THE MISSOURI OZARK FOREST ECOSYSTEM PROJECT: FINDINGS FROM TEN YEARS OF EVALUATING MANAGEMENT EFFECTS ON FOREST SYSTEMS

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ABSTRACT.—In 1989, the Missouri Department of Conservation initiated the Missouri Ozark Forest Ecosystem Project, a long-term, landscape-scale experiment to evaluate effects of even-aged, uneven-aged, and no-harvest management on the flora and fauna of oak ecosystems in southern Missouri. Here we report the ten-year findings. Pre-treatment data were collected from 1991-1995 and the first harvest entry occurred from 1996 to 1997. Post-treatment results presented here are from 1997-2000. Relative to the no-harvest sites, ground flora richness, total vegetative cover, and woody vines increased and legumes decreased after harvesting. There was little difference in ground flora response between even-aged and uneven-aged treatments. No treatment effects were detected on amphibian and reptile abundances, except American toad abundance declined on all treatments with the steepest declines observed on no-harvest sites. Small mammal abundance declined on no-harvest sites, yet remained the same on even-aged sites. Mature forest songbird abundance, particularly Ovenbirds, decreased and early successional songbird abundance increased in harvested sites. However, neither nest predation nor nest parasitism increased following treatments. Overall, harvest treatments have changed the faunal communities at landscape scales and even-aged treatments had the greatest effect. However, harvesting was not necessarily detrimental to plant and animal communities. Overall, forest management objectives, including regeneration, do not appear to conflict with other management objectives such as sustaining diverse forest overstories, ground flora, and wildlife communities.

Forest management is becoming more controversial and is increasingly under scrutiny. Often, the general public, environmental groups, and land managers disagree about forest management methods that are acceptable or suitable for managing public forest land. In particular, considerable controversy surrounds forest harvesting. Some advocate selection harvesting because they believe it is less detrimental to wildlife habitat and ecosystem function than clearcutting, while others believe that any kind of harvesting is harmful to forest habitats. Many of these beliefs are rooted in perception rather than grounded in scientific evidence. State and Federal forest management agencies have a responsibility to base forest management decision making on the best scientific evidence available.

The Missouri Ozark Forest Ecosystem Project (MOFEP) was initiated in 1989 by the Missouri Department of Conservation (MDC) to generate the best scientific evidence about the effects of even-aged, uneven-aged, and no-harvest management systems on the flora and fauna of upland oak ecosystems (Brookshire and others 1997). It is a long-term study, designed to extend for a least one 100-year rotation from the first harvest entry in 1996. It is also landscape scale with forest management compartments, each approximately 1000 acres in size, as observational units. It is also a fully replicated and designed experiment. It was initiated because the impacts of forest management on

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songbirds and other non-commodity forest attributes such as diversity of native plant and animal species have been poorly quantified in the Missouri Ozarks. The purpose of this paper is to summarize what has been learned through the first 10 years of study at MOFEP.

The MOFEP Study Sites and Treatments

MOFEP was designed to experimentally study the effects of forest management practices on the entire forest over entire rotations rather than simply in research plots immediately following harvesting. Therefore, the management practices selected for comparison, and the scale and timeframe of the study reflect those commonly used to operationally manage forests in the Ozark Highlands. MOFEP consists of nine forest sites ranging in size from 772 to 1, 271 acres, primarily within the Current River Oak Forest Breaks and the Current River Oak-Pine Woodland Hills landtype associations of the Ozark Highlands (fig. 1). These sites were selected because they contained mature, second-growth forests largely free of manipulation for > 40 years, were the size of administrative compartments commonly used by the Missouri Department of Conservation for managing forests, are owned by the Missouri Department of Conservation, and are in close proximity to each other. More detailed descriptions of the MOFEP sites were presented by Meinert and others (1997) and Kabrick and others (2000).

Each site was divided into areas having common slope and aspect and then divided into stands which averaged 12 acres in size (Brookshire and others 1997). A detailed landscape-scale soil mapping and ecological classification typing project was conducted on MOFEP in 1994-1995 (Kabrick and others 2000, Meinert and others 1997). This included characterizing important physical and vegetation characteristics of each study site.

Groups of three sites were allocated into "blocks" by spatial proximity (fig. 1). The three sites within each block were randomly assigned one of three treatments: (1) even-aged management with harvesting by clearcutting and intermediate thinning, (2) uneven-aged management with harvesting by single-tree selection and group selection, and (3) no-harvest management. Sheriff and He (1997) provided a more detailed description of blocking and treatment allocation to sites. Even-aged management has been practiced by MDC managers for at least three decades and uses clearcutting as the principal means of stand regeneration. With this method approximately 10 percent of the acreage in a forest compartment (i.e., a MOFEP site) was designated as "old growth" and will be excluded from future harvesting. About 10 to 15 percent of the remaining area is clearcut during each re-entry for forest regeneration. Thinnings (intermediate cuttings) are conducted periodically within stands to improve quality and increase growing space for residual trees. Rotation lengths are approximately 100 years with a 15-year re-entry.

Uneven-aged management, as practiced by MDC managers, is relatively new to upland oak ecosystems in the Ozarks. Uneven-aged management is commonly practiced in bottomland forests in Missouri and in mixed hardwood forests elsewhere where shade-tolerant species are prevalent, competitive and desirable. Forest management on the Pioneer Forest, a privately-owned forest in the Ozarks, suggests that uneven-aged management may be a viable silvicultural alternative in Missouri's upland forests where soils and climate favor oak species and limit competition by undesirable species (Loewenstein 1996). Following the guidelines developed by Law and Lorimer (1989), uneven-aged management in MOFEP included single-tree selection and group selection for timber harvest and forest regeneration. Just like with even-aged management, approximately 10 percent of the forest area was designated as "old growth." The remaining area was grouped into management units of 20 to 80 acres. Within each management unit, harvest objectives are set for the largest diameter tree (LDT), residual basal area (RBA), and q-value. The overall RBA is equivalent to B-level stocking with adjustments made for logging damage (Roach and Gingrich, 1968). Target q-value objectives average 1.5 but can range from 1.3 to 1.7 (Law and Lorimer 1989). Within harvested areas, group selection openings are also created to regenerate shade-intolerant species. These groups are approximately one to two tree heights in diameter, depending on aspect. At MOFEP, they are 70 feet (0.09 acres) on south-facing slopes, 105 feet (0.20 acres) on ridge tops, and 140 feet (0.35 acres) on north-facing slopes. These openings are to sum to about 5 percent of the total harvested area. For all harvesting, re-entries coincide with those of

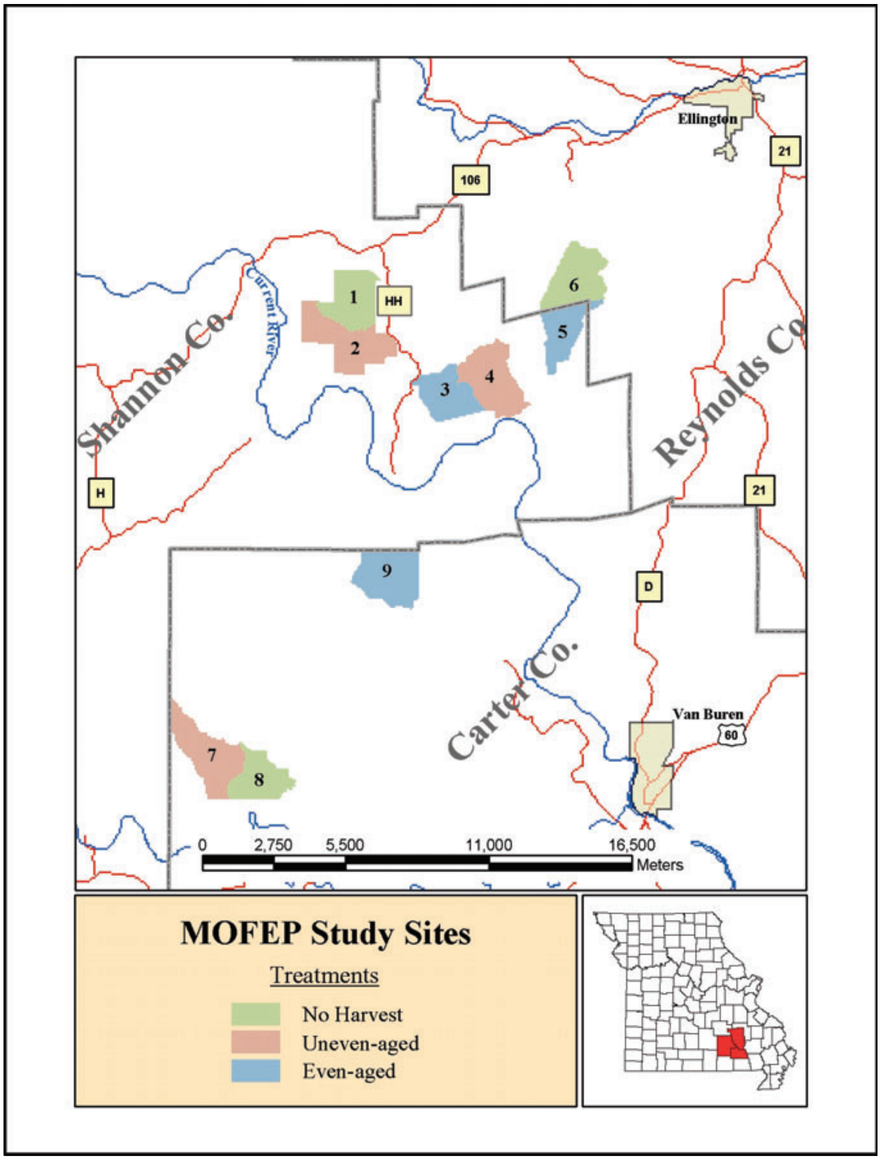


Figure 1.—Location of the nine MOFEP experimental sites (compartments) located in southeastern Missouri. Sites were allocated into blocks for statistical analyses by spatial proximity (sites 1 through 3 are in block 1, sites 4 through 6 are in block 2, and sites 7 through 9 are in block 3). Treatments (even-aged management, uneven-aged management, and no-harvest management) were randomly assigned within each block.

even-aged treatments. On uneven-aged sites, the LDT, RBA, and q-values were selected to create similar diameter distributions on a forest-wide basis as under even-aged management (see Brookshire and others, 1997).

The no-harvest management treatment will not be harvested. Wildfires are suppressed and natural events such as tornadoes, fires, insect and disease outbreaks are treated the same as on any other forest land owned by the MDC, except that salvage harvests will not occur. This treatment serves two purposes. It demonstrates patterns of forest development that result from natural disturbances and successional processes, and it also serves as an experimental "control" to compare with the two other management practices.

Methods

MOFEP comprises more than 28 different studies to more completely quantify the effects of forest management on the flora and fauna of Ozark forest ecosystems (Brookshire and Shifley 1997, Shifley and Brookshire 2000, Shifley and Kabrick 2002). Studies included soil characteristics and distribution, below- and above-ground carbon, microclimate, ground flora composition, woody vegetation composition and genetic variation of selected species, coarse woody debris distribution, hard- and soft-mast production, *Armillaria* fungi distribution and ecology, forest bird density and nesting success, herpetofaunal communities and distribution, small mammals abundances, leaf litter arthropod communities, and abundances of leaf-chewing insects. All projects on MOFEP share a common, randomized complete block design as the basis for statistical analyses; by necessity, each study has its own sampling and analysis protocols to adequately characterize the wide array of flora and fauna found at the study sites (Sheriff and He 1997, Sheriff 2002). MOFEP is a long-term project designed to extend beyond a single rotation. As such, flora and fauna are inventoried on a regular basis before and after harvest entries. In this paper we report on pre- and post-treatment differences as a consequence of the first harvest entry implemented from May 1996 to May 1997. Here we focus on the response of forest vegetation, songbirds, reptiles and amphibians, and small mammals. Specific data collection and analysis methods used in this paper are described below.

Vegetation

Vegetation was sampled in 648 permanent 0.5-acre plots distributed approximately equally among the nine MOFEP sites. At least one plot was established in each stand on all sites. This paper includes overstory data collected during inventories conducted in 1994-1995 (pre-treatment) and 1997-1998 (post-treatment). Within permanent plots, live and dead trees ≥ 4.5 inches DBH were sampled in 0.5-acre circular plots; trees between 1.5 and 4.5 inches DBH were sampled in four 0.05-acre circular subplots; trees at least 3.3 feet tall and less than 1.5 inch DBH were sampled in four, 0.01-acre circular subplots nested within the 0.05-acre subplots. Characteristics recorded for each tree included species, DBH, or size class for trees < 1.5 inches DBH and > 3.3 feet tall, status (e.g., live, dead, den, cut, blow-down), and crown class (e.g., dominant, codominant, intermediate, suppressed) (Jensen 2000). Plot and subplot data were combined to obtain plot averages by DBH or size class and all values are converted to an acre basis. Ground flora data (e.g., species, foliar coverage, and number of stems for woody seedlings <= 3.3 feet tall) were sampled in sixteen, permanently-marked, 3.3-feet by 3.3-feet quadrats located within 0.5-acre vegetation plots (Grabner 2000). Ground flora data included in this paper were collected from June 1 through August 25 in 1994 and 1995 (pre-treatment) and again in 1997 and 1998 (post-treatment).

Birds

Five bird species associated with mature forest—Acadian Flycatcher (*Empidonax virescens*), Wood Thrush (*Hylocichla mustelina*), Ovenbird (*Seiurus aurocapillus*), Worm-eating Warbler (*Helmitheros vermivorous*), and Kentucky Warbler (*Oporornis formosus*)—and six early successional species—Indigo Bunting (*Passerina, cyanea*), Yellow-breasted Chat (*Icteria virens*), Hooded Warbler (*Wilsonia citrina*), Prairie Warbler (*Dendroica discolor*), Blue-winged Warbler (*Dendroica pinus*), and White-eyed Vireo (*Vireo griseus*)—were focal species of the study. Species densities are collected using spot-mapping and reproductive data are collected by locating and monitoring nests. Spot mapping data were collected in seven, 110-acre spot-mapping plots per site and was done eight to ten times at 2- to 3- working day intervals from mid May through the end of June each year, except for the treatment year, since 1991. Each day, a single map was produced for each spot-map plot. Data from these spot maps were used to develop estimates of songbird territory densities by overlaying spot maps and creating composite territory maps for each species. To locate territories, we identified clusters of three or more observations of the same individual. Daily survival rates for nests located within spot mapping plots were estimated using methods of Mayfield (1961 and 1975). Nests were monitored every three to five days until nest fate was determined (Clawson and others 1997, Clawson and others 2002). In this paper, we include data collected from 1991 to 2000.

Amphibians and Reptiles

Amphibians and reptiles were sampled in twelve, randomly-located drift fence arrays (modified from Jones, 1981) on north- and east-facing, and south- and west-facing slopes within each site (Renken and Fantz 2002). Amphibians and reptiles were trapped in March – June and September – October in 1992-1995 (pre-treatment) and 1998-2000, and September – October 1997-2000 and March-June 1998-2000 (post-treatment). North- and east-facing and south- and west-facing slopes were sampled because they comprised 73 percent of the landscape on MOFEP.

Small Mammals

Small mammals were trapped using baited Sherman live traps on 2, 18.7-acre randomly-located grids on north- and east-facing slopes on each site (Fantz and Renken 2002). Each grid had 144 traps evenly spaced 25 meters apart. Animals were trapped for six consecutive nights on each site during April – May in 1994-1995 (pre-treatment) and 1998-2000 (post-treatment).

Analyses

To analyze harvesting effects on forest vegetation, we evaluated pre- and post-harvest differences using ANOVA. Treatment (even-aged, uneven-aged, and no-harvest management) and block were the main effects with an alpha = 0.05 (n= 9 sites). For trees, we evaluated changes in richness (per plot), trees per acre, quadratic mean diameter, basal area, and percent canopy cover. Where differences were found, we used a least significant difference test to identify attributes that differed from those of no-harvest sites. For ground flora, we evaluated pre- and post-harvest differences in percent cover of species groups (annuals/biennials, forbs, graminoids, legumes, shrubs, woody vines) as well as overall species richness (per plot) and percent ground cover (Kabrick and others 2002, Grabner and Zenner 2002).

To analyze songbird density during pre-treatment years (1991-1995), we used multivariate repeated-measures ANOVA. Year effects were not significant, so we used pre-treatment mean density as a covariate in the analysis of post-treatment data. To evaluate harvest treatment effects, we used a multivariate repeated-measures analysis of covariance with treatment and block as main effects and pre-treatment density as the covariate with an alpha = 0.1. We used this alpha level because power was low (n = 9 sites) in the experiment (Sheriff and He 1997). Contrasts were used to compare even-aged and uneven-aged treatments to the no-harvest (control) treatment (Gram and others 2003).

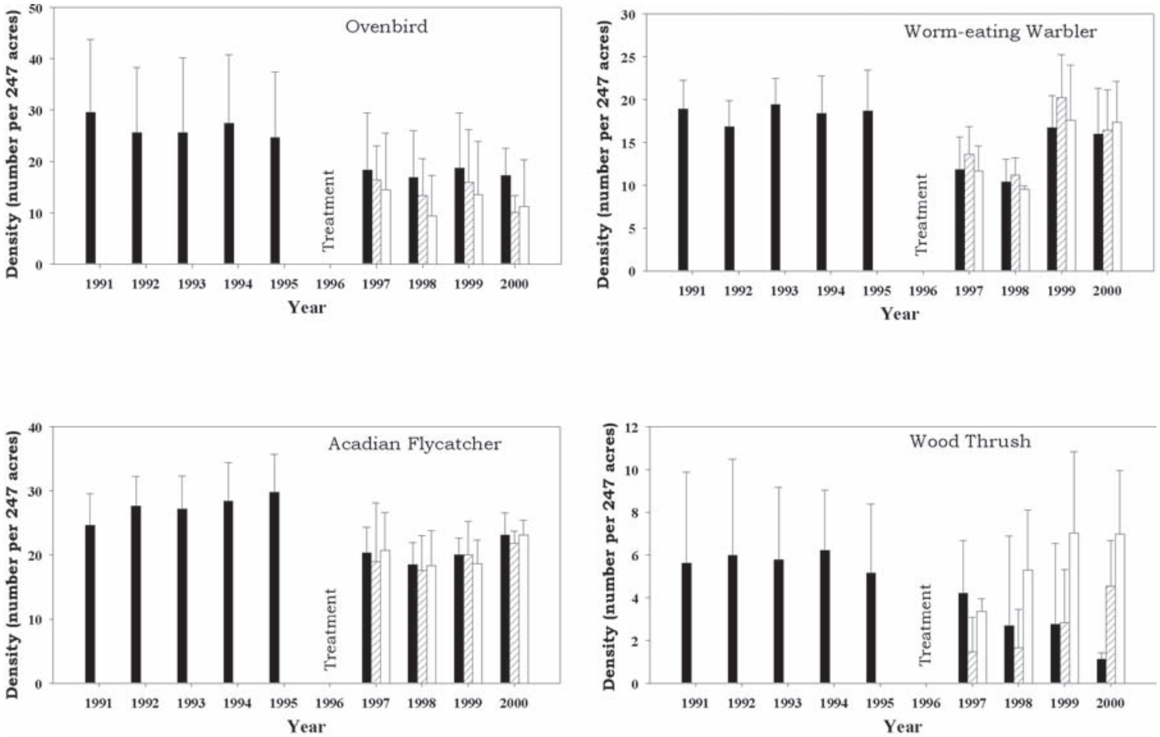
To analyze the first-entry harvest effects on amphibians, reptiles, and small mammal abundance, annual post-treatment (years 1998-2000) abundance estimates for overall small mammal abundance, overall amphibian and reptile abundance, and for thirteen focal species of amphibians and reptiles [Spotted Salamander (*Ambystoma maculatum)*, American Toad (*Bufo americanus)*, Common Five-lined Skink (*Eumeces fasciatus)*, Broad-headed Skink (*Eumeces laticeps)*, Central Newt (*Notopthalmus viridescens)*, Western Slimy Salamander (*Plethodon albagula)*, Southern Red-backed Salamander (*Plethodon serratus)*, Northern Spring Peeper (*Pseudacris crucifer)*, Green Frog (*Rana clamitans)*, Little Brown Skink (*Scincella lateralis)*, Northern Fence Lizard (*Sceloporus undulates)*, Northern Red-bellied Snake (*Storeria occipitomaculata)*, Smooth Earthsnake (*Virginia valerae*)] for 1998, 1999, and 2000 were subtracted from the mean pre-treatment abundance estimates for each site (Fantz and Renken 2002, Renken and Fantz 2002, Renken and others in press). These difference scores were the dependent variables in randomized complete block ANOVAs (Fantz and Renken 2002, Renken and Fantz 2002) and split-plot repeated measures ANOVA (Renken and others in press) models used to detect treatment effects. Treatment and block were main effects and the treatment x block interaction was the error term used to test main effects. An alpha of 0.10 was used for tests because power was low (n=9 sites) in the experiment (Sheriff and He 1997). In Renken and others (in press), tests of main effects were followed with contrasts (with an alpha of 0.03) to test differences among treatments (Renken and others in press). Qualitative comparisons were also made to examine the effect of treatment upon the species composition of the amphibian, reptile, and small mammal communities.

Results and Discussion

During the first harvest entry, 2.4 million board feet of timber were harvested on the three even-aged sites (3,360 board feet per harvested acre or 876 board feet per site acre) and 3.4 million board feet were harvested on the three uneven-aged sites (1,620 board feet per harvested acre or 932 board feet per site acre). On even-aged sites, 11 percent of the area was clearcut and 15 percent was thinned. On uneven-aged sites, 57 percent of the area was harvested with selection and group methods. Regardless of harvest method, black oak (*Quercus velutina* Lam.) and scarlet oak (*Q. coccinea* Muenchh.) in combination comprised 60 percent of the harvested basal area; white oak (*Q. alba* L.) and post oak (*Q. stellata* Wangenh.) accounted for an additional 20 to 30 percent. On a percentage basis, harvested trees included more scarlet and black oak basal area and less white oak and shortleaf pine (*Pinus echinata* Mill.) basal area than the sites had prior to harvest. The treatments significantly reduced the mean number of trees > 1.5 inches DBH per acre (P=0.05), basal area per acre (P=0.01), and percent canopy cover (P=0.01) on the harvested sites, but mean diameter was unchanged. Following treatment, the relative size distribution of trees by diameter class was virtually identical for each of the three treatments. On no-harvest sites, the total basal area increased an average of 1 ft^2/ac between 1995 and 1998. Following treatment, there was virtually no change in the density of trees in the reproduction size classes (taller than 3.3 feet and smaller than 1.5 inches DBH) except for the number of stump sprouts. More than 700 stump sprouts per acre occurred in clearcuts; fewer than 120/ac occurred in areas harvested by a combination of single tree and group selection. Stands that were not harvested averaged fewer than 7 sprouts per acre (Kabrick and others 2002).

Harvesting affected ground flora species composition at the site scale and most of the effects occurred directly within treated stands. The increased light levels caused by harvesting increased the mean species richness on harvested sites. However, richness unexpectedly decreased on no-harvest sites (P<0.01). We do not know if this decrease in no-harvest sites was due to sampling error or to some other phenomenon such as the drought that occurred throughout the late 1990's. We did find that total percent ground cover increased on all sites and increased most on harvested sites (P<0.01). In both even-aged and uneven-aged sites, annual and biennial species, which were essentially absent prior to harvesting, increased in mean relative cover after treatment (P=0.02), particularly in clearcuts and group selection openings. Woody vines such as summer grape (*Vitus aestivalis*) and early-successional shrubs such as blackberries (*Rubus pensilvanicus*) also increased (P=0.01), but primarily in clearcuts and group selection openings. Legumes such as common tick trefoil (*Desmodium nudiflorum*) and hog peanut (*Amphicarpa bracteata*) decreased (P<0.01) in harvested sites, most likely because the increased light favored other ground flora species (Grabner and Zenner 2002).

The mature forest bird species present during both the pre-treatment and post-treatment years of the study declined following treatment, even on no-harvest sites (figs. 2 and 3). Some early-successional bird species did not appear until after tree harvest. In post treatment years 1997-2000, treatment effects were found. They were: Ovenbird densities were lower (P=0.03) on even-aged sites than on no-harvest sites; Wood Thrush (P=0.07), Prairie Warbler (P<0.01), and White-eyed Vireo (P=0.04) densities were higher on even-aged sites than no-harvest sites; Kentucky Warbler (P<0.1), Indigo Bunting (P<0.01), and Yellow-breasted Chat (P<0.08) densities were higher on both even-aged and uneven-aged sites than no-harvest sites. No significant treatment effects were found for reproductive success: daily nest survival rates did not change significantly from pre- to post-treatment; brood parasitism rates were low (Gram and others, 2003), averaging 3.2 percent in both the pre- and post-treatment periods. In general, the forest management treatments affected bird species densities and each species had species-specific responses to even-aged and uneven-aged management. Although early successional bird species increased on the MOFEP sites, some used both small openings (e.g., group selection openings and clearcuts < 10 acres) and large openings (e.g., clearcuts > 10 acres) for nesting and some used only the large openings. Yellow-breasted Chats and Prairie Warblers rarely used openings that were smaller than 10 acres. Other early succession species such as Indigo Bunting, Hooded Warbler, White-eyed Vireo, and Blue-winged Warbler used both small and large openings. The bird community is dynamic and likely will continue to change through time, in composition and density, in response to harvest and re-growth of the forest (Clawson and others 2002, Gram and others 2003).



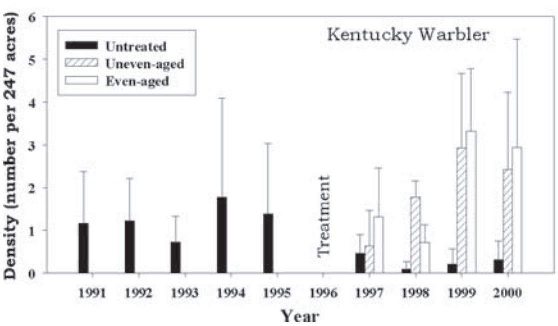


Figure 2.—Mean density of mature forest bird species per 247 acres (or per 100 ha) on MOFEP sites treatment pre- and post-treatment. Treatments were even-aged management, uneven-aged management, and no-harvest management (labeled "un-treated"). Pre-treatment years were 1991 through 1995. Post-treatment years shown were 1997 through 2000. Error bars are ± one standard error.

Prior to harvesting, eight species of small mammals and 43 species of amphibians and reptiles were captured on MOFEP sites. Following harvests, no species disappeared and no new species appeared. Harvest treatments did not affect overall amphibian and reptile abundance and the abundances of twelve of thirteen focal amphibians and reptiles (Fantz and Renken 2002, Renken and Fantz 2002, Renken and others in press, fig. 4). After treatment, small mammal abundance on even-aged site sites remained the same but declined slightly on uneven-aged sites and declined substantially on no-harvest sites (fig. 5). American toad abundance followed a similar pattern (fig. 6). The decline of small mammals and American toads on no-harvest sites suggests there was a natural decline in some animal populations within the region, perhaps associated with a regional drought during the years immediately following the first entry harvest (Renken and others in press). Even though some animal populations declined on no-harvest sites, conditions on even-aged, and to a certain extent on uneven-aged sites, buffered or dampened the decline the populations would have experienced. Even-aged sites may have had more invertebrate and seed food resources (Harper and Guynn 1999, Hooven 1973, Perry and others 1999), and more cover from predators than existed on no-harvest sites during the immediate post-treatment period.

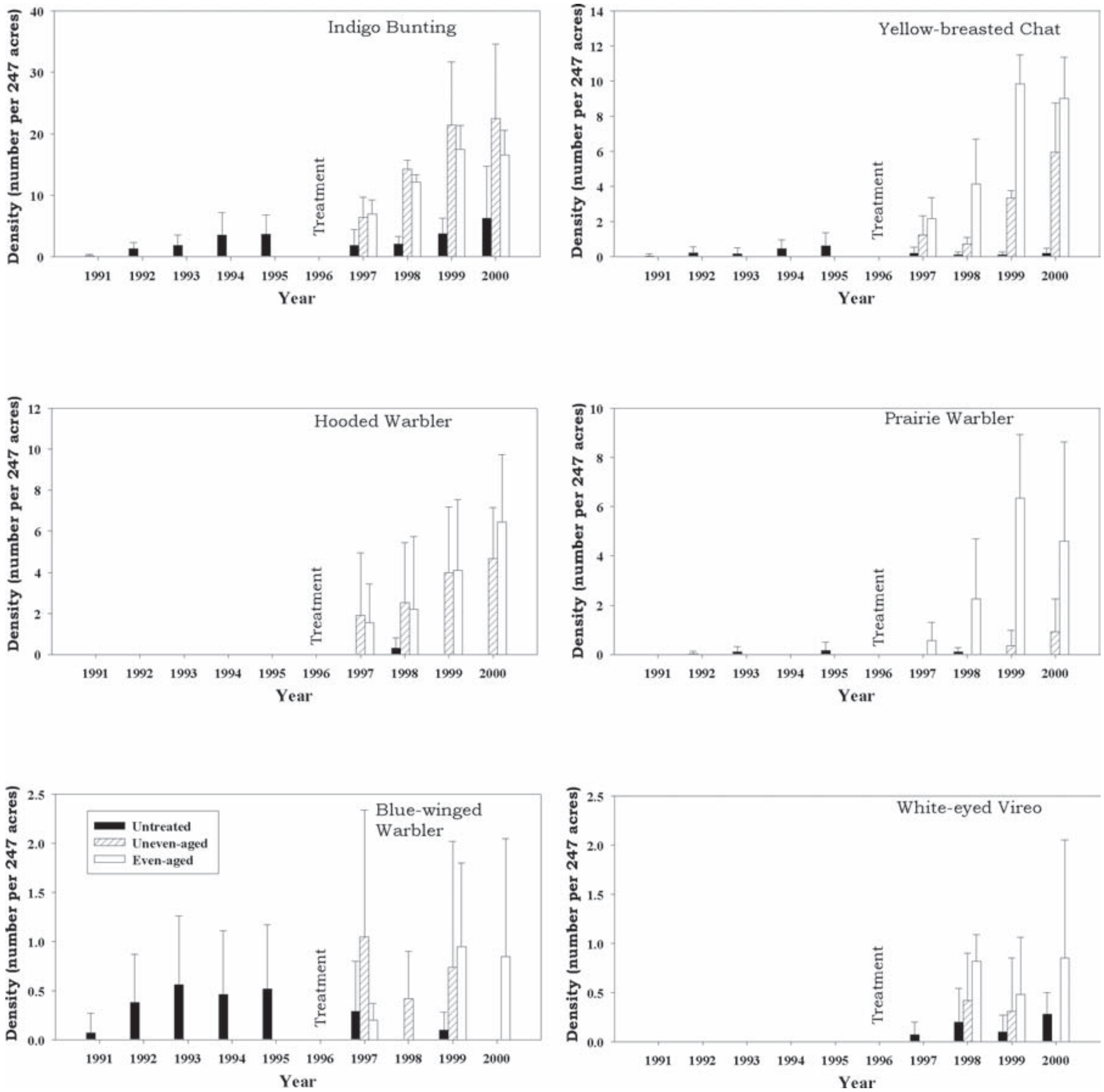


Figure 3.—Mean density of early-successional bird species per 247 acres (or per 100 ha) on MOFEP sites pre- and post-treatment. Treatments were even-aged management, uneven-aged management, and no-harvest management (labeled "un-treated"). Pre-treatment years were 1991 through 1995. Post-treatment years shown were 1997 through 2000. Error bars are ± one standard error.

Implications for Forest Management

Forest harvesting clearly affected the floral and faunal communities and, in general, the more intensive the harvesting, the greater the observed effects (e.g., effects of clearcut harvest > selection and group harvest). However, the effects of harvesting were not necessarily detrimental to the flora and fauna and in many cases were favorable. For example, relative to no-harvest sites, ground flora richness increased after harvesting largely because of the increased light reaching the forest floor and/or perhaps because of soil disturbance caused by harvesting favored the establishment of early-successional species. The numbers of many early-successional songbird species such as Indigo Buntings, Yellow-breasted Chats, and Prairie Warblers, have also responded to habitat created by the harvest treatments and have increased. Mature forest bird species such as Ovenbirds and Worm-eating Warblers were of considerable concern when MOFEP was initiated (Clawson and others 1997, Clawson and others 2002). However, mature forest bird species remain dominant and an important component of the species composition at MOFEP. For songbirds in particular, one of the greatest concerns was that

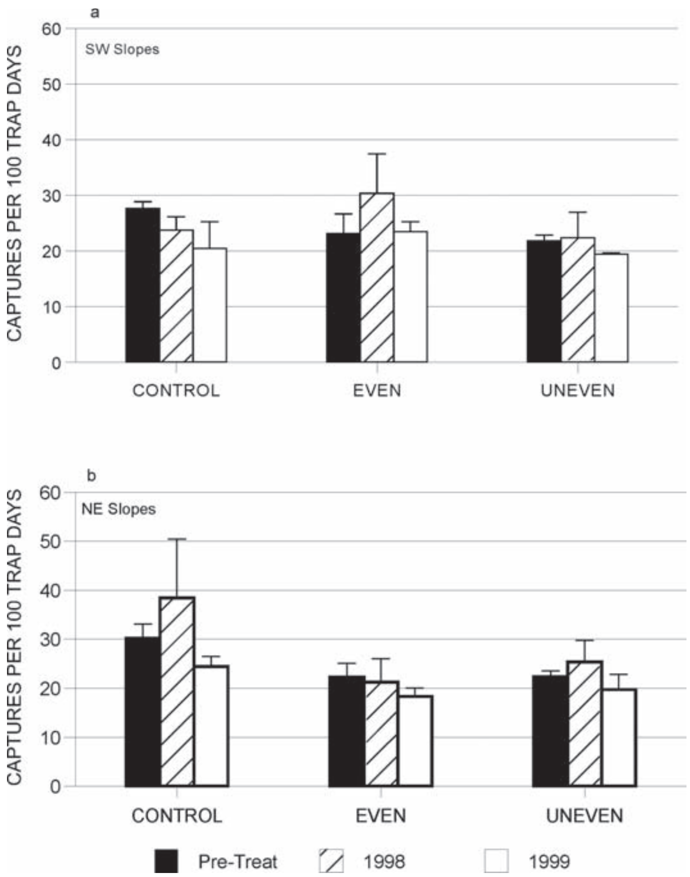


Figure 4.—Mean relative abundances of amphibian and reptiles by treatment type on southwest-facing (a) and northeast-facing (b) slopes on MOFEP sites pre- and post-treatment. Treatments were even-aged management, uneven-aged management, and no-harvest management (labeled "control"). Pre-treatment years were 1992 through 1995; data were combined. Post-treatment years shown were 1998 and 1999. A trap day is defined as a day-long period during which traps were operated. Error bars are ± one standard error.

harvesting would cause an increase nest parasitism, which reportedly increases with increasing forest fragmentation (Gibbs and Faaborg 1990, O'Conner and Faaborg 1993, Donovan and others 1995). However, we found neither nest predation nor nest parasitism increased following harvest treatments.

One surprising finding from MOFEP is that on no-harvest sites, plant species richness and the abundances of small mammals, reptiles, and amphibians have decreased while these same populations remained at or above pre-treatment levels on harvested sites (figs. 2 through 6). We do not fully understand the reasons for these declines on no-harvest sites and cannot rule out the possibility that treatments are affecting some of the animal populations on nearby no-harvest sites. Sampling error is another possible but unlikely explanation because the declines occurred with different animal and plant species. Gram and others (2003) and Renken and others (in press) speculated that wide-spread drought was partially to blame for some of these declines. For now, we cannot explain these declines and can only acknowledge the cyclical nature of many plant and animal populations.

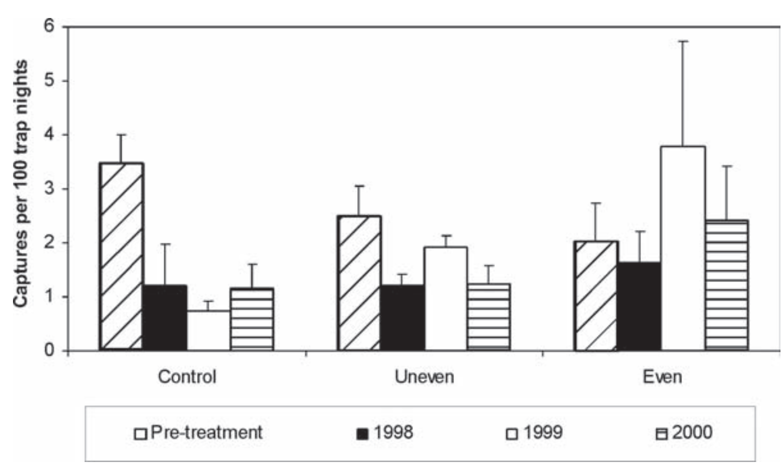


Figure 5.—Mean relative abundances of small mammals by treatment type on northeast-facing slopes on MOFEP sites pre-and post-harvest. Treatments were even-aged management, uneven-aged management, and no-harvest management (labeled "control"). Pre-treatment data were collected in 1994 and 1995; data were combined. Post-treatment years were 1998 through 2000. One trap night is defined as a night-long period during which traps were operated. Error bars are ± one standard error.

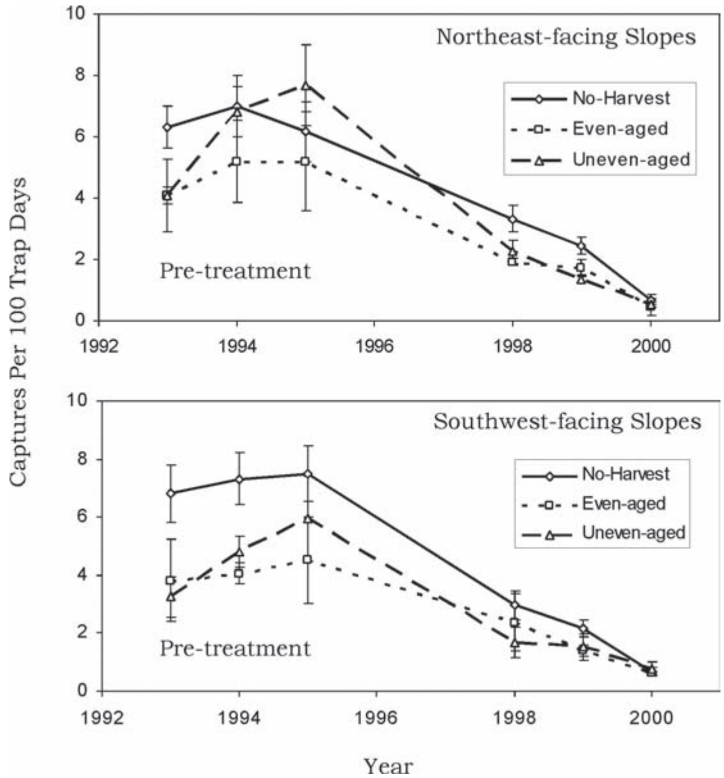


Figure 6.—Mean relative abundances of American Toads (*Bufo americanus*) on southwest-facing and northeast-facing slopes on MOFEP sites by treatment pre- and post-harvest. Treatments were even-aged management, uneven-aged management, and no-harvest management. Pre-treatment data shown were collected in 1993 through 1995. Post-treatment data shown were collected in 1998 through 2000. Error bars are ± one standard error.

Continued research through MOFEP will likely reveal explanations for these observed trends. It demonstrates that a larger-scale phenomenon may be affecting plant and animal populations in this ecosystem and shows the value of having control sites (in our case, no-harvest sites) for evaluating management effects on forest ecosystems.

Overall, it appears that forest management systems commonly used throughout the Central Hardwood Region are not negatively affecting most of the plant and animal populations discussed in this paper at landscape scales in the Missouri Ozarks. However, it is important to point out that these are only the ten-year findings from a study designed to extend for at least 300 years and it will require at least 100 years (i.e., one full rotation) before even-aged sites are fully regulated. It remains unknown if the trends observed to date will continue with repeated harvest entries. Moreover, as MOFEP becomes more fully integrated, other system components such as long term productivity, below-ground biodiversity, and long-term forest health issues will be included in analyses to develop a more comprehensive understanding of the effects of management on forest ecosystems.

Acknowledgments

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Literature Cited

Brookshire, B.L.; Jensen, R.; Dey, D.C. 1997. **The Missouri Ozark Forest Ecosystem Project: Past, present, and future.** In: Brookshire, B.L.; Shifley, S.R., eds. Proceedings of the Missouri Ozark Forest Ecosystem Project: An experimental approach to landscape research; 1997 June 3-5; St. Louis, MO. Gen. Tech. Rep. NC-193. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 1-24.

Brookshire, B.L.; Shifley, S.R. (eds.). 1997. **Proceedings of the Missouri Ozark Forest Ecosystem Project Symposium: an experimental approach to landscape research;** 1997 June 3-5; St. Louis, MO. Gen. Tech. Rep. NC-193. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 378 p.

Clawson, R.L.; Faaborg, J.; Gram, W.K.; Porneluzi, P.G. 2002. **Landscape-level effects of forest management in the Ozarks of Southeastern Missouri.** In: Shifley, S. R.; Kabrick, J.M., eds. Proceedings of the second Missouri Ozark Forest Ecosystem Project symposium: post treatment results of the landscape experiment. 2000 October 17-20; St. Louis, MO. Gen. Tech. Rep. NC-227. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 147-160.

Clawson, R.L.; Faaborg, J.; Seon, J. 1997. **Effects of selected timber management practices on forest birds in Missouri oak-hickory forests: pre-treatment results.** In: Brookshire, B.L.; Shifley, S.R., eds. Proceedings of the Missouri Ozark Forest Ecosystem Project: An experimental approach to landscape research; 1997 June 3-5; St. Louis, MO. Gen. Tech. Rep. NC-193. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 274-288.

Donovan, T.M.; Thompson, F.R., III; Faaborg, J.; Probst, J.R. 1995. **Demography of migratory birds in habitat sources and sinks.** Conservation Biology. 9: 1380-1395.

Fantz, D. K.; Renken, R.B. 2002. **Short-term responses of the small mammal communities to forest management within Missouri Ozark Forest Ecosystem Project sites.** In: Shifley, S. R.; Kabrick, J.M., eds. Proceedings of the second Missouri Ozark Forest Ecosystem Project symposium: post treatment results of the landscape experiment. 2000 October 17-20; St. Louis, MO. Gen. Tech. Rep. NC-227. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 161-170.

Gibbs, J.P.; Faaborg, J. 1990. **Estimating the viability of ovenbird and Kentucky warbler populations occupying forest fragments in central Missouri, U.S.A.** Conservation Biology. 4: 193-196.

Grabner, J.K. 2000. **Ground layer vegetation in the Missouri Ozark Forest Ecosystem Project: Pre-treatment species composition, richness, and diversity**. In: Shifley, S.R.; Brookshire, B.L.; eds. Missouri Ozark Forest Ecosystem Project: site history, soils, landforms, woody and herbaceous vegetation, down wood, and inventory methods for the landscape experiment. Gen. Tech. Rep. NC-208. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 107-123.

Grabner, J.K.; Zenner, E.K. 2002. **Changes in ground layer vegetation following timber harvests on the Missouri Ozark Forest Ecosystem Project**. In: Shifley, S. R.; Kabrick, J.M., eds. Proceedings of the second Missouri Ozark Forest Ecosystem Project symposium: post treatment results of the landscape experiment. 2000 October 17-20; St. Louis, MO. Gen. Tech. Rep. NC-227. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 66-83.

Gram; W.K.; Porneluzi, P.A.; Clawson, R.L.; Faaborg, J.; Richter, S.C. 2003. **Effects of experimental forest management on density and nesting success of bird species in Missouri Ozark forests.** Conservation Biology. 17:1324-1337.

Harper, C. A.; Guynn, D. C. Jr. 1999. **Factors affecting salamander density and distribution within four forest types in the Southern Appalachian Mountains.** Forest Ecology and Management 114:245-252.

Hooven, E. F. 1973. **Response of the Oregon creeping vole to the clearcutting of a Douglas-fir forest.** Northwest Science 47:256-264.

Jensen, R.G. 2000. **Pre-treatment woody vegetation inventory protocols.** In: Shifley, S.R.; Brookshire, B.L. (eds.). 2000. Missouri Ozark Forest Ecosystem Project: site history, soils, landforms, woody and herbaceous vegetation, down wood, and inventory methods for the landscape experiment. Gen. Tech. Rep. NC-208 St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 134-148.

Jones, K. B. 1981. **Effects of grazing on lizard abundance and diversity in western Arizona.** Southwestern Naturalist 26:107-115.

Kabrick, J.M.; Jensen, R.G.; Shifley, S.R.; Larsen, D.R. 2002. **Woody vegetation following even-aged, uneven-aged, and no-harvest treatments on the Missouri Ozark Forest Ecosystem Project sites.** In: Shifley, S.R.; Kabrick, J.M. eds. Proceedings of the second Missouri Ozark Forest Ecosystem Project Symposium: Post-treatment results of the landscape experiment; 2000 October 17-18; St. Louis, MO. Gen. Tech. Rep. NC-227. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 84-101.

Kabrick, J.M.; Meinert, D.; Nigh, T.; Gorlinsky, B.J. 2000. **Physical environment of the Missouri Ozark Forest Ecosystem Project sites.** In: Shifley, S.R.; Brookshire, B.L.; eds. Missouri Ozark Forest Ecosystem Project: site history, soils, landforms, woody and herbaceous vegetation, down wood, and inventory methods for the landscape experiment. Gen. Tech. Rep. NC-208. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 41-70.

Law, J.R.; Lorimer, C.C. 1989. **Managing uneven-aged stands**. In: Clark, F.B.; Hutchinson, J.G., eds. Central Hardwood Notes. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 6.08: 1-6.

Loewenstein, E.F. 1996. **Size- and age-structure of an uneven-aged oak forest.** Columbia, MO: University of Missouri. 167p. Ph.D. dissertation.

Mayfield, H. 1961. **Nesting success calculated from exposure.** Wilson Bulletin. 73: 255-261.

Mayfield, H. 1975. **Suggestions for calculating nesting success.** Wilson Bulletin. 87: 456-466.

Meinert, D.; Nigh, T.; Kabrick J. 1997. **Landforms, geology, and soils of the MOFEP study area.** In: Brookshire, B.L.; Shifley, S.R., eds. Proceedings of the Missouri Ozark Forest Ecosystem Project: An experimental approach to landscape research; 1997 June 3-5; St. Louis, MO. Gen. Tech. Rep. NC-193. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 56-68.

O'Conner, R.J.; Faaborg, J. 1993. **The relative abundance of the brown-headed cowbird (*Molothrus ater*) in relation to exterior and interior edges in forests of Missouri.** Transactions of the Missouri Academy of Science. 26: 1-9.

Perry, R. W.; Thill, R.E.; Peitz, D.G., Tappe, P.A. 1999. **Effects of different silvicultural systems on initial soft mast production**. Wildlife Society Bulletin 27:915-923.

Renken, R. B.; Fantz, D. 2002. **Immediate, landscape-scale impacts of even-aged and uneven-aged forest management on herpetofaunal communities of the Missouri Ozark Forest Ecosystem Project.**

In: Shifley, S. R.; Kabrick, J.M., eds. **Proceedings of the second Missouri Ozark Forest Ecosystem Project symposium: post treatment results of the landscape experiment.** 2000 October 17-20; St. Louis, MO. Gen. Tech. Rep. NC-227. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 171-183.

Renken, R. B.; Gram, W.K.; Fantz, D.K.; Richter, S.C.; Miller, T.J.; Ricke, K.B.; Russell, B.; Wang, X. In Press. **Effects of forest management on amphibians and reptiles in Missouri Ozark forests.** Conservation Biology.

Roach, B.A.; Gingrich, S.F. 1968. **Even-aged silviculture for upland central hardwoods**. Agric. Handb. 355. Washington, DC: U.S. Department of Agriculture, Forest Service. 39p.

Sheriff, S.L. 2002. **Missouri Ozark Forest Ecosystem Project: The experiment.** In: Shifley, S. R.; Kabrick, J.M., eds. Proceedings of the second Missouri Ozark Forest Ecosystem Project symposium: post treatment results of the landscape experiment. 2000 October 17-20; St. Louis, MO. Gen. Tech. Rep. NC-227. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 1-25.

Sheriff, S. L.; He, Z. 1997. T**he experimental design of the Missouri Ozarks Forest Ecosystem Project.** In: Brookshire, B.L.; Shifley, S.R., eds. Proceedings of the Missouri Ozark Forest Ecosystem Project: An experimental approach to landscape research; 1997 June 3-5; St. Louis, MO. Gen. Tech. Rep. NC-193. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 26-40.

Shifley, S.R.; Brookshire, B.L. (eds.). 2000. **Missouri Ozark Forest Ecosystem Project: site history, soils, landforms, woody and herbaceous vegetation, down wood, and inventory methods for the landscape experiment**. Gen. Tech. Rep. NC-208 St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 314 p.

Shifley, S. R.; Kabrick, J.M. (eds.). 2002. **Proceedings of the second Missouri Ozark Forest Ecosystem Project symposium: post treatment results of the landscape experiment.** 2000 October 17-20; St. Louis, MO. Gen. Tech. Rep. NC-227. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 228 p.