Forest Ecology and Management 359 (2016) 221–231

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Bat response to prescribed fire and overstory thinning in hardwood forest on the Cumberland Plateau, Tennessee

Maxwell R. Cox, Emma V. Willcox *, Patrick D. Keyser, Andrew L. Vander Yacht

Department of Forestry, Wildlife and Fisheries, 274 Ellington Plant Sciences Building, University of Tennessee, Knoxville, TN 37996, United States

ARTICLE INFO

Article history:
Received 17 July 2015
Received in revised form 22 September 2015
Accepted 29 September 2015

Keywords:
Bats
Clutter
Insect availability
Management
Overstory thinning
Prescribed fire

ABSTRACT

Across the Southeastern U.S., including the Cumberland Plateau of Tennessee, prescribed fire and overstory thinning are being used to restore areas of closed-canopy hardwood forest to open woodland and savanna. We used acoustic recording of bat echolocation call sequences to examine bat activity (relative use of an area for foraging) in hardwood forest stands subject to 4 prescribed fire and residual basal area treatments (spring prescribed fire with woodland [SpW] and savanna [SpS] residual basal areas, and fall prescribed fire with woodland [FaW] and savanna [FaS]) basal areas, as well as untreated controls, during summer of 2013 and 2014. When possible, we classified recorded echolocation call sequences to species using automated identification software (Sonobat™ 3.1.4, SonoBat™ Inc., Arcata, California). To minimize errors in species classification of recorded bat passes, we combined similar species in groups based on call characteristics prior to conducting analyses. Total bat activity ($P \leqslant 0.001$), as well as LABO/NYHU (eastern red bat [*Lasiurus borealis*] and evening bat [*Nycticeius humeralis*]; $P = 0.001$), EPFU/LANO (big brown bat [*Eptesicus fuscus*] and silver-haired bat [*Lasionycteris noctivagans*]; $P \leqslant 0.001$), PESU (tricolored bat [*Perimyotis subflavus*]; $P = 0.001$), and LACI (hoary bat [*Lasiurus cinereus*]; $P = 0.005$) activity was generally higher in SpS and FaS stands, where overstory basal area was lower, than in control, SpW, and FaW stands, where overstory basal area was higher ($P \leqslant 0.001$). Our results suggest these treatments reduce clutter (physical obstructions to flight and foraging including foliage, branches, and stems), leading to improved foraging conditions for bats, particularly larger bodied species with lower call frequencies that are adapted to fly and forage in open conditions. We found no evidence nocturnal flying insect prey abundance or biomass influenced activity of bats in treatment stands, indicating clutter is more important than prey availability in determining habitat use by bats in this system. Our study provides support for continued use of prescribed fire and overstory thinning to restore hardwood forest to woodland and savanna and as a strategy to maintain and enhance habitat for forest bats in the Southeastern U.S.

1. Introduction

In recent years, land managers have begun to increase their use of prescribed fire and overstory thinning in upland hardwood forests across the Southeastern U.S. in an attempt to restore and maintain the open woodland and savanna conditions that existed before the era of fire suppression (Delcourt and Delcourt, 1998; Brose et al., 2001, 2012). This includes upland hardwood forests of the Cumberland Plateau, where a number of oak woodland and savanna restoration projects are ongoing. The use of prescribed fire and overstory thinning in the region can modify habitat conditions for numerous bat species (Boyles and Aubrey, 2006). Understanding bat responses to such habitat modifications is critical given the unprecedented conservation crisis and population declines many species are facing as a result of multiple threats. Over the past decade, a rise in the number of wind energy installations (i.e., wind turbines) in the U.S. has caused increased mortality of numerous migratory tree-roosting bats (e.g., eastern red bat [*Lasiurus borealis*], hoary bat [*Lasiurus cinereus*], and silver-haired bat [*Lasionycteris noctivagans*]), all of which roost and forage in hardwood forest systems and can be influenced by management and restoration activities (Cryan and Veilleux, 2007; Lacki et al., 2007; Cryan and Barclay, 2009). More recently, White-nose Syndrome (WNS), a disease caused by the fungus *Pseudogymnoascus destructans*, has caused catastrophic population declines in numerous cave-hibernating bat species across the Eastern U.S., threatening once abundant populations with regional extirpation (Frick et al., 2010; Turner et al., 2011; Langwig et al., 2012). The disease currently infects 7 bat species, 5 of which are federally listed or being considered for listing (gray bat [*Myotis grisescens*], Indiana

* Corresponding author.
E-mail address: ewillcox@utk.edu (E.V. Willcox).

http://dx.doi.org/10.1016/j.foreco.2015.09.048
0378-1127/

bat [*M. sodalis*], northern long-eared bat [*M. septentrionalis*], little brown bat [*M. lucifugus*], and tricolored bat (*Perimyotis subflavus*); United States Fish and Wildlife Service, 2015). All of these species use Southeastern hardwood forest systems for roosting and foraging, particularly during the pre- and post-hibernation and maternity periods (i.e., spring, summer, and early fall; Barclay and Kurta, 2007; Lacki et al., 2007). This is an important time in the life-history of cave-hibernating bats because of the energetics associated with reproduction and entering and recovering from hibernation, especially if affected by WNS. Therefore, managing hardwood forests in proximity to hibernacula to provide high quality habitat during this period may be critical for population persistence and species recovery (Johnson et al., 2010).

Few studies have examined the effect of prescribed fire or silvicultural practices on bats in hardwood forest systems of the Southeastern U.S. Those studies that have been conducted generally focus on response of a single bat species to treatments with relatively few examining the bat community as a whole (Menzel et al., 2002; Owen et al., 2004; Lacki et al., 2009). No studies have been conducted examining the combined effect of prescribed fire and overstory thinning. Studies that have been conducted examining bat response to prescribed fire and silvicultural practices in other North American forest systems, have found prescribed fire and overstory thinning affect bat activity (relative use of an area for foraging) through changes in forest structure and availability of nocturnal flying insect prey (Grindal and Brigham, 1998; 1999; Loeb and Waldrop, 2008; Titchenell et al., 2011; Armitage and Ober, 2012). Changes in forest structure alter the degree of clutter (physical obstructions including foliage, branches, and stems, that impede flight and limit prey detection by reflecting echolocation calls) with which bats must contend (Lacki et al., 2007). Morphological variations in body size and wing shape, particularly wing loading (mass of the bat divided by its total wing area; WL) and aspect ratio (length of the wing squared divided by its surface area; AR), along with differences in echolocation call frequency and structure determine whether bats can fly and capture prey in clutter and, in turn, their habitat use and activity in a forest stand (Aldrich and Rautenbach, 1987; Norberg and Rayner, 1987). However, while bats may use a forest stand for foraging based on their adaptations to that environment, the availability of nocturnal insect prey may also play an important role in determining use, and in turn, activity in an area (Erickson and West, 2003; Fenton, 1990; Brigham et al., 1997; Jacobs, 1999; Lacki et al., 2007).

In light of the threats and population losses currently faced by bats in the Southeastern U.S., the effects prescribed fire and overstory thinning have on bat activity in hardwood forest systems warrants further investigation. Land managers need to understand how these practices affect bats in order to better manage populations and communities, in conjunction with oak savanna restoration efforts and other forest management objectives. We experimentally assessed how bats, forest clutter, and availability of nocturnal flying insect prey respond to prescribed fire and overstory thinning treatments. The objectives of our study were to (1) compare bat activity among 4 prescribed fire and overstory thinning treatments and untreated controls in upland hardwood forests of Tennessee's Cumberland Plateau and (2) determine the relative contributions of forest clutter and availability of nocturnal flying insect prey in explaining any observed changes in bat activity following prescribed fire and overstory thinning treatments.

2. Methods

2.1. Study area

We conducted our research at Catoosa Wildlife Management Area (CWMA), managed by the Tennessee Wildlife Resources Agency (TWRA), which encompasses 32,374 ha in Cumberland, Morgan, and Fentress Counties, TN, within the Cumberland Plateau and Mountainous physiographic province (DeSelm, 1994). It is comprised of oak-hickory dominated upland hardwood and pine-hardwood stands, approximately 80–100 years old. Prior to a pine bark beetle (*Dendroctonus frontalis*) outbreak in 1999–2000, short-leaf pine (*Pinus echinata*) was a major overstory component. Salvage cutting of short-leaf pine damaged or killed during the outbreak began in 2002. Shortly after, TWRA initiated an oak savanna restoration project involving prescribed fire and overstory thinning. Restoration activities began on our study area in 2008. At the initiation of this restoration, the overstory was comprised primarily of red maple (*Acer rubrum*; 2.89 m^2/ha), white oak (*Quercus alba*; 2.85 m^2/ha) sourwood (*Oxydendrum arboreum*; 1.86 m^2/ha), hickory (*Carya* spp; 1.13 m^2/ha), scarlet oak (*Q. coccinea*; 0.99 m^2/ha), blackgum (*Nyssa sylvatica*; 0.83 m^2/ha), and post oak (*Quercus stellate*; 0.83 m^2/ha). The midstory layer was dominated by blackgum, downy serviceberry (*Amelanchier arborea*), red maple, sourwood, and sassafras (*Sassafras albidum*). Groundcover consisted of a mixture of native grasses, forbs, legumes, and woody plant regeneration. Mean canopy cover within treatment stands was 85% and mean live overstory basal area 18 m^2/ha (Vander Yacht, 2013). Elevations within the study area range from 437 to 521 m above sea-level, slopes from 1% to 60%, and average stand aspects from 131° to 267°. The average annual precipitation in the area is 153 cm and the average annual temperature 12 °C (National Oceanic and Atmospheric Administration, 2013).

2.2. Experimental design

During spring of 2008, we delineated 10 20-ha study stands at CWMA. These stands were configured to minimize topographic variation and maximize core area. Using a completely randomized design with two replicates, we assigned one of 4 prescribed fire and overstory thinning treatments to 8 stands: spring prescribed fire with woodland residual basal area (low overstory thinning with target residual basal area of 14 m^2/ha; SpW), spring prescribed fire with savanna residual basal area (high overstory thinning with target residual basal area of 7 m^2/ha; SpS), fall prescribed fire with woodland residual basal area (FaW), and fall prescribed fire with savanna residual basal area (FaS). We left the remaining two stands untreated as controls. Commercial loggers completed overstory thinning in June 2008. We conducted prescribed fires in all fall treatment stands on October 11, 2010 and October 15, 2012 and in all spring treatment stands on March 22, 2011 and March 20, 2013.

2.3. Bat activity

To examine the effect of prescribed fire and overstory thinning on bat activity, we conducted bat echolocation call monitoring (Hayes, 2000) in all study stands 3 times each summer (May–July) for 2 years (2013–2014). In each study stand, we used Pettersson D500x (Pettersson Elektronik AB, Sweden) bat detectors to passively detect, record, and store full-spectrum bat echolocation call sequences (Ahlén and Baagøe, 1999; Fenton, 2000). We deployed bat detectors in a waterproof housing at the center of each study stand. We secured detector microphones at a 45° angle, approximately 3 m above the ground to monitor bat activity below the canopy (Armitage and Ober, 2012). We programmed each detector to start recording 30 min prior to sunset and to stop recording 30 min after sunrise. We collected call recordings in 5 study stands (1 detector/treatment type) for 7 consecutive nights (Hayes, 1997). At the end of the 7 nights, we relocated detectors to the remaining 5 study stands and collected call recordings for a further 7 nights.