Short-term Responses of the Small Mammal Communities to Forest Management Within Missouri Ozark Forest Ecosystem Project Sites

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Abstract.—We conducted a capture-recapture study on the northeast-facing slopes of the MOFEP sites in south central Missouri to determine the initial effects of even- and uneven-aged forest management on species composition, species richness, and relative abundance of the small mammal communities. We compared changes between pre-treatment (1994-1995) and post-treatment (1998-2000) measures. Species richness ranged from two to six species per site across years; eight different species were caught across all nine sites and years. Overall small mammal relative abundance estimates ranged from 0.23 to 7.75 individuals captured per 100 trap nights per site across years. Qualitative and quantitative evaluations indicate that forest management had no short-term effect on species composition or species richness, but did have an effect upon total small mammal relative abundance 2, 3, and 4 years after harvest. Even-aged management, and uneven-aged management to a lesser extent, appeared to have dampened a natural decline in small mammal relative abundance that was observed on control sites. Relative abundance estimates on treated sites were slightly higher than those on control sites.

Interest in North American forests has evolved from one of exploitation, to managed timber harvests, to conservation of the forest ecosystem. With this increased interest in managing forests for wildlife as well as trees, and in managing for all animals, not just game, threatened, or endangered species, natural resource management agencies have found they need information about the effects of their silvicultural practices on wildlife communities. Small mammals are an important component of forest ecosystems. They are prey for a number of predators, disperse plant seeds and mycorrhizal fungi spores, consume significant amounts of insects, including pest species, aerate and mix the soil through tunneling activity, create refuge tunnels used by other wildlife, and add to the organic content of forest soils (Elkinton *et al.* 1996, Madison 1997, Maser *et al.* 1978, Spurr and Barnes 1980).

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Forest management changes the structure and composition of the forest, especially conventional clearcutting, which can drastically alter forest wildlife habitat. Several researchers have evaluated the initial effects of forest management, mainly clearcutting, on small mammal communities inhabiting North American coniferous and deciduous forests and have reported different results (Buckner and Shure 1985; Clough 1987; Gashwiler 1959, 1970; Hooven and Black 1976; Kirkland 1974, 1977, 1978; Kirkland *et al.* 1985; Krull 1970; Lovejoy 1975; Martell 1983; Martell and Radvanyi 1977; Monthey and Soutiere 1985; Probst and Rakstad 1987; Ramirez and Hornocker 1981; Steventon *et al.* 1998; Sullivan 1979; Sullivan and Sullivan 1982; Sullivan *et al.* 1999; Tevis 1956; Verme and Ozoga 1981; Von Trebra *et al.* 1998; Yahner 1992). These differences emphasize the importance of potential sources of variation, including forest type, population levels of individual species in surrounding forests, study design, site variation, and specific management practices, in the pattern of responses of small mammals to forest management (Clough 1987, Kirkland 1990).

A review of 21 published studies evaluating the initial responses (sites were clearcut 6 or fewer years before sampling) of small mammals to conventional clearcutting of temperate North American forests revealed a general pattern of positive responses in small mammal populations in both coniferous and deciduous forests (Kirkland 1990). There was an initial increase in overall relative abundance on recent clearcuts reported in 15 of 20 studies. The effect of cutting on species richness and species composition was more variable. Eight studies reported an initial increase in species richness after clearcutting, four studies reported a decrease, and five studies reported no change. Species composition provided a more detailed look at small mammal community responses than species richness. Researchers reported species caught in uncut forests but not in clearcuts (mean=2.0, range=1-4 species), species caught in clearcuts but not in uncut forests (mean=2.4, range=1-5 species), no appearance or disappearance of species after clearcutting, and the appearance of non-forest dwelling mammals (for example, *Zapus* spp. and *Microtus* spp.) on clearcut areas.

Many studies specifically addressed changes in *Peromyscus* spp. populations following logging. Most concluded that there are more deer mice (*Peromyscus maniculatus*) on logged areas compared with adjacent forested habitat (Ahlgren 1966; Gashwiler 1959, 1970; Hooven and Black 1976; Martell and Radvanyi 1977; Tevis 1956; Verme and Ozoga 1981; Yahner 1992). Only one known study examined the effects of even-aged forest management on white-footed mice (*Peromyscus leucopus*) in Midwest oak-hickory forests (Root *et al.* 1990). In that study, population trends were similar between clearcut and control areas, although clearcuts generally had greater numbers of white-footed mice.

The Missouri Ozark Forest Ecosystem Project (MOFEP), initiated in 1989, is a long-term scientific experiment designed to examine the effects of forest management practices (even- and uneven-aged management) on multiple ecosystem components of southern Missouri's oak-hickory (*Quercus* spp. - *Carya* spp.) forest (Brookshire *et al.* 1997, Sheriff and He 1997, Sheriff this proceedings). Nine approximately 400-ha study sites have been established in Reynolds, Carter, and Shannon Counties. Each site is a compartment, which is the Missouri Department of Conservation's basic forestry management unit (Missouri Department of Conservation 1986). Each compartment is a collection of smaller units (stands). These nine sites are grouped into three blocks that each contain a no-harvest (control), uneven-aged management, and even-aged management site.

Studies of the effects of forest management on wildlife communities typically examine responses at the forest stand level. The MOFEP experiment provides a unique opportunity to examine responses at the compartment and landscape levels. The long-term experiment also provides the opportunity to examine conditions of small mammal communities before treatment, rather than solely after treatment. This paper reports on the initial (2, 3, and 4 years after first-entry timber harvest) effects of even- and uneven-aged forest management on the species composition, species richness, and relative abundance of small mammal communities occupying northeast-facing slopes of the MOFEP sites.

METHODS

Study Design and Field Sampling

To characterize the MOFEP small mammal communities, we conducted a capture, mark, and recapture study. Trapping occurred during April and May of 1994-1995 (pre-treatment) and 1998-2000 (post-treatment) (table 1). No trapping occurred during timber harvest (1996) and slashing (which continued until June 1997). Trapping was not conducted during Missouri's annual spring firearms turkey season in late April.

We randomly selected two locations on northeast-facing slopes on each of the nine MOFEP sites. At each location, a 12 x 12 station trapping grid was constructed with 25 m between stations (7.56-ha grid, two grids per site). We sampled only on northeast-facing slopes because we believed these locations would contain more small mammals due to a moister environment when compared to southwest-facing slopes. We selected 7.56 ha as a grid size to fit upon available northeast-facing slopes and to attempt to maximize the number of available traps within a grid. Only two grids were sampled per site for several reasons. First, the number of northeast-facing slopes large enough to contain a 7.56-ha grid was limited on several sites. Secondly, we estimated that one person

Table 1.—*Trapping periods for small mammals on northeast-facing slopes of MOFEP sites, 1994-2000. No trapping occurred during timber harvest (1996) and slashing (which continued through June 1997).*

Year	Block 1	Block 2	Block 3
1994	06-12 April	04-10 May	18-24 May
1995	12-18 April	10-16 May	24-30 May
1996	no trapping		
1997	no trapping		
1998	07-13 April	05-11 May	20-26 May
1999	06-12 April	03-09 May	18-24 May
2000	03-09 April	08-14 May	22-28 May

could check, rebait, and reset all traps within two 7.56-ha grids within an average workday. Grids within each block were simultaneously sampled during a 6-night trapping period (six grids sampled during the same 6-night trapping period). One Sherman small mammal box trap (7.7 x 8.9 x 22.9 cm) baited with a mixture of peanut butter and rolled oats was placed at each station. Traps were checked for captured animals and rebaited once daily. Captured animals were identified to species, individually marked by toe-clipping (except eastern chipmunks (*Tamias striatus*) and eastern woodrats (*Neotoma floridana*) were individually marked with nontoxic, waterproof markers), and released at the point of capture. Traps were disinfected with a dilute (10%) chlorine bleach solution between trapping periods as a precautionary measure against possible exposure to hantavirus. Yunger and Randa (1999) reported that this type of trap disinfection has no adverse effect on trappability of small mammals. Additional details about the study design are presented in Fantz and Renken (1997).

Deer mice and white-footed mice both occur in southern Missouri, and field identification of live animals is difficult due to overlap in external morphological characteristics (Schwartz and Schwartz 1981). We conducted standard body length measurements (total length, tail length, hind foot length, and ear length) and used measurements reported in Schwartz and Schwartz (1981) to distinguish between the two species (table 2).

Sites received varying degrees of treatment in 1996-1997 (Sheriff this proceedings), and trapping grids on these sites were impacted differently by these treatments. On the three uneven-aged sites, 83 percent, 99 percent, and 100 percent of the grids were within treated areas. On the three even-aged sites, 0.01 percent, 17 percent, and 32 percent of the grids fell within a clearcut, and 0 percent, 3 percent, and 23 percent were impacted by intermediate cutting. No less than 359 m separated the two trapping grids on a site.

Table 2.—*Characteristics used to distinguish between* Peromyscus *spp. captured on northeast-facing slopes of the MOFEP sites*

Characteristic	Species: *Peromyscus maniculatus*	Species: *Peromyscus leucopus*
Tail	Sharply bicolored; Tuft at tip	Not sharply bicolored; More sparsely furred and scaly, without tuft at tip
Tail length	< 63 mm	63 mm or greater
Hind foot length	< 20 mm	20 mm or greater
Ear length	< 15 mm	15 mm or greater

Data Analysis

Differences in species composition, species richness, and relative abundance of small mammal communities among treatments and years were qualitatively and quantitatively evaluated. Including pre-treatment data in the analysis allowed us to incorporate pre-existing conditions into our understanding of animal responses to treatment. A pre-treatment analysis of the MOFEP small mammal communities was presented in Fantz and Renken (1997).

The short-term effects of forest management on species composition were qualitatively examined. We compared species occurrences in pre-treatment and post-treatment periods to determine if individual species were affected by treatment. Specifically, we looked for species that were captured during pre-treatment but were absent after treatments, or species that were not captured during pre-treatment but were caught following treatments.

Species richness within small mammal communities was defined as the number of species caught on a site within a year. To test for the effects of treatments on species richness, we compared the mean species richness change on control sites to the mean species richness change on treatment sites using a randomized complete block analysis of variance (ANOVA) model (SAS 1989). Mean species richness change was defined as the difference between the pre-treatment (1994/1995) mean species richness and post-treatment mean species richness for each site for 1998, 1999, and 2000 separately. We then used these difference values for each site in the ANOVA to evaluate treatment effects. The main effects in the ANOVA model were block and treatment, with the block*treatment interaction used as the error term. An alpha level of 0.1 was used because of the small sample size (n=9) in the experiment (Sheriff and He 1997).

Small mammal relative abundance was defined as the number of individuals (excluding recaptures) captured per grid per 100 trap nights. One trap night is defined as one trap open for one night. Relative abundance estimates for each grid were calculated by dividing the total number of individuals captured on that grid by the total number of trap nights per grid (864 trap nights). Relative abundance estimates were averaged by site for each year. To test for the effect of treatment on relative abundance, we compared the mean relative abundance change on control sites to the mean relative abundance change on treatment sites using a randomized complete block ANOVA model (SAS 1989). The main effects in the ANOVA model were block and treatment, with the block*treatment interaction used as the error term. An alpha level of 0.1 was used because of the small sample size (n=9) in the experiment (Sheriff and He 1997).

RESULTS

Eight species of small mammals were captured on northeast-facing slopes of the MOFEP sites during 1994-1995 and 1998-2000. One species was an insectivore (Elliot's short-tailed shrew, *Blarina hylophaga*), two were sciurid rodents, (eastern chipmunk; southern flying squirrel, *Glaucomys volans*), and the remaining five species were cricetid mice and rats (woodland vole, *Microtus pinetorum*; eastern woodrat; golden mouse, *Ochrotomys nuttalli*; white-footed mouse; deer mouse). Scientific and common names follow Schwartz and Schwartz (1981), except for Elliot's short-tailed shrew, which follows George *et al.* (1981, 1982).

The species trapped most often were the white-footed mouse and deer mouse. Both species were captured on most sites across years. White-footed mice represented between 37 and 54 percent of individuals (all species combined) captured on all nine sites across years, and deer mice were between 24 and 52 percent of individuals (all species combined) captured on all nine sites across years. Field identification of *Peromyscus* spp. is difficult, especially for juveniles, and these two species may be lumped in future analyses. Eastern chipmunks were the third most frequently captured species (between 1 and 13 percent of individuals captured on all nine sites across years). The remaining five species were sporadic captures across sites and years.

Even-aged and uneven-aged forest management had no short-term effect on the species composition of the small mammal community on northeast-facing slopes. Species composition by treatment type for pre-treatment years combined compared to post-treatment years combined did not change (table 3). Most species (Elliot's short-tailed shrew, golden mouse, white-footed mouse, deer mouse, eastern chipmunk) were trapped on all treatment types during both pre-treatment and post-treatment

Table 3.—*Small mammal species composition of northeast-facing slopes of MOFEP sites. A plus means the species was captured at least once on at least one site within that treatment type and sampling period, and a minus means it was not captured during sampling. Pre-treatment represents 1994-1995 combined, and post-treatment represents 1998-2000 combined. CON = control sites, UAM = uneven-aged management sites, EAM = even-aged management sites.*

Species	Pre-treatment			Post-treatment		
	CON	UAM	EAM	CON	UAM	EAM
Blarina hylophaga	+	+	+	+	+	+
Tamias striatus	+	+	+	+	+	+
Glaucomys volans	–	–	+	–	+	+
Microtus pinetorum	+	–	–	–	–	+
Neotoma floridana	+	+	+	–	+	+
Ochrotomys nuttalli	+	+	+	+	+	+
Peromyscus leucopus	+	+	+	+	+	+
Peromyscus maniculatus	+	+	+	+	+	+

Time period / Treatment

sampling. The exceptions were the eastern woodrat, woodland vole, and southern flying squirrel. Eastern woodrats were not captured on control sites during post-treatment, although they were still captured within harvested sites during post-treatment. Only two woodland voles and six southern flying squirrels were trapped across all years, so it's impossible to draw any conclusions about these two species.

Species richness estimates per site ranged from two to six species (table 4). The number of species on each site typically did not vary by more than one species between pre-treatment and post-treatment years. Species richness means by treatment type ranged from 3.0 to 4.7 (table 5). There were no treatment effects on species richness 2, 3, or 4 years after timber harvest (1998, $F_{2,4}$=0.75, MSE=1.75, P=0.53; 1999, $F_{2,4}$=1.13, MSE=3.58, P=0.41; 2000, $F_{2,4}$=1.70, MSE=3.86, P=0.29).

Overall small mammal mean relative abundance estimates per site ranged from 0.23 individuals per 100 trap nights to 7.75 individuals per 100 trap nights (table 6). Mean relative abundance

Table 4.—*Species richness estimates by site and year for small mammals inhabiting northeast-facing slopes of MOFEP sites*

Site	Pre-treatment		Post-treatment		
	1994	1995	1998	1999	2000
Control					
1	5	4	3	2	4
6	4	3	4	4	4
8	4	6	2	3	2
Uneven-aged management					
2	5	4	3	4	4
4	4	5	3	3	3
7	2	3	3	3	3
Even-aged management					
3	3	5	3	5	6
5	3	3	5	6	5
9	3	4	3	2	3

Table 5.—*Mean species richness estimates (standard error) by treatment type and trapping period for small mammals inhabiting the northeast-facing slopes of MOFEP sites. Pre-treatment represents the 1994/1995 mean.*

Treatment	Pre-treatment 1994/1995	Post-treatment 1998	1999	2000
Control	4.3 (0.4)	3.0 (0.6)	3.0 (0.6)	3.3 (0.7)
Uneven-aged	3.8 (0.7)	3.0 (0.0)	3.3 (0.3)	3.3 (0.3)
Even-aged	3.5 (0.3)	3.7 (0.7)	4.3 (1.2)	4.7 (0.9)

estimates by treatment type ranged from 0.73 to 3.95 (fig. 1). We observed treatment effects on mean relative abundance 2, 3, and 4 years after timber harvest (1998, $F_{2,4}$=4.21, MSE=2.17, P=0.10; 1999, $F_{2,4}$=6.20, MSE=15.96, P=0.06; 2000, $F_{2,4}$=9.07, MSE=5.71, P=0.03).

DISCUSSION

Treatment had no effect on species composition and species richness of the small mammal communities inhabiting the northeast-facing slopes of the MOFEP sites. White-footed mice, deer mice, and eastern chipmunks were annually caught on most sites. The remaining five species were sporadic, localized captures. Six additional small mammal species (least shrew, *Cryptotis parva*; southeastern shrew, *Sorex longirostris*; eastern mole, *Scalopus aquaticus*; hispid cotton rat, *Sigmodon hispidus*; prairie vole, *Microtus ochrogaster*; southern bog lemming, *Synaptomys cooperi*) have been caught in pitfall and funnel traps used for capturing amphibians and reptiles on MOFEP sites, but we believe that these species most likely will not be captured on the small mammal grids. The two shrews are often caught in pitfall traps but rarely caught in box traps, and the fossorial eastern mole is seldom captured in conventional small mammal traps. Hispid cotton rats, prairie voles, and southern bog lemmings prefer grassy areas (Schwartz and Schwartz 1981), and very few (four, seven, and five individuals, respectively) were captured. The most likely place and time to have captured these three species would have been on 1- to 2-year-old clearcuts when the ground flora was relatively more sparse.

Table 6.—*Mean relative abundance estimates (standard error) (individuals captured / 100 trap nights) by site and year for small mammals inhabiting northeast-facing slopes of the MOFEP sites*

Site	Pre-treatment 1994	1995	Post-treatment 1998	1999	2000
Control					
1	6.54 (0.06)	2.43 (0.81)	0.64 (0.06)	0.87 (0.41)	1.22 (0.52)
6	2.37 (0.29)	3.82 (1.04)	2.66 (0.46)	0.98 (0.29)	1.91 (0.17)
8	1.91 (0.17)	3.76 (1.33)	0.23 (0.23)	0.35 (0.12)	0.35 (0.00)
Uneven-aged management					
2	2.89 (0.81)	2.49 (1.56)	1.33 (0.29)	2.37 (0.41)	1.91 (0.87)
4	1.45 (0.06)	1.68 (0.64)	1.50 (0.35)	1.50 (0.12)	1.27 (0.23)
7	1.22 (0.29)	5.56 (1.62)	0.75 (0.41)	2.03 (0.06)	0.75 (0.17)
Even-aged management					
3	3.01 (0.35)	3.99 (1.22)	2.14 (0.87)	7.75 (4.17)	4.51 (2.08)
5	0.93 (0.35)	1.56 (0.64)	1.79 (0.52)	3.53 (3.07)	2.08 (0.46)
9	1.04 (0.00)	1.97 (1.04)	0.52 (0.17)	0.58 (0.23)	0.93 (0.23)

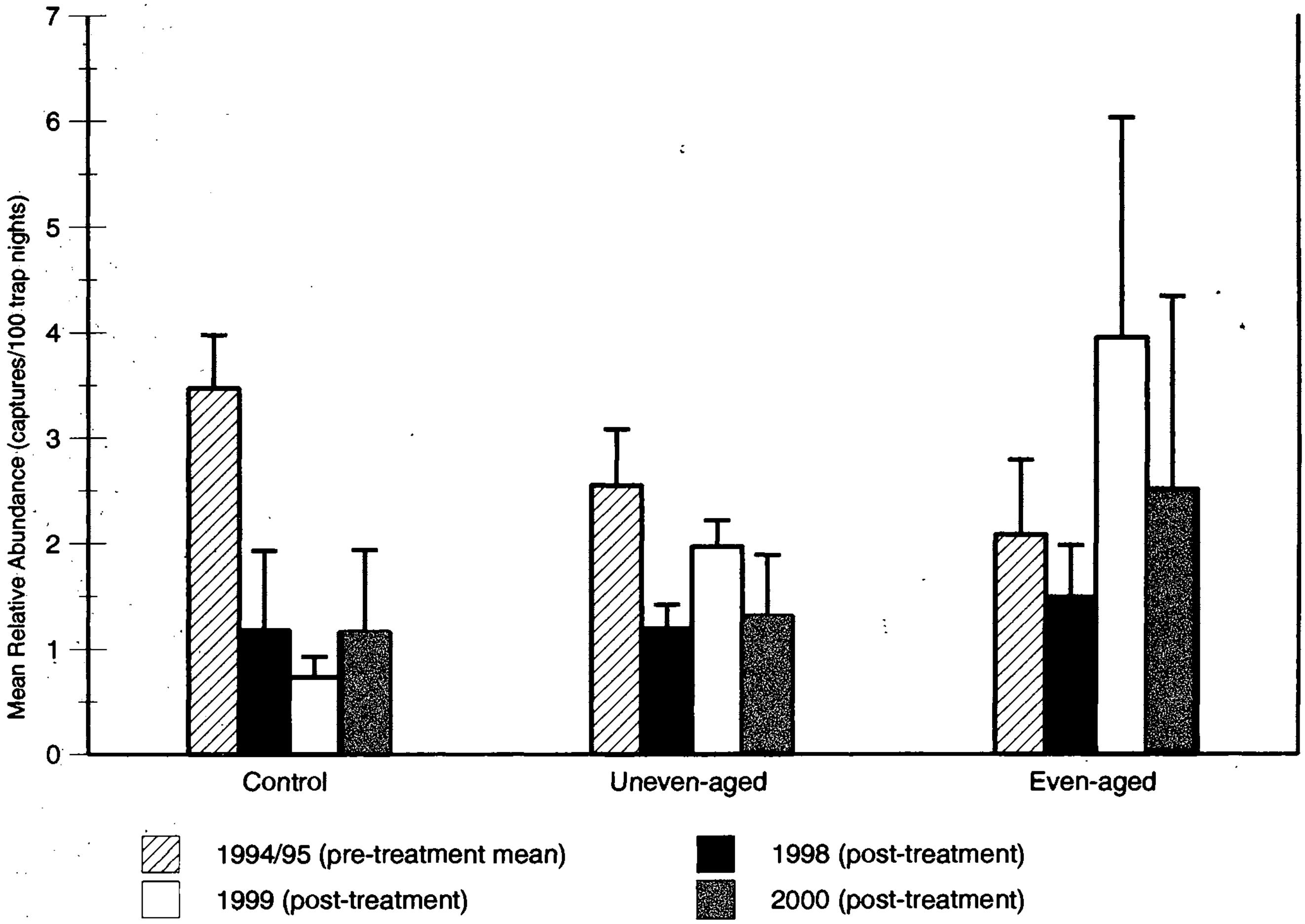

Figure 1.—*Mean relative abundance estimates (individuals captured / 100 trap nights) by treatment type and trapping period for small mammals inhabiting northeast-facing slopes of the MOFEP sites. Standard errors are shown by the lines at the top of the bars.*

Treatment did have an effect on the overall relative abundance of small mammals 2, 3, and 4 years after timber harvest. It appears that there was a natural decline in mean overall small mammal relative abundance, which was evident on the control sites. Even-aged management, and uneven-aged management to a lesser extent, appeared to have dampened this natural decline. Relative abundance estimates on treated sites were slightly higher than those on control sites. We think forest management may have dampened this decline by increasing available food sources and providing better cover for protection against most predators.

Temperate forest small mammals are characterized by seasonal and multi-annual population fluctuations in response to a variety of density-dependent and density-independent factors. Yahner (1992) reported significantly lower numbers of individuals during a drought year that presumably reduced the availability of terrestrial arthropods as a food resource. Arthropods, hard mast, soft mast, seeds, and green vegetation are the primary foods of the small mammal species inhabiting MOFEP sites (Hamilton 1941, Schwartz and Schwartz 1981, Whitaker 1966). Clearcut areas can produce large quantities of fruits, seeds, and insects (Ahlgren 1966, Hooven 1973, Lovejoy 1975, Tevis 1956). Perry *et al.* (1999) reported that in the Ouachita Mountains of Arkansas and Oklahoma, soft mast production did not significantly differ among five timber harvest treatments the first year after timber harvest, but was significantly greater in harvested stands (both even- and uneven-aged management stands) when compared to unharvested stands 3 years after cutting. Five years after cutting, they reported significantly greater soft mast production in shelterwood cuts and clearcuts (80-100 times greater than unharvested stands) when compared to single-tree selection, group selection, or unharvested stands.

The results presented in this paper are a preliminary look at the responses of the small mammal communities to even- and uneven-aged forest management on the MOFEP sites. Our plans are to sample in 2001 and then suspend sampling for a few years. We plan to further analyze data to examine the effects of forest management on small mammal communities and investigate species-specific and trophic group responses. Collaboration with other MOFEP researchers, especially those working on the invertebrate, hard mast, soft mast, and botany studies, may provide insight into the variation we observed.

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