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Effects of an ongoing oak savanna restoration on small mammals in Lower Michigan

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ABSTRACT

Oak (*Quercus* spp.) savannas have declined drastically in the midwestern United States since European settlement. Oak savanna restoration projects are primarily driven by species closely linked to this habitat type, such as the federally endangered Karner blue butterfly (*Lycaeides melissa samuelis*). However, it is essential that other species are monitored during restoration. Small mammals, due to their importance in ecosystem function, are particularly useful to study. The United States Forest Service is currently conducting an oak savanna restoration in the Manistee National Forest in Lower Michigan using forest thinning and prescribed burning. To understand management impacts on small mammal communities, we live trapped small mammals in each of the mechanically thinned plots (i.e., bulldozer, masticator, and shear cutter) and control plots in five blocks over six years (2008–2013), as well as measured vegetation variables each year. Initially, we used a permutation multivariate analysis of variance (perMANOVA) to determine if there were treatment and year interactions for both small mammal community assemblages and vegetation variables. We then compared changes in small mammal diversity, relative abundance, and vegetation variables among treatments using exploratory randomized block design analysis of variances (ANOVAs). Canopy cover was significantly lower in bulldozer and shear cutter thinned plots than control plots five years following thinning. We observed significant treatment by year interactions in how the small mammal community responded. A large increase in relative abundance of white-footed mice occurred one year post-thinning in all treatments. Within 1–2 years of treatment, thirteen-lined ground squirrels and meadow jumping mice, both open-canopy grassland species became established on thinned plots. The retention of brush piles in bulldozer and shear cutter plots provided important refuge habitat for small mammals following thinning. Restoration efforts were beneficial to the small mammal community overall and promoted grassland species to immigrate into the restored area.

1. Introduction

Historically, oak (*Quercus* spp.) savannas existed in a swath across the midwestern United States and served as a transition between eastern deciduous forests and western tallgrass prairies (Henderson, 1995; Nuzzo, 1986). Oak savanna comprises a variety of habitat types but is generally defined as having an open canopy dominated by fire-tolerant species with a dense, mosaic understory (Anderson, 1998; Asbjornsen et al., 2005; Leach and Givnish, 1999). Oak savannas have declined to the point where they are now considered critically endangered ecosystems as a result of changes made by European settlement and altered fire regimes (Leach and Givnish, 1999; Nuzzo, 1986). Compounding the loss of habitat and resultant fragmentation is a general lack of baseline information on intact oak savanna to help guide management practices (Asbjornsen et al., 2005).

Oak savanna restoration affects avian communities, with a general shift to more open-canopy assemblages (Brawn, 2006; Davis et al., 2000; Hartung and Brawn, 2005; Mabry et al., 2010). Species of concern, such as the red-headed woodpecker (*Melanerpes erythrocephalus*) and northern bobwhite (*Colinus virginianus*), have benefitted from savanna restoration (Brawn, 2006; Davis et al., 2000; Mabry et al., 2010). Less well understood is how small mammal communities respond to oak savanna restoration. Small mammals are important dispersers of seeds (Howe and Smallwood, 1982; Orrock et al., 2006) and hypogeous fungi (Maser et al.,

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1978), seed predators (Hulme, 1994), consumers of invertebrates (Churchfield et al., 1991), and are themselves an important food resource for predators (Korpimäki, 1984; Roemer et al., 2009). Perhaps more importantly for this study, small mammals can alter plant communities through selective herbivory, thus altering or delaying ecological succession (Ostfeld et al., 1997; Ostfeld and Canham, 1993; Weltzin et al., 1997).

Because small mammals play a vital role in ecosystems, it is important to assess how restoration methods affect their abundance and diversity. Several studies have investigated small mammal communities following clear-cutting (Kirkland, 1977), wildfires (Fontaine and Kennedy, 2012), and a combination of thinning and burning as forest management (Amacher et al., 2008; Greenberg et al., 2006; Zwolak and Foresman, 2007). Our study is unique given that restoration is being implemented at a small scale to assess effects of three thinning treatments before decisions are made on the methods that will be used to restore large areas in this region. By assessing the small mammal community during a restoration, we were able to monitor progress toward a functioning oak savanna ecosystem. Therefore, our objective was to assess how the small mammal community was affected by three thinning treatments implemented in an oak savanna restoration. We were most interested in observing whether species associated with grasslands would return to the study site, and if so, how long it would take them to colonize the site.

2. Methods

2.1. Study area

The study area, Pines Point, was located in the Manistee portion of the Huron-Manistee National Forests in Oceana County, Michigan, USA (Fig. 1). Historically, the site was oak-pine barrens (a savanna community), but has shifted to an eastern mixed deciduous forest, mainly due to fire suppression (USDA Forest Service, 2004). The study site was logged prior to 1938 when the Manistee National Forest was established (Albert, 1995). During our study, the area was undergoing restoration as part of the Draft Karner blue butterfly Habitat Management Strategy for the Huron-Manistee National Forests (USDA Forest Service, 2004). Pines Point consisted of primarily black oak (*Quercus velutina*), white oak (*Q. alba*), red pine (*Pinus resinosa*), and black cherry (*Prunus serotina*) and was surrounded by red pine plantations. The USDA Forest Service (USFS) conducted thinning from mid-June to mid-July in 2008. We systematically selected five, 3.2-ha experimental replicates, or blocks, based on similarities in soil type, vegetation composition, history of management, and proximity to currently occupied Karner blue butterfly sites. Each block consisted of four 0.8-ha treatment plots randomly assigned to a mechanical tree thinning technique (i.e., bulldozer, masticator, or shear cutter), or left as a control plot (Fig. 1).

Bulldozer-thinned plots had trees uprooted and large areas of overturned soil. The masticator reduced trees to woodchip-sized pieces and thus eliminated fully downed trees while leaving stumps intact in the ground. Finally, the shear cutter cut trees at the base, also leaving intact stumps in the ground. The USFS retained an average of 15–34% canopy cover within thinned plots. Downed trees within bulldozer and shear cutter plots were moved to form one brush pile per plot. On 1 July 2010, the USFS conducted a prescribed burn on the entire study area, including the control plots (Fig. 2). Brush piles were also burned at that time. Subsequent burns are planned to continue combating undesirable vegetation such as stump sprouts, saplings, and Pennsylvania sedge (*Carex pensylvanica*) from overtaking savanna restoration areas and to increase the coverage of fire-adapted herbaceous species, particularly wild lupine (*Lupinus perennis*).

2.2. Abundance

We captured small mammals with Sherman live traps arranged in 3 × 3 grids with 15-m spacing centered in each treatment plot ($n = 9$) for 36 traps per block (Fig. 1). We prebaited traps and left them open for 7 days prior to trapping. We live trapped five blocks in mid-October 2008, early to mid-September 2009, late August 2010 (about 7 weeks after the first prescribed burn), late August 2011, late June 2012, and mid-July 2013 (1 week before a second prescribed burn). We covered traps with pieces of rigid foam insulation and added cotton batting to protect captured animals from precipitation and temperature extremes. We baited traps with sunflower seeds, set them between 1700 and 2000, and checked them between 0600 and 1100. We recorded species identification, body mass (g), gender, reproductive status, and marked individuals with uniquely numbered ear tags (model 1005-1, National Band and Tag, Newport, Kentucky, USA). We did not mark masked shrews (*Sorex cinereus*) or northern short-tailed shrews (*Blarina brevicauda*) as these species lack pinnae.

We used minimum known alive numbers to represent small mammal relative abundance on each plot. We were unable to use standard mark-recapture methods to calculate abundance due to individual small mammals moving among treatment plots and blocks. Shannon's diversity indices were calculated per plot (Oksanen et al., 2012). For all procedures that included animal handling, we followed the standards set by the Animal Care and Use Committee of the American Society of Mammalogists (Sikes and Gannon, 2011) and this project was approved by the GVSU Institutional Animal Care and Use Committee [protocol #10-02-A].

2.3. Vegetation

We recorded vegetation data every year between June and July, and if a treatment was scheduled for that summer, vegetation data were collected prior to that treatment. We centered a 0.4-ha square subplot within each of the 0.8-ha plots (Fig. 1). We randomly assigned seven points within each subplot with a minimum distance of 20 m between each point. We estimated ground cover using a 2 m radius circular plot centered at each random point using visual estimation into the following cover classes (absent, 0–1%, 2–12%, 13–25%, 25–50%, 50–75%, and 75–100%). Microhabitat variables measured were percentages of bare ground, grass and sedges, woody vegetation less than 2 m tall, and woody debris (including downed trees, stumps, or branches). Canopy cover was measured using a spherical densiometer at each random point also using visual estimation into the following cover classes (0–5, 5–25, 25–50, 50–75, 75–95, 95–100). Data collected at each of the random points was averaged for each subplot by multiplying number of times a cover class was recorded by the midpoint of that class (e.g., for ground cover class 2–12 the midpoint value would be 7), adding the results for each class, and then dividing by 7 (i.e., total number of random sample points within the subplot).

2.4. Analysis

Initially, a permutation multivariate analysis of variance (perMANOVA) was used to determine if there was a treatment and year interaction for small mammal community assemblages as well as for all vegetation cover variables. Year was considered a fixed effect. Following this overall nonparametric analysis, we ran exploratory randomized block design ANOVAs on the differences between the planned year contrasts to compare the change in vegetation variables, Shannon's diversity of the small mammal community, and relative abundance of all captured small mammal species among treatments. These exploratory ANOVAs were used because there is no well-established statistical method for