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Roost networks of northern myotis (*Myotis septentrionalis*) in a managed landscape

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ABSTRACT

Maternity groups of many bat species conform to fission–fusion models and movements among diurnal roost trees and individual bats belonging to these groups use networks of roost trees. Forest disturbances may alter roost networks and characteristics of roost trees. Therefore, at the Fernow Experimental Forest in West Virginia, we examined roost tree networks of northern myotis (*Myotis septentrionalis*) in forest stands subjected to prescribed fire and in unmanipulated control treatments in 2008 and 2009. Northern myotis formed social groups whose roost areas and roost tree networks overlapped to some extent. Roost tree networks largely resembled scale-free network models, as 61% had a single central node roost tree. In control treatments, central node roost trees were in early stages of decay and surrounded by greater basal area than other trees within the networks. In prescribed fire treatments, central node roost trees were small in diameter, low in the forest canopy, and surrounded by low basal area compared to other trees in networks. Our results indicate that forest disturbances, including prescribed fire, can affect availability and distribution of roosts within roost tree networks.

1. Introduction

Nonrandom intraspecific associations among individuals have been documented in a variety of mammals, including bats (Alexander, 1974; Kerth, 2008). From an evolutionary perspective, advantages of forming nonrandom associations mostly exceed disadvantages, and several specific mechanisms underlying advantages have been posited (Alexander, 1974). Groups may form (fusion) as a defensive mechanism, for efficient information transfer, to facilitate food sharing, and for cooperative rearing of offspring (Alexander, 1974; Kerth, 2008). Disadvantages of group formation and causes for group separation (fission) include intragroup competition for resources, increased parasite loads, and disease transmission (Kerth, 2008). Therefore, group size may be in constant flux, i.e., fission–fusion, achieving optimal size to maximize fitness of its constituents in response to varying conditions (e.g., habitat dynamics, reproductive cycle; Kummer, 1971).

Fission–fusion dynamics have been documented in a number of bat species (Barclay and Kurta, 2007), yet few studies have investigated causal mechanisms or effects of changing habitat conditions on these dynamics (O'Donnell and Sedgeley, 1999). Indeed, effects of forest structure and degree and type of disturbance on fission–fusion dynamics have rarely been studied, yet the accepted paradigm is that defined social groups of animals should be one of the focal units of conservation (Willis and Brigham, 2004; Rhodes, 2007). Bat social groups may be regarded as a management unit because females of some bat species exhibit strong natal philopatry, returning to the same areas, and even to specific roost trees, in consecutive years (Crampton and Barclay, 1998; Sedgeley and O'Donnell, 1999; Kurta et al., 2002; Willis and Brigham, 2004). Roost switching within a maternity period also is common, and may be dictated in part by availability and ephemerality of roost trees (Lewis, 1995; Sedgeley and O'Donnell, 1999; Kurta et al., 2002).

Roost switching patterns can be viewed as networks among trees; a topology where roost trees are nodes and daily roost switching movements are edges within a network (Rhodes et al., 2006; Rhodes, 2007; Fortuna et al., 2009). Networks can be of many forms, including random and scale-free. In a random network, roost trees are essentially equally connected, with no roost tree being much more connected than other roost trees in the network (Barbási, 2002). In a scale-free network, there is an apparent "hub" or central node roost tree within the roost tree network that is more connected to other roost trees (Rhodes et al., 2006). If roost networks exist as scale-free networks, this suggests a relative importance among roost trees to bat maternity colonies. Conceptually, roost tree networks may be similar to primary (hub) and secondary roost trees as documented in Indiana myotis (*Myotis sodalis*; Barclay and Kurta, 2007). Roost networks may be specific to social groups of bats and could have implications for roost selection studies and habitat management. Although northern myotis

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(*Myotis septentrionalis*) have been shown to select for certain tree characteristics when roosting (Sasse and Pekins, 1996; Owen et al., 2002; Carter and Feldhamer, 2005), relative importance (e.g., used by more bats for more days) among trees used by social groups, primarily maternity colonies, has not been examined. Roost tree selection studies commonly give equal importance among all roost trees, comparing them to randomly located potential roost trees (Menzel et al., 2002; Miller et al., 2003). Central node roost trees may have unique characteristics that may be important in maintaining social organization.

Forest disturbances, including timber harvesting, fires, wind, and other causes, can affect availability and distribution of roost trees within roost tree networks (Chaverri et al., 2007; Perry et al., 2007). During maternity seasons, female northern myotis roost colonially in trees or snags with cavities or exfoliating bark, and roost selection may be affected by forest disturbances (Carter and Feldhamer, 2005; Garroway and Broders, 2007). Though northern myotis may use primary and secondary roost trees (Barclay and Kurta, 2007), this concept has not been well developed for northern myotis in Central Appalachian Mountains, nor in light of forest management practices.

Northern myotis switch roost trees frequently (every 1–5 days), and in the Central Appalachian Mountains, exhibit selection for certain roost tree characteristics, including distinct preferences for species (Owen et al., 2002; Menzel et al., 2002). In Canada, Garroway and Broders (2007) confirmed that northern myotis conform to fission–fusion models; however, these observations were not made in the context of forest disturbance and roost availability. Considering forest disturbances and its potential impacts on roost selection and networks of northern myotis (Barclay and Kurta, 2007), we conducted research focusing on these aspects of the species roosting ecology and formed several predictions. Because northern myotis have been documented exhibiting nonrandom association patterns in other parts of their range (Garroway and Broders, 2007), we predicted that (1) they would exhibit these same patterns in the Central Appalachian Mountains, forming delineable social groups. Further, we predicted that (2) the roost tree topology of northern myotis social groups would exist as scale-free networks rather than random networks, with definable central node roost trees. We posited that (3) physical characteristics of central node roost trees would be similar to other roost trees in networks. Lastly, (4) central node roost trees would be physically similar between stands that were and were not subjected to prescribed fire.

2. Methods

2.1. Study area

We conducted research at the Fernow Experimental Forest (FEF) in Tucker County, West Virginia. The FEF is a 1900-ha experimental forest managed by the U.S. Forest Service, Northern Research Station, and is located in the Unglaciated Allegheny Mountains subsection of the Appalachian Plateau Physiographic Province (Kochenderfer et al., 2007). Elevations range from 530 to 1100 m. Elklick Run, a 2.4-km fourth-order stream, roughly bisects FEF east to west. Approximately 5.5 km of dendritic intermittent and permanent streams feed into Elklick Run and incise steep slopes and plateau-like ridgetops (Madarish et al., 2002). Mean annual precipitation at FEF is 145.8 cm, ranging from 9.7 cm in October to 14.4 cm in June (Kochenderfer, 2006). Mean annual temperature is 9.2 °C, ranging from a mean of −18.0 °C in January to 20.6 °C in July (Kochenderfer, 2006). Vegetation at FEF is a mosaic of second- and third-growth, mixed-mesophytic and northern hardwood forest that has been managed by even (patch clearcut)- and uneven (single-tree selection variants)-aged silviculture since the mid-20th century, or has been left undisturbed following initial harvesting in Elkklick Run watershed from 1903 to 1911 (Schuler and Fajvan, 1999). Although American chestnut (*Castanea dentata*) and oak species, such as northern red oak (*Quercus rubra*), historically dominated the forest overstory, chestnut blight (*Cryphonectria parasitica*) and subsequent lack of intense disturbance, including fire and clearcutting, since the mid-20th century has allowed forest composition to shift toward shade-tolerant tree species, such as maples (*Acer* spp.) and American beech (*Fagus grandifolia*) (Schuler and Fajvan, 1999; Schuler, 2004). Prescribed fire recently has been used to promote oak regeneration in FEF forests that are currently dominated by sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), yellow-poplar (*Liriodendron tulipifera*), black cherry (*Prunus serotina*), American beech, sweet birch (*Betula lenta*), and basswood (*Tilia americana*) (Schuler, 2004).

In April or May (depending on management compartment) 2007 and 2008, prescribed fire treatments were conducted in three management compartments totaling 146 ha at FEF (121, 13, and 12 ha). Additionally, 48, 20-m radius plots were randomly located in each of the three management compartments, where all overstory or midstory trees, other than oak or hickory, were herbicided or girdled (Schuler, USDA Forest Service, personal communication).

2.2. Radiotelemetry

To capture bats, we erected mist nets (Avinet, Inc., Dryden, New York) over stream corridors, small pools, skidder trails, and service roads from May to August 2008–2009. We located mist netting sites within both fire and control treatments. We considered control treatments to be any area outside fire treatments. Mist netting was conducted for 5 h following sunset, unless prevented by periods of rain, wind ⩾20 kph, or temperatures <10 °C as these conditions can influence bat activity levels. We used Skin Bond® (Smith and Nephew, Largo, Florida) surgical cement to affix a 0.35-g radio-transmitter (Model LB-2N; Holohil Systems Ltd., Carp, Ontario, Canada) between the scapulae of captured female northern myotis. We attempted to locate diurnal roost trees of each radio-transmittered bat on a daily basis until the radio-transmitter battery completely discharged or the radio-transmitter became detached. Bat capture and handling protocols were approved by the Animal Care and Use Committee of West Virginia University (Protocol Number No. 08-0504) and followed guidelines of the American Society of Mammalogists (ACUC, 2011). We used a radio receiver and 3-element Yagi antenna (Wildlife Materials, Inc., Murphysboro, Illinois) to locate roost trees. To record roost tree locations within 10 m of their true geographic location, we used a Garmin GPSmap 60CSx global positioning unit (Olathe, Kansas). We conducted exit counts at a random set of roost trees throughout the pregnancy and lactation periods. We commenced exit counts approximately 1 h before sunset and continued until darkness prevented us from observing emerging bats.

2.3. Nonrandom association patterns

To determine if northern myotis roosted nonrandomly with conspecifics, we used daily roosting location data for each radio-transmittered bat. Similar to previous research examining nonrandom association patterns of bats, we calculated a half-weight association index for each pair (dyad) of radio-transmittered bats (Cairns and Schwager, 1987; Kerth and Konig, 1999; Garroway and Broders, 2007). The half-weight association index (HWI) was calculated as $x/[0.5 \times (n_a + n_b)]$ where x is the number of days that bats a and b were roosting in the same tree on the same day, and n_a and n_b are the number of days the roost trees of bats a and b were