THE INDIANA BAT: BIOLOGY AND MANAGEMENT OF AN ENDANGERED SPECIES ROOST FIDELITY IN KENTUCKY

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ROOST FIDELITY IN KENTUCKY

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Abstract

Objectives of this 5-year study (1996–2000) were to determine whether Indiana bats (*Myotis sodalis*) showed short- or long-term fidelity to particular roost trees or areas and to develop broadly applicable definitions for types of fidelity by bats. We radiotracked 60 Indiana bats captured near a hibernaculum in the Daniel Boone National Forest, Pulaski Co., Kentucky, during nine tracking periods (two in early spring, two in summer, and five in autumn). Sixteen bats were tracked in multiple periods. Bats used 280 roost trees of 17 species. Individuals switched trees every 2.21 days but commonly returned to previously used trees, in either a consecutive or nonconsecutive manner. Although there was a positive relationship between number of days tracked and number of trees used by individuals, bats often used particular trees and areas over multiple seasons or years. A kernel home-range analysis identified eight areas of repeated use within 4.75 km of the hibernaculum. Some bats used two or more of these areas, implying that individuals were aware of alternative tracts for use when existing roosts or areas became unsuitable. Biologists must consider various types of fidelity by Indiana bats when developing management plans for areas near hibernacula.

Key words: behavior, fidelity, hibernaculum, home range, Indiana bat, Kentucky, *Myotis sodalis*, roosts

Introduction

Consistent use of the same area by an animal likely is beneficial. For example, familiarity with an area probably increases foraging efficiency and decreases risk of predation (Greenwood and Harvey 1982). Lewis (1995) suggests that site fidelity by bats increases awareness of high-quality roosts and promotes social interactions, and fidelity is documented for several species of bat, especially those that roost in buildings or other artificial roosts (Barbour and Davis 1969). Unfortunately, fidelity by tree-dwelling species, like the Indiana bat (*Myotis sodalis*), is more difficult to detect and explain than in species that roost in relatively permanent structures, and to date, there has been no uniform approach to assessing fidelity of tree-roosting bats.

We typically think of fidelity as repeated use of a particular site, either by the species or an individual, over time. The "site" referred to, however, can be as specific as a single piece of bark, an entire tree, or a single cave or mine. In addition, a site can be a foraging area that is used repeatedly, either by an individual bat or by the species in general, or a route that is followed repeatedly by one or more bats as they travel between foraging areas. Furthermore, a site can be a particular geographic area, where several roost trees or caves occur close to one another.

Once sites of repeated use are identified, one must consider the frequency with which those sites are used and the intervals between visits to further solidify a definition of fidelity. For our discussion, fidelity includes return to a previously used roost tree by a single bat after using a different tree. Indiana bats typically switch roosts every 2–4 days (Gardner et al. 1991, Kurta et al. 1996, 2002), so in addition, we consider that a bat shows fidelity if it returns to a particular tree for at least 5 consecutive days.

We also develop a number of more-specific definitions of fidelity that are formulated specifically for Indiana bats but probably apply to other species as well. Bats that repeatedly use the same site at different intervals, whether for foraging, roosting, or hibernating, display "site fidelity" (SF). "Roost-site fidelity" (RSF) is repeated, consecutive (for z5 days) or nonconsecutive use of a site for roosting. A specific type of RSF is "roost-tree fidelity" (RTF), which is repetitive use of a particular roost tree, and a broader type of RSF is "roost-area fidelity" (RAF), which is repeated use of a group of roost trees in a particular area by one or more bats.

"Foraging-area fidelity" (FAF) is recurring use of a particular foraging site or travel corridor by one or more individuals. These types of fidelity are either general, i.e., displayed by different members of the same species (RSFs, RTFs, RAFs, FAFs), or specific to an individual bat (RSFi, RTFi, RAFi, FAFi). Fidelity of any type is considered short-term if observed during a single tracking period (typically 10–20 days) and long-term if observations encompass more than one tracking period.

Different types of fidelity already have been described for Indiana bats during summer. Gardner et al. (1991) defined and observed two types of RSF in Illinois. The first, single-summer fidelity (reuse of a particular tree within a season by specific individuals or other members of the species), exemplified short-term RTFi or RTFs. Gardner et al. (1991) also documented philopatry, reuse of particular trees or areas by bats from year to year (i.e., long-term RTF and RAF, respectively). In addition, they demonstrated long-term FAFi for Indiana bats by recapturing banded individuals in the same foraging areas over multiple years. Gardner et al. (1991) concluded that Indiana bats showed some degree of fidelity to areas and roost trees over multiple years.

Kurta et al. (1996) radiotracked Indiana bats in Michigan and reported that all bats carrying transmitters used the same forested wetland during three consecutive summers, thus exhibiting long-term FAFs and RAFs. In addition, several roost trees were occupied by different bats in different years (long-term RTFs). However, Kurta et al. (1996), like Gardner et al. (1991), never described reuse of any particular roost tree by an individual bat (RTFi) over multiple tracking periods. Kurta et al. (1996) concluded that Indiana bats did not show roost-site fidelity. Although Gardner et al. (1991) and Kurta et al. (1996) had similar results, lack of uniform definitions and differences in interpretation of degrees of fidelity probably contributed to the disparity in their conclusions.

Our objectives are to describe and quantify various aspects of roosting fidelity for the Indiana bat, based on our work in Kentucky. We are mainly interested in determining if Indiana bats show fidelity to particular roost trees or areas, from season to season or year to year, because such behavior has important management implications. Indiana bats have a patchy distribution across their range (U.S. Fish and Wildlife Service 1999), and it is critical to determine whether they show fidelity to particular areas. Sites of repeated use by individuals or by the species likely provide high-quality roosting conditions and should be preserved. Also, once repeated-use areas are identified and described, land stewards can manage other sites to obtain similar characteristics, thereby providing more potential habitat for the Indiana bat.

Methods

Study area—Our study site includes two caves (referred to as "SGC" and "NGP") that are used by Indiana bats on the Daniel Boone National Forest, in Pulaski Co., Kentucky. SGC supports a winter population of 200–300 Indiana bats and also serves as a site for autumn swarming (Cope and Humphrey 1977). In addition, there are two areas within the cave where Indiana bats roost in spring and autumn, prior to and immediately following deep hibernation. In summer, SGC is used occasionally as a dayroost by males, and it also is visited regularly at night, throughout summer, by varying numbers of Indiana bats that primarily roost in trees in the nearby forest during the day (Gumbert 2001, MacGregor et al. 1999). NGP often is used as a roosting site by a few Indiana bats (<20 individuals) in late summer and fall.

The area surrounding SGC is almost completely forested, thus providing a number of potential roost trees. The National Forest comprises 64% of the area contained in a 70-km^2 circle centered on SGC. Dominant types of forest on public land inside this circle include oak (38%) and pine (13%), with sizeable tracts of pine-oak (8%) and mixed hardwoods (8%). A well-developed network of roads provides access to most areas that bats use for roosting.

Field techniques—We captured bats associated with SGC by setting a harp trap at the cave's entrance and by mistnetting at ponds within 3 km of the cave. At NGP, we used a hand-held net to capture bats roosting on the ceiling. We attached lightweight radiotransmitters (0.52–0.68 g, Holohil Systems, Ltd., Carp, Ontario, Canada) between the scapulae of Indiana bats, using surgical adhesive (Skin-Bond Cement, Smith & Nephew, Inc., Largo, Florida), and placed a split-ring, plastic band (Size XCL, A. C. Hughes, Ltd., Hampton Hill, Middlesex, England) on the forearm. Bands displayed a number followed by the letters "KY." Bats were released at the point of capture, and we located roost trees daily, using a three-element Yagi antenna and telemetry receiver (Model TRX-1000, Wildlife Materials, Inc., Carbondale, Illinois).

Indiana bats were radiotracked during nine "tracking periods," between October 1996 and October 2000; two periods were in early spring, two occurred in summer, and five were in autumn (Table 1). We defined a "bat-event" as the collection of roosting locations for an individual bat during a single tracking period. A "bat-day" represented use of a tree by one bat for 1 day (Kurta et al. 1996). "Switching" occurred when a bat occupied a roost tree that it did not use on the previous day.

We performed an analysis of variance to test for differences in rate of switching within and among seasons and used least-squares regression to analyze the relationship between total number (log-transformed) of roost trees that were used by each bat and number of days that each bat was located (SAS Institute 1990). Some bats were only radiotracked in one period, whereas other bats were radiotracked in multiple periods. For each group, we calculated a separate regression line, and tested for differences in slope using a general linear models procedure (SAS Institute 1990).

Each roost tree was marked with a numbered, aluminum tag, and data were collected on characteristics of the roost (Gumbert 2001, MacGregor et al. 1999). In autumn 2000, we inventoried trees that previously were used as roosts to determine whether they were still suitable for roosting. Trees that lacked exfoliating bark or roosting crevices or those that were lying on the ground were deemed unsuitable for roosting by Indiana bats.

Analysis of home range—Locations of trees used by each bat were plotted using ArcView, version 3.2 (Environmental Systems Research Institute, Redlands, California) and analyzed with the animal-movement extension to ArcView (Hooge and Eichenlaub 1997). Using all known bat-days, we generated a kernel home range (Powell 2000), which enabled us to predict the likelihood of bats roosting in particular probability-use areas (50, 75, or 95% PUAs). We used distance (4.75 km) from SGC to the roost tree farthest from SGC yet still inside the kernel home range to define the radius of the study area.

Results

During nine tracking periods (Table 1), we placed 116 radiotransmitters on 91 Indiana bats (70 males, 21 females). We never located 31 individuals (14 males, 17 females) but found 60 animals (56 males, 4 females) at least once, including 49 bats (48 males, 1 female) that we located on more than 5 days. Transmitters functioned for 921 days, and we documented 805 bat-days during 80 bat-events. Sixteen Indiana bats were radiotracked and located in multiple tracking periods—13 bats for two periods, two bats for three periods, and one bat for four tracking periods. We refer to bats that were located in multiple tracking periods as "multi-period bats."

Indiana bats roosted in 280 trees of 17 species. Pines (*Pinus* spp., 58%), oaks (*Quercus* spp., 25%), and hickories (*Carya* spp., 10%) were most common (Gumbert 2001, MacGregor et al. 1999), and 84% of roost trees were snags (dead trees). Average diameter of roost trees at breast height was 30.3 cm (range = 6.4–76.3 cm).

Fidelity to trees—We recorded 463 roost switches over 921 tracking days or one switch/2.21 days. Transmitters functioned for 640 days during autumn, 164 days in summer, and 117 days in spring. Frequency of switching within each season did not vary among years (all $P < 0.30$), but there was a difference in

Table 1.—Summary of radiotracking Indiana bats in the Daniel Boone National Forest, Kentucky.

Year	Season	Dates	Tracking period	Number of bat-days	Number of bat-events	Number of trees used	Number of trees reused
1996	Autumn	8–30 October	1	90	10	33	—
1997	Autumn	22 September–9 October	2	122	12	70	1
1998	Spring	20 April–4 May	3	47	5	15	1
	Summer	5 July–8 August	4	59	10	21	2
	Autumn	5–23 October	5	123	13	54	5
1999	Spring	11–25 April	6	65	8	19	2
	Summer	28 June–16 July	7	83	9	20	2
	Autumn	4–26 October	8	99	7	34	5
2000	Autumn	3–30 October	9	117	6	37	5

frequency of switching by season ($F_{2, 63}$ = 5.54; P < 0.006). Switching occurred more frequently in summer (1/2.03 days) and autumn (1/2.05 days) than in spring (1/3.36 days). There was a positive relationship between number of trees used (log-transformed) and number of bat-days for bats that were tracked in only one period (r^2 = 0.53; n = 44; P < 0.001) and for multi-period bats (r^2 = 0.49; n = 16; P < 0.003; Fig. 1). However, slope of the regression line for single and multi-period bats differed (t_{59} = 3.93; P < 0.001) indicating that bats tracked in multiple periods added new trees at a slower rate than expected if the relationship were constant (Fig. 1).

There were 17 bat-events for which bats were located on less than 5 days. For 28 bat-events, we found bats roosting in at least one particular tree for 5 or more consecutive days during a single tracking period (RTFi). Overall, consecutive use of roost trees by an individual bat ranged from 2 to 12 days, with bat 879KY using the same mockernut hickory (*Carya tomentosa*) every day that it was located, 12 days in a row. Use of the same tree, but on nonconsecutive days, was much more common; in 56 (78%) of 72 bat-events in which bats were tracked for 3 or more days, bats returned to a previously used roost tree after roosting in another (RTFi). One Indiana bat used a short-leaf pine (*Pinus echinata*) for 16 days (twice for 7 days in a row), returning to this tree three times in the 23 days that it was located; thus, this bat displayed both consecutive and nonconsecutive short-term RTFi.

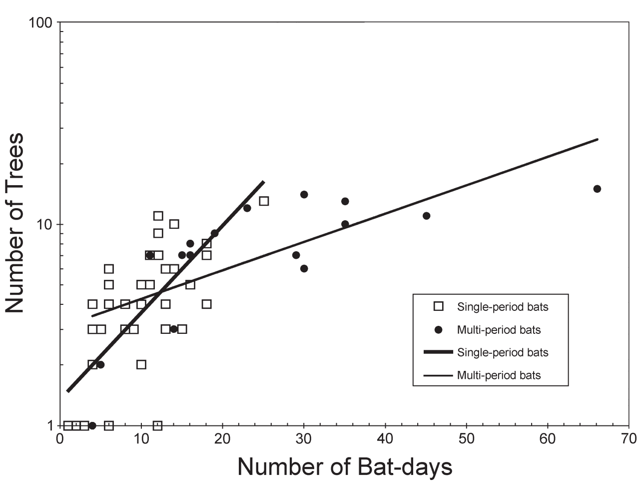

Figure 1.—Relationship between number of days that a bat was radiotracked (bat-days) and number of different trees used, for bats tracked in only one period or in multiple periods. Equations for regression lines were: log (number of trees) = 0.0431 ..number of days + 0.1287, and log (number of trees) = 0.0142 ..number of days + 0.4866, for single and multiple periods, respectively.

Bats used 145 of 280 roost trees for only 1 bat-day. Forty-two trees were occupied for 2 bat-days; 57, for 3–4 bat-days; and 36, for 5 or more bat-days. Most (262) trees were used in only one tracking period (Table 1); 13 trees were used in two periods, and five trees were used in three periods. Most (249) trees were used by only one bat that was radiotracked, but 31 trees were occupied by multiple bats carrying transmitters, although not always on the same day. Ten trees were used simultaneously by more than one bat carrying a transmitter, and as many as five bats with a transmitter were found in the same tree on the same day (Table 2).

We conducted emergence counts at selected trees that were used by multiple bats. Counts conducted at seven roost trees indicated as many as 10 bats were roosting with one or more bats carrying a transmitter (Gumbert 2001). We also observed interspecific roosting behavior. On one occasion, a northern bat (*Myotis septentrionalis*) roosted with a male Indiana bat under a piece of bark on a dead red maple (*Acer rubrum*). On another day, three big brown bats (*Eptesicus fuscus*) and an Indiana bat roosted in a short-leaf pine (tree 420); the big brown bats roosted under exfoliating bark, ca. 4 m up the bole, but we did not observe the specific site occupied by the Indiana bat.

Fidelity to areas—A kernel home-range analysis of 805 bat-days showed that eight distinct areas were most important as roosting habitat, but bats did not use all areas equally (Table 3). Four "core areas" (Yellow Jacket, Bethel Church, Double Tarkiln, and Bat Ridge) included both 50 and 75% PUAs, and a 95% PUA surrounded all tracts (Fig. 2). Area (16.9 km^2) of the 95% PUA was less than 25% of the total area (70.5 km^2) within a 4.75-km radius of the hibernaculum. The 75% PUA made up 8% of the area inside the circle, and the 50% PUA only accounted for 2%. Most roost trees (76%) were in one of the four core areas. Core areas were similar in size, with similar habitats (e.g., stands of older forest dominated by both oaks and hickories or pine) and areas of disturbance. Disturbances were either natural (e.g., storm damage) or man-made (e.g., logging activities). Number of bat-days spent in core areas (n = 402) was more than twice the number spent in roosting areas with only 75% PUAs (n = 172; Table 3).

Of 60 bats that were radiotracked, 35 roosted exclusively in one of the eight areas listed in Table 3, all

Table 2.—Ten trees with concurrent use by different Indiana bats wearing radiotransmitters.

Tree	Area[a]	Number of days used by at least one bat	Number of days used by multiple bats	Total number of bat-days	Maximum number of bats in tree	Tracking periods[b]
21	95% PUA	6	5	11	2	1
29	95% PUA	3	2	7	3	1
44	Bartley Ridge	5	2	7	2	1
130	Bat Ridge	19	12	40	5	4, 7
131	Bat Ridge	5	2	8	3	4
461	95% PUA	2	1	3	2	1
639	Bauer Road	9	1	10	2	8
656	Bat Ridge	5	4	11	3	7
678	Bethel Church	6	1	7	2	9
789	Bauer Road	2	1	3	2	5

[a] Table 3.
[b] Table 1.

Table 3.—Use of eight roosting areas by Indiana bats on the Daniel Boone National Forest, Kentucky (Fig. 1). Most bats were found in a 95% probability-use area (PUA) predicted by a kernel home-range analysis. Four core areas contained a 50% PUA, and summaries for 75% PUAs include data for the enclosed 50% PUAs.

Area	Total number of tracking periods	Total bat-days	Total number of bats	Total number of trees	Area (km^2)
Yellow Jacket					
50% PUA	7	76	6	31	0.25
75% PUA	7	79	6	33	0.89
Double Tarkiln					
50% PUA	7	110	4	27	0.47
75% PUA	7	136	7	34	1.40
Bat Ridge					
50% PUA	4	77	11	15	0.31
75% PUA	5	110	11	29	1.17
Bethel Church					
50% PUA	5	66	5	19	0.20
75% PUA	6	77	6	24	0.85
Valentour Road					
75% PUA	3	27	3	6	0.18
Hyden Ridge					
75% PUA	4	40	4	14	0.28
Bartley Ridge					
75% PUA	1	33	3	11	0.17
Bauer Road					
75% PUA	5	72	7	15	0.48
Combined					
95% PUA	9	787	56	14	16.91

of which contained 75% PUAs. Twelve bats roosted in two separate areas; two of these bats spent at least 40% of their time in each area, whereas the other 10 bats spent at least 79% of their time in only one of the areas. One bat used three areas that contained 75% PUAs, and one roosted in two areas with 75% PUAs, as well as in an area outside the 95% PUA. The seven remaining bats roosted in both an area that contained a 75% PUA

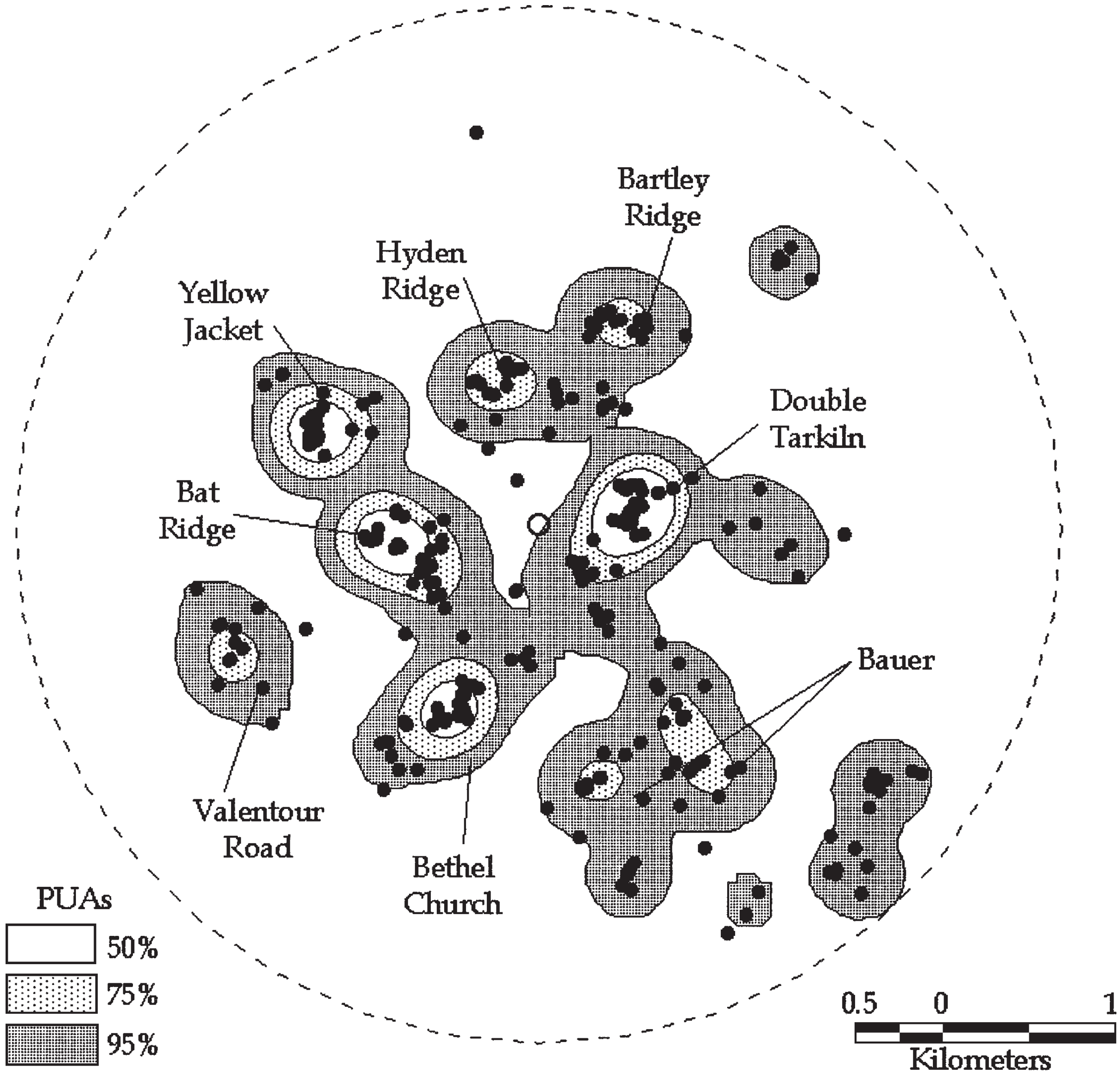

Figure 2.—Kernel home range for 280 trees used by Indiana bats from 1996 to 2000. An open circle at the center of the study area indicates the local hibernaculum (SGC). A circle of 4.75km radius (dashed lines) surrounds the cave. Only one roost tree, which was used for 1 bat-day and located over 7 km from SGC, is not shown.

and outside the 95% PUA (Fig. 2). Only four bats never were found inside the 95% PUA, but each was radiotracked for less than 5 days.

Multi-period bats—Data for multi-period bats represented almost half (49%) the total of bat-days. Of the 16 multi-period bats, 14 were found on more than 10 days, and half were located on more than 25 days. Three multi-period bats used different roost trees and areas from one tracking period to the next, showing no long-term RTFi or RAFi. Nine were found in the same areas (long-term RAFi), but in different trees, over multiple tracking periods. The other four multi-period bats roosted in one or more trees that they used during a previous tracking period (long-term RTFi and long-term RAFi). Of eight trees used in multiple tracking periods by these four bats, four trees were occupied in different seasons of the same year, three were used during 2 years, and one was used in 3 different years.

In the last tracking period, we relocated four multi-period bats and used these bats to illustrate types of fidelity. Bat 1947KY, which used different areas and sets of roost trees for the two periods that it was radiotracked, showed neither long-term RAFi nor RTFi. The other three bats showed long-term RAFi, using the same areas and sometimes the same roost trees as in

Table 4.—Use of trees by three multi-period bats and condition of those roost trees at the end of the study in autumn 2000.

Bat	Tree	Area[a]	Number of bat-days per tracking period[b]					Status in 2000	Condition of tree
			4	5	7	8	9		
2044KY	151	Bethel Church	1	—	—	—	—	Unsuitable	On ground
	156	Bethel Church	6	2	—	—	—	Unsuitable	On ground
	775	Bethel Church	—	1	—	—	—	Unsuitable	On ground
	190	Bethel Church	—	2	—	—	—	Unsuitable	On ground
	718	Bethel Church	—	5	—	—	—	Suitable	Good bark[c]
	700	Bethel Church	—	5	—	—	—	Unsuitable	On ground
	672	Valentour Road	—	—	—	—	16	Suitable	New
	679	Valentour Road	—	—	—	—	4	Suitable	New
	688	Valentour Road	—	—	—	—	1	Suitable	New
	678	Bethel Church	—	—	—	—	1	Suitable	New
	669	Bethel Church	—	—	—	—	1	Suitable	New
2339KY	144	Hyden Ridge	—	7	—	—	—	Unsuitable	On ground
	752	Hyden Ridge	—	1	—	—	—	Suitable	Good bark
	725	Hyden Ridge	—	1	—	—	—	Suitable	Good bark
	747	Hyden Ridge	—	3	—	—	—	Unsuitable	On ground
	741	Hyden Ridge	—	1	—	—	—	Suitable	Good bark
	485	Hyden Ridge	—	—	—	—	4	Suitable	New
	673	Hyden Ridge	—	—	—	—	6	Suitable	New
	680	Hyden Ridge	—	—	—	—	1	Suitable	New
	420	Hyden Ridge	—	—	—	—	6	Suitable	New
	681	Hyden Ridge	—	—	—	—	1	Suitable	New
	689	Hyden Ridge	—	—	—	—	1	Suitable	New
	685	Hyden Ridge	—	—	—	—	2	Suitable	New
2342KY	122	Double Tarkiln	—	—	8	3	—	Unsuitable	Tight bark
	130	Bat Ridge	—	—	1	—	—	Unsuitable	No bark
	188	Double Tarkiln	—	1	—	—	—	Unsuitable	No bark
	196	Double Tarkiln	—	11	1	—	—	Unsuitable	On ground
	421	Double Tarkiln	—	—	—	—	1	Suitable	New
	483	Double Tarkiln	—	—	—	—	3	Suitable	New
	623	Double Tarkiln	—	—	—	3	1	Suitable	Good bark
	634	Double Tarkiln	—	—	—	1	—	Suitable	Good bark
	650	Double Tarkiln	—	—	—	2	—	Suitable	Good bark
	659	Double Tarkiln	—	—	—	5	—	Suitable	Good bark
	684	Double Tarkiln	—	—	—	—	5	Suitable	New
	690	Double Tarkiln	—	—	—	—	4	Suitable	New
	732	Double Tarkiln	—	2	—	1	9	Suitable	Good bark
	750	Double Tarkiln	—	1	—	—	—	Suitable	Good bark
	759	Double Tarkiln	—	—	—	3	—	Unsuitable	On ground

[a] Table 3; Fig. 2.
[b] Table 1.
[c] Tree used by bat 952KY for 3 days in period 9.

previous tracking periods (Table 4). Though it roosted in the same area in periods 5 and 9, bat 2339KY did not use any particular tree in both periods and, thus, did not show long-term RTFi. Bat 2044KY (tree 156) and bat 2342KY (trees 122, 196, and 732) used the same roost trees in multiple tracking periods, exhibiting long-term RTFi.

Longevity of roost trees—In autumn 2000, we reassessed suitability of trees that had been used by three bats (2044KY, 2339KY, and 2342KY) in previous tracking periods (Table 4). Tree 718, a shortleaf pine used by bat 2044KY in two previous periods, was the only tree in this bat's repertoire that was still suitable in period 9. Although bat 2044KY did not roost in tree 718 during period 9, this pine was used by a different Indiana bat (952KY) for 3 bat-days (RTFs). Three trees used by bat 2339KY in period 5 still had exfoliating bark in period 9, although this bat only used new trees in the latter period. For 10 of its 23 bat-days in period 9, bat 2342KY roosted in two of six previously used trees, although all six were suitable.

Discussion

Our definitions provide a way to standardize classification of fidelity by Indiana bats, as well as other tree-dwelling species. Small radiotransmitters, however, are short-lived, and researchers may need to radiotrack the same bats multiple times before obtaining sufficient data to describe fidelity in a particular species. Fidelity likely varies between species, but we predict that it also varies within a species, depending on gender, reproductive condition, region, season, or overall quality of habitat (Kunz 1982).

Fidelity to trees—Other researchers attribute frequent roost-switching and use of multiple trees to a lack of, or low degree of, roost fidelity (Betts 1996, Kalcounis and Hecker 1996, Kurta et al. 1996). As in previous studies (Gardner et al. 1991, Kurta et al. 1996, 2002), we observed frequent roost-switching, but most bats that we tracked reused trees, either consecutively or nonconsecutively, within single tracking periods. Although this type of short-term fidelity is described in the literature (Gardner et al. 1991, Humphrey et al. 1977, Kurta et al. 1996), its significance is understated or ignored. We agree with Kurta et al. (1996, 2002) that number of trees used by an Indiana bat continues to increase as long as the bat is radiotracked. It is likely that, as our study continues, we will continue to find such a positive relationship, because trees that are suitable now will fall down, lose bark, or become otherwise unsuitable for roosting. Accordingly, we feel that the positive correlation between total trees and bat-days observed in each study is more related to the ephemeral nature of roost trees than to a lack of fidelity, per se, to particular roost trees.

Our data indicate that, as long as a roost is suitable, it is likely to be used in future tracking periods. Reuse of certain trees in multiple seasons or years (Table 1) indicates that, out of a collection of suitable roost trees used by a single bat, particular roost trees provide higher-quality roosting conditions than others do. O'Donnell and Sedgeley (1999) label trees used for long periods of time or by many bats from the same population as "focal roosting trees," and this term seems appropriate for trees in our study that were used concurrently by multiple bats or in multiple tracking periods. Use of focal roost trees by multiple bats may facilitate social interaction between members of the population (O'Donnell and Sedgeley 1999). Also, we surmise that high-quality roosts for Indiana bats may be suitable for other species of bat as well, because Indiana bats occasionally roost in trees used by other species (Gardner et al. 1991, Foster and Kurta 1999, this study).

Suitable roost trees are ephemeral and can become unusable quite unexpectedly, so individual bats may use several trees to avoid being caught unprepared when a roost tree is destroyed (Kurta et al. 1996, 2002). Ormsbee (1996) hypothesizes that tree-dwelling bats actually show fidelity to areas rather than to particular roost trees, since favored trees (snags) are temporary. We found that bats are faithful to both areas and particular trees within those areas, though they are probably less dependent on the continued suitability of specific trees than on areas (see also Kurta and Murray 2002).

Fidelity to areas—The tendency for bats to roost in the same area, day after day, may relate to fidelity to nearby foraging habitat and also serve to maintain social interactions between members of the population (O'Donnell and Sedgeley 1999). Bats that use two areas tend to stay in one primary area, switching to another (secondary) area for only a few days. Bats that exhibit this behavior may be interacting with other individuals of the population, because primary roosting areas for some bats serve as secondary roosting areas for others. It is also possible that bats are familiarizing themselves with another area in preparation for loss of multiple roost trees in their primary roosting area. Like trees, areas probably are ephemeral, and their suitability probably changes from 1 year to the next. For example, suitabilities of different roost trees in a storm-damaged area are likely to decline at similar rates, because each tree was killed or damaged at approximately the same time (Gumbert 2001).

Indiana bats in Illinois, Indiana, and Michigan apparently return to the same areas year after year to roost and raise their young (RAF; Gardner et al. 1991, Humphrey et al. 1977, Kurta and Murray 2002, Kurta et al. 1996, 2002). In Kentucky, Indiana bats behave in a similar manner—the 75% PUAs defined by the kernel home range were used by as many as 11 bats in as many as seven tracking periods (Table 3). Species-level fidelity to roosting areas likely facilitates communication between individuals (O'Donnell and Sedgeley 1999) and supports the hypothesis that Indiana bats are highly social (Miller and Allen 1928).

Like Gardner et al. (1991) and Kurta et al. (1996, 2002), we tracked the same individuals to the same areas in multiple years (long-term RAFi). Individual bats that show long-term fidelity to a particular roosting area are probably more familiar with that area than if they were using several areas equally. Familiarity with roosting areas may aid in predator avoidance, foraging efficiency, and emergency roost-switching induced by changes in weather or disturbances near the original roost (e.g., Gardner et al. 1991, Gumbert 2001, Kurta 1994, Kurta and Foster 1995).

Management implications—Management of habitat near hibernacula of Indiana bats should include the conservation, creation, and maintenance of suitable roost trees and areas and include long-term population assessments to identify core roosting areas. Managing for roost trees may involve implementing cutting regimes (e.g., shelterwood and highgrade cuts—Vonhof 1996) that maintain multi-aged stands and retain a component of mature trees following harvest, leaving dead and damaged trees standing, and leaving all trees previously used by Indiana bats. Silvicultural managers should work to create numerous areas of mixed-forest types, ages, and stand conditions near hibernacula, while maintaining a continuing supply of suitable roost trees. When feasible, wildlife biologists should initiate long-term studies that emphasize radiotracking individual bats over multiple seasons and years. Furthermore, when opportunities arise, biologists should undertake studies to assess and monitor effects of drastic disturbances on roosting strategies of the Indiana bat, including fidelity to trees and areas.

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