Synthesis and Integration of Pre-treatment Results from the Missouri Ozark Forest Ecosystem Project

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Abstract.—Integrating results across disciplines is a critical component of ecosystem management and research. The common research sites, landscape-scale experimental design, and breadth of research subjects in Missouri Ozark Forest Ecosystem Project provide circumstances conducive for addressing multidisciplinary questions. Our objectives were to (1) summarize the treatment and block effects for pre-treatment studies, (2) identify potential relationships among taxa at different scales by comparing site and ecological landtype (ELT) patterns of diversity and relative abundance, and (3) explore abundance patterns of taxa across year of Missouri Department of Conservation land acquisition classes. We found few pre-treatment effects, but block 3 frequently was different from blocks 1 and 2. Many potential interactions were identified, most of which were between species from different taxonomic groups. Our results suggest that many relationships within an ecosystem are apparent only among species at fine spatial scales. Future analyses will include use of multivariate and spatially explicit models.

A distinct advantage of adopting a multidisciplinary experimental approach to studying the effects of forest management practices on ecosystem sustainability is the opportunity for integration. The Missouri Ozark Forest Ecosystem Project (MOFEP) includes more than 15 individual research studies that are conducted within the same nine experimental sites during the same time period (Brookshire *et al.* 1997). These studies focus on biotic and abiotic characteristics of the ecosystem, and all projects include both pre-and post-treatment data collection to evaluate the effects of three different forest management treatments on the organisms or elements of interest (Sheriff and He 1997). The common research sites, landscape-scale experimental design, and breadth of research subjects in MOFEP provide an ideal opportunity for integrating research results across disciplines, a critical component of ecosystem management (Christensen *et al.* 1996, Ehrlich 1986, Jones and Lawton 1995, Larsen *et al.* 1997).

Traditional management strategies have emphasized control of single groups of organisms such as forest trees, migratory birds, and game species (Christensen *et al.* 1996), but the current shift to ecosystem management, which emphasizes long-term sustainability of ecosystem diversity and function, has prompted research on the effects of management protocols on all aspects of an ecosystem, both physical and biological (Brookshire *et al.* 1997, Franklin 1996, Kurzejeski *et al.* 1993, Levin 1992). As with the analysis of any complicated biological community, results from research on isolated parts of a system are not ecologically independent and may not completely reflect the ecosystem as a whole. Synthesis of results from research on different parts of the Ozark forest ecosystem provides an assessment of the MOFEP experimental design and, eventually, will lead to development of a model depicting the effects of the treatments on an intact ecosystem. Incorporated in this ecosystem model will be numerous relationships among biotic and abiotic elements that control ecosystem diversity and function, the ultimate goal of long-term ecosystem sustainability (Christensen *et al.* 1996).

Determining the appropriate scale of analysis is a primary question in synthesizing MOFEP research results and identifying potential

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interactions (Shifley *et al.* 1995). The major experimental scale of MOFEP is the site (Sheriff and He 1997), stratified by ecological landtype (ELT; Miller 1981). MOFEP includes nine sites that comprise three replicates in a randomized complete block design with three treatments (Brookshire and Hauser 1993, Sheriff and He 1997). Combined data from the pre-treatment phase of the project provide an opportunity to characterize differences and general trends among sites. Although MOFEP is designed to test hypotheses at the landscape level, it may be necessary to evaluate data at finer scales to identify potential multidisciplinary interactions that are important in maintaining ecosystem integrity.

Many factors may contribute to variation across sites. Because recent studies have shown that land-use history can influence modern forest characteristics (Foster 1992, Orwig and Abrams 1994), we include a preliminary examination of this factor in this paper. All the sites in MOFEP are owned by the Missouri Department of Conservation (MDC), but various sites were purchased at different times between 1925 and 1952 (MDC, personal communication). Under MDC, sites were managed for forests (Cunningham and Hauser 1989). Land use of each site prior to MDC acquisition included logging disturbance, fire suppression, and grazing, but the precise land-use history is unknown. For the purposes of this study, we use year of acquisition by MDC as an indicator of recent land-use history. Because two MOFEP studies found significant differences due to land-use history (Marquis and Le Corff 1997, Sork *et al.* 1997), we evaluated associations among abundance patterns of taxa across year of land acquisition classes.

Within the MOFEP experimental design, pre-treatment data have been collected on the distribution and abundance of a wide variety of organisms and environmental characteristics. Our objectives are to (1) summarize the treatment and block effects for pre-treatment studies, (2) identify potential relationships among taxa at different scales by comparing site and ELT patterns of diversity and relative abundance, and (3) explore abundance patterns of taxa across year of MDC land acquisition classes.

METHODS

Data for this paper were obtained from 12 investigations presented at the 1997 MOFEP Symposium (for details on data collection, see the individual papers in this volume), including studies of woody plant genetic structure, snags and down wood, berry-producing plants, acorn production, surface soils, and seven studies of taxonomic groups at various levels (woody vegetation, ground flora, small mammals, leaf-chewing insects, forest interior birds, herpetofauna, and *Armillaria* distribution). When necessary, we calculated site and ELT-level summary statistics from additional data provided by investigators.

We compiled a summary of pre-treatment Analysis of Variance (ANOVA) results found in 12 MOFEP investigations to present treatment and block effects. We summarized the main effects of treatment and block and their interactions assigning significance at $P < 0.1$. From each study, we included density or abundance, diversity, species richness, and genetic inbreeding coefficient F_{IS} as dependent variables, based on the variables reported by the investigators. The woody vegetation study (Kabrick *et al.* 1997) reported results for multiple measures of density and volume. To avoid counting these highly correlated variables, we included only results for density (number of trees per acre). Similarly, Sork *et al.* (1997) reported results for six measures of woody plant genetic structure, but, for the three species studied, we included only one measure of genetic diversity (expected heterozygosity H_E) and a measure of inbreeding (F_{IS}).

To identify general trends among study sites, we analyzed variation in species richness and density or relative abundance of five taxonomic groups (woody vegetation, ground flora, small mammals, herpetofauna, and forest interior birds) among sites with one-way ANOVA. We also tested for site differences in mean plot diversity (Simpson's diversity index or genetic diversity as measured by expected heterozygosity H_E) with ground flora, woody vegetation, small mammals, herpetofauna, and H_E of three tree species. We performed correlation analyses between taxonomic groups to look for similar abundance patterns across sites. Because individual species within a taxonomic group may exhibit different abundance patterns among sites, we analyzed variation among sites in density/relative abundance of 24 individual species from seven different taxonomic groups (see Appendix A) with one-way ANOVA.

To identify potential interactions among individual species, we performed correlation analyses on density or relative abundance of 24 species from seven different taxonomic groups by site and of 17 species from five taxonomic groups (see Appendix A) by site stratified by ELT (only including the most common ELT's, south- and west-facing slopes or ELT 17 and north- and east-facing slopes or ELT 18). To illustrate patterns among both taxonomic groups and species, we present some of the results in scatter plots.

Patterns among taxonomic groups also were correlated across year of MDC acquisition to explore the potential effect of land-use history on taxa abundance patterns. The experimental sites were acquired over a 28-year period; site 6 was purchased in 1925, sites 3, 4, and 5 in 1938, sites 1 and 2 in 1944, and sites 7, 8, and 9 (which make up replicate block 3) in 1952 (MDC, personal communication). We analyzed data on ground flora, woody vegetation, small mammals, herpetofauna relative abundance, and genetic inbreeding coefficient F_{IS} for three tree species. Because we have only four classes of land-use history, we use the correlations to detect trends. Differences among sites in geology and soil characteristics also confound interpretation of the effects of land-use history on species abundance and distribution. To illustrate the patterns with year of MDC acquisition, we present some of the results in histograms.

RESULTS

Treatment and Block Effects

Treatment main effects only were reported for three of 57 variables from 10 studies, including *Rubus enslenii* abundance (Fantz and Hamilton 1997), ground flora species richness (Grabner *et al.* 1997), and density of the moth caterpillar *Dichomeris ligulella* on white oak (*Quercus alba*) (Marquis and Le Corff 1997). Fantz and Hamilton (1997) and Grabner *et al.* (1997) found that sites assigned to even-aged treatment were different from sites assigned to uneven-aged and unmanaged treatments for *Rubus enslenii* and ground flora species richness, whereas Marquis and Le Corff (1997) found that sites assigned to uneven-aged treatment were different for *Dichomeris ligulella*. Investigators found treatment interaction effects for two variables. Acorn production and density of the moth caterpillar *Telphusa latifasciella* on white oak showed significant treatment interaction effects with year and year by ELT, respectively (Marquis and Le Corff 1997, Vangilder 1997).

Twelve studies tested data for block effects (table 1). Summarizing results from these studies, we found a significant block main effect for 19 of 57 variables, with block 3 different from blocks 1 and 2 in 13 of these cases. Although 38 variables did not exhibit significant block effects, eight of these variables had significant block interaction effects (see individual papers mentioned in table 1 for interaction terms).

Diversity and Abundance Patterns Among Sites

We did not find a general trend among sites for species richness (ANOVA, $F_{8,36} = 0.1$, $P = 0.99$; fig. 1a) or diversity (ANOVA, $F_{8,54} = 0.2$, $P = 0.99$; fig. 1b); in fact, within a taxonomic group, differences among sites were uncommon. We also did not find a general trend among sites for density/abundance of taxonomic group species (ANOVA, $F_{8,27} = 0.1$, $P = 0.99$; fig. 1c), but select taxonomic groups showed variability among sites. Ground flora and herpetofauna were negatively correlated (Pearson's $r_7 = -0.71$, $P < 0.05$), indicating a potential relationship between ground flora cover and abundance of reptiles and amphibians.

The 24 species examined did not exhibit a common abundance pattern among sites (ANOVA, $F_{8,207} = 0.2$, $P = 0.99$), but we found 25 significant correlations between species pairs. At $P < 0.05$, we would expect by chance to find only 14 significant correlations with 276 pairwise tests. The significant correlations, 20 of which were between species from different taxonomic groups, represent potential interactions between species that may warrant further investigation. For example, shortleaf pine (*Pinus echinata*) and wood thrush (*Hylocichla mustelina*) density were positively correlated

Table 1.—*Summary of block effects across 12 MOFEP investigations. (Note: The sampling and design of the ANOVAs differed across investigations, but all included a block main effect.)*

MOFEP Investigation	Block main effect SIG	Block main effect NS	3 different from 1 & 2	2 different from 1 & 3	1 different from 2 & 3	Source of data (this volume)
Woody vegetation						Kabrick *et al.*
Total tree density	x		x			
Quercus alba density	x		x			
Quercus coccinea density		x				
Quercus velutina density	x			x		
Pinus echinata density		x				
Woody plant genetic structure						Sork *et al.*
Carya tomentosa H_E		x				
Quercus alba H_E		x				
Sassafras albidum H_E	x				x[1]	
C. tomentosa F_{IS}		x				
Q. alba F_{IS}		x				
S. albidum F_{IS}	x		x[2]			
Ground flora						Grabner *et al.*
Species richness		x				
Diversity		x				
Snags and down wood						Shifley *et al.*
Snag abundance		x				
Down wood abundance		x				
Armillaria distribution						Bruhn et al.
A. gallica abundance	x		x			
A. mellea abundance	x		x			
Oak leaf-chewing insects						Marquis & Le Corff
Insect density on *Q. alba* [3]		x				
Insect density on *Q. velutina*		x				
Lithophane antennata on *Q. alba*	x			x		
Chionodes sp. on *Q. alba*		x				
Telphusa latifasciella on *Q. alba*		x				
Spargonothis pettitana on *Q. alba*		x				
Dichomeris ligulella on *Q. alba* [3]	x			x		
Chionodes sp. on *Q. velutina*		x				
Telphusa latifasciella on *Q. velutina* [3]		x				
Tortricidae sp. on *Q. velutina*	x			x		
Spargonothis pettitana on *Q. velutina*		x				
Dichomeris ligulella on *Q. velutina* [3]	x		x			
Forest interior birds						Clawson *et al.*
Ovenbird density	x		x			
Worm-eating warbler density	x		x			
Kentucky warbler density		x				
Wood thrush density		x				

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MOFEP Investigation	Block main effect SIG	NS	3 different from 1 & 2	2 different from 1 & 3	1 different from 2 & 3	Source of data (this volume)
Acadian flycatcher density [3]		x				
Small mammals						Fantz & Renken
Species richness		x				
Total mammal abundance		x				
Peromyscus sp. abundance [3]		x				
Herpetofaunal community						Renken
Species richness		x				
Total amphibian and reptile abundance [3]		x				
Surface soils						Spratt
Carbon in A-horizon soil		x				
Total sulfur in A-horizon soil		x				
Organic sulfur in A-horizon soil		x				
Organic sulfur production	x		x			
Cellulose mineralization rate	x				x	
Lignin mineralization		x				
Exchangeable potassium		x				
Exchangeable magnesium	x		x			
Berry-producing plants						Fantz & Hamilton
Vaccinium arboreum abundance	x		x			
V. stamineum abundance	x		x			
V. vacillans abundance		x				
Rubus occidentalis abundance		x				
R. pensilvanicus abundance		x				
R. flagellaris abundance		x				
R. enslenii abundance		x				
Acorn production						Vangilder
Acorn density [3]		x				
Oak tree diameter at breast height (d.b.h.)		x				
Oak tree canopy area	x		x			
Totals	19	38	13	4	2	

[1] Block 1 > 2 but 1 = 3 and 2 = 3
[2] Block 3 > 1 but 1 = 2 and 2 = 3.
[3] Significant block interaction effect.

(Pearson's r_7 = 0.84, $P < 0.05$; fig. 2a), and sassafras (*Sassafras albidum*) relative abundance was negatively correlated with spotted salamander (*Ambystoma maculatum*) relative abundance (Pearson's r_7 = -0.85, $P < 0.05$; fig. 2a).

Stratifying site by ELT, we found six significant correlations in 136 pairwise tests on ELT 17 (south- and west-facing slopes), including negative relationships between shortleaf pine density and sassafras genetic inbreeding coefficient F_{IS} (Pearson's r_7 = -0.81, $P < 0.05$; fig. 2b), and smooth earth snake (*Virginia valeriae*) relative abundance and white oak density (Pearson's r_7 = -0.79, $P < 0.05$; fig. 2b). On ELT 18 (north- and east-facing slopes), we also found six significant correlations in 136 pairwise tests, but none of the significant correlations were between the same species as in ELT 17. For example, sassafras relative abundance was positively correlated with ground skink

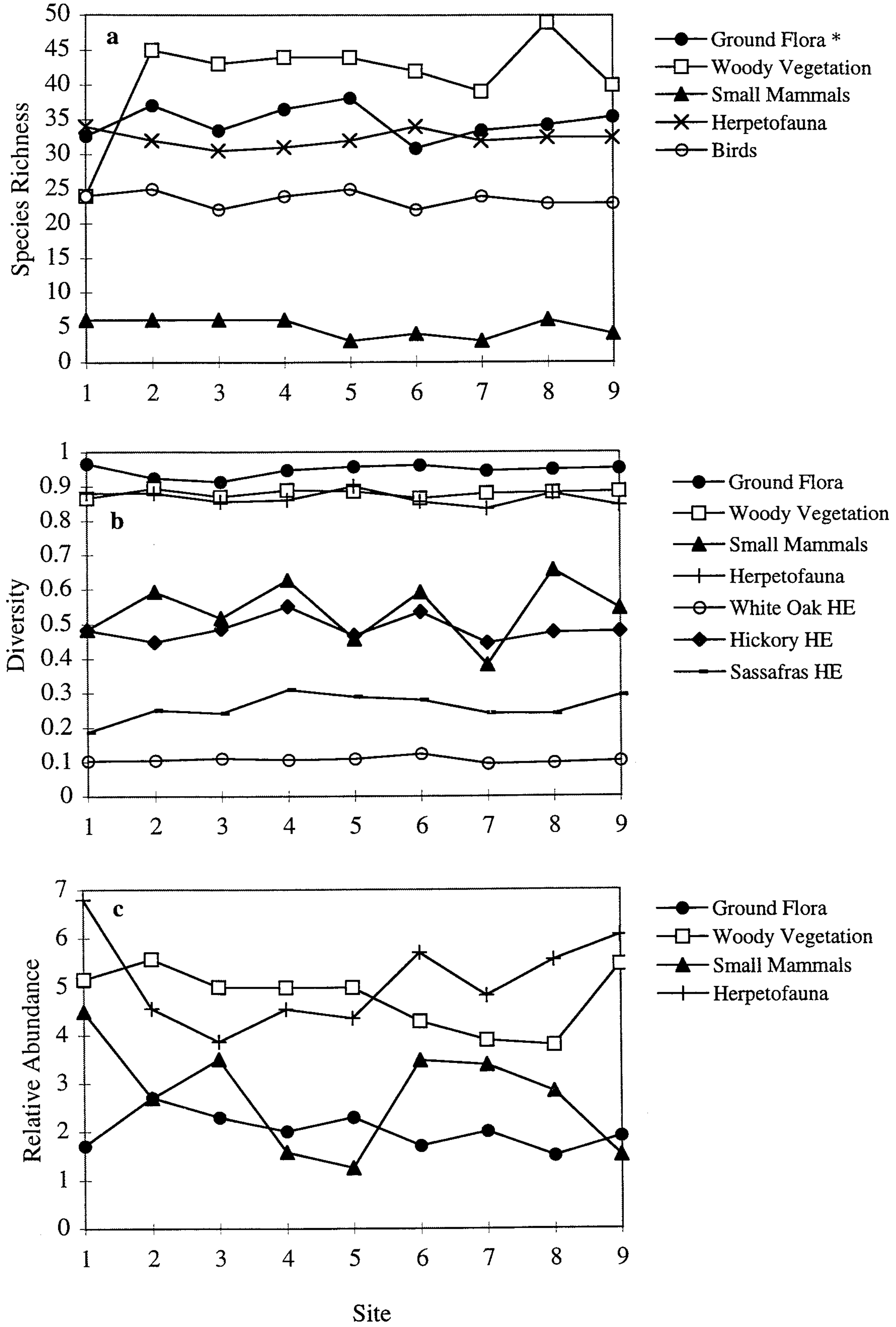

Figure 1.—*Scatter plots of (a) species richness, (b) diversity using Simpson's diversity index, and (c) relative abundance in each experimental site for select taxa. Points are connected only to visually discern patterns among sites and taxa.*
** species richness x 0.1.*

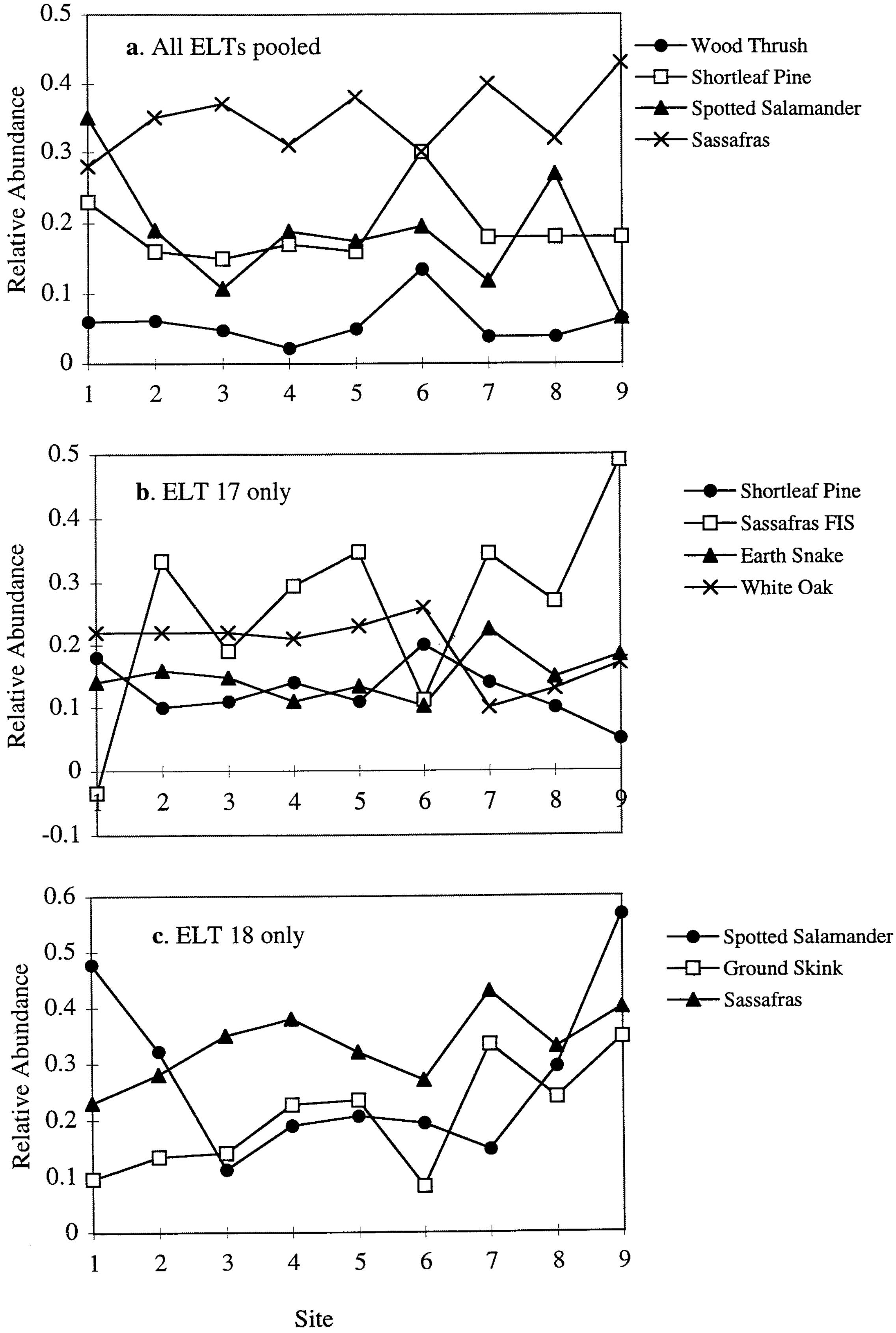

Figure 2.—*Scatter plots of relative abundance in each experimental site (a) for all ELTs combined, (b) for ELT 17, and (c) for ELT 18 for select species from individual MOFEP studies. Points are connected only to visually discern patterns among sites and taxa.*

(*Scincella lateralis*) relative abundance (Pearson's $r_7 = 0.87$, $P < 0.05$; fig. 2c) and negatively correlated with spotted salamander relative abundance (Pearson's $r_7 = -0.78$, $P < 0.05$; fig. 2c). In ELT 17 and 18, five and four, respectively, of the six significant correlations were between species from different taxonomic groups. Furthermore, many of the significant correlations found in ELT 17 and 18 were not significant at the overall site level (three correlations from ELT 17 and none from ELT 18 were significant at the site level).

Patterns by Year of Land Acquisition by MDC

We found high correlations (Pearson's $r > 0.85$) between six groups, but two correlations were particularly noteworthy. Woody vegetation density was strongly correlated with ground flora cover (Pearson's $r_2 = 0.95$, $P < 0.05$; fig. 3), and woody vegetation was negatively correlated with sassafras inbreeding coefficient F_{IS} (Pearson's $r_2 = -0.99$, $P < 0.05$; see also Sork *et al.* 1997). In general, species that were significantly correlated in patterns of density/abundance by site were also correlated by year of acquisition by MDC.

DISCUSSION

Synthesis of the MOFEP results indicated that treatment class was rarely a significant main effect in the pre-treatment data. These findings will facilitate interpretation of the effects of each management protocol although the pre- versus post-treatment analyses planned in the MOFEP experimental design do not require treatment class similarity prior to treatment. Because the MOFEP randomized block design has low statistical power (high probability of Type II error) due to only three replicates of each treatment class, it may have been difficult to detect statistical differences among treatments (Sheriff and He 1997). It is unlikely that studies that found similar means among pre-treatment classes were affected by low statistical power. Studies that showed apparently different means among pre-treatment classes that were not statistically different, however, may be suffering from Type II error (not rejecting a null hypothesis when it is false). In reviewing the investigations included in this paper, we found that some studies clearly did not have pre-treatment differences and other studies may have had pre-treatment differences that were not detectable statistically because of high variance around sampling means and low statistical power.

Given the scale of the MOFEP project, further replication of sites is not feasible. However, we can reduce some problems associated with low replication by increasing sampling within sites

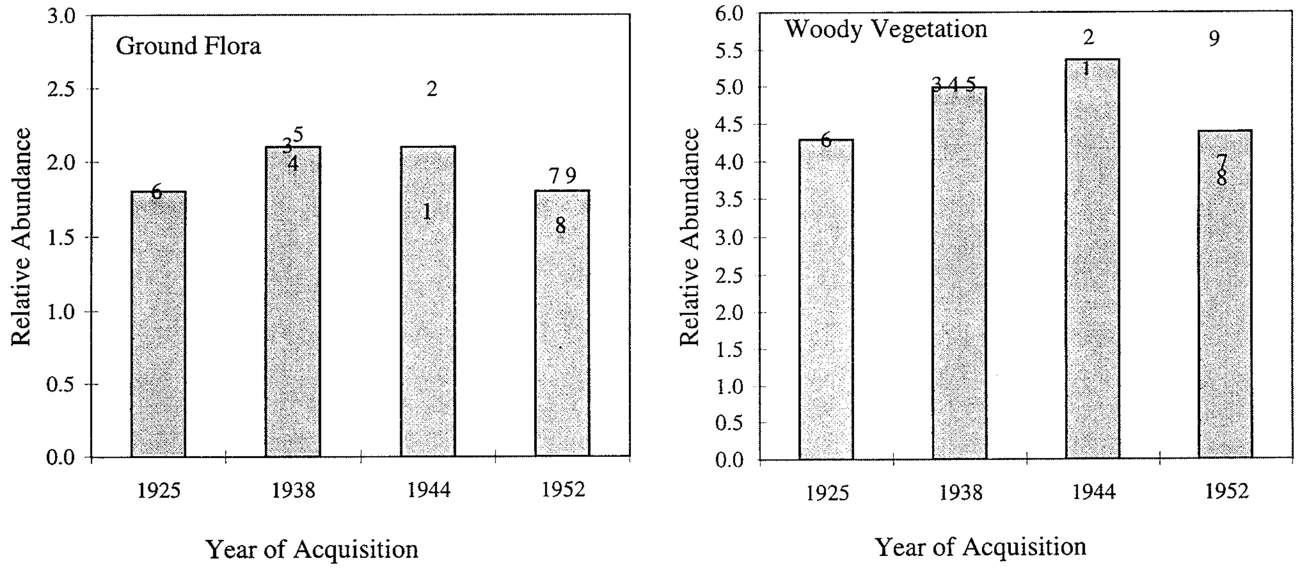

Figure 3.—*Mean relative abundance of ground flora and woody vegetation in sites with different years of acquisition by the Missouri Department of Conservation. Site 6 was purchased in 1925, sites 3, 4, and 5 in 1938, sites 1 and 2 in 1944, and sites 7, 8, and 9 (which make up replicate block 3) in 1952. Numbers near bars indicate the mean of the corresponding site.*

for individual investigations within the framework of the universal randomized block design (e.g., sample more leaves per tree, more trees per plot, or more plots per site). For example, Marquis and Le Corff (1997), before determining their sampling protocol, statistically evaluated the sample sizes necessary to adequately estimate the mean and variance in insect density. Retrospective power analyses or calculation of confidence intervals (Steidl *et al.* 1997) for pretreatment studies also would facilitate statistical evaluation of the sampling design of each investigation and may suggest sampling changes that would increase statistical power during future phases of the project.

Differences among blocks were found in a third of the studies, with block 3 most commonly different from blocks 1 and 2. Geographically, block 3 is located south of blocks 1 and 2 in the Peck Ranch Wildlife Area, and the three sites in block 3 were acquired by MDC after all other sites were acquired. Blocks 1 and 2, on the other hand, are adjacent to each other in Carr Creek and Cardareva State Forests (block 1) and Cardareva, Paint Rock and Deer Run State Forests (block 2); sites 3 and 4 are continuous yet located in different blocks. It is not clear that variability among sites is smaller within blocks 1 and 2 than within different blocks, suggesting that the blocking groups may not be optimal (see also Kabrick *et al.* 1997, Shifley *et al.* 1997). Two sites in block 3 (sites 7 and 8) are sharply different from all other sites in soil texture, stoniness, subsoil acidity, and geological strata (Kabrick *et al.* 1997). Sites 7 and 8 also have longer and less steep slopes than other sites (Meinert *et al.* 1997). The distinct geographical and physical characteristics of sites 7 and 8 may account for the dominant block effect in MOFEP studies. Thus, some results indicate that a different blocking design might have been preferable, but that overall, the randomized block experimental design and the assignment of blocks is satisfactory.

We did not find differences among sites for pretreatment patterns of species richness and diversity within most taxonomic groups, preventing detection of interactions among taxonomic groups. Because taxonomic groups consist of ecologically different species, it is likely that community-level measures, such as species richness and diversity, conceal relationships among individual species. When comparing density/relative abundance, however, we found differences among sites within taxonomic groups and for individual species, but we did not find a general trend across sites. Variability across sites detected in density/abundance measures suggests that these measures may best illustrate interactions among ecosystem elements. We detected few potential relationships among taxonomic groups, except between ground flora cover and herpetofauna relative abundance. When comparing patterns of species' density/abundance, we identified 25 potential interactions and 80 percent of these interactions were between species from different taxonomic groups. Direct and indirect interactions are usually species-dependent, and our results suggest that it is necessary to look at the species level to identify these potential interactions. The predominance of intertaxa correlations confirms the importance of integrating data among taxa because it is likely that some of these relationships influence widespread ecosystem processes.

When we stratified site by ELT, we found additional relationships among species that may be apparent only on an ecologically fine scale. It is particularly notable that few of the significant correlations identified on the site level existed when site was stratified by ELT. In addition, correlations between organisms on ELT 17 were not found on ELT 18. The most appropriate scale for determining potential interactions is probably dependent on the size, ecological constraints, and mobility of the species or elements of interest. In general, plants may be more closely associated with an ELT than animals, and specialist herbivorous insects may be more dependent on a specific ELT (which contains its host plant) than insectivorous birds. Furthermore, relationships among organisms can vary in different landscapes, vertically in the forest, by time, or by season, indicating that stratification may be necessary to reveal the scope of interactions present in an ecosystem. For example, oak herbivores vary extensively in species presence and density among months (Marquis and Le Corff 1997). A more complete understanding of ecosystem processes will develop from an increased awareness of many small-scale interactions that, when combined with other interactions, explain the more complex, multivariate interactions.

Land-use history is an example of a factor that may influence patterns of species distribution and abundance (Foster 1992, Orwig and Abrams 1994). Unfortunately, unequal sample sizes among year of acquisition classes and the confounding effects of geological and soil differences make it difficult to attribute any specific association directly to land-use history. Nonetheless, we found a statistically significant correlation between ground flora cover and woody vegetation density when compared by year of acquisition that was not evident when compared by site alone. These results suggest that patterns of species succession in plant communities may be directly related to land-use history. MOFEP investigators of tree genetic structure and oak herbivore communities found statistically significant patterns by year of MDC acquisition in their data analyses (Marquis and Le Corff 1997, Sork *et al.* 1997). Notably, the patterns among the studies that examined the relation of year of acquisition were different, suggesting that land-use history may have dissimilar effects on current patterns of diversity, abundance, and genetic structure of different species. Although these results are not conclusive, they do suggest that land-use history is a factor worth considering in future analyses.

Patterns we have identified in this preliminary analysis of the pre-treatment data may represent direct interactions among species, indirect interactions that are mediated by unknown factors, or spurious relationships that have no ecological significance. Some relationships appear ecologically plausible, such as the inverse relationship between ground flora cover and herpetofauna relative abundance, whereas other interactions are less likely to be ecologically significant, such as the positive correlation between wood thrush and shortleaf pine density. Indirect interactions often are the most difficult to recognize and may require extensive investigation to uncover the mediating factors. Our next step is to further evaluate potential relationships among species with spatially explicit statistical analyses and modeling. By using geographic information systems (GIS) and geostatistic tools, we plan to address questions focused on the spatial dependence of different organisms within the MOFEP landscape relative to different ecosystem attributes such as soil characteristics and geo-landform properties (Cressie 1993, Goodchild *et al.* 1993). With information about relationships among species and environmental characteristics at different spatial scales, we can build on existing landscape-level models that involve simulation over time of ecological attributes related to the location and configuration of specific areas (Baker 1989, Sklar and Costanza 1991). For example, investigators have used various habitat suitability models (e.g., cartographic and Bayesian models) to predict species abundance, herbivory effects, and lek sites relative to elevation, water resources, and vegetation type (Hyman *et al.* 1991, Milne *et al.* 1989, Nisbet and Reed 1983). We will also rely on multivariate regression and correlation analyses to identify interactions that may not be spatially dependent. Thus, our future goals involve integrating the MOFEP data to create predictive models of ecosystem processes.

To fully integrate components of the Ozark forest ecosystem, multidisciplinary studies are necessary to address questions about the effects of disturbance on ecosystem integrity and the specific interactions that maintain various ecosystem functions. It is very likely that these multidisciplinary studies will identify critical components of the ecosystem that individual studies do not find, particularly for processes that affect more than one trophic level. As we gain more information about the parts of an ecosystem, we will be better equipped to put the parts together to understand the complexities of ecosystems as a unit, and, thus the impacts of management on the functioning of these ecosystems.

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Appendix A.—*List of species (and their taxonomic groups) used in species correlation analyses*

Armillaria Distribution
Armillaria gallica
A. mellea

Woody Vegetation
Quercus alba (white oak)
Q. velutina (black oak)
Q. coccinea (scarlet oak)
Pinus echinata (shortleaf pine)

Forest Interior Birds[1]
Seiurus aurocapillus (ovenbird)
Helmitheros vermivorous (worm-eating warbler)
Oporornis formosus (Kentucky warbler)
Hylocichla mustelina (wood thrush)
Empidonax virescens (Acadian flycatcher)

Woody Plant Genetic Structure
Carya tomentosa F_{IS} (mockernut hickory genetic inbreeding coefficient)
Quercus alba F_{IS} (white oak genetic inbreeding coefficient)
Sassafras albidum F_{IS} (sassafras genetic inbreeding coefficient)

Small Mammals[1]
Peromyscus maniculatus (deer mouse)
P. leucopus (white-footed mouse)

Herpetofauna
Ambystoma maculatum (spotted salamander)
Bufo americanus (American toad)
Scincella lateralis (ground skink)
Virginia valeriae (smooth earth snake)

Ground Flora
Cornus florida (flowering dogwood)
Desmodium nudiflorum (tick trefoil)
Sassafras albidum (sassafras)
Vitis aestivalis (summer grape)

[1] Groups of species not included in the correlation by site stratified by Ecological Landtype (ELT).