Changes in Ground Layer Vegetation Following Timber Harvests on the Missouri Ozark Forest Ecosystem Project

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Abstract.—The Missouri Ozark Forest Ecosystem Project (MOFEP) is a landscape-scale experiment to test for effects of the following three common forest management practices on upland forests: 1) even-aged management (EAM), 2) uneven-aged management (UAM), and 3) no-harvest management (NHM). The first round of harvesting treatments was applied on the nine MOFEP sites in 1996. One forest component evaluated on MOFEP is the ground layer vegetation. Pre-treatment ground flora data were collected from permanent sample plots during the summers of 1994 and 1995; post-treatment data were gathered in 1999 and 2000. We evaluated differences between pre- and post-treatment values for ground flora parameters including species richness, percent ground cover, and relative abundances of several functional plant groups. Tests for treatment effects for each parameter were performed using analysis of variance on the difference between pre- and post-treatment means on each site. Significant treatment effects were observed for species richness, percent ground cover, and the relative abundance of annual/biennial species, woody vines, and legumes. Mean species richness per plot decreased significantly on all control (NHM) sites and increased slightly on both EAM and UAM sites. Total percent ground cover increased on all sites; harvested sites increased more than NHM sites. Annual/biennial species increased slightly on all sites, but most consistently on EAM sites. Woody vines increased on all sites, but most noticeably and consistently on EAM and UAM sites. The relative abundance of legumes decreased significantly on harvested sites and increased slightly on NHM sites.

To better understand the treatment effects described above, we also analyzed ground flora data at the plot level to determine if the treatments affected uncut as well as cut plots within harvested sites. Overall, patterns observed among uncut plots on harvested sites mirrored those observed for the NHM, or control, sites. Specifically, species richness declined, percent cover remained unchanged, and there were no noticeable changes in the relative abundances of most plant groups. Conversely, plots directly impacted by the harvests mirrored the results seen for treated sites: species richness increased, cover increased dramatically, annuals/biennials and woody vines increased in abundance, and legumes decreased noticeably in abundance. Our results provide no evidence that the harvests have impacted areas other than those locations that were actually cut.

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Increasingly, public forest land managers are being required to scientifically defend management practices and to identify potential impacts of those practices on multiple ecosystem components and processes. The Missouri Ozark Forest Ecosystem Project (MOFEP) is a long-term, large-scale experiment designed to evaluate effects of three standard forest management practices currently practiced on Missouri's public and private lands (Brookshire and Hauser 1993, Brookshire and Shifley 1997, Kurzejeski *et al.* 1993). The three practices, or treatments, being evaluated include: 1) even-aged management (EAM), 2) uneven-aged management (UAM), and 3) no-harvest management (NHM). Typically on Missouri's State-owned forests, forest inventories and management prescriptions are implemented on a 10- to 15-year re-entry cycle for each compartment (MOFEP experimental sites average 423 ha in size and are equivalent to compartments). The first round of harvesting treatments was implemented on MOFEP sites from May 1996 through May 1997. This paper documents initial changes in ground layer vegetation (both woody and herbaceous) following this first round of harvesting treatments on the MOFEP sites.

Ground layer vegetation is an important component of any forested landscape. The composition and structure of the ground flora contributes greatly to overall forest biodiversity, to wildlife habitat quality, and to the character of future forest stands. Understory plant species have been successfully used as indicators of potential site productivity, soil moisture status, and disturbance history (Cajander 1926, Daubenmire 1976, Rowe 1956). Very few studies of ground flora response to timber harvesting have been conducted in Missouri. Earlier projects typically focused either on wildlife forage and cover values, or on woody regeneration (Crawford 1971, 1976; Crawford and Harrison 1971; Murphy and Crawford 1970). One recent project, conducted in southern Missouri, compared clearcut stands of various ages, but did not have the benefit of pre-treatment data (Unger 1994).

MOFEP provides one of the first opportunities in Missouri to experimentally test for effects of forest management practices at a landscape scale on the ground layer vegetation of upland Ozark forests. Information about the MOFEP ground flora will serve not only to address vegetation questions, but will also aid in the interpretation of many of the other MOFEP studies, both at the landscape (among-site) and local (within-site) scales.

METHODS

Study Area

There are nine MOFEP experimental units or compartments, hereafter referred to as sites in this paper. All nine MOFEP sites are in the Current River Hills Subsection of the Ozark Highlands, located in Carter, Reynolds, and Shannon Counties of southeastern Missouri (see figure 1 in Sheriff, this proceedings). The sites range in size from 314 to 516 ha (776 to 1,275 ac). The Current River Hills Subsection can be characterized as a deeply dissected landscape with broad to narrow ridges, steep sideslopes, and narrow valleys associated with the Current, Jacks Fork, Eleven-Point, and Black Rivers (Nigh *et al.* 2000). The MOFEP study sites are all within the Current River watershed and primarily encompass upland landscape positions; they do not include landform features associated with large creeks or rivers. Local relief within the MOFEP sites ranges from 46 to 137 m (150 to 450 ft). MOFEP sites include landscape positions of all aspects and have slopes ranging from 0 to >60 percent.

Bedrock geology of the MOFEP sites includes Ordovician sandstones, cherts, and dolomites from the Roubidoux and Gasconade formations, as well as Cambrian cherts and dolomites from the Eminence formation (Kabrick *et al.* 2000, Meinert *et al.* 1997). Soils of the MOFEP sites are fairly typical of the Current River Hills Subsection, with patterns in parent materials, texture, base saturation, and depth to bedrock strongly associated with the geology and landforms on which they occur (Kabrick *et al.* 2000; Meinert 1998, 2001; Meinert *et al.* 1997). Multiple soil parent materials are common and are characterized by mode of deposition or by type of bedrock if weathered in place. Dominant parent materials in the upland MOFEP sites are hillslope sediments, loess, and residuum (Meinert 1998, 2001; Meinert *et al.* 1997).

Experimental Design and Treatment Implementation

MOFEP is unique in being a true field experiment with nine large landscape-scale experimental units arranged in a randomized complete block design. The three silvicultural treatments being tested (even-aged management (EAM), uneven-aged management (UAM), and no-harvest management (NHM)) form a gradient from complete canopy removal to partial removal to no canopy removal. Even-aged management, as conducted by the Missouri Department of Conservation, involves clearcutting and intermediate thinnings, and it has been practiced on publicly owned forest lands in Missouri for more than 30 years (Missouri Department of Conservation 1986). MOFEP sites 3, 5, and 9 were designated as EAM sites. Uneven-aged management involves combinations of single-tree removals with scattered small group openings throughout the sites and is a relatively new technique for public land management in Missouri. MOFEP sites 2, 4, and 7 were selected as UAM sites, and the harvests were implemented following prescription guidelines presented in Law and Lorimer (1989). As the name implies, no timber harvesting will occur on the no-harvest management sites (1, 6, and 8) for the duration of the project. The NHM sites will serve as control replicates for the experiment and will provide valuable information on changes that occur over time in mature upland Ozark forests in the absence of active management.

MOFEP was designed as a long-term study (>100 years), with harvests to be conducted every 10 to 15 years. The nine MOFEP sites, or experimental units, were grouped into three replication blocks. Treatments were randomly assigned within blocks so that each block contains one EAM site, one UAM site, and one NHM site (figs. 1 and 2 in Sheriff, this proceedings; Sheriff and He 1997). The first round of harvesting treatments was implemented on MOFEP study sites from May 1996 through May 1997 (Brookshire *et al.* 1997). For a more detailed description and discussion of the strengths and weaknesses of the MOFEP experimental design, see Brookshire *et al.* (1997), Sheriff and He (1997), and Sheriff (this proceedings). For more complete descriptions of the first round of harvesting treatments as well as the volume, density, and composition of woody vegetation removed, see Kabrick *et al.* (this proceedings) and Sheriff (this proceedings).

Ground Flora Data Collection

MOFEP ground flora data were collected on the same 645 0.2-ha (0.5 ac) permanent circular plots used for the woody vegetation projects (Brookshire and Dey 2000, Kabrick *et al.* 1997 and this proceedings, Shifley *et al.* 1997). Vegetation plots were initially located in a stratified random manner, ensuring 1 plot per stand, for a range of 70 to 74 plots per site (table 1). For the ground flora data collection, 16 permanently marked 1-m² quadrats were sampled within each 0.2-ha (0.5 ac) plot. For a

Table 1.—*Number of MOFEP vegetation plots according to the management they received as a result of the 1996 harvest treatment implementation. Site-level treatments refer to the three treatments being experimentally tested: even-aged management (EAM), uneven-aged management (UAM), and no-harvest management (NHM).*

Block	Site	Site-level Treatments	Clearcut Plots	Plots in Group Openings	Plots with intermediate selection cuts	Plots with Multiple Treatments	Uncut Plots	Total Number of Plots
1	1	NHM	-	-	-	-	73	73
1	2	UAM	-	16	33	0	24	73
1	3	EAM	7	-	16	1	48	72
2	4	UAM	-	21	25	0	28	74
2	5	EAM	8	-	13	9	40	70
2	6	NHM	-	-	-	-	71	71
3	7	UAM	-	8	21	0	42	71
3	8	NHM	-	-	-	-	70	70
3	9	EAM	7	-	4	1	59	71
Totals:	9 sites	3 treatments	22	45	112	3	458	645

diagram of the MOFEP vegetation plot design, see figure 1 in Kabrick *et al.* (this proceedings).

Within each 1-m^2 quadrat, all herbaceous plants, and all woody plants with live foliage less than 1 m above the ground, were identified to species and assigned estimates of percent live foliar coverage. Plants not identifiable to the species level were labeled to genera when possible, or to the next most precise taxonomic level known (e.g., family, functional group, monocot or dicot, etc.). Nomenclature follows that of Steyermark (1963). Our sample included individuals rooted within the quadrat frame as well as those not rooted in but with live foliage hanging over the frame. Numbers of stems less than 1 m tall were recorded for all tree species; total percent ground cover (vegetation <1 m tall) was recorded for each quadrat. Although not summarized for this report, estimates of percent cover were also recorded for features such as rock, bare ground, leaf litter, dead wood, non-vascular species, and canopy closure. For a more detailed description of methods used to collect MOFEP ground flora data, see Grabner (2000).

Pre-treatment data used for this report were collected during the summers (June 1 through August 25) of 1994 and 1995; post-treatment data were gathered from June through August of 1999 and 2000. MOFEP sites were sampled in the same order and, as a result, during the same basic period each year to avoid potentially confounding seasonal effects. Immediate post-harvest data were collected in 1997 but were incomplete and were not used for this report. Ground flora data were not collected in 1998 due to budget constraints.

Numerical Analyses

Calculations and Plant Groups

Species richness per plot was calculated as the total number of species identified on the 16-m^2 quadrat samples within each 0.2-ha (0.5 ac) plot. Mean total percent ground cover per plot was calculated by summing the total coverages for each quadrat and then dividing by 16. Percent relative cover was calculated by summing the coverage of each individual species (or species group) on each plot, dividing by the sum of all species coverages on that plot, and then multiplying by 100. For all analyses, pre-treatment means were calculated as the average of 1994 and 1995 values, and post-treatments means were calculated as the average of 1999 and 2000 values.

Functional plant groups used for this report were 1) exotic species (all life forms), 2) native annual and/or biennial species, 3) native non-leguminous forbs, herbaceous vines, and ferns, 4) native grasses, sedges, and rushes, 5) native legumes, 6) native shrubs, 7) native trees, 8) native woody vines, and 9) unknowns.

Analysis of Variance and Confidence Limits

Analyses for this report were conducted at two levels: among sites and within sites. Analysis of variance (ANOVA) was used to test for treatment effects among sites. Response variables were plotted and checked for adherence to the assumptions of the analysis of variance (particularly the equal variance assumption). Our analysis indicated transformations were not needed, so we proceeded with untransformed response variables. Variables tested included mean plot richness, mean percent ground cover per plot, and the percent relative cover of each of the functional plant groups described above. The ANOVA model used for these analyses was as follows:

$$Y_{ij} = \mu + \text{block}_i + \text{treatment}_j + \epsilon_{ij},$$

where "μ" is the mean difference between post- and pre-treatment values, block_i is the blocking effect, treatment_j is the site-level harvesting treatment effect (EAM, UAM, or NHM), and ϵ_{ij} is the error term $N(0, \sigma^2)$. All ANOVAs were performed using the PROC GLM statement in SAS for Windows (version 8).

Upper and lower 95 percent confidence intervals around the means were calculated for each site using pooled variance estimates based on plot data. Simple scatter plots of the mean differences with error bars showing lower and upper confidence limits illustrate treatment effects identified by the ANOVAs for each site.

Due to the landscape-level design of this study, analysis of variance was not performed for within-site data. We conservatively assumed that vegetation plots within sites could not be considered independent sample points. Rather, for the within-site data, mean post- minus pre-treatment differences and their associated confidence intervals were computed. For this analysis, confidence intervals that did not include zero were considered to represent "significant" treatment effects.

RESULTS

Treatment Effects Among Sites (Landscape-scale Analyses)

The MOFEP experimental design allows testing for treatment effects by comparing differences between pre- and post-treatment observations. Tables 2 and 3 provide the results of significant ANOVAs and a list of the site-level pre- and post-treatment mean values used in these analyses, respectively. Significant treatment effects ($\alpha<0.05$) were detected for mean species richness and percent ground cover per plot, as well as for the relative abundances of several plant groups (tables 2A and B). Noticeable changes in species richness occurred on the control sites (i.e., NHM sites 1, 6, and 8), where richness *decreased* by an average of 1.8 species per plot (95% CI: -3.2 to -0.5, p=0.02) from the pre- to post-treatment samples. Conversely, EAM sites (3, 5, and 9) and UAM sites (2, 4, and 7) showed increases in richness by an average of 1.8 species (95% CI: 0.4 to 3.1, p=0.02) and 2.3 species (95% CI: 0.9 to 3.6, p=0.01) per plot, respectively (table 3, fig. 1A). In all sites, ground cover increased from pre- to post-treatment. NHM sites had the smallest increase in ground cover (2.2% with a 95% CI from 0.8 to 3.7%, p=0.01). EAM sites (6.3% with a 95% CI from 4.8 to 7.7%, p<0.01) and UAM sites (6.7% with a 95% CI from 5.5 to 8.4%, p<0.01) increased more in ground cover than did NHM sites (ANOVA contrast (EAM+UAM)/2 vs. NHM, difference estimated to be 3.3%, p=0.06) (table 3, fig. 1B).

Significant treatment effects were also observed at the site level for annual and biennial species, woody vines, and legumes. Annuals and biennials, essentially not present on most sites prior to the harvests, increased consistently in mean relative percent cover on all EAM sites (0.5% with a 95% CI from 0.4 to 0.6%, p<0.01). The patterns were less consistent on both UAM and NHM sites, where annual and biennial species increased by an average of 0.2 percent relative cover (95% CI from 0.1 to 0.3%, p=0.01), but with confidence intervals for three of the six sites (1, 2, and 4) overlapping zero (fig. 2A). Mean relative percent cover of woody vine species (e.g., *Vitis* spp., *Parthenocissus quinquefolia*, etc.) increased in all sites following treatment, but the increase was most noticeable and consistent for the EAM (3.7% with a 95% CI from 2.9 to 4.5%, p<0.01) and UAM sites (3.3% with a 95% CI from 2.5 to 4.0%, p<0.01). NHM sites (1.6% with a 95% CI from 0.8 to 2.4, p<0.01) had a significantly smaller increase than the harvested sites (ANOVA contrast (EAM+UAM)/2 vs. NHM, difference estimated to be 2.6%, p=0.02) (fig. 2B). Mean relative percent cover of legumes (e.g., *Desmodium* spp. and *Lespedeza* spp.) decreased noticeably on all treated sites (UAM: -5.2% with a 95% CI from

Table 2.—*Analysis of variance tables for significant variables at the site scale. Testing for treatment effects on structural and compositional parameters: mean post-pre differences in A) mean species richness and mean percent ground cover, and B) mean relative cover of annual/biennial species, woody vines, and legumes.*

A)

		Species richness			Percent ground cover		
Source	DF	Sum of squares	F	P	Sum of squares	F	P
Block	2	0.29	0.19	0.83	24.43	14.66	0.01
Treatment	2	29.8	20.01	<0.01	39.56	23.74	<0.01
Error	4	2.98	--	--	3.33	--	--

B)

		Annual/biennial abundance			Woody vine abundance			Legume abundance		
Source	DF	Sum of squares	F	P	Sum of squares	F	P	Sum of squares	F	P
Block	2	0.17	17.39	0.01	16.55	36.99	<0.01	8.66	6.42	0.06
Treatment	2	0.13	13.65	0.02	7.5	16.77	0.01	81.43	60.4	<0.01
Error	4	0.02	--	--	0.89	--	--	2.7	--	--

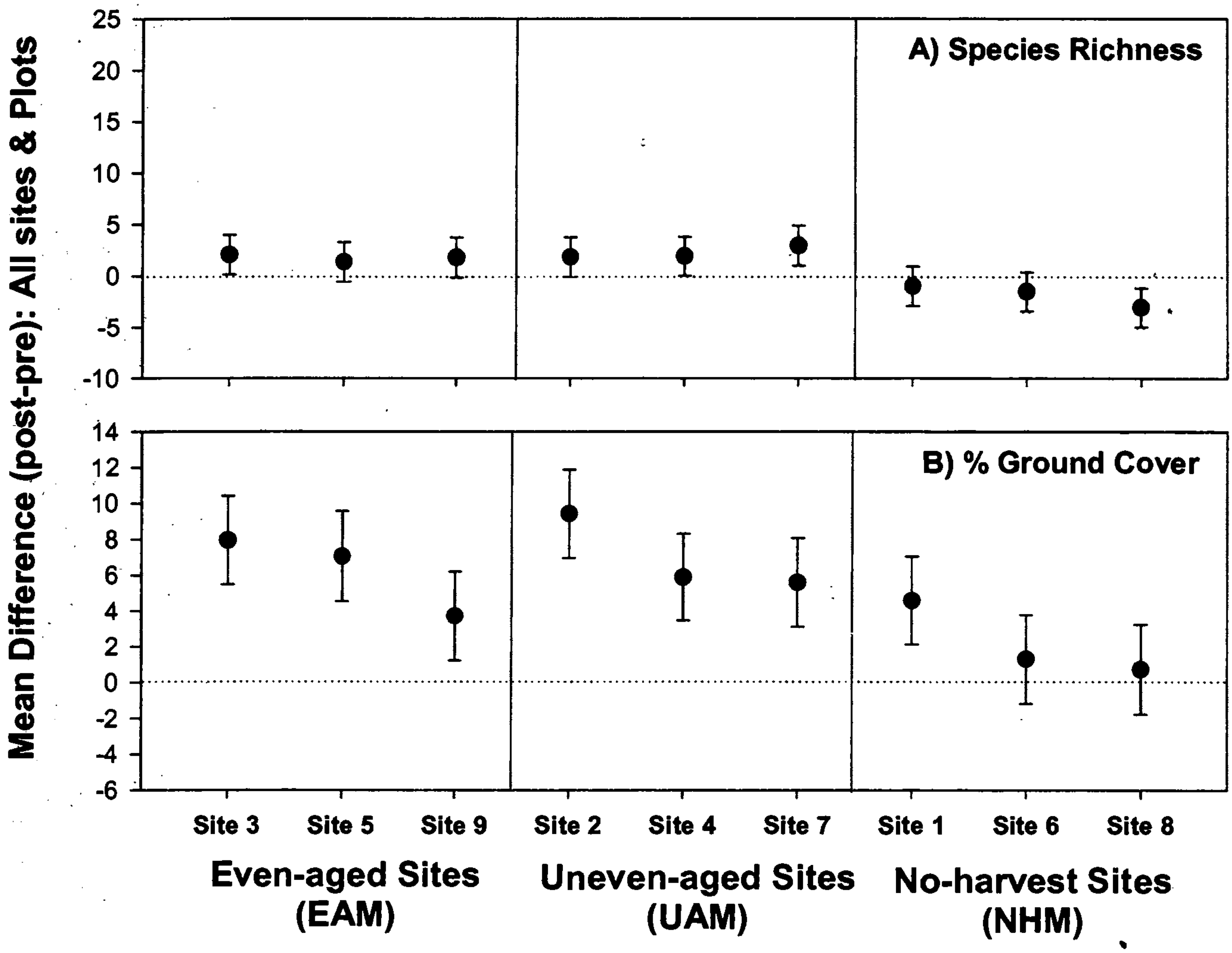

Figure 1.—*Mean differences between post- and pre-treatment site-level data for A) mean species richness per plot, and B) mean percent ground cover per plot. Error bars are 95 percent confidence intervals.*

Table 3.—*Mean values calculated per site and used in ANOVAs to test for treatment effects among sites. "pre" = the mean of pre-treatment data from 1994 and 1995; "post" = the mean of post-treatment data from 1999 and 2000. Units for relative cover are in percent.*

			Mean species richness		Mean % ground cover		Relative cover by exotics		Relative cover by annuals / biennials		Relative cover by forbs		Relative cover by graminoids		Relative cover by legumes		Relative cover by shrubs		Relative cover by tree species		Relative cover by woody vines			
block	site	trt	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post	pre	post
1	3	eam	45.3	47.4	21.0	29.0	0.0	0.0	0.2	0.5	10.4	9.8	2.3	4.6	19.8	16.8	9.9	9.9	43.9	40.3	13.3	17.6	0.3	0.4
2	5	eam	56.5	57.9	23.4	30.4	0.1	0.0	0.4	0.9	12.4	11.5	3.8	6.6	25.1	19.0	9.2	9.8	39.1	37.0	9.6	14.8	0.3	0.4
3	9	eam	48.0	49.8	19.4	23.2	0.1	0.1	0.6	1.2	8.7	8.9	4.5	7.6	25.2	21.1	15.8	15.4	42.5	41.3	2.3	3.9	0.3	0.5
1	2	uam	45.6	47.4	26.6	36.0	0.0	0.0	0.4	0.4	10.2	9.8	1.8	4.4	20.3	14.6	11.3	11.3	33.5	32.2	22.4	26.5	0.3	0.8
2	4	uam	52.1	54.1	22.0	27.9	0.0	0.0	0.4	0.5	10.9	11.7	1.9	4.0	25.8	19.8	9.1	10.3	38.7	35.7	12.8	17.4	0.4	0.5
3	7	uam	37.5	40.5	19.7	25.3	0.0	0.1	0.2	0.7	4.8	5.3	2.1	8.8	22.8	19.0	12.0	12.4	43.6	37.9	14.3	15.4	0.2	0.5
1	1	nhm	32.9	32.0	15.6	20.2	0.0	0.0	0.2	0.3	8.3	7.3	1.4	1.3	23.6	25.9	13.4	13.4	42.5	38.5	10.3	12.9	0.1	0.4
2	6	nhm	37.3	35.8	18.3	19.6	0.0	0.0	0.2	0.5	5.8	6.1	2.1	3.6	32.5	32.5	7.4	8.2	46.7	41.7	5.2	7.3	0.1	0.2
3	8	nhm	39.2	36.1	14.8	15.6	0.1	0.1	0.3	0.6	6.3	5.6	2.6	4.9	19.0	21.4	13.6	13.8	50.2	45.0	7.8	7.9	0.3	0.6

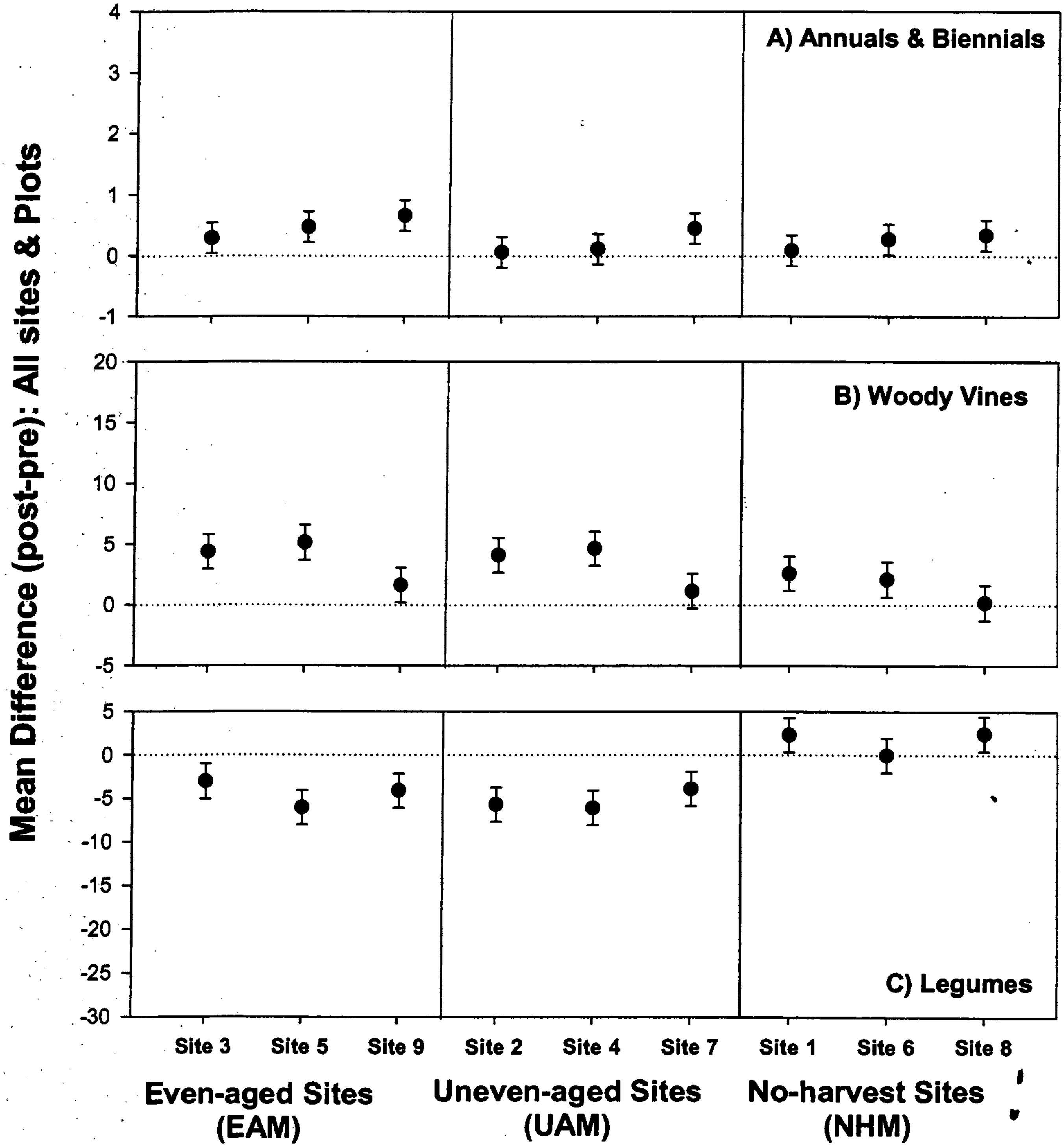

Figure 2.—*Mean differences between post- and pre-treatment site-level data for A) mean relative cover by annual/biennial species per plot, B) mean relative cover by woody vines per plot, and C) mean relative cover by legumes per plot. Error bars are 95 percent confidence intervals.*

-6.5 to -3.9%, p<0.01; EAM: -4.4% with a 95% CI from -5.7 to -3.1%, p<0.01), while either increasing or remaining unchanged on control sites (1.6% with a 95% CI from 0.2 to 2.9%, p=0.03) (fig. 2C). No significant treatment effects were observed at the site level for other functional groups such as exotics (p=0.33), nonleguminous forbs, herbaceous vines and ferns (p=0.27), grasses and sedges (p=0.15), shrubs (p=0.14), trees (p=0.31), and unknowns (p=0.24) (table 3).

Treatment Effects Within Sites ("Local Scale" Analyses)

Given that 69 percent of vegetation plots on EAM sites (147/213) and 43 percent of those on UAM sites (94/218) were not harvested during this first round of treatment (table 1), we wanted to determine whether the site-level treatment effects described above were also evident *within* treated sites on plots not directly impacted by the harvesting. In other words, we wanted to know whether there was evidence of actual landscape-level changes across the treated sites, or whether the effects were restricted to cut plots only.

In general, there was little evidence of harvesting effects anywhere except on plots directly impacted by tree removal. Comparisons of pre- and post-treatment conditions on uncut plots within treated sites essentially mirrored those observed among control sites for the site-scale analyses presented above. As with no-harvest sites (1, 6, and 8), uncut plots within both EAM and UAM sites decreased noticeably in mean species richness (figs. 3A and 4A) and showed no change in percent ground cover (figs. 3B and

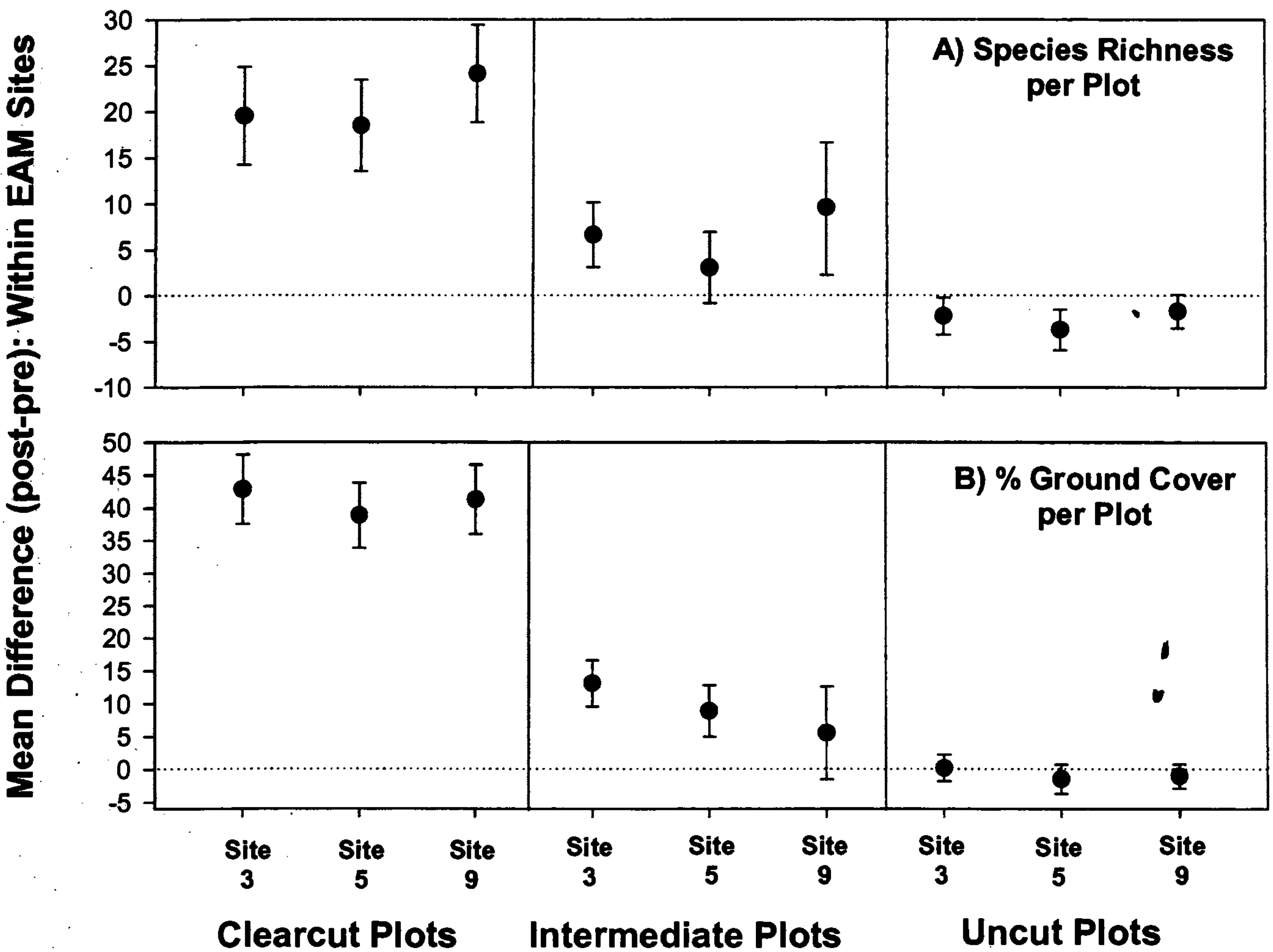

Figure 3.—*Mean differences between post- and pre-treatment data within even-aged management sites only for A) mean species richness per plot, and B) mean percent ground cover per plot. Error bars are 95 percent confidence intervals.*

4B). Plots subjected to intermediate thinnings (EAM) or single-tree selection (UAM) increased slightly (although usually not significantly) in species richness; plots located in group openings (UAM) or clearcuts (EAM) increased significantly in species richness (figs. 3A and 4A). All harvested plots increased substantially in mean percent total ground cover (figs. 3B and 4B), with native woody vine and shrub species such as *Vitis aestivalis* (summer grape) and *Rubus pensylvanicus* (blackberry) contributing largely to this increase (table 4B).

Within-site responses of functional plant groups following the harvests were somewhat variable, although still similar to those we observed when evaluating site-level means. Annual and biennial species including *Erechtites hieracifolia* (fireweed), *Erigeron* spp. (daisy fleabanes), and *Gnaphalium* spp. (cudweed) increased their presence on cut plots of all types (clearcuts, group openings, intermediate and selection cuts), although not consistently (figs. 5A and 6A). Woody vines such as *Vitis aestivalis* and *Parthenocissus quinquefolius* (Virginia creeper) increased in abundance across most plots, but most noticeably in clearcuts, group openings, and other cut plots (figs. 5B and 6B). As with the site-level means for both EAM and UAM sites, legumes decreased significantly in abundance on all harvested plots, but remained basically unchanged on most uncut plots (figs. 5C and 6C). This decrease was due primarily to marked declines in the abundance of two very common species, *Desmodium nudiflorum* (common tick trefoil) and *Amphicarpaea bracteata* (hog peanut) (table 4A).

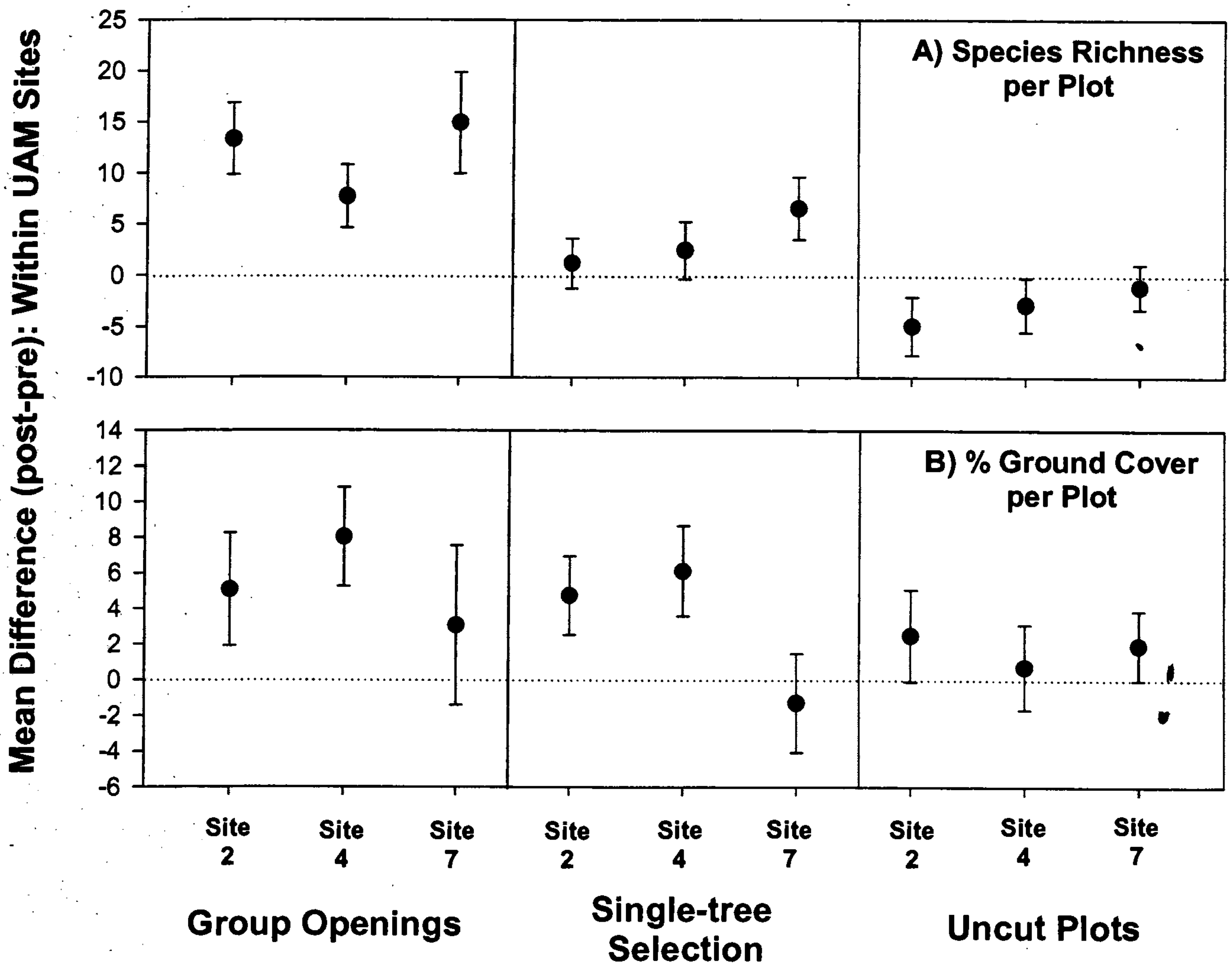

Figure 4.—*Mean differences between post- and pre-treatment data within uneven-aged management sites only for A) mean species richness per plot, and B) mean percent ground cover per plot. Error bars are 95 percent confidence intervals.*

Table 4A.—*Species that showed the greatest decreases in mean relative cover and frequency on plots that had been either clearcut or subjected to intermediate thinnings or single-tree selection*

Decreased in: Mean Relative Cover per Plot	Decreased in: Mean Relative Frequency per Plot
Clearcut Plots	
Desmodium nudiflorum (legume)	*Galium concinnuum (forb)*
Amphicarpaea bracteata (legume)	*Psoralea psoralioides (legume)*
Psoralea psoralioides (legume)	*Desmodium nudiflorum (legume)*
Cornus florida (understory tree)	*Vitis vulpina (woody vine)*
Sassafras albidum (understory tree)	*Hepatica nobilis (forb)*
Cercis canadensis (understory tree)	*Cimicifuga racemosa (forb)*
Vaccinium stamineum (shrub)	*Carex cephalophora (sedge)*
Cimicifuga racemosa (forb)	*Phryma leptostachya (forb)*
Hepatica nobilis (forb)	*Viola sororia (forb)*
Vaccinium vacillans (shrub)	*Botrychium virginianum (fern)*
Plots with Intermediate/Selection Cuts	
Amphicarpaea bracteata (legume)	*Viola sororia (forb)*
Cornus florida (understory tree)	*Rubus occidentalis (shrub)*
Asimina triloba (understory tree)	*Passiflora lutea (vine)*
Desmodium nudiflorum (legume)	*Agrimonia pubescens (forb)*
Sassafras albidum (understory tree)	*Carex retroflexa (sedge)*
Amelanchier arborea (understory tree)	*Cornus florida (understory tree)*
Vaccinium vacillans (shrub)	*Aristolochia serpentaria (forb)*
Cimicifuga racemosa (forb)	*Muhlenbergia sobolifera (grass)*
Quercus marilandica (tree)	*Asimina triloba (understory tree)*
Corylus americanus (understory tree)	*Smilax pulverulenta (vine)*

Table 4B.—*Species that showed the greatest increases in mean relative cover and frequency on plots that had been either clearcut or subjected to intermediate thinnings or single-tree selection*

Increased in: Mean Relative Cover per Plot	Increased in: Mean Relative Frequency per Plot
Clearcut Plots	
Vitis aestivalis (woody vine)	*Vitis aestivalis (woody vine)*
Rubus pensylvanicus (shrub)	*Panicum boscii (grass)*
Quercus alba (tree)	*Scleria triglomerata (sedge)*
Potentilla simplex (forb)	*Rubus pensylvanicus (shrub)*
Scleria triglomerata (sedge)	*Potentilla simplex (forb)*
Pteridium aquilinum (fern)	*Parthenocissus quinquefolius (woody vine)*
Panicum boscii (grass)	*Ulmus alata (understory tree)*
Parthenocissus quinquefolius (woody vine)	*Heliopsis helianthoides (forb)*
Heliopsis helianthoides (forb)	*Carex nigromarginata (sedge)*
Carex nigromarginata (sedge)	*Nyssa sylvatica (tree)*
Plots with Intermediate/Selection Cuts	
Vitis aestivalis (woody vine)	*Vitis aestivalis (woody vine)*
Vaccinium arboreum (shrub)	*Sanicula gregaria (forb)*
Rubus pensylvanicus (shrub)	*Juniperus virginiana (tree)*
Nyssa sylvatica (tree)	*Ulmus rubra (tree)*
Quercus coccinea (tree)	*Viola spp. (forb)*
Parthenocissus quinquefolius (woody vine)	*Carex nigromarginata (sedge)*
Ulmus rubra (tree)	*Sassafras albidum (understory tree)*
Carex nigromarginata (sedge)	*Erechtites hieracifolia (forb)*
Quercus alba (tree)	*Lindera benzoin (understory tree)*
Sanicula gregaria (forb)	*Cercis canadensis (understory tree)*

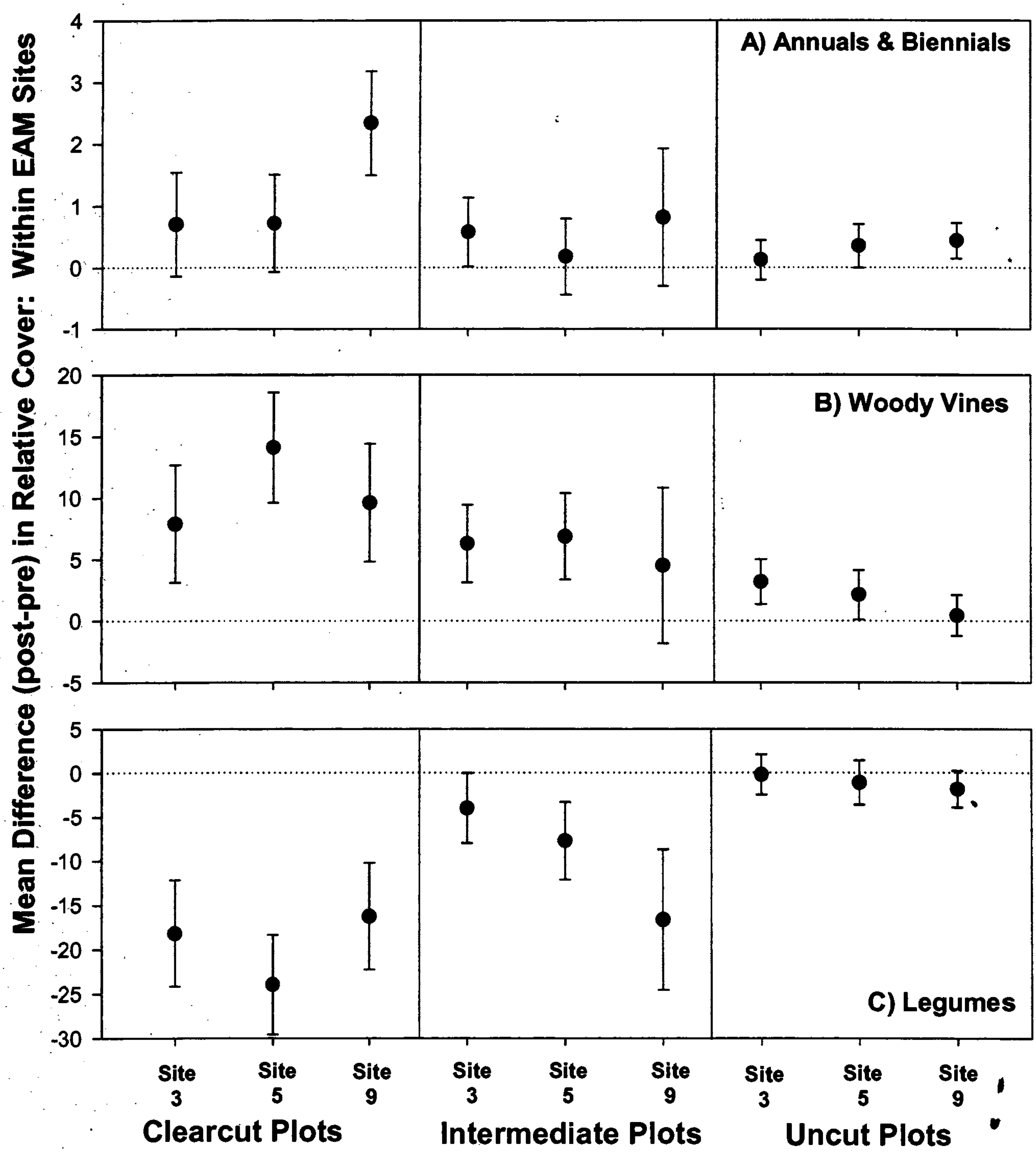

Figure 5.—*Mean differences between post- and pre-treatment data within even-aged management sites only for A) mean relative cover by annual/biennial species per plot, B) mean relative cover by woody vines per plot, and C) mean relative cover by legumes per plot. Error bars are 95 percent confidence intervals.*

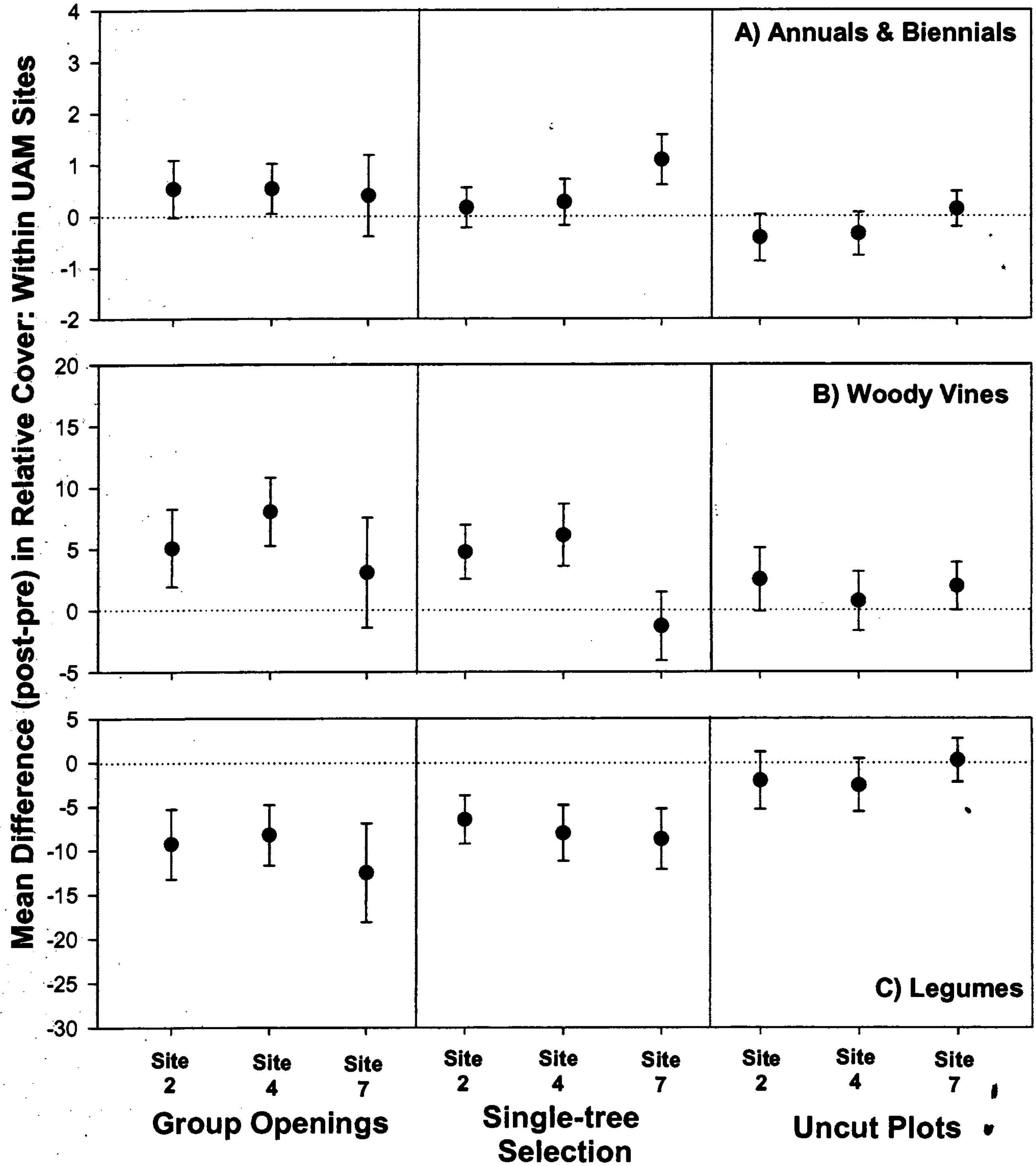

Figure 6.—*Mean differences between post- and pre-treatment data within uneven-aged management sites only for A) mean relative cover by annual/biennial species per plot, B) mean relative cover by woody vines per plot, and C) mean relative cover by legumes per plot. Error bars are 95 percent confidence intervals.*

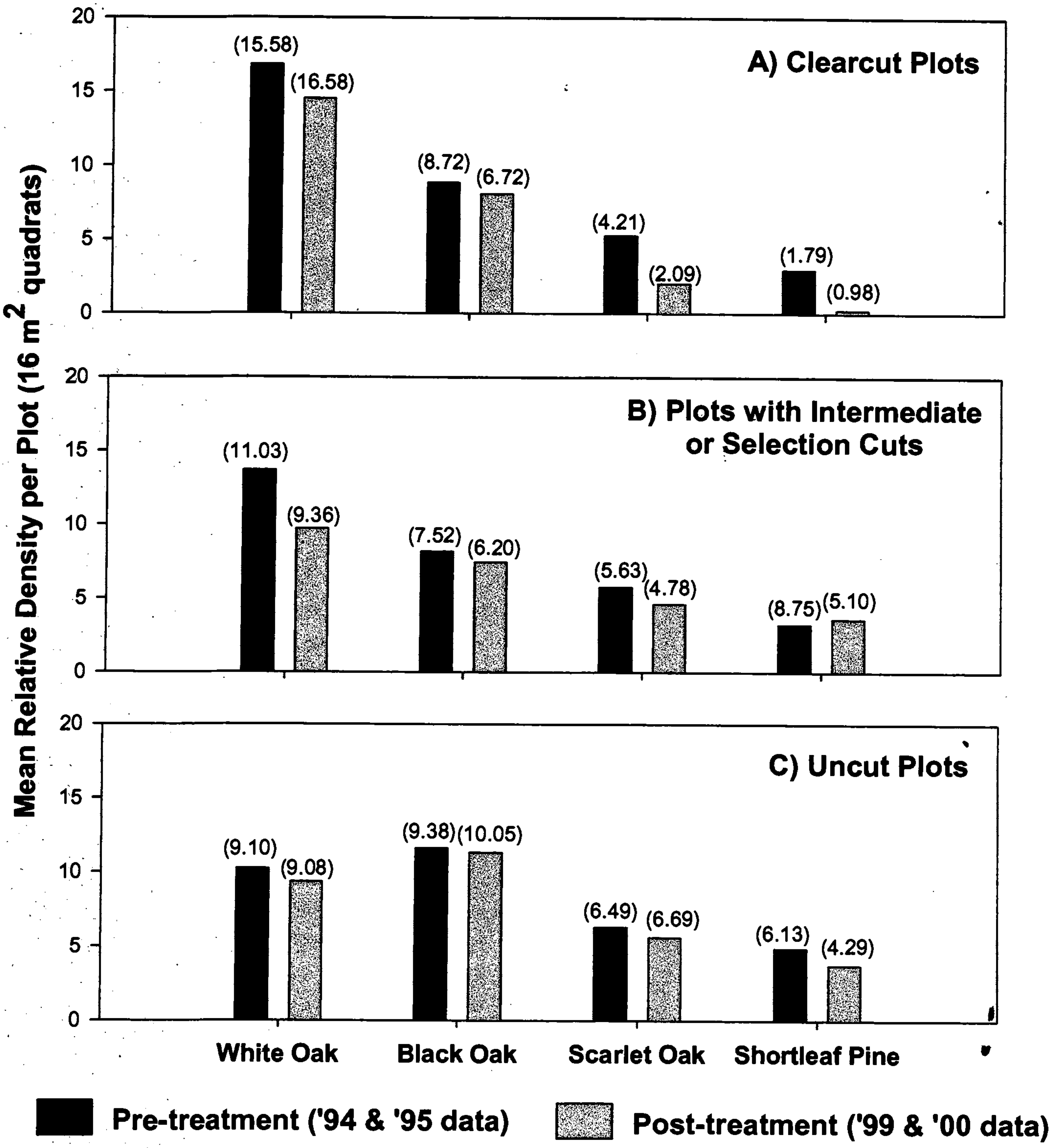

Figure 7.—*Comparison of pre- and post-treatment relative densities for white oak* (Quercus alba), *black oak* (Q. velutina), *scarlet oak* (Q. coccinea), *and shortleaf pine* (Pinus echinata) *seedlings (<1 m tall) on plots subjected to A) clearcutting, B) intermediate thinning (EAM sites) or single-tree selection (UAM sites), or C) no cutting. Numbers above bars are standard deviations.*

Coverage by graminoids increased across most plots on treated sites, but the increase was generally greater on clearcut and group opening plots, specifically for species such as *Panicum boscii* (panic grass), *Scleria triglomerata* (nut rush), and *Carex nigromarginata* (black-edged sedge). Patterns in average relative cover for all shrubs and trees, and for overall tree density, were less clear and did not reveal clear relationships to the harvesting treatments (table 3). Table 4 lists the ground flora species that changed most drastically from pre- to post-treatment in relative cover and/or frequency on harvested plots.

In addition to evaluating changes in the relative cover and density of all tree species (<1 m tall), we wanted to focus briefly on a few key species of economical and ecological importance within the MOFEP region. To do this, we looked at changes in mean stem density per plot for *Quercus alba* (white oak), *Q. velutina* (black oak), *Q. coccinea* (scarlet oak), and *Pinus echinata* (shortleaf pine). On clearcut plots, shortleaf pine, scarlet oak, and white oak decreased noticeably in mean seedling stem density per plot (fig. 7). On intermediate and/or selectively cut plots, white oak again decreased, but the densities of the other three species did not change appreciably. Little evidence of change in densities was observed for uncut plots.

SUMMARY AND DISCUSSION

The Missouri Ozark Forest Ecosystem Project (MOFEP) is a large-scale, long-term project that experimentally tests for effects of even-aged management (EAM), uneven-aged management (UAM), and no-harvest management (NHM) on upland forest components. Pre- (1994, 1995) and post-treatment (1999, 2000) data were collected from 645 permanent vegetation plots as part of the MOFEP ground flora study. Analyses of ground flora data for this report were conducted at two levels: 1) following the experimental model using among-site data in an analysis of variance (ANOVA) framework, and 2) using within-site data to see if ground flora changes in treated sites were confined to harvested plots only.

Patterns in ground flora species richness, total percent ground cover, and species composition observed among treatments at the site level were similar to those observed within treated sites, among cut and uncut plots. We observed no evidence that changes due to the harvesting have occurred anywhere except on cut plots. In general, patterns among uncut plots on treated sites mirrored those observed among control sites; patterns among intermediate (EAM) and selectively cut (UAM) plots were similar to each other; and plots in clearcuts (EAM) and group openings (UAM) exhibited similar responses for the variables evaluated.

Based on our experience and on existing literature describing early-successional plant responses to canopy removal, we expected that variables such as species richness and ground cover would increase on harvested plots. What we did not expect, however, was the significant decrease in mean plot richness on control sites and on uncut plots within treated sites. One explanation for this decrease may be the exceptionally dry weather in southern Missouri during 1999 and 2000. On cut plots within treated sites, the dramatic increase in light availability may have enabled many plant species to overcome (or at least ignore) the stresses caused by drought. At this point, it is somewhat difficult to confidently describe pre- to post-harvest changes in abundance or frequency for most of the individual plant species encountered on MOFEP sites. Reasons for this difficulty include: 1) normal variations over time in plant populations related to weather, life history traits, and other natural factors not controlled for in this study, 2) the fact that 60 to 70 percent of the species encountered occurred on less than 10 percent of the plots (i.e., very low sample numbers for most species), and 3) year-to-year differences in crew bias and sampling error. Further work is needed to determine if patterns exist (both at landscape and local scales) with regard to which individual species (and groups of species) are decreasing or increasing noticeably in abundance on cut and on uncut plots, and how this might be related to life history traits or some other aspect of plant population biology.

Annual and biennial species, which were essentially not present on MOFEP vegetation plots prior to treatment, increased moderately in mean relative cover after harvests, particularly on clearcut and group opening plots, where they were able to take advantage of the dramatically increased light. Woody vines such as the summer grape (*Vitis aestivalis*) and early-successional shrubs like blackberries (*Rubus* *pensylvanicus*) increased drastically in abundance on cut plots from pre- to post-treatment, particularly on clearcut and group opening plots.

Another result that was somewhat surprising was the decline in mean relative cover for legumes, both at the landscape scale among all treated sites, and at a more local scale among all harvested plots within both EAM and UAM sites. A large part of this decline seems to be explained by marked decreases in abundance from pre- to post-treatment for two of the most common ground flora species encountered on MOFEP sites: common tick trefoil (*Desmodium nudiflorum*) and hog peanut (*Amphicarpa bracteata*). Prior to treatment, each of these species typically occurred on 85 to 95 percent of all MOFEP plots, and they were always among the top 10 species in terms of mean relative cover (Grabner *et al.* 1997). These legumes are generalists within a closed-canopy forest environment, but do not appear to be as successful in conditions of increased light. It will be interesting to see if and when these common forest legumes regain their relative dominance on cut plots.

MOFEP is now at the juncture where field observations and experimental analyses must be combined with the concepts of patch dynamics and hierarchy theory to develop a coherent, spatially explicit, across-scale understanding of forest dynamics. Understanding what controls the rate and direction of vegetational change across spatial scales will be critical to developing appropriate management and conservation plans. We have engaged in a long-term, large-scale experiment to evaluate the effects of forest management practices on several ecosystem components. Results from this study suggest that anthropogenically induced disturbances in the form of different forest management practices at a local level (i.e., a stand) can dominate, statistically speaking, the ground-layer vegetation at site scales. But, as our analyses revealed, it is quite possible to show significant treatment effects at the site scale, and yet have these treatment effects spatially confined to the areas actually treated. Post- and pre-treatment differences between 10 and 30 percent for species richness and between 30 and 50 percent for ground cover on 11 percent of all vegetation plots (i.e., all clearcut plots) within even-aged sites (fig. 3) were large enough to translate into statistically significant differences at the site level. Are the results of this study therefore suggestive of processes that occur at larger, site-level or landscape scales? What would constitute a true site-level effect?

Results from this study highlight the need for a distinction between statistical and biological significance. Whether observed changes in this study are biologically significant may depend on the scale to which we want to reference the change, i.e., are we interested in stand-level or site-level processes. At the stand scale, dramatic differences were observed along a gradient of no harvest, intermediate plots (i.e., thinned areas), and clearcut areas. As MOFEP continues, we will be able to track species invasions, species recovery, and species turnover at the stand level. Site-level questions, on the other hand, will not only focus more on questions that scale up the results gleaned from stand manipulation, but will also need to be expanded to include more process research. For example, will changes in the composition of the understory continue to be proportional to the area treated or is there a point where those changes will become non-linear? In other words, is there a critical level of site-scale fragmentation, where a combination of habitat loss and dispersal limitation affects the heterogeneity of the ground-layer flora at the stand scale?

Because the characteristics of ecological systems at relatively fine scales differ from those at broader scales, these differences must be reflected in the questions and approaches used to study systems (Wiens 1989). Consequently, site-level questions are not merely stand-level questions scaled up. We contend that future efforts should be directed toward developing predictive models that scale stand-level results up to the site level. As with the ground flora study, most projects associated with MOFEP employ some sort of plot or subsampling approach to data collection, and will therefore have similar challenges for interpreting data—before concluding whether or not there is a landscape change. Creative new statistical designs may be needed to address scaling issues and process research within the framework of MOFEP.

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LITERATURE CITED

Brookshire, B.L.; Hauser, C. 1993. The Missouri Ozark Forest Ecosystem Project. In: Gillespie, Andrew; Parker, George R.; Pope, Phillip E.; Rink, George, eds. Proceedings, 9th Central hardwood forest conference; 1993 March 8-10; West Lafayette, IN. Gen. Tech. Rep. NC-161. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 289-307.

Brookshire, B.L.; Jensen, R.G.; 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 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: 1-25.

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.

Brookshire, B.L.; Dey, D.C. 2000. Establishment and data collection of vegetation-related studies on the Missouri Ozark Forest Ecosystem Project study 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: 1-18.

Cajander, A.K. 1926. The theory of forest types. Actaea Forestalia Fennica. 29: 1-108.

Crawford, H.S. 1971. Wildlife habitat changes after intermediate cutting for even-aged oak management. Journal of Wildlife Management. 35(2): 275-285.

Crawford, H.S. 1976. Relationships between forest cutting and understory vegetation: an overview of eastern hardwood stands. Res. Pap. NE-349. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 9 p.

Crawford, H.S.; Harrison, W.M. 1971. Wildlife food on three Ozark hardwood sites after regeneration cutting. Journal of Wildlife Management. 35(3): 533-537.

Daubenmire, R. 1976. The use of vegetation in assessing the productivity of forest lands. Botanical Review. 115-143.

Grabner, Jennifer K.; Larsen, David R.; Kabrick, John M. 1997. An analysis of MOFEP ground flora: pre-treatment conditions. In: Brookshire, Brian L.; Shifley, Stephen R., eds. 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: 169-197.

Grabner, Jennifer 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.

Kabrick, J.M.; Larsen, D.; Shifley, S. 1997. Analysis of MOFEP woody vegetation and environmental data. In: Brookshire, Brian L.; Shifley, Stephen R., eds. 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: 150-168.

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 Forest Experiment Station: 41-70.

Kabrick, J.M.; Jensen, R.G.; Larsen, D.R.; Shifley, S.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.

Kurzejeski, E.W.; Clawson, R.L.; Renken, R.B.; Sheriff, S.L.; Vangilder, L.D.; Hauser, C; Faaborg, J. 1993. Experimental evaluation of forest management: the Missouri Ozark Forest Ecosystem Project. In: Transactions of the 58th N.A. Wildlife and Natural Resources Conference: 599-609.

Law, Jay R.; Lorimer, Craig 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: Note 6.08: 1-6.

Meinert, D. 1998. Soil-geo-landform relationships and the Lower Ozarks Project (Chilton Creek). Technical report prepared for The Missouri Chapter of The Nature Conservancy.

Meinert, D. 2001. Soils of the Missouri Ozark Forest Ecosystem Project. Technical report prepared for the Missouri Department of Conservation.

Meinert, D.; Nigh, T.; Kabrick, J. 1997. Landforms, geology, and soils of the MOFEP study area. In: Brookshire, Brian L.; Shifley, Stephen R., eds. 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: 56-68.

Missouri Department of Conservation. 1986. Forest management guidelines. Missouri Department of Conservation. 81 p.

Murphy, D.A.; Crawford, H.S. 1970. Wildlife foods and understory vegetation in Missouri's national forests. Tech. Bull. 4. Jefferson City, MO: Missouri Department of Conservation. 47 p.

Nigh, T.; Buck, C.E.; Grabner, J.K.; Kabrick, J.M.; Meinert, D. 2000. An ecological classification system for the Current River Hills Subsection. Draft field manual, Missouri Department of Conservation.

Rowe, J.S. 1956. Uses of undergrowth plant species in forestry. Ecology. 37(3): 461-473.

Sheriff, S.L.; He, Z. 1997. The experimental design of the Missouri Ozark Forest Ecosystem Project. In: Brookshire, Brian L.; Shifley, Stephen R., eds. 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: 26-40.

Sheriff, S.L. 2002. Missouri Ozark Forest Ecosystem Project: The experiment. In: Kabrick, John M.; Shifley, Stephen R., eds. Proceedings of the Second Missouri Ozark Forest Ecosystem Project Symposium: Post-treatment results of the landscape experiment; 2000 October 16-20; St. Louis, MO. Gen. Tech. Rep. NC-227. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 1-25.

Shifley, S.R.; Brookshire, B.L.; Larsen, D.R.; Herbeck, L.A.; Jensen, R.G. 1997. Snags and down wood on upland oak sites in the Missouri Ozark Forest Ecosystem Project. In: Brookshire, Brian L.; Shifley, Stephen R., eds. 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: 248-256.

Steyermark, J.A. 1963. Flora of Missouri. Ames, IA: The Iowa State University Press. 1,728 p.

Unger, Irene M. 1994. The effects of clear-cut logging on the herbaceous community of a Missouri deciduous forest. Columbia, MO: University of Missouri. 81 p. M.S. thesis.

Wiens, J.A. 1989. Spatial scaling in ecology. Functional Ecology. 3: 385-397.