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Effects of shelterwood harvest and prescribed fire in upland Appalachian hardwood forests on bat activity

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ABSTRACT

Little is known about the effects that oak forest regeneration treatments consisting of a combination of shelterwood harvesting and prescribed fire have on bats, despite increasing use of these treatments. We quantified changes in bat activity levels in relation to oak forest regeneration treatments consisting of harvesting at 50% and 70% retention levels and prescribed fire in two upland Appalachian hardwood forests in Ohio. We monitored bat activity immediately post-harvest, three growing seasons post-harvest, and after application of prescribed fire to harvested stands before the fourth growing season. Total bat activity levels were higher in thinned and thinned and burned treatments than in unthinned controls in all years, but did not differ between harvest treatment levels immediately post-harvest, three growing seasons post-harvest, or between harvest treatment levels within years. Total bat activity post-prescribed fire changed only in the 50% retention harvest treatment blocks, wherein activity decreased. Activity levels of big brown (*Eptesicus fuscus*) bats were greater in harvested treatment blocks than controls in all years. Activity levels of eastern red (*Lasiurus borealis*), and *Myotis* spp. and tri-colored (*Perimyotis subflavus*) collectively did not differ among treatment blocks post-fire, but were greater in harvested treatment blocks than controls three growing seasons post-harvest. Community composition was strongly related to vegetation volume, with eastern red bats and *Myotis* and tri-colored bats displaying positive relationships with clutter in low height strata, and big brown bats displaying a negative relationship with clutter in all height strata. The positive relationship between eastern red and *Myotis* and tri-colored bats and clutter in low height strata may explain why activity levels of these species decreased post-prescribed fire. Our study suggests that the harvesting component of oak forest regeneration treatments may benefit bats for several years, and that while bat activity levels may decline post-prescribed fire, overall activity levels are nonetheless greater than in unthinned areas.

1. Introduction

Oak (*Quercus* spp.) forests account for a substantial proportion of forested habitats in the eastern United States (Smith et al., 2004). In recent decades however, reduced or little oak regeneration in this region has become common (Brooks, 2003; Nowacki and Abrams, 2008; Pierce et al., 2006). These decreases are attributed to changes in natural disturbance patterns, particularly wildfire, that have allowed oak competitors to establish successional pathways (Abrams, 1992; Brooks, 2003; Nowacki and Abrams, 2008; Spetich and He, 2008). Because oaks are valuable to both wildlife (McShea et al., 2007) and humans (Marschall et al., 2014; Ward, 2002), forest management techniques designed to promote oak regeneration have been developed and are being implemented in managed forests across the eastern United States. These treatments generally utilize a combination of timber harvesting and prescribed fire to remove mid and understory competitors such as red maple (*Acer rubrum*) and to increase solar exposure for more shade-intolerant oak seedlings and saplings (Albrecht and McCarthy, 2006; Brose et al., 1999; Hutchinson et al., 2005; Iverson et al., 2008). Although these techniques have demonstrated effectiveness for improving oak recruitment (Brose et al., 2013), little currently is known about how the combination of thinning and prescribed fire affect bats.

Relative to many other aspects of bat ecology, the impacts of forest thinning on bats are well understood. Vegetation density, and understory structural volume of woody vegetation in general, can significantly impede maneuverability and foraging efficiency of bats (Siemers and Schnitzler, 2004). Because of this, it is expected

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that bat activity should be greatest in areas of reduced vegetation structure, and indeed, studies on bat activity in managed forest landscapes generally have found that decreases in canopy volume following forest harvest increase bat activity levels (Loeb and Waldrop, 2008; Menzel et al., 2002; Titchenell et al., 2011). Even within unthinned forest stands, bat activity levels are positively related to canopy openness and presence of canopy gaps (Ford et al., 2005; Fukui et al., 2011; Menzel et al., 2005). It is apparent, then, that the vegetative characteristics of forests are an important factor in determining bat community composition and activity levels (Adams et al., 2009; Hodgkison et al., 2004; Menzel et al., 2005; Smith and Gehrt, 2010) and that differences in bat activity between harvested and unharvested forests, or among treatment levels, are due in large part to structural differences in forest condition (Adams et al., 2009; Owen et al., 2004). Relatedly, changes in vegetation structure as a result of forest management also impact bat prey, which also have been found to be related to bat activity (Dodd et al., 2012). Low activity levels of bats within clearcuts, and the higher levels of bat activity in clumps of retained trees within clearcuts, however, suggest that some level of vertical structure is important for bats (Hogberg et al., 2002).

Conversely, the effects of fire on bats have been poorly studied, but theoretical impacts have been discussed relative to changes in forest structure and bat foraging efficiency, roosting behavior, and prey availability (Carter et al., 2002; Perry, 2012; Johnson et al., 2012). To date, the majority of studies on the effects of fire on bat activity have focused on pine-dominated landscapes (Armitage and Ober, 2012; Buchalski et al., 2013; Loeb and Waldrop, 2008). Differences in forest type are known to play significant roles in patterns of bat activity (Kalcounis et al., 1999; Tibbels and Kurta, 2003), and there is reason to believe that effects of fire may vary across regions based on its roles within different forest and ecosystem types (Brown and Smith, 2000). It also is unclear how the reintroduction of fire to eastern hardwood forest ecosystems after a century of fire suppression will alter current ecosystem processes.

Prescribed fire is capable of having significant impacts on forest structure through reductions in understory volume and creation of canopy gaps; even moderate intensity fires can top-kill mature trees and remove saplings from the understory (Hutchinson et al., 2008; Signell et al., 2005). Fire also may alter insect prey abundance and distribution (Campbell et al., 2007; McCullough et al., 1998; Swengel, 2001). Decreases in canopy volume and understory vegetation resulting from prescribed fire may increase bat activity similar to patterns seen in studies of forest harvest (Perry, 2012). Indeed, some studies have observed greater levels of activity in burned areas in relation to decreased vegetation structure (Armitage and Ober, 2012; Buchalski et al., 2013; Smith and Gehrt, 2010), but this has not been observed in all studies (Loeb and Waldrop, 2008). As suggested by Fisher and Wilkinson (2005) in their review of fire impacts on mammals in the boreal forest, differences in responses to prescribed fire may be related to the heterogeneous nature of fire intensity across space.

Mid- and overstory trees killed by prescribed fire (Bagne et al., 2008; Signell et al., 2005) may create roosts for cavity-dwelling forest species as fire-killed trees senesce and decay, or conversely, may weaken and remove existing snags and roosts (Boyles and Aubrey, 2006). In studies on the northern long-eared bat (*Myotis septentrionalis*), Johnson et al. (2009) and Lacki et al. (2009) both documented preferential roosting in burned forest stands, with bats apparently benefitting from increased solar radiation provided by canopy openings. Similarly, Perry et al. (2007) found that 5 of the 6 bat species preferred to roost in or near stands that had undergone partial harvest, midstory removal, and burning. The relationship between roosting area use and activity has been relatively unexamined, but preferential use of recently burned stands with abundant roosts may result in non-additive changes in bat activity levels within burned areas as some bat species exhibit specific patterns of activity around roosts (Johnson et al., 2011).

Our objectives in this study were to (1) determine whether total bat activity changed as a result of oak forest regeneration treatments consisting of overstory retention harvest and prescribed fire, (2) determine whether presence and relative activity of individual bat species changed as a result of oak forest regeneration treatments, and (3) assess the specific relationship between interspecific levels of bat activity relative to vegetation volume. We predicted *a priori* that bat activity would be negatively related to vegetation volume, with activity levels greater immediately post-harvest than 3 years post-harvest, and would increase following prescribed fire as a result of decreased vegetation volume. Relative to individual species patterns, we predicted that activity of big brown (*Eptesicus fuscus*) and eastern red (*Lasiurus borealis*) bats would be negatively related to vegetation volume, whereas *Myotis* spp. and tri-colored bats (*Perimyotis subflavus*) activity would be relatively insensitive to vegetation volume.

2. Methods

2.1. Study area and design

This study was conducted in Richland Furnace (82°36′W longitude, 39°10′N latitude) and Zaleski (82°23′W longitude, 39°15′N latitude) State Forests, Ohio; both forests lie in the unglaciated Allegheny Plateau region, where topography is characterized by numerous hills and drainages (Kerr, 1985). Within the study area, slopes ranged from 10% to 24%, and elevation ranged from approximately 213 to 304 m above sea level. Within each forest we selected six 10-ha study blocks. We designated four study blocks within each forest as harvest treatments and two as controls. Within each forest, two of the harvest treatment blocks were reduced to 50% of full stocking and two to 70% of full stocking. We used a systematic sampling design to establish 8 sampling points with at least 60 m spacing within each treatment block for use in bat activity and vegetation monitoring. Harvest treatment blocks were commercially thinned between June 2005 and March 2006, and subsequently were burned by the Ohio Department of Natural Resources Division of Forestry in either fall 2009 or spring 2010. To meet logistical needs and management objectives, burn unit size ranged from ~10 to 30 ha. Backing and strip fires were used to control fire intensity; despite this, burn intensity was highly variable, with temperatures ranging from ~426 to 537 °C (R. Williams, unpublished data). Fifty and 70% overstory retention harvests combined with prescribed fire 3–5 years post-harvest are consistent with recommendations for promoting regeneration and recruitment of oak species (Brose et al., 1999; Iverson et al., 2008).

2.2. Bat activity

We sampled bat activity using Anabat II broadband ultrasonic bat detectors (Titley Electronics, Ballina New South Wales, Australia) connected to voice activated micro-cassette recorders in May–August 2006 and June–September in 2009 and 2010. Because we used micro-cassette recorders with limited storage capacity, we monitored for three hours nightly beginning one half-hour before sunset. We monitored activity at all sampling sites in two treatment blocks simultaneously on nights when monitoring occurred. Sampling order was random without replacement, but due to logistical constraints, we monitored treatment blocks within the same forest. We hung detectors 1.5 m above ground level oriented upward at a 45° angle and facing away from nearby vegetation to maximize bat detection (Weller and Zabel, 2002) and did not sample during rain.