AUTUMN ROOSTING HABITAT OF MALE INDIANA BATS (*MYOTIS SODALIS*) IN A MANAGED FOREST SETTING IN KENTUCKY

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Abstract—In early October 1996 and in late August and late September 1997, during the autumn pre-hibernation swarming period, a total of 22 male Indiana bats (*Myotis sodalis*) were captured by the use of a portable harp trap at the entrance to a cave hibernaculum located on the Daniel Boone National Forest in Pulaski County, Kentucky. Each bat was fitted in the field with a lightweight (0.52 g) transmitter (Holohil Systems Ltd, model LB-2) attached between the scapulae with surgical adhesive (Skin-bond), released at the point of capture within 4 hours after being caught, and subsequently tracked daily to roost trees by the use of a three-element Yagi antenna and receiver (Wildlife Materials, Model TRX-1000), during daylight hours, until its transmitter failed or it entered the hibernaculum for the winter. Each roost tree that was used by a transmittered Indiana bat was marked in the field with paint and/or plastic flagging and its location was plotted on a topographic map. Information that was collected for each tree included tree species, condition (live/dead), diameter at breast height (dbh), and (if available) the past management of the stand in which the tree was located. During 1997, percent canopy closure was measured at each roost tree by means of a concave spherical densiometer (Robert E Lemmon Forest Densiometers, Model-C). Habitat use in response to past management was evaluated by: (a) defining the analysis area to include all land (5740 ha) located within the smallest circle that could be drawn, with the bat hibernaculum as the center, that would include all known roost trees (N = 102); (b) determining the relative proportions of each type of managed habitat available to the bats within the analysis area; and (c) comparing habitat use versus availability with respect to past management practices that had taken place within each stand where known roost trees were located. The analysis area as defined above was virtually 100 percent forested, with various oak-pine, oak, yellow pine, and pine-oak forest types on the ridgetops and upper slopes and cove hardwood forest types on the lower slopes and in the stream valleys. Nearly 74 percent (4001 ha) of the analysis area was in public ownership (U. S. Forest Service); the remaining 26 percent (1445 ha) was privately owned. An impounded section of the Cumberland River, forming a 294 ha strip which extended through the northern portion of the circle, was excluded from the analysis.

During both years combined, roosting Indiana bats were located a total of 212 times in 102 different roost trees. Dead trees (snags) accounted for 86 percent (N = 88) of all roost trees found and 92 percent (N = 194) of all bat days (each day that a bat was tracked to a roost tree was defined as 1 bat day regardless of whether or not a bat had previously been found roosting in that particular tree); live trees accounted for 14 percent of all roost trees (N = 14) and 8 percent of all bat days (N = 18). Although Indiana bats were found roosting in 13 species of trees, the majority of these (79 percent) were pines (*Pinus* sp.) and oaks (*Quercus* spp.). Pine snags made up 43 percent of all roost trees (N = 44) and nearly 50 percent of all bat days (N = 105); no bats were found roosting in live pines. Oak snags (N = 25) and living oaks (N = 12) comprised 36 percent of the roost tree sample and 27 percent (N = 57) of all bat days. The most frequently used roost tree species were shortleaf pine, *Pinus echinata* (33 roost trees, 83 bat days), Virginia pine (*P. virginiana*) (11 roost trees, 21 bat days), scarlet oak, *Quercus coccinea* (15 roost trees, 19 bat days), and white oak, *Q. alba* (12 roost trees, 16 bat days).

Roost trees used by male Indiana bats during this study ranged in size from 8.4 cm to 86.6 cm (mean = 30.8 cm) dbh. Although no evening emergence counts were conducted at the individual trees, 3 different snags (2 shortleaf pines, 1 hardwood) were used simultaneously by 2 transmittered bats on a total of 8 different days, and 1 shortleaf pine snag was used simultaneously by 3 transmittered bats on 2 different days a week apart. Another shortleaf pine snag was used by different transmittered bats during successive years. These observations indicate that certain trees may be locally important as autumn roosting sites to Indiana bats that hibernate in nearby caves.

Roost tree switching was frequent for most individual Indiana bats that were monitored. In 1996, 10 bats used 1-8 different roost trees each during the 1-18 days that they were found, switching roosts a total of 46 times (including some returns to previously used trees) at an average of once every 2.0 days. In 1997, 12 bats used 2-11 roost trees each during 4-15 days of tracking, changing trees a total of 75 times for an average of once every 1.6 days. Several switched roost trees virtually every day, while others returned repeatedly to 2 or 3 particular trees. Although frequent roost tree switching was normal for most bats, in many cases all of the trees used by any individual Indiana bat during its tracking period were relatively close to one another. For the 20 bats that were found 4 times or more during both years combined, distances between roost

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trees ranged from 48 m to 2688 m, and the area of the smallest circle that could be drawn to include all roost trees used by an individual bat ranged from 0.4 ha to 568 ha. The most sedentary Indiana bats (N = 6) used 2-7 different roost trees each within a total area of 4.5 ha or less; an additional set of bats (N = 11) used 3-11 different roost trees each within a total area of 10 ha to 105 ha; and the most nomadic bats (N = 3) used 3-5 roost trees scattered over areas ranging from 518 ha to 568 ha. There did not appear to be any direct relationship between the number of times that a bat was found during a tracking period and the total area within which all of its documented roost trees were located.

As measured from the ground, canopy closure (cc) at all roost trees (N = 70) used by transmittered Indiana bats during the 1997 fall season ranged from 20 percent to 93 percent (mean = 80 percent), with 19 trees (34 bat days) located in fairly open canopy forest (<60 percent cc), 17 trees (27 bat days) in an intermediate canopy range (60-80 percent cc), and 34 trees (61 bat days) in closed canopy situations (>80 percent cc). Since most of the bats were roosting beneath loose bark in the upper portions of snags, however, there was no reasonable method available which would allow canopy closure to be measured at the actual roosts. An attempt was made to remedy this situation by using only the most open measurement that was made at each roost tree. This resulted in a canopy closure range from 0 percent (for roost trees located at the edges of large openings) to 92 percent, with 44 bat days spent in open canopy roosts (<60 percent cc), 35 bat days in intermediate canopy roosts (60-80 percent cc), and 43 bat days in closed canopy roosts (>80 percent cc).

Two separate tracts within the study area had been managed under a prescribed burning regime designed to control hardwood regeneration and maintain an open forest dominated by shortleaf pine - conditions geared toward the restoration of habitat for the federal endangered red-cockaded woodpecker (*Picoides borealis*). These tracts totaled 8 percent (436 ha) of the total amount of habitat within the analysis area, and harbored 12 of the 102 Indiana bat roost trees that were documented during both years combined. Roost tree use in prescribed burns (6 of 33 roost trees) was double the expected level (based upon the total amount of that habitat type available) during the 1996 tracking period, and equal to the expected level (6 of 70 roost trees) during the 1997 tracking period.

Although 26 percent (1445 ha) of the potential Indiana bat habitat within the study area was under private ownership, nearly all (100 of 102) of the roost trees documented were on National Forest System lands, some of which included stands where some form of timber management had taken place in recent years. During the 1996 and 1997 fall telemetry periods, approximately 17 percent of the study area (897 ha) that had been clearcut during the past 35 years yielded 0 roost trees and 0 bat days during both years combined; this was much lower than the expected level of use (16 roost trees, 35 bat days) based upon the total amount of that habitat available. Forested habitat which had not been actively managed during the past 50 years made up 44 percent of the study area (2367 ha) in 1996 and harbored 28 roost trees with 82 bat days of use as compared to an expected 15 roost trees and 39 bat days; this habitat was thus used at about twice the expected level based on its availability. This habitat type covered about 42 percent (2299 ha) of the study area in 1997, yielding 47 roost trees and 76 bat days, about 1.5 times the expected 30 roost trees and 51 bat days. Two-age shelterwood cuts (harvested during the past 5 years) and high-graded stands (up to 10 years old) comprised about 2.6 percent of the study area (143 ha) in 1996 and held 5 Indiana bat roost trees with 8 bat days of use, 4-5 times the expected level based on availability. In 1997, additional 2-age shelterwood cutting had increased the proportion of this habitat type to nearly 4 percent of the study area (211 ha), with 18 roost trees and 36 bat days documented here (6-7 times the expected levels). During both years combined, uninventoried habitats (including privately-held tracts and portions of a designated Forest Service wilderness) made up about 37 percent of the study area (2039 ha) and harbored 5 documented roost trees (of 38 expected) and 10 bat days (of 80 expected).

Although the total proportion of the study area that had been recently managed by the use of the 2-age shelterwood harvest method was too small to allow for a statistical verification of these preliminary results (i.e. that Indiana bats may actually be selecting this habitat type for roosting), some additional observations made during this telemetry study appear appropriate for this presentation. Stands that were harvested by the 2-age shelterwood method from 1993-1995, under Daniel Boone National Forest guidelines that called for the retention of 40 live trees and 5 snags/ha (16 live trees and 2 snags/acre), yielded 1 documented Indiana bat roost tree and 1 bat day during both years combined - slightly below expected levels of use. Stands that were harvested by the 2-age shelterwood method from 1996-1997, however, under different guidelines that called for the retention of 40 live trees/ha and additionally all snags, shagbark hickories, hollow trees, and trees with large dead limbs, harbored 15 Indiana bat roost trees and 27 bat days - well above expected levels of use. These observations and results suggest that timber harvesting by the 2-age shelterwood method, in concert with the retention of good numbers of snags and other suitable types of roost trees, can provide favorable roosting conditions for male Indiana bats during the autumn pre-hibernation period, at least over the short term.