Forest Ecology and Management 400 (2017) 353–362

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Low-basal area treatment and prescribed fire to restore oak-pine savannas alter small mammal communities

Marie-Eve Jacques *, Stephen W. Hallgren, Duncan S. Wilson [1]

Department of Natural Resource Ecology and Management, 008C AgHall, Oklahoma State University, Stillwater, OK 74078, United States

ARTICLE INFO

Article history:
Received 2 April 2017
Received in revised form 7 June 2017
Accepted 8 June 2017
Available online 20 June 2017

Keywords:
Burn
Coarse woody debris
Distance of vulnerability
Ground cover
Peromyscus
Reithrodontomys

ABSTRACT

Following decades of fire suppression many oak-pine savanna ecosystems have shifted to closed-canopied forests. Restoration of these ecosystems to their savanna condition is seen as a way to reduce woody species encroachment and dangerous fuel loads, and restore community species composition. The management practices to achieve these goals typically involve thinning and prescribed fire. We assessed how thinning to reduce basal area combined with frequent prescribed fire influenced small mammal communities and their habitat. We focused on six habitat variables that can influence small mammal abundance and species composition: stand basal area of live trees and snags, volume of coarse woody debris, percent ground cover, forest floor depth, and distance of vulnerability, a measure of understory vegetation structure and animal vulnerability to predators. Although savanna restoration reduced basal area by 80%, there was no change in snag density or coarse woody debris volume. Savanna restoration significantly increased the ground cover of graminoids, forbs, bare ground, and down woody debris and reduced forest floor depth and distance of vulnerability. These habitat changes likely contributed to the significant differences between small mammal communities in restored and non-restored stands. Restoration treatments caused a large increase in abundance of White-footed Mouse (*Peromyscus leucopus*) and important changes in community assemblages. Least Shrew (*Cryptotis parva*), Fulvous Harvest Mouse (*Reithrodontomys fulvescens*), Eastern Harvest Mouse (*R. humulis*), and Hispid Cotton Rat (*Sigmodon hispidus*) were caught only in restored stands, while House Mouse (*Mus musculus*), Plains Harvest Mouse (*R. montanus*), and Texas Mouse (*P. attwateri*) were caught only in non-restored stands.

1. Introduction

Oak-pine savannas of south-central United States evolved over thousands of years under a largely anthropogenic fire regime (DeSantis et al., 2010a; Stambaugh et al., 2013). Starting in the 1920's, Euro-American settlers altered this disturbance regime through fire suppression (Guyette et al., 2006; Stambaugh et al., 2013). Increased tree densities, decreased understory herbaceous vegetation biomass, denser midstories, and altered species composition followed, leading to changes in plant communities and vegetation structure (Chapman et al., 2006; DeSantis et al., 2011; 2010b). Restoration treatments have been implemented to reduce stand basal area (BA), with the goal to increase understory productivity and carrying capacity for wildlife. Mechanical or chemical tree thinning followed by frequent prescribed fires was found to be effective to reduce tree densities and increase understory vegetation productivity (Brose and Van Lear, 1998; Masters et al., 1993). As these savanna restoration treatments gain popularity and become more widespread, it is important to determine their effects on wildlife habitat and wildlife communities to better inform land managers (Fontaine and Kennedy, 2012). It is thus important to assess the response of small mammals to savanna restoration because changes in small mammal communities could potentially alter ecosystem services.

Small mammals provide crucial ecosystem services such as seed and mycorrhizal fungal spore dispersal (Hollander and Vander Wall, 2004; Pyare and Longland, 2001; Schickmann et al., 2012), nutrient cycling (Reichman and Seabloom, 2002), and soil structure (Reichman and Seabloom, 2002). They are also important in the diet of many predacious avian, reptilian, and mammalian species (Clark, 2002; Korschgen and Stuart, 1972; McVey et al., 2013). Moreover, some species are hypothesized to regulate ectoparasite populations of cervids (Kaunisto et al., 2012), while other species are hosts to parasites and vectors of diseases (Charles et al., 2012; Pitts et al., 2013). As small mammals provide ecological

* Corresponding author.
E-mail address: marieeve.jacques@okstate.edu (M.-E. Jacques).
[1] Present address: University of Oklahoma, South-Central Climate Science Center, Norman, OK 73019, United States.

http://dx.doi.org/10.1016/j.foreco.2017.06.022

services and act as parasite hosts, changes in their community structure and in their habitat use through the direct and indirect effects of land management practices should be monitored carefully.

Savanna restoration can potentially affect small mammals through changes in their predation pressure and basic life requirements: water, food, and shelter. Changes in some environmental characteristics can be indicative of changes in small mammal habitat and small mammal communities. First, changes in stand BA can affect predation rates, food sources, and microclimate through changes in cover and overstory biomass (Hayes, 1996; Heithecker and Halpern, 2006; Torre and Díaz, 2004). Second, changes in the BA of snags (standing dead trees) can affect corridors for movement, nesting ground, food, and cover from predators (Kalies et al., 2012). Third, changes in the volume of coarse woody debris (CWD) can also influence protective cover for movement, nesting habitat, and forage grounds (Fauteux et al., 2012; Pearce and Venier, 2005). Fourth, changes in ground cover may alter shelter, food, and predation pressure, leading to difference in small mammal species and abundance (small mammals show species specific affinities for certain ground cover types; Jones et al., 2003; Kalies et al., 2012; Stancampiano and Schnell, 2004). Fifth, changes in the forest floor (litter and duff) depth can influence the abundance of some small mammal species by influencing the abundance of insects (Churchfield, 1982; Ober and DeGroote, 2011) and providing a moderated micro-climate protecting animals from extreme temperatures and low humidity (Matlack et al., 2002). Finally, changes in the distance of vulnerability (DOV), a measure of understory vegetation structure and animal vulnerability to visual predators, can influence species composition and abundance (Perry and Thill, 2005). Measuring how these six characteristics change with restoration can potentially explain changes in small mammal communities.

Our primary goal was to determine how savanna restoration in oak-pine forests altered small mammal habitat and how these changes altered small mammal communities. We monitored six habitat characteristics pre- and post-restoration: (1) BA of live trees, (2) BA of snags, (3) CWD volume, (4) ground cover, (5) forest floor (litter and duff) depths, and (6) the DOV. We hypothesized savanna restoration would induce significant changes in small mammal habitat which would alter small mammal communities. We expected restoration to decrease the BA of live trees, forest floor depth, and DOV, to increase the BA of snags and CWD volume, and to alter ground cover. We also expected restoration to alter small mammal communities by favoring species that required open spaces and increased forest floor productivity.

2. Materials and methods

2.1. Study site

Research was conducted at Pushmataha Wildlife Management Area (PWMA) in Pushmataha County, southeast Oklahoma (34°32′N, 95°21′W) located near Clayton, Oklahoma, U.S., at the western edge of the Ouachita Mountains. The county has a mean annual temperature of 17 °C (January being the coldest month) and a mean annual rainfall of 1256 mm (Oklahoma Climatological Survey, 2015). The average growing season has 214 days (Oklahoma Climatological Survey, 2015). Following fire suppression, the oak-pine forest was dominated by Post Oak (*Quercus stellata* Wangenh.) and Shortleaf Pine (*Pinus echinata* Mill.) and the understory vegetation was mainly Little Bluestem (*Schizachyrium scoparium* (Michx.) Nash), Big Bluestem (*Andropogon gerardii* Vitman), and Sedges (*Carex* L. spp.) (Masters et al., 1993).

Oklahoma Department of Wildlife Conservation (ODWC) established PWMA as a deer refuge in 1946 (Masters et al., 1993) and it has grown to cover 7690 ha of rugged terrain, with slopes from 0 to 60%. ODWC managed PWMA for game species, such as White-tailed Deer (*Odocoileus virginianus* (Zimmermann)), Elk (*Cervus elaphus* L.), and Eastern Wild Turkey (*Meleagris gallopavo silvestris* Vieillot) (Masters and Engle, 1994). Restoration reduced stand density by timber harvesting and maintained the open condition through prescribed burning. Prior to 1946, PWMA was used for ranching and selective timber harvest (Masters, 1991).

We studied the effects of restoration treatments on small mammal habitat and communities by comparing four restored and four non-restored stands (Fig. 1a, b). Restored stands averaged 57 ha (range: 38–73 ha) and non-restored stands averaged 54.75 ha (range: 23–80 ha). Restored stands were thinned in 2008 and 2009 to a target BA of 7 m^2 ha^{-1}. Thinning was not done within 15 to 50 m of water courses to maintain riparian corridors and protect streams. Non-restored stands had not been thinned within the past 20 years. Restored stands were burned 5 or 6 times between 1997 and 2012 and again in March 2013 just prior to the start of this study. Two of the four restored stands were burned during the study in February 2014. Non-restored stands were burned 3 to 5 times between 1997 and 2012. One non-restored stand was burned during the study in March 2014. Growing season burns were preferred, although most burns were conducted during the dormant season between January and March, due to logistical constraints. Restored stands were oak-pine savannas, while non-restored stands were closed canopied oak-pine forests. Prior to restoration, all stands were closed canopied oak-pine forests.

Habitat characteristics and small mammal populations were measured along one 370 m transect placed in the middle of each stand. To reduce edge effects, stands were selected to be at least 420 m by 60 m and without roads (active or abandoned), human infrastructure, water bodies, or watercourses. All stands were located on soils of the Carnasaw-Stapp association (Soil Survey Staff – NRCS, 2013).

2.2. Habitat measurements

We measured habitat variables at 10 m intervals along each transect for a total of 37 plots per stand. Measurements were taken between May and August 2013. Not all characteristics could be measure at the same time and repeated visits were required. Each habitat variable was measured across all stands in a period of 10 days or less to minimize variation due to temporal change.

We measured the BA of snags and live trees at the plot center through a variable radius plot design, using a Criterion® RD 1000 (Laser Technology Inc.) set at a BA factor of 2.3 m^2 ha^{-1}. Tallied trees were recorded as conifer (Shortleaf Pine) or hardwood.

CWD volume (m^3 ha^{-1}) was assessed by measuring all logs within a circular six-meter diameter plot. CWD was defined as any woody debris longer than 910 mm, >75 mm in diameter, <45° from horizontal, and detached from a tree. Only the portion of each log within the circle was measured. Length and diameter at the small and large end of all logs were recorded and volume was calculated using the formula of the frustum of a right circular cone. The volume of all logs within a circle was then totaled and transformed to m^3 ha^{-1}.

We measured ground cover in the same circular plots using Daubenmire percent cover classes (Daubenmire, 1959). Ground covers were: graminoids with basal rosettes (e.g., Rosette Grass [*Dichantelium* Gould]), other graminoids, forbs, legumes, litter, woody plants, rocks, bare ground, and down woody debris (DWD). USDA (2015) defined graminoids as "grass or grass-like plant, including grasses (Poaceae), sedges (Cyperaceae), rushes (Juncaceae), arrow-grasses (Juncaginaceae), and quillworts (Iso-