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# *Robinia pseudoacacia* (Black Locust) as Day-roosts of Male *Myotis septentrionalis* (Northern Bats) on the Fernow Experimental Forest, West Virginia

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**Abstract** - During the summer of 2003, we captured and radiotagged ten male *Myotis septentrionalis* (northern bats) on the Fernow Experimental Forest (FEF) in the Allegheny Mountains of West Virginia to investigate day-roost selection. Of 16 roosts that were located, 13 were in *Robinia pseudoacacia* (black locusts), five in snags and eight in live trees. The other three roosts occurred in a *Sassafras albidum* (sassafras) snag and two live *Acer saccharum* (sugar maples). All live trees used as roosts were medium to large, canopy-dominant trees with considerable amounts of exfoliating bark and numerous broken limbs and cavities. Snags used as roosts were smaller than trees and other snags in surrounding stands, whereas live trees used as roosts were larger than other trees and snags in surrounding stands. Similar to previous research on female northern bats in the Allegheny Mountains, we observed a strong preference for both live and snag black locust as roosts over other available species. The high abundance of black locust as an important component on the FEF has been a relatively recent development dating to the early 1900s. Use of live canopy-dominant black locust with characteristics of mature forest trees lends support that older forests with decadent conditions provide important day-roost habitat, whereas use of both canopy dominant live trees and long-lasting black locust snags may support the ecological concept of roosting "areas" for northern bats.

## Introduction

*Myotis septentrionalis* Trouessart (northern bat) is found throughout the Appalachian Mountains where it frequently is the most numerous bat species documented in trapping surveys (Broders et al. 2003, Lacki and Hutchinson 1999, Menzel et al. 2003, Owen et al. 2004). Nonetheless, most aspects of the species' non-hibernacula roosting and foraging ecology in the Appalachians are known only from a small body of recent research in Kentucky (Lacki and Schweirjohann 2001), West Virginia (Menzel et al. 2002; Owen et al. 2002, 2003), New Hampshire (Sasse and Pekins 1996), Nova Scotia (Broders et al. 2003) and New Brunswick (Broders and Forbes 2004). In part, this stems from its common, unprotected status at the national level in both the United States and Canada, in contrast to more high-profile endangered species such as *M. sodalis* Miller and Allen (Indiana bat). Still,

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research indicates that the northern bat primarily is a forest-obligate species from both the standpoint of maternity roost characteristics of females (Foster and Kurta 1999, Menzel et al. 2002) and its foraging habits (Broders et al. 2003, Owen et al. 2003). As such, this species might serve as a good ecological/wildlife indicator species for oak (*Quercus* spp.)-hickory (*Carya* spp.), mixed mesophytic, and northern hardwood forest types along the Appalachian Mountains.

Menzel et al. (2002), Owen et al. (2002), and Owen et al. (2003) examined the roost requirements and foraging habitat use of female northern bats in intensively managed industrial forests of the Allegheny Mountains portion of the central Appalachians in West Virginia. They observed that northern bats foraged predominately in structurally complex, intact or lightly thinned mixed mesophytic forests. Female northern bats in West Virginia used cavities in live trees and snags of a wide diversity of tree species as maternity roosts, similar to Lacki and Schewierjohann's (2001) data from Kentucky. However, many roost snags or trees were below the immediate forest canopy and in densely stocked stands with considerable clutter. This is in contrast to the observations that many myotids choose maternity roosts in exposed trees or snags that maximize solar exposure (Broders and Forbes 2004, Kurta et al. 1993, Menzel et al. 2001, Weller and Zabel 2001). In West Virginia, almost one-third of the roosts documented were in small *Robinia pseudoacacia* L. (black locust) snags in forest stands previously clearcut or subjected to repeated heavy thinning. Although black locust is a shade-intolerant pioneer species capable of rapid growth, Owen et al. (2002) hypothesized that black locust used were those out-competed, overtopped, and suppressed by other competing woody species, leaving a small but rot-resistant and sturdy, long-lived snag. Snag longevity, combined with high relative abundance in managed forest stands, were the two characteristics believed to explain female northern bats' preferential use of black locust.

Male northern bats, unlike females, should not require day-roosts in the summer with the same set of constraints, i.e., roosts suitable for maternity activity (Broders and Forbes 2004). Accordingly, we became interested in examining male northern bat roost selection in a similar mixed mesophytic-northern hardwood forest that contained more older, mature stands nearing "gap-phase" successional dynamics with large live trees and abundant snags (Clebsch and Busing 1989), along with a diversity of other structural conditions from both early- and mid-successional stands (Schuler 2004). The objective of our study was to document the summer roost ecology of the male northern bat on the Fernow Experimental Forest (FEF). We predicted that male northern bats would choose a wide array of live tree and snag roosts with either exfoliating bark or an extant cavity, but that no discernable pattern of tree species or surrounding structural characteristic would be documented.

## Study Site and Methods

We conducted our study on the FEF in Tucker County, WV. The FEF is a 1473-ha forest that has been maintained for long-term forest management and ecological research by the USDA Forest Service Northeastern Research Station since 1951. Located within the Unglaciated Allegheny Plateau Province of the central Appalachians, the topography of the FEF is rugged with elevations that range from approximately 533 to 1112 m (Mardarish et al. 2002). Underlain by the Greenbrier Limestone, the FEF contains several small cave systems, including Big Springs Cave, which is a winter hibernaculum for 3 myotid species: *M. lucifugus* LeConte (little brown bat), the Indiana bat, and the northern bat (Ford et al. 2002; Madarish et al. 2002; C. Stihler, West Virginia Division of Natural Resources, pers. comm.). The climate is cool and moist with annual precipitation exceeding 155 cm. The upland forest cover is predominately a mixed mesophytic-Allegheny hardwood type at lower and mid-elevations and a northern hardwood type at the highest elevations (Braun 1950). Overstories of *Tsuga canadensis* Carriere (eastern hemlock) and dense shrub layers of *Rhododendron maximum* L. (rosebay rhododendron) dominate riparian zones (Owen et al. 2004). The FEF consists of a mix of older, unharvested second-growth forest stands originating from widespread harvests in the early 1900s and similarly aged stands periodically altered by diameter-limit and selection cutting, as well as younger stands (< 25 years) regenerated by clearcutting or deferment cutting (Schuler 2004). In addition to structural heterogeneity created by a diversity of stand ages and stockings from previous land-use practices, overall tree species assemblages have changed with European settlement and forest exploitation. Shade-intolerant "disturbance" species that require large light gaps, such as *Lirodendron tulipifera* L. (yellow poplar), *Prunus serotina* Ehrhart (black cherry), and black locust, were historically uncommon, but are now common in stands that were clearcut (Schuler and Gillespie 2000). Conversely, decades of fire-suppression and creation of partial gaps through cultural activities such as selection cutting have allowed a tremendous increase in some shade-tolerant species such as *Acer saccharum* Marshall (sugar maple) in other FEF stands (Schuler 2004).

We captured adult male northern bats using a single 9- x 2.4-m mistnet positioned at the head of a small creek issuing from Big Springs Cave on June 12, 20, 26, and 30, 2003 for approximately 1–1.5 hr after sunset. Upon capture, we determined age by examining the degree of epiphyseal-diaphyseal fusion (Anthony 1988), mass, and forearm length. We attached LB-2 radiotransmitters (0.46–0.54 g; Holohil Systems Ltd., Woodlawn, ON, Canada) to the hair between the scapulae with Skin Bond® (Pfizer Hospital Products Group, Inc., Largo, FL). We violated the recommendation that transmitter weight not exceed 5% of body mass (Aldridge and Brigham 1988; but see Kurta and Murray 2002) as our transmitters averaged 8.4% ± 0.1 (mean ± SE) of bat body mass. However, because we were only interested in day-roost selection, the resulting weight bias probably had minimal effect. We located roosts using TRX-1000S receivers and folding, two- or three-element Yagi antennas (Wildlife Materials Inc., Carbondale, IL). We tracked all bats daily until the transmitter unit failed or dropped from the bat.

At each male northern bat roost, we recorded the roost condition (live tree or snag and snag condition), roost species, presence of exfoliating bark or apparent cavities, diameter at breast height (dbh), roost height, and geo-referenced location using a TSC1 global positioning system (Trimble Navigation Ltd., Sunnyvale, CA). We measured roost-tree distances from the capture site and the roost-site's slope aspect within the ArcView 3.2 geographic information system (ERSI Inc., Redlands, CA). To assess the immediate forest overstory conditions surrounding roosts, we used the point-quarter method to measure and record the species, condition (snag or live), dbh (cm), and height (m) of the nearest overstory stems to the roost (Higgens et al. 1994, Owen et al. 2002). To assess use versus availability of roost types, we also counted the number of both live trees and snags by species that appeared capable of serving as a northern bat roost (i.e., presence of exfoliating bark, broken limbs or tops, and cavities); picking a random azimuth from each roost, we surveyed along a 20- x 100-m transect starting just beyond the roost measurement plot into the surrounding forest stand (Betts 1997, Menzel et al. 2002).

We compared male northern bat roost-size characteristics to neighboring overstory stems counted using the point-quarter method with non-parametric Wilcoxon tests (SAS Institute 1990). We used chi-square tests to examine differences in roost species (black locust versus others) and condition (snag versus live tree) with those of the surrounding forest stands (Stokes et al. 1995). Because we generated general *a priori* hypotheses about male northern bat roost characteristics being highly variable relative to that observed for females and because our study was still regarded as exploratory in scope, the use of Bonferroni adjustments to correct *P*-values for multiple comparisons on habitat data was unwarranted (Perneger 1998). We report mean values for roost measures as mean ± SE.

## Results

Over 4 nights in the summer of 2003, we netted 12 male northern bats, four female northern bats, and one *Pipistrellus subflavus* F. Cuvier (eastern pipistrelle). We placed radiotransmitters on ten males and tracked these bats to 16 different roosts. Mean transmitter retention time was 3.0 ± 0.4 days, and the mean number of roosts used per bat was 2.3 ± 0.4. Two bats shared roosts simultaneously or roost-switched among previously identified roosts during our tracking periods. The mean distance of roosts from the capture site at the head of Big Springs Creek was 463.0 ± 64.1 m.

Three bats roosted solely in snags, and seven bats roosted solely in live trees. Of the snags used as roosts, five were black locust snags and one was a

*Sassafras albidum* Nuttall (sassafras) snag. The mean dbh of the snag roosts was 16.6 ± 1.5 cm, and their mean height was 10.3 ± 1.2 m. All five black locust snags were graded as stage 4 with both loose bark and a clean surface and few or no intact branches, whereas the sassafras snag was graded as stage 6 with a broken top, mostly clean bark, and no remaining limbs (Payne and Bryant 1994). The 24 overstory stems surrounding the six snag roosts in the point-quarter sampling had larger dbh (mean = 31.9 ± 3.2 cm; $Z = 2.9$, $P = 0.003$) and were smaller (mean = 21.3 ± 1.4 m; $Z = 6.3$, $P < 0.0001$). Of live trees used as roosts, eight were black locust and two were sugar maples. The mean dbh of live tree roosts was 53.4 ± 6.3 cm, and mean height was 31.5 ± 1.7 m. Conversely, the 40 overstory stems surrounding the 10 live tree roosts in the point-quarter sampling had smaller dbh (mean = 25.9 ± 2.6 cm; $Z = -6.2$, $P < 0.0001$) and were taller (mean = 19.8 ± 1.7 m; $Z = -6.6$, $P < 0.0001$). All roosts, whether in snags or live trees, had sections of visibly loose or exfoliating bark, and all snags had visible cavities. Moreover, all of the live roosts had either large broken limbs or broken tops.

Although black locust did account for 34% of all woody stems ($n = 297$) scored as potential roosts on all transects, the species was still used more as a roost than would be expected based on availability in the surrounding forest stands ($\chi^2 = 14.6$, *d.f.* =1, $P < 0.0001$). Other species scored as potential roosts (> 2% of transect counts) included: *Quercus rubra* L. (northern red oak) 11.7%, sassafras 8.7%, *Betula lenta* L. (black birch) 8.4%, *Acer rubrum* L. (red maple) 7.7%, sugar maple 7.3%, yellow poplar 4.0%, *Fraxinus americana* L. (white ash) 3.4%, eastern hemlock 3%, black cherry 3%, and *Tilia americana* L. (basswood) 2.3%. Snags accounted for 46.1% of the woody stems scored as potential roosts across transect counts. Snags were not used as roosts over live trees more than expected based on availability in the surrounding forest stands ($\chi^2 = 0.29$, *d.f.* =1, $P = 0.58$). All of the roosts were located in designated "biological control" compartments or in areas outside of ongoing silvicultural research on the FEF in older, mature second-growth that had originated in the early 1900s (Schuler 2004, Schuler and Gillespie 2000). These unmanaged compartments on the FEF (range 2–31 ha) or portions thereof account for approximately 71% of a 200-ha area represented by a circular polygon radiating from the capture site to the furthermost day-roost (total unmanaged area on the FEF is currently 37%).

## Discussion

Contrary to our expectations, male northern bats on the FEF exhibited a strong roost selection pattern heavily skewed towards large, canopy-dominant live black locusts and small, below-canopy black locust snags. The black locust snag use was consistent with the pattern shown by female northern bats in West Virginia studied on more intensively managed forests (Menzel et al. 2002, Owen et al. 2002) and structurally similar to two males tracked to small-diameter trees (species not reported) with cavities by Lacki and Schwierjohann (2001) in Kentucky. However, we did not expect that male northern bats would show strong preference for large, live black locust. Use of black locust on the FEF by male northern bats, as well as by female northern bats on nearby industrial forests, are in part a function of the abundance of the tree species in the second-growth and/or more recently regenerated forests in the central Appalachians. In other words, roost choices by both sexes of northern bats show considerable plasticity that likely is very adaptable to local landscape characteristics. Unlike the females on nearby industrial forest landscapes (Menzel et al. 2002, Owen et al. 2002), male northern bats on the FEF had a full range of forest stand ages and structure conditions to select from in close proximity to their capture site and within the observed distances to roosts. Our results demonstrate an affinity for roosts in older forest stand conditions with abundant large trees and snag with exfoliating or plate-like bark and/or cavities. The other two live tree roosts we documented were very large sugar maples, each with large amounts of exfoliating bark somewhat resembling that of a *Carya ovata* Miller (shagbark hickory). Additionally, both had numerous broken limbs and apparent cavities. Coupled with their foraging habits in cluttered forested uplands and forested riparian areas (Broders et al. 2003, Owen et al. 2003), northern bats should be useful management indicator species for assessing mature forest ecosystem integrity in the Appalachians.

We found roost selection of black locust to be ecologically interesting when the historic tree species assemblage patterns of the FEF and the Allegheny Mountains are considered. Use of black locust would appear to be a relatively recent development for northern bats. Witness tree data from regional land surveys in the late 1700s through mid-1800s suggests that black locust was much less abundant than now (Abrams and McCay 1996, Schuler and Gillespie 2000). On the FEF, black locust appeared as a major component of hardwood regeneration following the clearcut harvest of the area's primary forest as well as pasture abandonment in the early 1900s, culminating with its high relative importance values in the 1940–50s when these stands were approximately 30 years old. Restricted mainly to the southern and central Appalachian Mountains and the Ozark and Ouachita Highlands, black locust can be abundant in areas with high site indices following a stand-replacing disturbance such as clearcutting (Beck and Hooper 1986, Boring et al. 1981). However, as the stand develops, most black locust individuals lose competitiveness with other fast-growing shade-intolerants or succumb to *Megacyllene robiniae* Forster (black locust borer) (Della-Bianca 1983, Leopold et al. 1985), though some do become large canopy-dominant trees (Fowells 1965,) as has occurred on the FEF. Range-wide, black locust displays its best growth form in the central Appalachian region and elsewhere just west of the Allegheny Front where the FEF is located (Clarkson 1958, Strausbaugh and Core 1977).

Although canopy-dominant black locust used by northern bats on the FEF will be present for decades to come, continued recruitment of black locust only will occur in forest openings greater than 0.16 ha (Miller et al. 1995). Schuler (2004) predicted that successional patterns in unmanaged forests and those subject to selective harvests should continue to shift forests on the FEF and elsewhere in the central Appalachians towards those dominated by shade-tolerant species such as sugar maple. As evidenced by northern bats in this study and by Indiana bats on the FEF (Ford et al. 2002), large sugar maple are occupied as bat roosts. With characteristics such as sloughing bark, high susceptibility to heart rot and primary excavator activity (i.e., *Dryocopus pileatus* L. [Pileated Woodpecker]) along with subsequent cavity formation (Carey 1983), an increase in sugar maples attaining old-growth attributes probably will mitigate for future reductions in black locust. This ameliorating factor could be especially important for female northern bats on the FEF as demonstrated elsewhere (Broders and Forbes 2004). Perhaps less desirable from a silivicultural and an overall wildlife management standpoint in the central Appalachians (Miller and Kochenderfer 1998, Miller and Smith 1993), reductions in stand-replacement management techniques that favor black locust alternatively may benefit northern bats by preserving more intact roost areas where bats exhibit roost loyalty, as demonstrated by other bat species in North America (Veilleux and Veilleux 2004, Willis and Brigham 2004, Willis et al. 2003). Our data were insufficient in sample size and time (Lacki and Baker 2003) to conclusively infer that male northern bats at the FEF demonstrate an affinity to a single roost area comprised of several roosts with a forest stand. However, in each instance where a northern bat in our study switched from one tree or snag to another, none moved more than 100 m to alternative roosts, thereby indicating that the roost areas concept might be applicable to northern bats.

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