Report to the Daniel Boone National Forest Management Team
Indiana Bat Roost Tree Use Monitoring - 1996-97 Summary
South Goldson Cave and vicinity
Pulaski and McCreary Counties
Somerset Ranger District

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Purpose and Introduction

The original purpose of the monitoring study was to address concerns raised by USFWS-Cookeville as to whether or not intensive management within the proposed RCW HMA was adversely affecting other federal listed species that occurred in the area, particularly the Indiana bat. This particular study area was selected because it was the only place on the Forest where habitat adjacent to an Indiana bat hibernaculum was actively being managed for RCW recovery by the use of prescribed burning and hardwood midstory removal.

We trapped Indiana bats at the entrance to South Goldson Cave, an Indiana bat hibernaculum, during the autumn swarming periods in 1996 and 1997. The bats were banded for later recognition, fitted with radio transmitters, and released at the point of capture. Starting with the day following capture, bats were tracked daily to roost trees for as long as the transmitters remained functional.

During both years combined, roost tree data was obtained for 22 male Indiana bats. Female bats trapped and tagged at the cave entrance during the first year went directly into hibernation and did not use roost trees, so in 1997 no females were transmittered. The 22 males were found a total of 212 times and used 102 different roost trees. Some roost trees were used only once during the study, while others were used repeatedly by one or more transmittered bats. One tree was used both years by different Indiana bats.

We located Indiana bat roost trees as far as 2.7 miles from the cave, a distance that proved to be consistent for both years. This distance was used to help define a habitat use analysis area. Using the distance from the cave to the farthest roost tree as the radius, we drew a circle that included all documented Indiana bat roost trees on a topographic map. Within the circle, past management history of each stand located on National Forest System land was determined from CISC data (with some field checking). This gave us a set of background habitat conditions within the total area likely to be used by the bats, and allowed us to evaluate the relative proportions of various habitat types available for use (in terms of such parameters as RCW management and timber management) and compare this to how these habitats were actually used by Indiana bats for roosting.

The 1996 telemetry period coincided with the beginning of harvest activity for the Double Tarkiln timber sale on the Somerset RD. This sale was cut according to the Indiana Bat Prudent Measures and the subsequent Biological Opinion that resulted from the 1995-96 Formal Consultation process with USFWS-Cookeville, and thus was one of the first "bat shelterwood" timber sales on the DBNF. Timber harvest continued through the summer and fall of 1997, and the last units were still being cut as we began our telemetry monitoring in late September, 1997.

The information presented here is summarized from the first 2 years of our Indiana bat monitoring project. Data from 1998 is still being compiled as part of a Masters Thesis project at Eastern Kentucky University.

Results and Discussion

1. Roost Tree Species Used by Indiana Bats.

The following text table summarizes the various species of trees that were used by roosting Indiana bats during the 1996 and 1997 fall telemetry monitoring periods (also see Table 1).

Tree Species Group	Total Trees	Bat Days*	Total Snags	Total Live
Total Pine	44	105	44	0
Total Oak	37	57	25	12**
Total Misc Hardwood	21	50	19	2***
Summary	102	212	88	14

* = A bat day is defined here as the use of a tree by one transmittered bat for 1 day. If the same tree is used by the same bat on 3 different days, it still counts as only 1 tree but would have a bat day value of 3.

** = 10 healthy WO, 1 damaged ScO, 1 damaged NRO.

*** = 2 healthy SBH.

Numbers of roost trees/bat days by tree species:
Pines = SLP (32/83), VaP (11/21), PP (1/1).
Oaks = ScO (15/19), WO (12/16), NRO (6/14), BO (3/7), ChO (1/1).
Misc Hardwoods = PNH (6/18), RM (5/16), Sour (5/6), Tulip (3/8), SBH (2/2).

Snags made up 86% of all roost trees used by transmittered male Indiana bats. Live trees used included healthy WO and SBH with exfoliating bark as well as storm-damaged red oaks that would have been identified as "Term and Condition 10" trees in the BO.

2. Roost Tree Size

The following text table is a compilation of Indiana bat roost trees used during the first 2 years of this study by size (dbh in inches).

Year	N	DBH Range	Mean
1996	33	3.7-34.1"	12.5"
1997	70	3.3-22.4"	11.5"

Roost trees used by male Indiana bats during autumn at Somerset averaged smaller in diameter than those used by females and juveniles at summer maternity sites in Illinois, Missouri, and Michigan, but were similar in size to those used by summer males in Illinois (occupying the same range as maternity colonies) and by autumn-roosting Indiana bats of both sexes at a cave on the Berea RD (James Kiser's study).

3. Movements Between Roost Trees

Some individual trees were used by 2-3 different transmittered Indiana bats, either simultaneously or at different times (or even during different years). To date, all such trees have been snags. This indicates that particular roost trees may have long term value to Indiana bats which occupy a local hibernaculum as long as they remain in suitable condition (i.e. standing and with loose bark and/or bole crevices).

Roost tree switching was frequent. In 1996, 10 radiotracked bats used 1-8 different roost trees each during 1-18 days that they were followed, changing roosts an average of once every 2 days. In 1997, 12 monitored bats used 2-11 roost trees each during 4-15 days of tracking, switching roosts an average of once every 1.6 days.

Some bats returned to previously used trees while others seemed to select new trees virtually every day (see Table 2). Bat #863 used 6 different trees in the 6 days it was monitored, and bat #414 used 11 trees in 12 days of tracking. Bat #805, on the other hand, used just 3 trees in 15 days and 2 additional bats (#454 and #504) used 4 trees in the 13 days that they were followed. Human disturbance may have played a role in roost tree switching by a few bats but all indications were that this role was minor. One bat flew from its roost tree during the day as we approached on foot, and at least 2 others flew off as plastic flagging was being tied to their roost trees. On the other hand, 1 Indiana bat was found on the ground at the base of a tree and was actually picked up and handled by a biologist, yet it continued to roost in that same tree for several days thereafter, and several low-roosting bats were observed at close range (and even photographed in situ) but continued roosting in the same locations on subsequent days. During the 1998 fall monitoring period, an Indiana bat flew out of its roost tree in the center of a 2-age shelterwood cut when plastic flagging was torn from the roll by a biologist standing 12-15 feet from the tree; this bat moved totally out of range of the receiver but reappeared about 10 minutes later and moved into a split-bole snag located about 60 feet from its original roost tree. During 1997, 2 Indiana bats continued to use roost trees in an active 2-age shelterwood cut for several days despite the fact that trees were being harvested within a few hundred feet of their roosts.

During both years, we looked at the distances that individual Indiana bats moved while switching roost trees, and recorded the data in kilometers and hectares (Table 2) so that no one would be able to comprehend the results. For the 20 bats that were found using 2 or more different roost trees, the smallest circle that could be drawn to include all roost trees used by each individual bat ranged from about 0.4 ha (just under 1 acre) to 568 ha (about 1300 acres). Six Indiana bats spent their entire monitoring periods roosting in total areas of 4.5 ha (11 acres) or less; 11 others used roost trees spread over 10 to 105 ha (24 to 250 acres); and the remaining 3 used trees scattered over much larger areas. In real terms, this means that about 1/3 of the radio tagged Indiana bats that were monitored had all of their roost trees located in an area smaller than the average size of a cutting unit on the DBNF.

For 19 of the 22 Indiana bats that were transmittered, the distance moved by each bat from the original capture point at the hibernaculum to the set of roost trees that it used was considerably greater than the distances between the individual trees used by that bat for roosting. Keep in mind, however, that no single bat was followed for more than 18 days.

4. Percent Canopy Closure at Roost Trees

During the 1997 monitoring period, percent canopy closure was measured with a concave spherical densiometer from the ground near bases of each of the 70 documented Indiana bat roost trees. Canopy closure values ranged from a low of 20% at a tree located in a very open portion of an active 2-age shelterwood cut to a high of 93% in what looked to be closed canopy forest (see Figures 1 through 4).

The following text table is a summary of canopy closure information for 122 bat days spent in these 70 roost trees.

INDIANA BAT ROOSTS AND PERCENT CANOPY CLOSURE (1997)

Range	Mode	Bat Days <60%	60-80%	>80%	Measurement Used
20-93%	80%	34	27	61	Total Percent CC
0-90%	72%	44	35	43	Lowest Percent CC

2-age Shelterwood Cuts/Highgrades	20-81%	36 Bat Days
Red-cockaded Woodpecker Rx Burns	24-71%	6 Bat Days
Natural Canopy Gaps (Storm Damage)	24-88%	23 Bat Days
Edges of Woods Roads and Gravel Roads	80-90%	5 Bat Days
General Closed Canopy Forest	79-93%	55 Bat Days

During 1997, half (61 of 122) of the total number of bat days recorded for Indiana bats were in trees where percent canopy closure was measured at 80% or greater. This data taken by itself indicates that the bats preferred to roost in trees located in more or less closed canopy forest. However, it should be understood that these bats were usually roosting 50 feet or more above the ground in dead overstory trees - places that were in full sun during much of the day but where it was not be humanly possible to measure true canopy closure at the actual roost sites themselves. In an attempt to compensate for this, canopy closure use was refigured using only the most open of the 4 measurements made below each roost tree. When this was done, Indiana bat roost distribution was rather evenly spread across the 3 canopy closure categories. Using this analysis, only about 35% (43 of 122) of the total number of bat days were spent in closed canopy situations - a figure that was more in line with information reported elsewhere for the species. [Note: The Indiana Bat HSI Model lists sites with canopy cover ranging from 60-80% as providing optimal conditions for roosting habitat and 50-70% as optimal for foraging habitat.]

To provide some estimate of canopy closure in the general forest and in areas affected by both man-made and natural disturbance, canopy closure summaries for several habitat types used by Indiana bats in the study area appear at the bottom of the text table above. This data is not additive; for example, days that a bat spent in a roost tree located in a canopy gap that was within a RCW burn would appear in the totals for both categories.

Individual Indiana bats appeared to differ in their selection of roost trees with respect to percent canopy cover (Figure 5). During 1997, there were 5 bats (#705, 863, 023, 540, and 494) that roosted primarily (30 of 38 bat days) in trees where canopy closure was less than 60% as measured from the ground. At the same time, there were 4 Indiana bats (#165, 666, 805, and 304) that roosted mostly (42 of 46 bat days) in closed canopy forest

where canopy closure was above 80%. The remaining 3 bats used roost trees in a variety of situations.

Among the open canopy roosting bats, #705 spent at least 1 day in a live shagbark hickory in old growth forest, then moved 1.7 miles to spend 8 of the next 10 days in the split boles of 2 logging-damaged trees in an active 2-age shelterwood unit; #540 roosted for all 4 days that it was tracked in this same active 2-age shelterwood cut (twice in logging-damaged trees and twice in retained snags); #023 roosted for the 4 days it was found in a retained snag and a logging-damaged red maple in a recently harvested 2-age unit; #494 spent 5 of its 13 bat days in a logging-damaged tulip poplar in a 5-10 year old highgrade unit that was sold to the government after being cut over; and #863 spent all 6 days that it was tracked in a RCW burn unit located on Bowman Ridge.

Among closed canopy bats, #666 used only live white oaks in a closed canopy forested ravine; #605 used the tops of 3 dead shortleaf pines located within sight of one another on a south-facing slope; and #805 used the tops of 2 huge shortleaf pines but also roosted for 2 days beneath bark scraps on a small understory sourwood snag.

4. Indiana Bat Responses to Prescribed Burning

Prescribed burning for RCW had been carried out on about 8 percent of the Indiana bat study area (Tables 5 and 6) in 1995. One RCW area (Wildcat Branch) had been highgraded prior to be sold to the Forest Service and subsequently prescribed burned, while the other (Bowman Ridge) has been managed for RCW for a relatively long time by the Somerset RD. These 2 areas together had 18% (6 of 33) of the Indiana bat roost trees documented during 1996 and 9% (6 of 70) of the roost trees documented in 1997, and similar results were noted when bat days were considered. The data showed a preference on the part of our transmittered Indiana bats for RCW-managed areas during 1996 and no preference either way during 1997. We might add that the Wildcat Branch area was located across Lake Cumberland from the rest of the study area, and that in 1996 2 transmittered Indiana bats were heard there nearly every day from the other side of the lake, but only on a few days did personnel and time availability allow us to make the 1-hour drive to Wildcat Branch and actually document where the bats were roosting. The 1996 data, therefore, under-represents the use that the bats made of areas managed by prescribed fire (and by highgrading). Favored roosting sites for Indiana bats in burned areas were fire-killed red maples where the heat had popped the bark away from the boles.

5. Indiana Bat Response to Timber Management

Although about 27% of the total land located within the Indiana bat circle was in private ownership, nearly all of the documented roost trees during both years (33 of 33 in 1996, 68 of 70 in 1997) were on National Forest System lands. This provided an excellent opportunity to look at Indiana bat roost tree use in a setting where data was readily available on past and ongoing timber management practices (Tables 3, 7, and 8).

1996 Results

During 1996 (Table 7), clearcuts that were less than 35 years old made up about 17% of the study area (Table 4) but harbored no documented Indiana bat roost trees, and uninventoried stands (including private lands and the Beaver Creek Wilderness) made up about 34% of the study area and likewise had no roost trees. Both of these habitat types were avoided by Indiana bats. General forest (44% of the study area, 84% of the roost trees) and

2-age shelterwoods combined with highgrades (3% of the study area, 15% of the roost trees) were habitat types favored by Indiana bats. Results were similar for bat day calculations (Table 8); general forest had 91% of the bat days on 44% of the study area while 2-age + highgraded stands had 9% of the bat days on 3% of the study area.

1997 Results

During 1997 (Table 7), clearcuts that were less than 35 years old still made up about 17% of the study area (Table 4) but once again harbored no documented Indiana bat roost trees; uninventoried stands (including private lands and the Beaver Creek Wilderness) continued to make up about 34% of the study area but had only about 7% of the roost trees. Both of these habitat types continued to be avoided by Indiana bats. General forest (42% of the study area, 67% of the roost trees) and 2-age shelterwoods combined with highgrades (4% of the study area, 26% of the roost trees) again were habitat types favored by Indiana bats. Results were again similar for bat day calculations (Table 8); general forest had 62% of the bat days on 44% of the study area while 2-age + highgraded stands had 30% of the bat days on 4% of the study area.

Some Points for Discussion

General forest was used by roosting Indiana bats at 1.5 to 2 times expected levels based on availability, making this a preferred roosting habitat for the bats. All roost trees that were found in general forest were in stands 50 years old or older, and most roosts were located fairly large snags that once formed part of the overstory, in live overstory white oaks, or in natural canopy gaps created by ice, wind, or fire damage. This indicates that it may often take 50 years or longer for an even-aged stand to acquire characteristics (snags of suitable size, natural gaps and irregularities in the canopy, etc.) that provide good roosting habitat for Indiana bats.

Clearcuts less that 35 years old made up a substantial part of the Indiana bat monitoring area (about 17%) during both years but received no roosting use by transmittered Indiana bats. The fact that young clearcuts were avoided as roosting habitat for Indiana bats was not surprising since there were virtually no snags available in these areas.

Although clearcutting clearly reduces the numbers of roost trees available for use by Indiana bats in particular areas for a fairly long time (our monitoring data shows that 50 years seems like a good guess), the overall impact of this across the landscape is difficult to assess. Clearcut units on the DBNF are fairly small (30 acres or less) and the bats should be able to move to adjacent areas when roost trees disappear. However, there is evidence (from this study and others) that individual bats return again and again to particular trees, and that some trees are used by multiple bats even during the fall swarming period. Add to this the fact that about 1/3 of the Indiana bats that were tracked during this study roosted in suites of trees that were spread over total areas smaller than 30 acres, and the possibility remains that clearcutting has the potential to adversely affect local populations of Indiana bats.

During this study, 2-age shelterwood harvest areas (all of which had been cut since 1993) and highgraded stands (generally 10 years old or younger) were used by roosting Indiana bats at 4 to 7 times expected levels based on availability, making these preferred roosting habitats as well.

The most frequently used roost trees in these cut stands were hardwoods that were damaged during timber harvest. These trees had the tops partly

or completely broken out, and had boles that were split, splintered, or cracked. One such tree, a broken-off tulip poplar in a highgrade, had been in this condition for up to about 10 years and was used on 6 different days by Indiana bats; the root system of this tree was still living and there were small patches of epicormic foliage along the trunk, and clusters of live and dead suckers grew up from the base. Many other logging-damaged trees that were used by roosting Indiana bats were in similar condition or were in the process of becoming that way. Such trees, although created during timber harvest activities, are likely to remain standing for many years and should be retained as "Term and Condition 10 trees" (=immediately suitable roost trees) during site preparation and should be protected from post-harvest firewood cutting (as should all standing dead or damaged trees in proposed firewood units).

Retained snags in 2-age shelterwood harvest areas and highgrades were also used as roosts by Indiana bats. Although these trees will probably not persist as long on the landscape as logging-damaged trees that still have living root systems, these snags can still provide good roosting habitat for Indiana bats at least over the short term.

The main reasons why Indiana bats seem to be selecting roost trees located in partial harvest areas are most likely: (1) the open nature of the cut units provides easy and uncluttered bat access to roost sites; (2) there is plenty of sunlight on these trees to warm the roosts during the day; (3) 2-age shelterwood harvest areas and highgrades provide relatively open foraging areas for the bats around the crowns of the residual trees [Note: we were able to document several transmittered Indiana bats that were foraging at night in 2-age shelterwood cuts and that had previously roosted either within the cutting units or immediately adjacent to them.]. Warm roosting sites should be especially important to Indiana bats during the summer maternity period (while the young are developing) and during the fall pre-hibernation period (when digestion efficiency should be maximized to allow the buildup of enough fat reserves to get the bats through the winter months).

All 2-age shelterwood cuts are not created equal (see text table below).

INDIANA BAT ROOST TREE USE IN 2-AGE SHELTERWOOD CUTS, SOMERSET RANGER DISTRICT, 1996 AND 1997

Roost Trees Found	Total Bat Days	Habitat Acres Avail	2-age Shelterwood Type
1	1	178	Regular (retain 2 snags/acre)
16	29	243	Bat (retain all snags/culls; retain shagbark hickory; 50 BA strips/clumps)

Within our study area, 2-age shelterwood units that were harvested under the old DBNF snag guidelines (retain an average of 2 snags/acre) received some use by Indiana bats (1 roost tree for 1 day likely in 1996 but it was near dark when we arrived on site and the bat began to forage before we could confirm its roost site; 1 roost tree for 1 day confirmed in 1997). Harvest units for the Double Tarkiln sale, on the other hand, were cut under the new "Bat Shelterwood" guidelines developed through the Formal Consultation process from the Prudent Measures BE and subsequent Biological

Opinion from USFWS-Cookeville. These guidelines called for the retention of all snags, hollow trees, trees with major damage to large limbs or boles, and live shagbark or shellbark hickories (all of which would be immediately available as roost sites for Indiana bats), and also required that some of the 16 live trees/acre with dbh of 9" or larger that would be retained throughout each harvest unit be arranged in 50 BA strips, clumps, or clusters to provide variation in forest structure during subsequent stand regeneration. As can be seen in the text table above, the monitoring results from the first 2 years of radiotracking indicate that Indiana bats selected roost trees in 2-age shelterwood harvest areas cut under "bat guidelines" at a much higher rate than those cut under "2 snags per acre" guidelines [Note: and also at a much higher rate (in proportion to overall availability by habitat type) than those in general forest].

We must use caution while interpreting the results of the first 2 years of the Indiana bat monitoring project at Somerset. There is little doubt that 2-age shelterwood cuts that have been harvested under the bat guidelines were heavily used as roosting habitat by Indiana bats during our study, and that highgrade cuts containing large dead/damaged trees were also heavily used. However, some of our appellants claim that this is merely because Indiana bats were so loyal to traditional roosting areas that they have continued to use them even when habitat has become severely degraded. It is difficult to entirely dismiss this alternative interpretation since we have no data on where many of these bats roosted prior to timber harvest (such data would be impossible to obtain, of course).

We did monitor one Indiana bat that moved 1.7 miles from a shagbark hickory in an old woods to take up residence in logging-damaged trees in an active 2-age unit. This provided some indication that our bat shelterwoods are of high value to Indiana bats that also roost in mature general forest, and that they may even attract Indiana bats at least in the short term. The only way to clearly demonstrate that these cuts provide and maintain good Indiana bat habitat, however, will involve some long term monitoring. In the future, we hope to recapture some of the bats that have previously been tracked to roost trees to see whether they return year after year to the same areas as opposed to moving about in response to changes in roosting habitat conditions (including natural disturbance and timber management).

All roost trees that were used in 1997, and most of those used in 1996, have been marked with permanent metal numbered tags, and their locations have been plotted on topographic maps. An important aspect of roost tree use monitoring will be to revisit these trees annually over time, compare how long different species of trees remain in usable condition for Indiana bats, and compare how long snags remain standing in various types of habitat. If snags located in 2-age units fall over much more quickly than those in forest interiors, we may need to make adjustments to ensure adequate numbers of roost trees near harvest areas.

We may wish to explore some alternative ways of providing roost trees for Indiana bats on the Forest. During the past year, I have seen photos of 2 trees in Indiana that were axe-girdled about 5 years ago and which now (1998) harbor Indiana bat maternity sites, and I have seen a maternity colony in a dead tree that was left in place to drown when a pond was enlarged by the landowner.

In closing, let me once again emphasize that the Somerset RD Indiana bat monitoring project began as an attempt to document whether or not Indiana bats are adversely affected by intensive management for RCW (primarily the use of prescribed fire). The results thus far have indicated that fire does not adversely affect Indiana bat roosting habitat, and may actually

improve it.

The Somerset monitoring project also proved to be an unexpected early test of the effectiveness of the implementation of the Indiana Bat Prudent Measures and subsequent Biological Opinion. During the first year of monitoring, several units from a 2-age shelterwood sale that had been cut under the old Forest Plan guidelines (2 snags/acre) fell within the bat circle, and no use by the Indiana bat was documented. At the same time, the first unit of the Double Tarkiln 2-age shelterwood (Prudent Measures guidelines) had just been completed, and 2 days of use by 1 Indiana bat were documented within just a few days after cutting (Table 3). I still remember Tim Reed's comment after he and Joe Placke tracked that bat to its roost tree - "John, we found bat #454, and you absolutely won't believe where it is roosting..." During the second year of monitoring, it soon became apparent that many of the transmittered bats were roosting in or adjacent to the 2-age shelterwood cuts, and on those occasions where we stayed late in the study area to see where some of the bats were going at night we learned that they were foraging in them as well. Not only that, but the bats were using active (while they were still being cut) 2-age units both for roosting and for foraging.

Could these cuts could be considered as "habitat improvements" for Indiana bats? The answer to this question is unknown at this time. They may be of considerable value to the bats in areas where natural disturbance that creates gaps in the forest canopy (ice, wind, or fire damage) has not taken place, or in areas where much of the forest is relatively young and even aged, or in areas where the disturbance that has occurred is down in the ravines rather than up on the ridges (where Indiana bats seem to prefer to roost in our highly dissected terrain). We could probably provide good roosting and/or foraging habitat for Indiana bats in other ways by using group selection or single tree selection harvest methods, by girdling small groups of mature trees on ridgetops and upper slopes, by leaving trees in place to drown while building seasonal upland ponds, etc.

All in all, my gut feeling now is that our 2-age bat shelterwood cuts are providing small patches of really excellent roosting and foraging habitat for Indiana bats, at least in the short term. Over the long term, however, it will be more difficult to make such a claim until additional monitoring is done and more data becomes available - particularly on the movements of individual Indiana bats and the longevity of roost trees within cutting units.

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Table 1--Roost tree use by 22 Indiana bats during 1996 and 1997 in the Cave Creek Study Area, Pulaski Co., KY.

Tree Species	Roost Tree Condition (live/snag)	1996 Trees Used	1996 Bat Days	1997 Trees Used	1997 Bat Days	Total Trees Used	Total Bat Days
Shortleaf pine (*Pinus echinata*)	snag	9	36	24	47	32	83
Pitch pine (*Pinus rigida*)	snag	-	-	1	1	1	1
Virginia pine (*Pinus virginiana*)	snag	-	-	11	21	11	21
Black oak (*Quercus velutina*)	snag	2	6	1	1	3	7
Chestnut oak (*Quercus prinus*)	snag	1	1	-	-	1	1
Northern red oak (*Quercus rubra*)	snag	5	13	-	-	5	13
	damaged	1	1	-	-	1	1
Scarlet oak (*Quercus coccinea*)	snag	8	12	6	6	14	18
	damaged	-	-	1	1	1	1
White oak (*Quercus alba*)	snag	-	-	2	2	2	2
	live	1	1	9	13	10	14
Pignut hickory (*Carya glabra*)	snag	3	13	3	5	6	18
Shagbark hickory (*Carya ovata*)	live	1	1	1	1	2	2
Red maple (*Acer rubrum*)	snag	2	6	3	10	5	16
Sourwood (*Oxydendron arboreum*)	snag	-	-	5	6	5	6
Tuliptree (*Liriodendron tulipifera*)	snag	-	-	3	8	3	8
Totals		33	90	70	122	102	212

Table 2--Autumn roost tree use summary for individual Indiana bats during 1996 and 1997 in the Cave Creek Study Area, Pulaski Co., KY: days found; numbers of roost trees used; distances from hibernaculum; and area of smallest circle that includes all roost trees used by each bat.

1996 Bat No.	No. Days Found	No. Roost Trees Used	Dist. From Cave (km)	Roost Circle Area (ha)	1997 Bat No.	No. Days Found	No. Roost Trees Used	Dist. From Cave (km)	Roost Circle Area (ha)
183	1	1	1.94	--	023	4	2	0.65	0.4
356	2	1	1.94	--	540	4	4	1.32	2.2
259	5	3	3.22	91.6	863	6	6	4.15	72.4
572	6	4	3.36	10.2	666	8	4	1.34	2.2
043	6	5	2.76	72.4	165	11	3	2.66	0.4
313	8	3	3.82	518.1	705	11	5	3.60	567.7
504	13	4	3.05	52.3	103	12	7	0.98	4.5
454	13	4	3.82	547.6	304	12	9	2.74	28.3
414	18	7	2.09	21.9	414	12	11	1.22	35.5
605	18	8	2.11	21.9	494	13	6	2.28	43.5
					204	14	10	3.38	104.3
					805	15	3	1.94	2.9
$\bar{X}$	9.0	4.0	2.81	167.0	$\bar{X}$	10.2	5.8	2.19	72.0

Table 3--Roost tree ownership and management class summary during 1996 and 1997 within the Cave Creek Study Area, Pulaski Co., KY.

Mgmt Class	Ha Available Within CCSA 1996	1997	>1996< RT	BD	>1997< RT	BD	Habitat Characteristics of Management Class
1	583	556	1	1	10	24	Forest 100+ years old (Age Year 1850-1899)
2	1549	1508	19	51	35	50	Forest 70-100 years old (Age Year 1900-1928)
3	235	235	8	30	2	2	Forest 50-70 years old (Age Year 1930-1964)
4	897	897	0	0	0	0	Clearcuts <35 years old (Age Year 1965-1990)
5	71	71	0	0	1	1	2-age shelterwood cuts (1993-1995 reg mgmt)
6	29	97	1	2	15	27	2-age shelterwood cuts (1996-1997 bat mgmt)
7	1178	1178	0	0	2	6	Pvt and within DBNF Proclamation Boundary
8	260	260	0	0	3	4	FS uninventoried + wildlife openings
9	24	24	0	0	2	8	FS high graded only (recently acquired)
10	19	19	4	6	0	0	FS high grade/burned (recently acquired)
11	334	334	0	0	0	0	FS Beaver Creek Wilderness
12	267	267	0	0	0	0	Pvt and outside Proclamation Boundary
13	294	294	-	-	-	-	Non-habitat (Lake Cumberland)
	5740	5740	33	90	70	122	Totals

RT = individual roost trees; BD = bat days (1 roost tree used 6 days would count as 6 BD); FS = Forest Service (National Forest System lands); Pvt = Privately owned tracts; Age Year = Birth year of a stand (from CISC) for FS inventoried stands.

Table 4--Proportion calculations for groupings of potential Indiana bat roosting habitat during 1996 and 1997 within the Cave Creek Study Area, Pulaski Co., KY.

1996 (ha)	1996 Prop	1997 (ha)	1997 Prop	Habitat Categories Included
897	.165	897	.165	Class 4 (clearcuts harvested 1965-1990)
2367	.435	----	---	Class 1+2+3 (closed canopy forest) in 1996
----	---	2299	.422	Class 1+2+3 (closed canopy forest) in 1997
143	.026	----	---	Class 5+6+9+10 (2-age + highgrade) in 1996
----	---	211	.039	Class 5+6+9+10 (2-age + highgrade) in 1997
2039	.374	2039	.374	Uninventoried (FS+Pvt)
5446	1.000	5446	1.000	Total hectares of potential habitat

Table 5--Indiana bat response to prescribed burning (1995 burns) during 1996 and 1997 in the Cave Creek Study Area, Pulaski Co., KY: habitat proportions available and numbers of roost trees (RT) observed and expected.

Treatment	Total ha	Prop-ortion	>>1996<< RT Obs	RT Exp	>>1997<< RT Obs	RT Exp	>>Total<< RT Obs	RT Exp
Burned	436	.080	6*	3	6	6	12	8
Unburned	5010	.920	27	30	64	64	90	94
Total	5446	1.000	33	33	70	70	102	102

* a< 0.05

Table 6--Indiana bat response to prescribed burning (1995 burns) during 1996 and 1997 in the Cave Creek Study Area, Pulaski Co., KY: habitat proportions available and numbers of bat days (BD) observed and expected.

Treatment	Total ha	Prop-ortion	>>1996<< BD Obs	BD Exp	>>1997<< BD Obs	BD Exp	>>Total<< BD Obs	BD Exp
Burned	436	.080	13*	7	6	10	19	17
Unburned	5010	.920	77	83	116	112	193	195
Total	5446	1.000	90	90	122	122	212	212

* a< 0.025

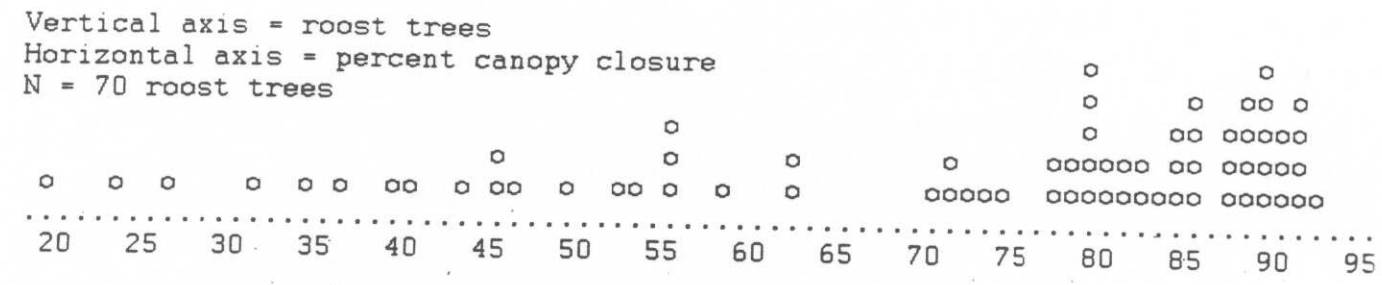
Table 7--Indiana bat response to timber management: numbers of roost trees (RT) observed and expected under various timber management regimes during 1996 and 1997 in the Cave Creek Study Area, Pulaski Co., KY.

Treatment	1996 Total Area (ha)	1996 Proportion	>>1996<< RT Obs	RT Exp	1997 Total Area (ha)	1997 Proportion	>>1997<< RT Obs	RT Exp
Clearcut <35 years old	897	.165	0	5	897	.165	0	11
Forest >50 years old	2367	.435	28	15	2299	.422	47	30
2-age shelterwood/HG	143	.026	5	1	211	.039	18	3
Uninventoried	2039	.374	0	12	2039	.374	5	26
Total	5446	1.000	33	33	5446	1.000	70	70

Table 8--Indiana bat response to timber management: numbers of bat days (BD) observed and expected in roosts located within various timber management regimes during 1996 and 1997 in the Cave Creek Study Area, Pulaski Co., KY.

Treatment	1996 Total Area (ha)	1996 Proportion	>>1996<< BD Obs	BD Exp	1997 Total Area (ha)	1997 Proportion	>>1997<< BD Obs	BD Exp
Clearcut <35 years old	897	.165	0	15	897	.165	0	20
Forest >50 years old	2367	.435	82	39	2299	.422	76	51
2-age shelterwood/HG	143	.026	8	2	211	.039	36	5
Uninventoried	2039	.374	0	34	2039	.374	10	46
Total	5446	1.000	90	90	5446	1.000	122	122

Figure 1--Percent canopy closure (as measured from the ground) for individual Indiana bat roost trees in 1997 within the Cave Creek Study Area, Pulaski Co., KY.



Note: Percent canopy closure ranges at roost trees located in various habitat types were as follows: highgrades and 2-age shelterwood cuts 20%-81% (N = 15); prescribed burns 24%-71% (N = 6); natural canopy gaps 54%-88% (N = 16); edges of woods roads 80%-90% (N = 5); and forest interior 79%-93% (N = 28). See text.

Figure 2--Percent canopy closure (as measured from the ground) by bat day for Indiana bats roosting in 1997 within the Cave Creek Study Area, Pulaski Co., KY.

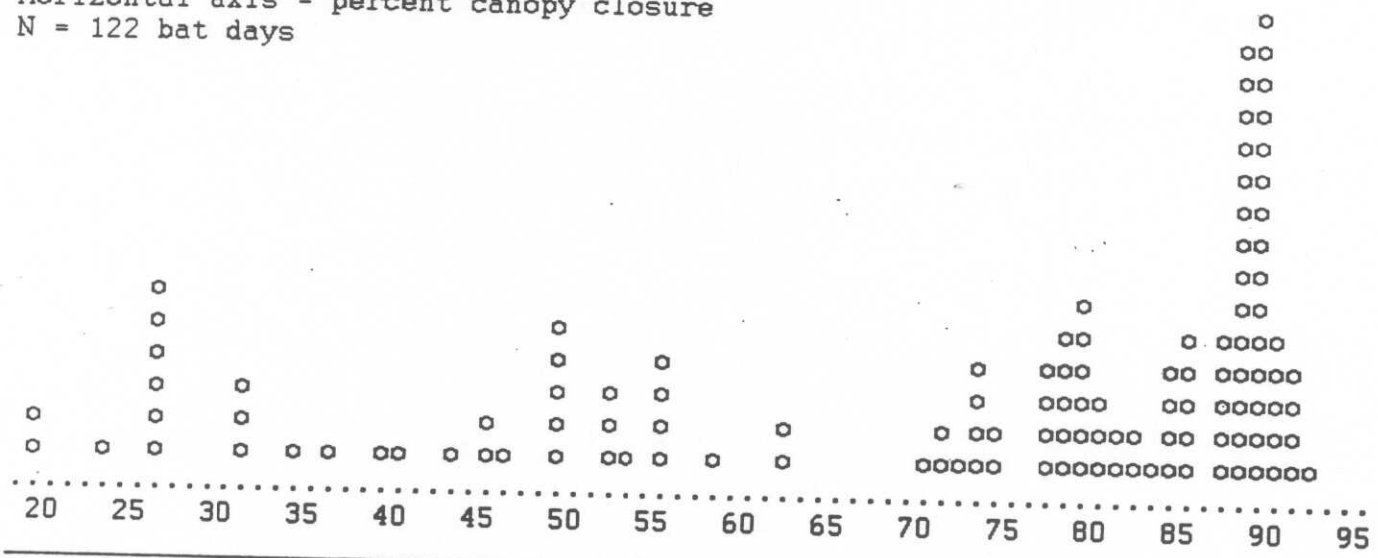


Figure 3--Minimum percent canopy closure (as measured from the ground) by bat day for Indiana bats roosting in 1997 within the Cave Creek Study Area, Pulaski Co., KY.

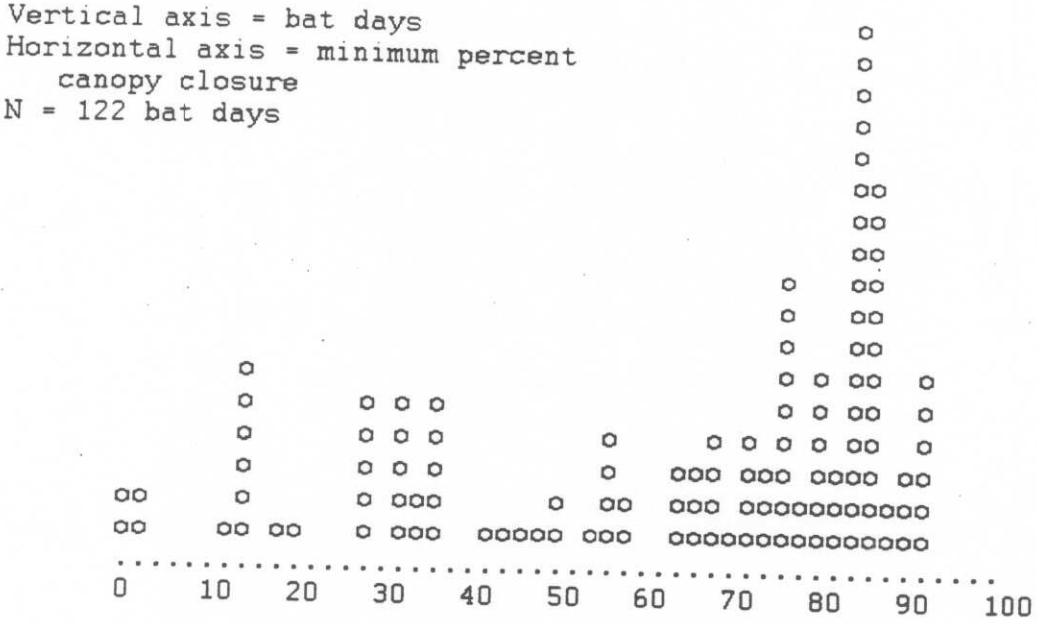
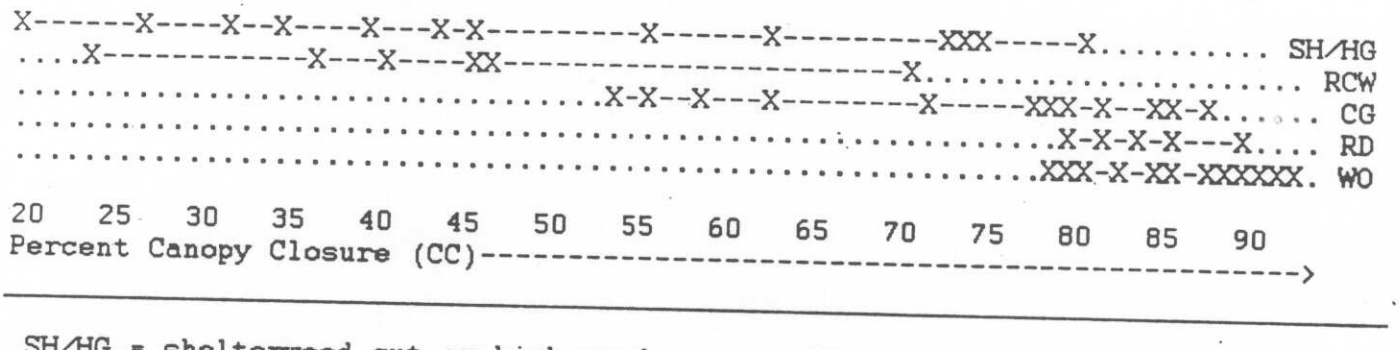
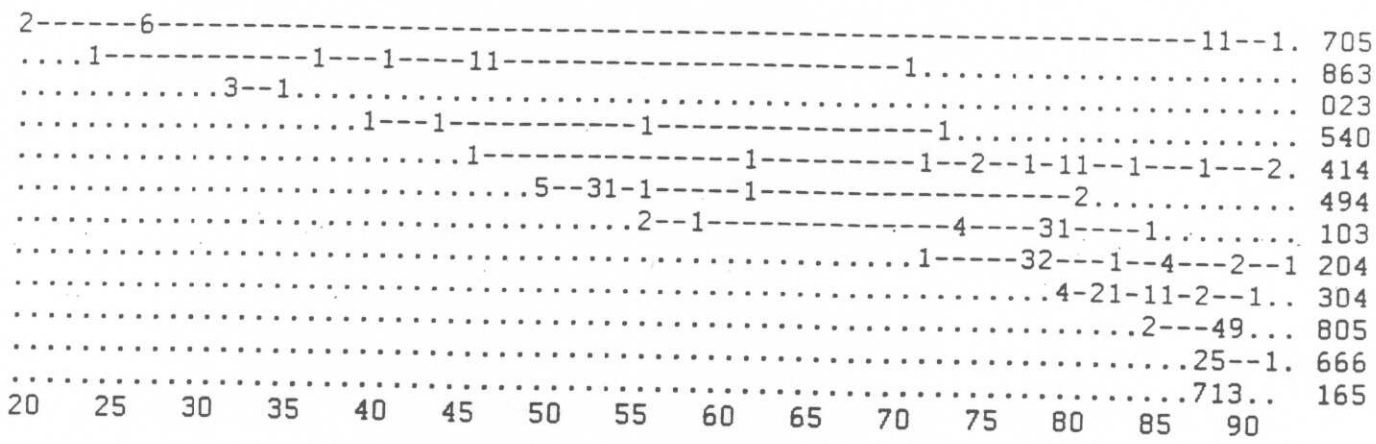


Figure 4--Percent canopy closure at Indiana bat roost trees in 1997 arranged by general habitat management category (N = 70), Cave Creek Study Area, Pulaski Co., KY.



SH/HG = shelterwood cut or high grade
CG = canopy gap of 2 or more dead trees
RCW = prescribed burns (1995) for RCW
RD = edges of gravel roads
WO = woods (forest interior)
[CC Range = 20%-93% for all trees]

Figure 5--Percent canopy closure at roosts trees selected by individual Indiana bats in 1997 (N = 122), Cave Creek Study Area, Pulaski Co., KY.



In Figure 5, the 3-digit number to the right represents the transmitter frequency for an individual Indiana bat that was radiotracked in 1997. The single-digit numbers in the chart represent the numbers of bat days that each individual bat spent roosting in a tree at a particular percent canopy closure value. Dashes connecting the numbers indicate the ranges of canopy closures selected by each individual Indiana bat.

Indiana Bat Roost Tree Slides - New - 3/2/99

INDIANA BAT ROOST TREES (1996-97): PINES

Tree Species	Total Trees	Bat Days	Snags	Live
SHORTLEAF PINE	32	83	32	0
VIRGINIA PINE	11	21	21	0
PITCH PINE	1	1	1	0
TOTAL PINE ROOSTS:	44	105	44	0

INDIANA BAT ROOST TREES (1996-97): OAKS

Tree Species	Total Trees	Bat Days	Snags	Live
SCARLET OAK	15	19	14	1
WHITE OAK	12	16	2	12
NORTHERN RED OAK	6	14	5	1
BLACK OAK	3	7	3	0
CHESTNUT OAK	1	1	1	0
TOTAL OAK ROOSTS:	37	57	25	14

INDIANA BAT ROOST TREES (1996-97): MISC HDWD

Tree Species	Total Trees	Bat Days	Snags	Live
PIGNUT HICKORY	6	18	6	0
RED MAPLE	5	16	5	0
SOURWOOD	5	6	5	0
TULIP POPLAR	3	8	3	0
SHAGBARK HICKORY	2	2	0	2
TOTAL MISC HARDWOOD:	21	50	19	2

INDIANA BAT ROOST TREE SUMMARY (1996-97)

Species Group	Total Trees	Bat Days	Snags	Live
PINES	44	105	44	0
OAKS	37	57	25	14
MISC HARDWOODS	21	50	19	2
TOTALS:	102	212	88	16

ROOST TREE USE FOR INDIVIDUAL INDIANA BATS (1996)

1996 Bat #	Days Found	Trees Used	Dist to Cave	Roost Tree Circle Area
183	1	1	1.2 mi	---
356	2	1	1.2	---
259	5	3	2.0	229 acres
572	6	4	2.1	26
043	6	5	1.7	181
313	8	3	2.4	1295
504	13	4	1.9	131
454	13	4	2.4	1369
414	18	7	1.3	55
605	18	8	1.3	55
Average:	9	4	1.8 mi	418 acres

INDIANA BAT ROOST TREE USE IN 2-AGE SHELTERWOOD CUTS, SOMERSET RANGER DISTRICT, 1996 AND 1997

Roost Trees Found	Total Bat Days	Acres Avail	2-Age Shelterwood Type
1	1	178	Regular (keep 2 snags/acre)
16	29	243	Bat (keep all snags/culls; 50 BA strips/clumps; feathered edges)

INDIANA BAT ROOSTS AND PERCENT CANOPY CLOSURE (1997)

Range	Mode	Bat Days <60%	Bat Days 60-80%	Bat Days >80%	Measurement Used
20-93%	80%	34	27	61	Total Percent CC
0-90%	72%	44	35	43	Lowest Percent CC

2-age Shelterwood Cuts/ Highgrades	20-81%	36 Bat Days
Red-cockaded Woodpecker Rx Burns	24-71%	6 Bat Days
Natural Canopy Gaps (Storm Damage)	24-88%	23 Bat Days
Edges of Woods Roads/ Gravel Roads	80-90%	5 Bat Days
General Closed Canopy Forest	79-93%	55 Bat Days

CLEARCUTS AND INDIANA BATS

1. Clearcuts harvested 1965-1991 made up about 16% of the area within the bat circle. We expected to find about 16 of our 102 roost trees in this habitat type; we found none. These bats did not roost in clearcuts less than 50 years old.

2. Clearcuts averaged less than 30 acres in size within the bat circle. Of 20 Indiana bats that were tracked at least 4 days, about 35% (7) had all of their known roosts in 30 acres or less while 65% (13) used trees spread over more than 30 acres. The average for 20 bats was 275 acres.

3. Clearcutting reduces the numbers of roost trees available for Indiana bats. The overall impact of this, however, is difficult to assess.

2-AGE SHELTERWOOD CUTS, HIGHGRADES, AND INDIANA BATS

1. Shelterwood cuts and highgrades made up about 4% of the area within the bat circle. We found 23 roost trees in these partial harvest areas, many more than the 4 we had expected. Indiana bats thus seem to prefer these areas for roosting.

2. Our appellants claim that Indiana bats are loyal to traditional roosting areas and will continue using them even when habitat becomes severely degraded. The only way to clearly demonstrate that partial harvesting provides/maintains good habitat will involve some long term monitoring.

SOME SUGGESTIONS FOR MAINTAINING OR ENHANCING ROOSTING HABITAT FOR INDIANA BATS WHILE HARVESTING TIMBER

1. Retain some mature/overmature trees in harvest areas; favor oak, hickory, cottonwood, and elm.

2. Retain large diameter snags and shagbark hickory.

3. If wolf trees/culls are to be removed to provide growing space for young trees, girdle them with an axe or chainsaw to create maternity roosts.

4. Small ponds and road ruts can provide important water sources for Indiana bats and other wildlife.