

EFFECT OF TRAIL USERS AT A MATERNITY ROOST OF RAFINESQUE'S BIG-EARED BATS

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*While bat-roosting sites continue to be targets of vandalism, Hood Branch Rock Shelter in Natural Bridge State Park, Kentucky, provides habitat for *Corynorhinus rafinesquii* (Rafinesque's big-eared bat). The shelter lies immediately adjacent to a hiking trail (Upper Loop Trail); therefore, the bats are potentially subject to disturbance by park visitors. This study monitored the behavior patterns of park visitors using the trail for potential disturbance effects at the shelter, and compared these data to population size and activity patterns of *C. rafinesquii* inhabiting the shelter from March to September 1998. Data indicate that a bypass trail directed many visitors away from the entrance to the shelter, but some visitors used the trail adjacent to the shelter and exhibited behavior potentially disruptive to the bats. The shelter was occupied by a maternity colony of *Corynorhinus rafinesquii* from late April to mid-July, a period in which access to the shelter was restricted due to debris and washouts along the trail from a severe storm in winter 1998. However, the shelter was abandoned by the bats within two weeks after the trail was cleared of debris. Although cause and effect cannot be directly inferred from collected data, the likelihood that the bats abandoned the shelter because of human intrusion is strong. The suitability of this shelter as a maternity roost of *C. rafinesquii* may be jeopardized by park visitors hiking the adjacent trail, suggesting closure of the Upper Loop Trail as the most viable option for protecting *C. rafinesquii* in Hood Branch Rock Shelter.*

Although conservation measures directed toward the preservation of bats should consider both roosting sites and above-ground foraging habitats (Pierson 1998), most efforts have addressed the protection of roosting sites. Roosting sites are situated in predictable habitats and are located in fixed positions in the landscape (Fenton 1997), and are important to the ecology of bats, providing habitat for feeding, resting, rearing of young, and hibernation (Kunz 1982). Conservation of bats through protection of roosting sites is confounded by a tendency in some species to switch roosts to meet their annual or seasonal habitat requirements, or to avoid predation and parasite infestation (Lewis 1995). Roost fidelity, however, is common in cave bats, with populations of many species entirely dependent on particular caves, mines, or rock shelters at various periods in their annual cycle (Kunz 1982; Lewis 1995).

Protection of roosting sites is an important strategy in the conservation of rare species of bats (Tuttle & Taylor 1994; Fenton 1997). The American Society of Mammalogists has established guidelines for researchers studying bats at roosting sites (ASM 1992), and set protocols exist for protecting bat roosting sites on federal lands (Lera & Fortune 1979). Many agencies that manage public lands in Kentucky have gated or fenced the entrance to roosting sites known to harbor populations of sensitive bat species (Lacki 1996). Regardless, bats occupying roosts where access is not restricted remain vulnerable to human disturbance.

The forms of human disturbance at bat roosting sites and their effects on bats are well documented (e.g., Tuttle 1979; Rabinowitz & Tuttle 1980; MacGregor 1991), and studies have examined the frequency of human intrusion into bat roosting sites (Tuttle 1979; Rabinowitz & Tuttle 1980). Limited information exists, however, on the behavior of humans at the

entrance to bat roosts, and the need for such data has been expressed, especially for big-eared bats due to their extreme sensitivity to disturbance at maternity roosts (Bagley 1984).

Disturbance at summer maternity roosts can have a number of negative effects on bats including accidents to, and abandonment of, young bats, and increased energetic expenditures as the colony size declines (Herreid 1967; Gillette & Kimbrough 1970; Mohr 1972; Tuttle 1975; McCracken 1989). *Corynorhinus rafinesquii* (Rafinesque's big-eared bat) is a species that has been documented in need of protection in Kentucky (KSNPC 1996). This species forms summer maternity colonies in rock shelters at the northern range of its distribution (Hurst & Lacki 1999), requires a narrow range of temperature conditions inside roosting sites (Jones 1977), and is sensitive to human disturbance (Clark 1990). Further, although roost switching does occur in this species, data for populations in Kentucky show that some roosts are more important for reproduction than others (Hurst 1997; Hurst & Lacki 1999).

Corynorhinus rafinesquii has historically used a rock shelter in Natural Bridge State Park, Kentucky, as a summer roosting site. Measures taken to minimize disturbance by park visitors include the construction of an alternate trail to direct visitors away from the roost, and the placement of a 1-m tall fence and posted sign at the entrance to the roost. In this study, I evaluated the effectiveness of the alternate trail at keeping visitors away from the entrance to the roost, and monitored the response of bats to behavior of visitors.

STUDY AREA

Natural Bridge State Park is located in eastern Powell County, Kentucky, and is situated on the Cumberland Plateau

province (McFarlan 1954). The physiography of the region includes various rock formations and a network of cliffs derived from Rockcastle sandstones and conglomerates (McGrain 1983). The outcropping rocks date back to the Pennsylvanian Period and include a layer of Beatyville shale underneath (McFarlan 1954). Below these rocks exists a layer of Mississippian Mammoth Cave limestone (McFarlan 1954). The existence of a sandstone surface layer, along with the limestone beds below, creates a geologic environment conducive to cave-dwelling bats. The surface rocks form highly weathered cliffs that contain numerous overhangs or shelters, while erosive forces forming caves have altered the limestone beneath (McGrain 1983). *Corynorhinus rafinesquii* use both limestone caves and sandstone rock shelters as roosting sites in Kentucky (Barbour & Davis 1969; 1974).

Hood Branch Rock Shelter is situated at the base of a southeast-facing cliff (~110°) at the headwaters of Upper Hood Branch, a tributary that drains the eastern half of the park. The shelter is a deep overhang comprised of two rooms with an entrance 22 m wide and 5.5 m high. A collapsed ceiling in the rear room created a domed surface that provides a dark zone during daytime in which *Corynorhinus rafinesquii* have historically formed maternity colonies (Hurst & Lacki 1997).

The vegetation of the park is representative of the mixed mesophytic forest type of the Central Hardwood Forest region (Preston 1989). The forest habitat in the immediate vicinity of the shelter is yellow-poplar (*Liriodendron tulipifera*), white oak (*Quercus alba*), chestnut oak (*Q. prinus*), sugar maple (*Acer saccharum*), and red maple (*A. rubrum*), with various pines (*Pinus* spp.) on top of the cliff. A thick shrub midstory is dominated by rhododendron (*Rhododendron maximum*), and the canopy closure in front of the shelter is ~75%.

Two hiking trails pass within < 0.1 km of the entrance to the shelter. Both trails form part of Hood Branch Trail which begins at a parking lot for the skylift in the park. Hood Branch Trail is 6.4 km in length and provides park visitors access to the Natural Bridge. Approximately 3 km from the trailhead, Hood Branch Trail forks into the Upper Loop and a shortcut trail called Reubens Cutoff. The Upper Loop passes immediately adjacent to the entrance of the shelter, with a 1-m tall wooden fence serving as a partition between the entrance to the shelter and the trail. The front room contains a posted sign that reads "Fragile Habitats - Stay on Trail." Reubens Cutoff lies ~0.1 km from the entrance to the shelter. Reubens Cutoff was built in 1996 in an attempt to steer most park visitors off the Upper Loop and away from the shelter. Prior to this study, the extent to which this management prescription had influenced patterns of use by park visitors at the shelter was unclear.

METHODS

Sampling to assess patterns of use by park visitors was conducted semi-monthly on Saturdays and Sundays between 11 April and 20 September 1998. Weekend days were chosen for sampling because they reflect highest visitor use at the park

(W. Francis, Natural Bridge State Park Naturalist, pers. comm.). On each day, the study sampled to qualify visitor use of the trails, and the intensity, duration and severity of visitor disturbance at, or inside, the shelter. Sampling sessions were 2 hours long between 1000 to 1330 hrs and again between 1400 to 1800 hrs EDT, respectively, and all days were either sunny or partly cloudy. Time observed, trail used, the size of the group, and the sex and estimated age as either adult or juvenile (≤ 16 years) was recorded for each group of trail visitors (defined as ≥ 1 person). For groups entering the shelter, records included the length of time spent inside and any noticeable activities that might have been disruptive to roosting bats. The hidden observer location permitted undetected monitoring activity on both the Upper Loop and Reubens Cutoff, while also keeping the entrance to the shelter in view. Binoculars with 7 x 35 magnification facilitated observation of park visitors.

A severe winter snowstorm in early 1998 resulted in numerous felled trees in the park and poor trail conditions at the start of sampling, requiring occasional off-trail travel. Park personnel cleared most debris from Reubens Cutoff by the start of surveys on 11 April, and passage to the entrance of the shelter along the Upper Loop between 28 June and 12 July 1998. Therefore, half of the sampling took place when visitor access to the shelter was difficult (i.e., limited access) and half after access to the shelter was improved (i.e., free access).

Sampling sessions by monitoring the shelter floor for evidence of visitor use supplemented the data. Following the cleanup of debris by 12 July along the Upper Loop, the soil on the surface of five large rocks on the floor of the outer room of the shelter was smoothed using a small brush. On the evenings of subsequent sampling dates, after the emergence of bats, evidence of foot traffic and any additional signs of visitor use were recorded and rock surfaces were resmoothed to allow the experiment to be repeated on subsequent sampling dates.

A comparison of levels of visitor use between trails and trail condition using 2-way analysis of variance (SAS Institute, Inc. 1992) examined variables including mean passage rate (# of groups/2-hr session) and mean group size. Frequency of groups (%) was calculated by age composition (i.e., all adult, all juvenile, mixed) and sex composition (i.e., all male, all female, mixed) among trail and trail condition classes. Student's *t*-tests investigated use by time of day. Tests were significant when $p \leq 0.05$. To quantify disturbance at the shelter, I calculated the frequency of groups (%) that entered or disturbed the shelter along the Upper Loop. Patterns in sex and age class associated with disturbance at the shelter were then examined.

Four methods assessed patterns of shelter use by bats: flight activity, emergence counts, roost surveys, and recovery of discarded moth wings on the shelter floor. Observation using a night vision viewer (210 Technology, ITT Night Vision, Roanoke, Va., USA) and Wheat lamps with infrared filters (Wratten #87, Eastman Kodak) of bat activity at the shelter provided the number of bats entering and exiting the shel-

ter for one hour post-sunset on 11 and 26 April, 16 May, 20 and 28 June, and 12 July 1998. Recorded flight activity data included the number of bats observed entering and exiting per hour; and emergence counts as the minimum known number of bats observed (# exiting - # entering) per count.

Roost surveys were completed on 25 March, 11 April, 24 May, 28 June, 25 July, 2 and 8 August, and 13 and 20 September 1998. All bats observed were recorded by species, with attention paid to any presence of non-volant young. These data were combined with levels of flight activity and emergence counts to develop a semi-monthly profile of use by bats. Recovery of all freshly discarded moth wings from the floor of the outer room of the shelter on the same day roost counts were conducted provided an index to feeding activity of *Corynorhinus rafinesquii*. The species is a "moth specialist" in Kentucky (Hurst & Lacki 1997).

RESULTS

Visitor use of the trails did not vary by time of sampling for either passage rate ($t = 0.86$; $p = 0.39$; $df = 46$; equal variances) or group size ($t = 0.28$; $p = 0.78$; $df = 88$; equal variances). Visitor use of the trails increased as the season progressed (Table 1), probably due to the enhanced access after the trail clearing of the Upper Loop ($F = 9.72$; $p = 0.0032$) between 28 June and 12 July, although passage rate remained higher on Reubens Cutoff than along the Upper Loop ($F = 17.7$; $p = 0.0001$). The interaction between effects was not significant ($F = 2.43$; $p = 0.1261$). Group size did not vary by either trail condition ($F = 0.12$; $p = 0.73$) or trail used ($F = 0.94$; $p = 0.34$). However, because only 20% (18/90) of the groups used the Upper Loop, data indicate that Reubens Cutoff reduced visitor

Table 1. Use of Trails by Visitors at Natural Bridge State Park, Powell County, Kentucky, from April to September 1998.

Parameter/Trail	Trail Condition	
	Limited Access (April - June) Mean \pm SE (n)*	Free Access (July - September) Mean \pm SE (n)
Passage rate (# groups/ 2 hr)		
Upper Loop	0.33 \pm 0.65 (12)	1.17 \pm 1.27 (12)
Reubens Cutoff	1.75 \pm 1.42 (12)	4.25 \pm 3.11 (12)
Group size (#/ group)		
Upper Loop	2.75 \pm 0.96 (4)	2.71 \pm 1.2 (14)
Reubens Cutoff	3.28 \pm 1.55 (21)	3.02 \pm 1.39 (51)

*Sample size for group rate is based on the number of 2-hr sampling sessions, whereas sample size for group size is based on the number of groups observed.

Table 2. Sex and Age Composition of Groups of Visitors Using the Upper Loop and Reubens Cutoff Trails at Natural Bridge State Park, Powell County, Kentucky, from April to September 1998.

Parameter/Trail	Trail Condition	
	Limited Access (April - June) # / %	Free Access (July - September) # / %
Upper Loop		
Female groups	0 / 0	0 / 0
Male groups	1 / 25	5 / 35.7
Mixed sexes	3 / 75	9 / 64.3
Reubens Cutoff		
Female groups	0 / 0	0 / 0
Male groups	3 / 14.3	6 / 11.8
Mixed sexes	18 / 85.7	36 / 70.6
Upper Loop		
Adult groups	3 / 75	0 / 0
Juvenile groups	0 / 0	0 / 0
Mixed ages	1 / 25	2 / 14.3
Reubens Cutoff		
Adult groups	12 / 57.2	38 / 74.5
Juvenile groups	2 / 9.5	0 / 0
Mixed ages	7 / 33.3	13 / 25.5

*Sample size for group rate is based on the number of 2-hr sampling sessions, whereas sample size for group size is based on the number of groups observed.

exposure to the shelter.

Patterns in sex and age composition showed that the majority of groups were of mixed sexes and comprised of adults (Table 2). Use of the trails by juveniles was low, especially for the Upper Loop where no group comprised solely of juveniles was recorded. Groups comprised exclusively of females were scarce in April, May, and June, but increased in frequency during the second half of the summer. No group comprised solely of females was observed using the Upper Loop. An adult male was present in each group that used the Upper Loop.

The frequency of entry into the shelter by Upper Loop groups was low (5.55%; $n = 1$), but the overall percentage of groups exhibiting behavior judged as having a potential disturbance effect was slightly higher (16.7%; $n = 3$). All groups exhibiting disturbance behavior were recorded prior to the clearing of debris along the Upper Loop. Perhaps the energy required to circumnavigate the debris and washouts resulted in a tendency to stop and rest once groups reached the base of the cliff where the shelter was situated.

Behaviors judged as having a disturbance effect were: flash photography, loud vocalizations, use of flashlights, discarding debris, eating a meal inside the shelter, and urination at the entrance. All those exhibiting disturbance behavior were adult groups comprised either solely of males, or both males and females. The amount of time spent at the entrance or inside the

Table 3. Use of Hood Branch Rock Shelter by Rafinesque's Big-Eared Bats in Natural Bridge State Park, Powell County, Kentucky, 1998.

Sampling Date	Activity (Bats/hr)	Emergence Count (# bats)	Roost Count (# bats)	Discarded Moth Wings (n)
25 Mar			0	6
11 Apr	1	0	0	3
26 Apr	19	4		
16 May	48	18		
24 May			17	29
20 Jun	45	19		
28 Jun	53	33	16 (young)	41
12 Jul	94	4		
25 Jul			0	47
2 Aug			0	3
8 Aug			1	7
13 Sep			1	0
20 Sep			1	21

shelter by those groups exhibiting disturbance behavior was between 16 and 31 minutes.

Four of the five sampling dates showed the shelter was entered, with no evidence of entry detected on 20 September, the final date of sampling. However, floor surveys indicated the shelter was regularly entered outside of sampling sessions. The average frequency of rocks showing sign of entry was 32%. The survey on 25 July discovered a small fire had been built inside the shelter sometime after the 12 July visit. Data from floor surveys indicate disturbance rates based on weekend sampling sessions alone underestimated the level of disturbance, as weekend sampling sessions detected no obvious disturbance in July, August, or September. Perhaps entry into the shelter is more frequent on weekdays when overall visitation is low, as likelihood of being "caught" inside the shelter by park personnel or other passing trail visitors is lower.

Two species of bats, *Corynorhinus rafinesquii* and *Myotis septentrionalis* (northern bat), use the shelter during this study. The lone *M. septentrionalis*, identified by its smaller size and its gleaning behavior inside the outer room of the shelter, was seen on the evening of 12 July. Additional evidence of use by species other than *C. rafinesquii* was not recorded. No bat was observed during the initial visit on 25 March (Table 3). However, evidence of use was prevalent in the form of discarded moth wings and scattered fecal remains. Bat activity at the entrance to the shelter was observed on 26 April and increased to a peak on 12 July.

Observation of a cluster of this species roosting on the back side of an overhang to the right of the domed ceiling in the rear room on 16 May confirmed use of the shelter by *Corynorhinus rafinesquii*. An emergence count later that evening produced 18 bats (Table 3). The number of *C. rafinesquii* emerging from the shelter remained stable until 28 June, when 33 were recorded. A visit inside the shelter after the emergence of bats that

evening resulted in an additional 16 non-volant young hanging on the right hand side of the domed ceiling in the rear room. Whether any young had already taken flight is uncertain but suspected for several reasons. First, there was a large increase in the number of bats emerging compared with earlier sampling dates. Second, there was extensive flight activity at the entrance to the shelter, some of which appeared erratic and potentially attributable to young bats learning to fly. Third, the non-volant young observed inside the shelter appeared to be in the late stages of development. Regardless, the combined population estimate of 49 for the colony of *C. rafinesquii* was the largest ever recorded at the shelter.

Bat activity remained high at the shelter on 12 July, but the emergence count resulted in only 4 bats, indicating the original colony had abandoned the shelter and *Corynorhinus rafinesquii* were coming from another roosting site (Table 3). A visit inside the shelter on 25 July showed bats used the site but were not present, despite an extensive number of discarded moth wings on the shelter floor. Subsequent visits on 2 and 8 August, and 13 and 20 September never resulted in more than a single *C. rafinesquii* roosting inside the shelter.

DISCUSSION

Corynorhinus rafinesquii used the shelter as both a feeding and a maternity roost in summer 1998. Further, the size of the colony, and especially the number of young observed, suggest that this shelter is an important maternity site of this species in Kentucky. Observations also indicate that shelter abandonment in early to mid-July was associated with increased use of the Upper Loop Trail by park visitors and disturbance inside the shelter. Although direct cause and effect cannot be positively discerned from these data, the documentation of disturbance suggests that use of the shelter by *C. rafinesquii* was inhibited by park visitors.

Data indicate that Reubens Cutoff did steer a high percentage of users of Hood Branch Trail off the Upper Loop and away from the shelter, although human disturbance was documented throughout most of the sampling period. Further, the presence of a posted sign at the shelter entrance did not provide sufficient deterrence to some park visitors, particularly groups that included adult males.

In contrast to mammals of similar size, bats have small litters and extended periods of infant dependency (Findley 1993), which places bats at risk of population decline when subject to habitat alteration. Reproductive rates are not density dependent and cannot offset the increased mortality of adults that occurs when roosting habitats are altered or lost. Disturbance at roosting sites is believed to be the most significant factor in the decline of bat populations in North America, particularly for bats that do not roost in man-made structures (Barbour & Davis 1969; Harvey 1976; Humphrey & Kunz 1976).

Females of *Corynorhinus rafinesquii* give birth to only a single young per growing season (Jones 1977), making this species extremely vulnerable to disturbance at maternity sites.

Although *C. rafinesquii* roost in a variety of natural and man-made structures, including trees, limestone caves, unoccupied buildings, mines, old cisterns, bridges, and culverts (Barbour & Davis 1969, 1974; Jones 1977), the majority of summer colonies in Kentucky are in sandstone rock shelters in summer (Hurst 1997; J. MacGregor, U.S. Forest Service, unpub. data). Thus, adequate protection of these roosting shelters is crucial to the long-term conservation of this species in Kentucky. *Corynorhinus rafinesquii* was formerly listed as a federal Category 2 candidate species by the U.S. Fish and Wildlife Service (Federal Register Vol. 50, No. 181, p. 37965), and is currently listed as a threatened species in Kentucky (KSNPC 1996).

There is no legal mandate to protect this bat in Kentucky as *Corynorhinus rafinesquii* is not currently afforded federal protection under the Endangered Species Act of 1973, and the state of Kentucky does not officially recognize its own existing state list of threatened and endangered species. Consequently, further declines in the numbers of this species are imminent unless land stewards choose to be proactive and institute conservation measures. Based on these data, existing strategies of Natural Bridge State Park personnel to protect *C. rafinesquii* (e.g., alternate hiking route, posted sign and wooden fence at the entrance to the shelter) appear inadequate to prevent disturbance by park visitors at the maternity roost, regardless of whether disturbance is unintentional or not. Given that other colonies of *C. rafinesquii* in Kentucky are known to be philopatric to a single maternity roost throughout summer (Hurst 1997; Hurst & Lacki 1999), protection of bats using Hood Branch Rock Shelter from human disturbance throughout the maternity season is essential if this roosting site is to remain a suitable maternity habitat of this species.

RECOMMENDATIONS

Options available for the protection of this roosting site include: maintaining existing policies and protective measures, the construction of a gate or fence to prohibit entrance into the shelter, or closure of the Upper Loop Trail to park visitors. Existing policies and protective measures are inadequate. In fact, placement of a sign at an entrance to a roosting site may actually serve as a stimulus for entry (MacGregor 1991). Construction of a gate or fence requires considerable cost and is usually implemented primarily at roosting sites of bats afforded federal protection under the Endangered Species Act, with funds obtained through federal sources. Unfortunately, placement of gates has in some instances resulted in declines in bat populations due to a variety of factors, including changes in roost microclimate, increased vulnerability to predators, or flying mishaps by bats attempting to negotiate their way past the gate (Tuttle 1977, 1986; Richter *et al.* 1993).

Closure of the Upper Loop Trail appears the most viable option for protecting *Corynorhinus rafinesquii* in Hood Branch Rock Shelter. Closure would not necessarily have to be permanent, but could be restricted from 15 May to 15 August,

the length of the maternity season of *C. rafinesquii* (Jones 1977; Hurst & Lacki 1999). This would protect bats during the maternity season, while opening up the trail to park visitors throughout the remainder of the year. Costs of this strategy include placement of signs at the two entry points to the trail and supplemental enforcement by park personnel. Further, use of educational programs and materials provided at the entrance to Hood Branch Trail could justify to park visitors the need to stay off the Upper Loop Trail during the prohibited time period. Because of a long history of man's persecution of bats, public education is considered a critical element in the long-term conservation of North American bats (Tuttle 1979; ASM 1992; Fenton 1997), and is a proactive measure recommended for use at Natural Bridge State Park, Kentucky.

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