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Effects of 3 forest management systems on herpetofaunal diversity over 23 years in the Missouri Ozarks

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ABSTRACT

Sustainable forest management is vital in today's human-dominated landscapes. An important part of sustainable management is protecting biodiversity, including herpetofauna (reptiles and amphibians). To examine the effects of landscape-scale forest management on a diverse herpetofauna community in oak-dominated forests in the Missouri Ozarks, we experimentally assessed differences in herpetofaunal diversity among 3 treatments (i.e., forest management systems) over 2 decades through the Missouri Ozark Forest Ecosystem Project. We assigned 9 forest compartments to 1 of 3 blocks, such that each block contained 3 compartments, and then randomly assigned 1 compartment within each block to a treatment: even-aged; uneven-aged; or no-harvest management. Management entries occurred in 1996 and 2011. We installed 12 herpetofauna trap arrays per compartment; 6 on north and east slopes and 6 on south and west slopes. We conducted trapping for 14 years during the 23 year study period, and used a variety of metrics to assess diversity, including species richness, Shannon Diversity, Jaccard's and Morisita's Indices of Similarity, and species-list occupancy. Results indicated minimal difference in herpetofaunal diversity among treatments at the landscape-scale after 23 years of management. Notable year-to-year variations in diversity were observed through time across treatments, likely due to changes in detectability. However, detection did not differ among treatments in species-list occupancy models, indicating that species richness and similarity metrics assessing differences between forest management strategies without accounting for detection are reliable for this study. We found no evidence that overall herpetofaunal diversity was negatively impacted by even-aged, uneven-aged, or no-harvest forest management in the Missouri Ozarks at the scale of forest compartments over this time period.

1. Introduction

In the current age of human-dominated landscapes, it is vital to sustainably manage natural resources to provide resources for humans and maintain biodiversity (Meyfroidt and Lambin, 2011). Temperate forests serve a number of roles including providing forest products, storing carbon, protecting water quality, and maintaining biodiversity by providing habitat for plants and animals (Li et al., 2011; Meyfroidt and Lambin, 2011; Wei and Zhang, 2011). Timber harvests can be economically profitable, but can have negative effects on forest wildlife, including amphibians and reptiles (collectively known as herpetofauna; Liu, 1993; Creedy and Wurzbacher, 2001; Calkin et al., 2002).

Herpetofauna are important components of forest ecosystems. They can compose a significant portion of the animal biomass and serve as an important link between trophic levels (Regester et al., 2006; Whiles et al., 2006; Semlitsch et al., 2014). Unfortunately, they are declining at alarming rates globally including in developed countries such as the USA (Gibbons et al., 2000; Stuart, 2004; Adams et al., 2013; Alroy, 2015). Forest structure affects herpetofaunal diversity and abundance (Loehle et al., 2005; Connette and Semlitsch, 2013; Maigret et al., 2014). These taxa are particularly vulnerable to habitat changes because they are small relative to the scale of human land-management, with limited home range sizes and movement capability compared to other vertebrate taxa (Semlitsch et al., 2009).

At the local scale of forest stands or patches amphibians can be negatively impacted by timber harvests (deMaynadier and Hunter, 1995; Harpole and Haas, 1999; Herbeck and Larsen, 1999; Homyack and Haas, 2009; Semlitsch et al., 2009). How-

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ever, with regard to herpetofaunal diversity as a whole, and particularly reptiles, some studies have indicated positive or mixed effects of forest management (Renken et al., 2004; Loehle et al., 2005). Some reptile species benefit from drastic reduction in canopy cover (Greenberg, 2001; Loehle et al., 2005) whereas other reptile species seem to prefer intermediate levels of disturbance from forest management activities such as intermediate thinning or single-tree selection (Todd and Andrews, 2008). Some studies have shown differences in herpetofaunal species composition at the local scale following forest management activities (Greenberg et al., 1994; Loehle et al., 2005), which can lead to more herpetofaunal diversity at the landscape scale (Loehle et al., 2005). These findings are similar to other taxa in the Central Hardwoods such as forest plants (Belote et al., 2008) and songbirds (Morris et al., 2013), for which disturbance can foster diversity at the landscape level. Few studies have assessed herpetofaunal diversity in response to forest management in a holistic manner, with long-term data at the landscape scale across multiple herpetofauna taxa, including pre-management data and control compartments (Renken et al., 2004; Gardner et al., 2007; Moorman et al., 2011; Popescu et al., 2012). To examine the effects of landscape-scale forest management on a diverse herpetofauna community, we experimentally assessed landscape-scale differences in herpetofaunal diversity among 3 forest management systems over 2 decades through the Missouri Ozark Forest Ecosystem Project.

The Missouri Ozark Forest Ecosystem Project (MOFEP) was initiated in 1989, when uneven-age forest management (UAM; Law and Lorimer, 1989) was being introduced as an alternative to even-age management (EAM) for oak-dominated forests on lands managed by the Missouri Department of Conservation (MDC) in the Missouri Ozarks (Brookshire et al., 1997). The introduction of UAM to MDC lands was concurrent with growing concerns about neotropical-migrant songbird decline, and increased nest parasitism by brown-headed cowbirds (*Molothrus ater*) in fragmented forests in the Midwest (Clawson et al., 1997). MOFEP grew into a comprehensive project to examine many aspects of forest ecology in relation to EAM and UAM, including forest-product economics, neotropical-migrant songbirds, floristic diversity, herpetofaunal and small-mammal diversity and abundance, hard- and soft-mast production, soils, fungi, and many other studies (Knapp et al., 2014).

We predicted that at the landscape scale, over the course of two management entries, salamander and anuran species richness and diversity would decline in both EAM and UAM compartments on MOFEP, as compared to NHM compartments, due to reductions in moisture and increases in temperature of leaf litter and surface soil (deMaynadier and Hunter, 1995; Semlitsch et al., 2009; Homyack et al., 2010, 2011). Due to the varied habitat requirements of the snake and lizard species present on the compartments, we predicted negligible effects of EAM and UAM on species richness of these reptiles relative to NHM compartments over two management entries. However, we expected lower similarity between the species composition before and after two decades of management activities on EAM and UAM compartments, relative to NHM compartments, when combining reptiles and amphibians together, both because of turnover in reptiles and decline in amphibian species richness.

2. Methods

2.1. MOFEP experimental design and site descriptions

MOFEP was designed as an experiment, fully replicated and randomized at the landscape level and intended to last at least 1 full Ozark forest rotation, approximately 100 years (Sheriff and He, 1997). There are 9 MOFEP forest management compartments in the study, each of which was divided into forest stands, at which scale management activities such as clearcutting or thinning are executed as part of the compartment's management strategy. The compartments ranged from 312 to 514 ha, with 44–82 stands ranging from 0.2 to 62 ha. The compartments were assigned to 3 experimental blocks, and within each block 1 of 3 compartments was randomly assigned to each of 3 treatments: EAM, UAM, and no-harvest management (NHM), which also served as controls in this experiment (Fig. 1; Rota et al., in press). Management decisions and actions on MOFEP compartments mirrored concurrent management practices of other forested state lands in the Ozarks, and as management practices changed through time, management practices on MOFEP were, and will continue to be, changed accordingly. For example, group openings were executed on MOFEP UAM compartments during the 1996 harvest entry, but not during the second entry in 2011 (see below for details).

Even-age management has been used by MDC forest managers for several decades to manage forested lands in the Ozarks. Management tools include clear-cutting and intermediate thinning. On MOFEP, 7–9 stands of 3–13 ha each were clearcut in each EAM compartment in each management entry, composing approximately 10–15% of each compartment's total area per entry (Kabrick et al., 2002; Knapp et al., 2014). Some stands that were not clearcut were thinned as necessary to maintain healthy growth of desired trees, particularly oaks (*Quercus* spp.); 2–24% of each compartment was thinned during entries (Knapp et al., 2014). Total area within each EAM compartment subjected to forest management techniques across both harvest entries combined ranged from 23 to 27% clearcut and 26 to 40% thinned (Knapp et al., 2014). The time between management entries was 15 years. This temporal pattern generally results in clearcutting an entire site over the course of about 80–100 years (Brookshire et al., 1997). Management prescriptions for each stand were generated according to recommendations based on Roach and Gingrich's (1968) treatise on EAM, with the objective of maintaining B-level stocking in the long-term.

Uneven-age management guidelines on MDC lands generally followed recommendations by Law and Lorimer (1989) and Larsen et al. (1999). With the exception of a few small landscape features such as sinkholes and glades, UAM stands were approximately 8–32 ha (Brookshire et al., 1997). Uneven-age management has been shown to be effective at regenerating oaks under certain conditions in the Ozarks, although it is not as effective as EAM for regenerating oaks in most cases (Larsen et al., 1999; Jensen and Kabrick, 2008; Fan et al., 2015; Olson et al., 2016). Management tools for UAM stands on MOFEP included single-tree selection, as well as group openings in 1996. Single-tree selection occurred across 14–69% of UAM compartments (Knapp et al., 2014), averaging 48% of each compartment per entry. Despite affecting a larger area of each compartment compared to EAM management, similar amounts of biomass were removed between the two management strategies (Kabrick et al., 2002; Morris et al., 2013), with UAM effects distributed more widely across each compartment during an entry. Group openings were circular areas of tree removal similar to clearcuts in terms of reduced basal area, and were designed to mimic natural disturbance events such as wind-thrown dominant trees, allowing small areas of light to reach the forest floor and promote tree regeneration. These openings were placed within the matrix of single-tree selection stands. Group openings were 21–43 m in diameter depending on aspect (Renken et al., 2004), with larger openings on north slopes to allow an equal amount of light to reach the ground. Although group openings can achieve similar oak regeneration to single-tree selection (Jensen and Kabrick, 2008; Fan et al., 2015), the effort required by foresters