Thompson, F.; Probst, J.R.; Raphael, M.G. 1992. **Impacts of silvicultural practices on neotropical migratory birds: overview and management recommendations.** Executive summaries. National training workshop, status and management of neotropical migratory birds: 82-83.

Thompson, F.; Fritzell, E.K.1990. **Bird densities and diversity in clearcut and mature oak-hickory forests.** Res. Pap. NC-293. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 7 p.

Twedt, D.J. 2004. **An objective method to determine an area's relative significance for avian conservation.** Gen. Tech. Rep. PSW-191. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.

Van Lear, D.H.; Brose, P.H. 1999. **Clemson researchers find prescribed fire regenerates oak forests.** Tree Farmer 3: 8-10.

Van Lear, D.H.; Waldrop, T.A. 1989. **History, uses, and effects of fire in the Appalachians.** Gen. Tech. Rep. SE-54. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station.

Ward, J.S.; Gluck, E. 1999. **Using prescribed fire to release oak seedlings from shrub competition in southern Connecticut.** In: Stringer, J.; Loftis, D., eds. Proceedings of the 12th central hardwoods conference; 1999 March 1-3; Lexington, KY. Gen. Tech. Rep. SRS-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 283-287.

Webb, W.L.; Behrend, D.F.; Saisorn, B. 1977. **Effect of logging on songbird populations in a northern hardwood forest.** Wildlife Monograph. 55: 6-35.

Welsh, C.J.; Healy, W.M. 1993. **Effects of even-aged timber management on bird species diversity and composition in northern hardwood forests of New Hampshire.** Wildlife Society Bulletin. 21: 143-154.

Whiles, MR.; Grubaugh, J.W. 1996. **Importance of coarse woody debris to southern forest**

herpetofauna. In: McMinn, J.W.; Crossley, D.A., eds. Biodiversity and coarse woody debris in southern forests; 1993 October 19-20; Athens, GA. Gen. Tech. Rep. SE-94. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 94-100.

Wilcove, D. 1985. **Nest predation in forest tracts and the decline of migratory songbirds.** Ecology. 66: 1211-1214.

Wood, P.B.; Nichols, J.V. 1995. **Effects of two-age timber management on songbird density and reproductive success.** Progress report to the Monongahela National Forest, Elkins, WV.