Journal of the Alabama Academy of Science, Vol. 67, No. 1, January, 1996.

MOVEMENTS OF GRAY BATS (*MYOTIS GRISESCENS*) BETWEEN ROOST SITES AND FORAGING AREAS[1]

Troy L. Best
Department of Zoology and Wildlife Science and
Alabama Agricultural Experiment Station,
331 Funchess Hall, Auburn University, AL 36849-5414

and

M. Keith Hudson
Alabama Department of Conservation and Natural Resources,
Game and Fish Division,
309 Knightsbridge Road, Florence, AL 35631

ABSTRACT

Radiotelemetric monitoring was conducted in the vicinity of two inland roost sites in northern Alabama to determine if streams and other waterways were the most common routes taken by adult female gray bats (*Myotis grisescens*) from the inland roost sites to foraging areas on a large reservoir in northern Alabama. Gray bats primarily used tributaries of large waterways as foraging areas and flyway routes to gain access from relatively land-locked roost sites to open-water habitats, but they also flew overland to other tributary systems, which they followed to open-water habitats. Observations of these bats at the same sites at similar hours on different nights indicates that individuals may occupy specific home ranges.

INTRODUCTION

With few exceptions (Hays and Bingham, 1964; Gunier and Elder, 1971; Elder and Gunier, 1978; Timmerman and McDaniel, 1992), the gray bat (*Myotis grisescens*) is restricted to cave habitats (Hall and Wilson, 1966; Barbour and Davis, 1969; Tuttle, 1976*a*, 1979), which are in proximity to large bodies of water where the bats forage (Tuttle, 1976*a*, 1976*b*). Summer colonies use caves that are within 1 km of a large river or lake and rarely are found in caves located >4 km from such places (Tuttle, 1976*b*). At evening emergence, the bats fly to their feeding area, often forming a continuous stream of bats from the cave entrance to the water's edge. The bats usually fly in the

[1]Manuscript received 1 December 1995; accepted 15 March 1996.

forest canopy, occasionally wandering to drink and forage over farm ponds (Tuttle, 1976*b*). Tuttle (1976*b*) found that departing gray bats always took a direct route toward a river or reservoir, and La Val et al. (1977) and Thomas (1994) noted that gray bats do not always go to the nearest body of water, but some may fly over land to more distant foraging sites.

Gray bats usually forage over water and in adjacent riparian vegetation up to 70 km from their roosting caves (La Val et al., 1977; Tuttle, 1976*a*, 1976*b*; Thomas and Best, in press). These bats primarily feed on flying insects (Tuttle, 1976*b*; Lacki et al., 1995; T. L. Best et al., in litt.), but few studies of the foraging ecology of gray bats have been conducted. The only detailed studies of gray bats associated with reservoirs were at Norris Reservoir, Tennessee, and at Guntersville Reservoir, Alabama (Rabinowitz, 1978; Thomas and Best, in press; T. L. Best et al., in litt.).

Several colonies of the endangered gray bat (Greenwalt, 1976) are located near impoundments of the Tennessee River and its tributaries in northern Alabama; most of the larger colonies of gray bats (i.e., $\geq$100 individuals) are located within 1 km of impounded water, but two exceptions are Indian Cave, north of Athens, Limestone Co., and Blowing Spring Cave, north of Rogersville, Lauderdale Co. It was expected that gray bats from these and other localities move directly (or nearly so) toward open water to forage, but it was not clear which routes bats from these two caves would take. The objective of the research reported herein was to determine if streams and other waterways were the most common routes taken by gray bats to large reservoirs.

MATERIALS AND METHODS

Radiotelemetric monitoring was conducted in the vicinity of the colonies of gray bats at Indian Cave, Limestone Co., Alabama, located on Sulphur Creek, which flows into the Elk River, a tributary of the Tennessee River, and Blowing Spring Cave, Lauderdale Co., Alabama, located on First Creek, which flows into Wheeler Reservoir (Fig. 1). Using a modified harp trap (Tuttle, 1974), gray bats were captured at Indian Cave and Blowing Spring Cave as they emerged on 19 July and 16 August 1994, respectively. To eliminate differences in behavior between sexes and ages, only adult females (post-lactating) were used in our study. Bats were aged as young-of-the-year or adult. Young-of-the-year were differentiated by the prominent vascularization present at the wrist (Barbour and Davis, 1969; Anthony, 1988). Hair was partially removed from a 1-cm^2 area on the back with scissors, and a small radiotransmitter (0.8 g, model BD-2A with reed switch, Holohil Systems Ltd., Woodlawn, Ontario, Canada) was attached to 10 adult females at each cave (a total of 20 bats) using non-toxic Skin-Bond cement (Smith and Nephew United, Inc., Largo, FL). Transmission distance for these radiotransmitters is ca. 1-2 km, but may be >10 km over open water or at monitoring sites with no physical obstructions. These procedures caused no apparent distress to the bats (Thomas and Best, in press).

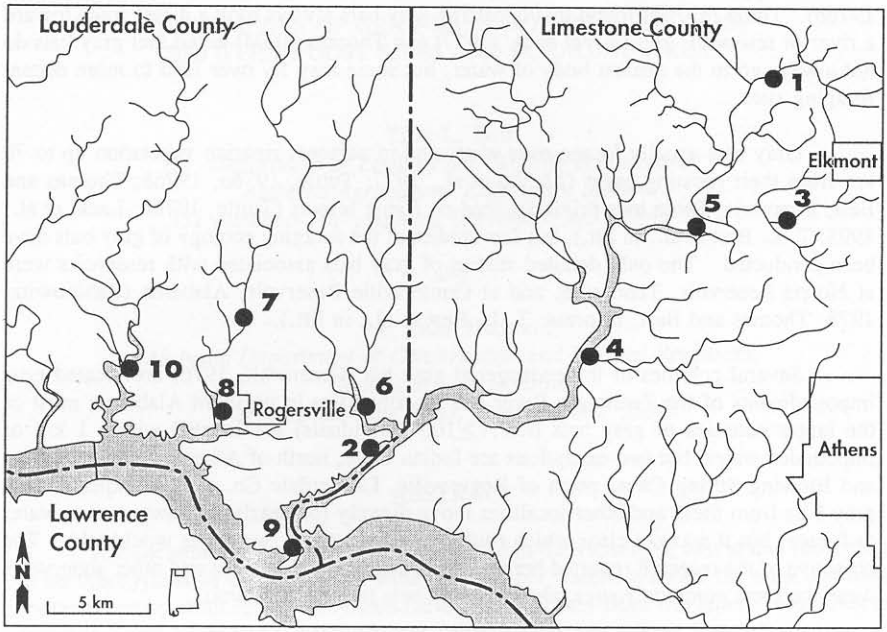

Fig. 1. Sites monitored during a study of flyways used by gray bats (*Myotis grisescens*) in northern Alabama in 1994. Second Creek (site 10), First Creek (sites 7 and 8), and the Elk River (sites 1-5 and 9) flow into Wheeler Reservoir, which is located in the lower-left of the figure. Anderson Creek (site 6) flows into the Elk River. Sites monitored 19-29 July were: 1) Bridge on Elk River, Alabama Highway 127, T1S, R5W, SE 1/4 Section 11, Limestone Co.; 2) Bridge on Elk River, US Highway 72, T3S, R7W, NE 1/4 Section 11, Lauderdale Co.; 3) Indian Cave on Sulphur Creek, T2S, R5W, NW 1/4 Section 1, Limestone Co.; 4) Bridge on Elk River E of Lentzville, T2S, R6W, NE 1/4 Section 25, Limestone Co.; 5) Oxbow in Elk River, T2S, R5W, NE 1/4 Section 4, Limestone Co. Sites monitored 16-26 August were: 6) Boat ramp on Anderson Creek, T2S, R7W, SW 1/4, Section 35, Lauderdale Co.; 7) Blowing Spring Cave, about 5 kilometers N Rogersville, T8S, R4W, NE 1/4 Section 19, Lauderdale Co.; 8) Boat ramp S of bridge on First Creek, US Highway 72, T3S, R7W, NW 1/4 Section 6, Lauderdale Co.; 9) Boat ramp at mouth of Elk River, T3S, R7W, NE 1/4 Section 28, Lauderdale Co.; 10) Boat ramp N of bridge on Second Creek, US Highway 72, T2S, R8W, SW 1/4 Section 27, Lauderdale Co.

Previous experiences in monitoring movements of gray bats by the use of radiotelemetry have shown that these bats regularly fly distances >10 km each night. However, bats with radiotransmitters were detected during only 0.3% of the attempts to locate them by Thomas and Best (in press). To maximize the number of successful attempts to locate bats with radiotransmitters in the present study, we selected monitoring sites that were adjacent to the shortest over-water routes the bats might use to access Wheeler Reservoir on the Tennessee River. In addition, location of each monitoring site allowed us to obtain data from habitats adjacent to streams or rivers. Five teams of two observers each monitored the bats nightly (1945-0600 h CDT) using TRX-2000S radioreceivers (Wildlife Materials, Inc., Carbondale, IL) and collapsible three-element Yagi antennae. The five teams of observers monitored at sites 1-5 during July and at sites 6-10 during August (Fig. 1). Each radiotransmitter frequency usually was monitored on a 1-min rotational basis throughout each night; each minute of monitoring was counted as an attempt to locate a bat. For 10 consecutive nights at each of the two study areas, data recorded during every attempt to locate a bat included names of observers, location, date, frequency monitored, time that monitoring of each frequency began and ended, whether or not a bat was detected, and direction of radiotransmission. These data provided information on when bats with radiotransmitters were active and where they were detected during foraging forays.

RESULTS

Study area at Indian Cave

During 19-29 July 1994, 29,306 attempts were made to locate the 10 bats with radiotransmitters attached at Indian Cave. Of these 10 bats, radiotransmissions were received from nine. One was not located after release. Activity areas of bats generally were over the Elk River, which flows southward into Wheeler Reservoir (Fig. 1). Bats were not detected upstream from Indian Cave (site 3) on the Elk River. Ten nights of monitoring upstream at the Highway 127 bridge (site 1; Fig. 1) did not result in the detection of any bats with radiotransmitters. Thus, all bats were detected in the area between Indian Cave and Wheeler Reservoir. Only two of the bats returned to Indian Cave; one (no. 041) was detected the night it was released, as it moved from the oxbow in the Elk River (site 5; Fig. 1) toward Indian Cave, and the other (841) returned to Indian Cave each night from 22 through 29 July.

Gray bats apparently used the Elk River as a flyway and foraging area. This is substantiated by the detection of a bat (364) west of the oxbow in the Elk River (site 5) at 2138-2201 h, then north of Lentzville (site 4) at 2213-2214 h on 19 July. Another bat (540) was detected west of the oxbow in the Elk River (site 5) at 2151-2156 h, then north of Lentzville (site 4) at 2225-2226 h on 19 July. The same bat (540) was detected at Lentzville (site 4) at 2359-2400 h, then at the Highway 72 bridge (site 2) at 2400-0011 h on 20 July. Another bat (841) was detected north of Lentzville (site 4) at 0117-0238 h, then at the Highway 72 bridge (site 2) at 0312-0313 h on 20 July. The same bat (841)

occurred north of the Highway 72 bridge (site 2) at 2134-2225 h, then at the oxbow in the Elk River (site 5) at 2253-2257 h, then at Indian Cave (site 3) at 2342-2343 h, and then back to the oxbow in the Elk River (site 5) at 2356-0001 h on 22 July. This bat (841) regularly moved between Indian Cave (site 3) and the oxbow in the Elk River (site 5), and on 25 July was detected at the Highway 72 bridge (site 2). Apparently, this bat spent most days roosting at locations other than Indian Cave. On 19 July, one bat (897) moved downstream from Indian Cave (site 3) to the oxbow on the Elk River (site 5), to Lentzville (site 4), and then to the Highway 72 bridge (site 2).

Four bats (170, 540, 841, 897) were detected on two or more occasions at the same monitoring site, indicating that bats may have areas where they regularly forage or pass through (i.e., individual home ranges; Thomas and Best, in press). One bat (170) was present at the Highway 72 bridge (site 2) between 2200 and 0100 h on the nights of 19-22 July, another (540) at Lentzville (site 4) between 2200 and 0100 h 19-21 and 23 July, another (841) at the oxbow in the Elk River (site 5) between 2200 and 0100 h on 22-26 July and between 2000 and 2100 h on 26-28 July, and another (897) at the Highway 72 bridge (site 2) between 2200 and 2400 h on 19 and 21-22 July.

Study area at Blowing Spring Cave

During 16-26 August 1994, 29,244 attempts were made to locate the 10 bats with radiotransmitters attached to them at Blowing Spring Cave (site 7). Of these 10 bats, radiotransmissions were received from five. The remaining five were not located after release. Activity areas of bats were at Blowing Spring Cave (site 7), Anderson Creek (site 6), and the mouth of the Elk River (site 9). Surprisingly, bats were not detected at First (site 8) or Second (site 10) creeks, two tributaries of the Tennessee River, which were the shortest over-water routes to Wheeler Reservoir. Three of the five bats that were detected returned to Blowing Spring Cave (site 7). One (236) was detected there on 18, 21, and 22 August, another (300) in the early morning and the following evening of 25 August, and the other (982) returned to Blowing Spring Cave 19, 20, and 24 August.

Some bats apparently moved to the Elk River via Anderson Creek, then used the Elk River as a flyway and foraging area. This is substantiated by the detection of a bat (081) at Anderson Creek (site 6) and at the mouth of the Elk River (site 9) on the nights of 16 and 18 August. One bat (982) was detected at Anderson Creek (site 6) on 23 August, but only at Blowing Spring Cave (site 7) on the nights of 19, 20, and 24 August. Another bat (236) moved between Blowing Spring Cave (site 7) and the mouth of the Elk River (site 9). Yet another (250) was detected only at the mouth of the Elk River (site 9).

Four bats (081, 236, 250, 982) were detected on two or more nights at the same monitoring site. One (081) was present at Anderson Creek (site 6) between 2000 and 2300 h on the nights of 16 and 18 August and at the mouth of Elk River (site 9) between

2000 and 0520 h on 16, 18, 23, and 24 August. Another bat (236) was present at Blowing Spring Cave (site 7) between 0300 and 0530 h on 18, 21, and 22 August and at the mouth of Elk River (site 9) between 2200 and 0205 h on 16-20 and 22 August, another (250) between 2200 and 0400 h at the mouth of Elk River (site 9) on 17-18 August, and another (982) between 2000 and 2400 h at Blowing Spring Cave (site 7) on 19, 20, and 24 August.

DISCUSSION

Gray bats usually forage over water and adjacent riparian vegetation after emergence from their roost site. Foraging usually occurs below treetop height, sometimes $\leq$2 m (La Val et al., 1977). Some individuals fly directly cross-country, without any distinctive foraging behavior. In most instances, the flight path of bats flying cross-country takes them over water again within a few minutes. La Val et al. (1977) reported that gray bats fly downstream more often than upstream (although several flew upstream), suggesting a preference for the wider downstream sections of streams as opposed to the more narrow, upstream portions. Some gray bats use even the smallest of permanently flowing streams, but most use the larger streams (La Val et al., 1977).

Gray bats are known to move 30-70 km during foraging forays (Tuttle, 1976*a*; La Val et al., 1977; Thomas and Best, in press), although the usual foraging range of these bats is $<$12 km (range 1-35 km; Tuttle, 1976*a*; La Val et al., 1977). Because of uneven terrain and because the radiotransmitters are small, radioreceivers usually cannot detect signals from distances $>$1-2 km. Thus, at any one time, most (or all) of the bats with radiotransmitters were out of the range of our radioreceivers. In the present study, bats with radiotransmitters were detected during 0.2% of our attempts to locate them. This is similar to a previous study (0.3%) conducted upstream on the Tennessee River at Guntersville Reservoir, Alabama (Thomas and Best, in press).

During July and August, when our radiotelemetry study was conducted, young-of-the-year had become volant and adults did not always return to the cave where they began each night's foraging activity. It appears that gray bats were using alternate roost sites. There was always a monitoring team stationed at the capture site, and while it initially was expected that bats with radiotransmitters would return to these sites on a regular basis, they returned only sporadically or not at all.

In July, we expected gray bats to leave Indian Cave, then go along Sulphur Creek to the Elk River and proceed by the shortest over-water route toward Wheeler Reservoir. This is the movement pattern that actually appeared to be exhibited by the bats. In August, we expected the bats to leave Blowing Spring Cave, then go along First or Second creeks to Wheeler Reservoir (the shortest over-water routes to the reservoir). However, none of the bats were detected at either of these creeks, despite the fact that another colony of this species inhabits a cave on First Creek near Wheeler Reservoir. In late July, female gray bats have completed raising their young, and by mid-August,

they probably have copulated and begun preparation for entry into hibernation. Thus, the bats studied in August had little reason to remain in the vicinity of Blowing Spring Cave. Because the entrance of the cave was monitored each night from 16 through 25 August, we believe the absence of five of the 10 bats indicates that many had moved to alternate roosts or toward their hibernation cave (probably Fern Cave, Jackson Co., Alabama). Because three of the five bats we detected in August were at the mouth of the Elk River, it is possible they traveled overland to the reservoir or that they used other routes along smaller waterways to gain access to the reservoir, but this was not verified.

We must emphasize that all of our monitoring sites (Fig. 1) were on the Elk River, its tributaries, or other tributaries of the Tennessee River (First, Second, and Anderson creeks) and that constant radiocontact was not maintained with each bat. Thus, it is possible that bats moved to areas away from the Elk River and other tributaries to forage; possibly to adjacent woodlands or agricultural fields. However, because of the known affinity of gray bats for open-water habitats (Tuttle, 1976*a*, 1976*b*; Thomas and Best, in press), we believe that most of the time bats were out of the range of our radioreceivers they were foraging over Wheeler Reservoir. Because we only detected bats with radiotransmitters over open-water habitats and never over adjacent riparian habitats or nearby woodlands or agricultural fields, we believe that the gray bats we monitored primarily traveled and foraged over open-water habitats. However, we did detect bats at sites that would have required them to fly overland to other tributaries of the Tennessee River, which they then used as flyways to Wheeler Reservoir. Our conclusion that gray bats primarily travel and forage over open-water habitats also is supported by previous research on this species at other reservoirs along the Tennessee River (Tuttle, 1976*a*, 1976*b*; Thomas and Best, in press) and by studies conducted in Missouri (La Val et al., 1977).

Previous research also has shown that foraging activities of gray bats seem to be restricted to a home range (Tuttle, 1976*a*; Thomas and Best, in press). We monitored some bats that returned to the same foraging sites at about the same time on ≥ 2 nights. Although our data are not conclusive, when coupled with similar data from Thomas and Best (in press) and the observations of Tuttle (1976*a*), there seems to be a strong indication that individual gray bats occupy a specific home range. Perhaps, these bats forage within a relatively well-defined home range where they search for insect prey in a regular manner.

In conclusion, results of our research indicate that gray bats primarily use tributaries of large waterways as foraging areas and flyway routes to gain access from relatively land-locked roost sites to open-water habitats, but they also fly overland to other tributary systems, which they follow to open-water habitats. Future studies are needed to determine if these bats forage over woodlands, agricultural fields, or other areas away from water as they are moving between open-water habitats.

ACKNOWLEDGMENTS

We thank R. R. Currie and R. R. Hannan of the United States Fish and Wildlife Service and F. Planer and J. A. Schoenholz of the United States Department of Agriculture Boll Weevil Eradication Program for their many helpful suggestions, personnel of the United States Fish and Wildlife Service, and J. R. Woehr of the Alabama Department of Conservation and Natural Resources for granting permits to conduct the research. J. Nugent and E. Sandlin allowed access to the caves. P. Robeson allowed us to monitor sites in Joe Wheeler State Park. We thank J. L. Nugent and family for their hospitality and logistical support, T. E. Rodriguez for preparing the figure, and especially A. N. Chadwick, W. S. Cvilikas, T. Devine, L. M. Gilley, A. B. Goebel, T. D. Hadlock, N. S. Hawkins, T. H. Henry, W. M. Kiser, B. A. Milam, and L. Mitchell for assistance in the field. M. D. Adam, G. R. Hepp, G. Hill, and two anonymous reviewers critically evaluated an early draft of the manuscript. Fieldwork was funded by the United States Department of Agriculture-Animal and Plant Health and Inspection Service Boll Weevil Eradication Program. Radiotelemetry equipment was provided by The Tennessee Valley Authority. This is research contribution no. 15-944945 of the Alabama Agricultural Experiment Station.

LITERATURE CITED

Anthony, E. L. P. 1988. Age determination in bats. Pp. 53-55, *in* Ecological and behavioral methods for the study of bats (T. H. Kunz, ed.). Smithsonian Institution Press, Washington, D.C., 533 pp.

Barbour, R. W., and W. H. Davis. 1969. Bats of America. The University Press of Kentucky, Lexington, 286 pp.

Elder, W. H., and W. J. Gunier. 1978. Sex ratios and seasonal movements of gray bats (Myotis grisescens) in southwestern Missouri and adjacent states. The American Midland Naturalist, 99:463-472.

Greenwalt, L. A. 1976. To the list of endangered and threatened species, Fish and Wildlife Service added the gray bat, Mexican wolf, and two butterfly species. The Federal Register, 41:17736-17740.

Gunier, W. J., and W. H. Elder. 1971. Experimental homing of gray bats to a maternity colony in a Missouri barn. The American Midland Naturalist, 86:502-506.

Hall, J. S., and N. Wilson. 1966. Seasonal populations and movements of the gray bat in the Kentucky area. The American Midland Naturalist, 75:317-324.

Hays, H. A., and D. C. Bingham. 1964. A colony of gray bats in southeastern Kansas. Journal of Mammalogy, 45:150.

La Val, R. K., R. L. Clawson, M. L. La Val, and W. Caire. 1977. Foraging behavior and nocturnal activity patterns of Missouri bats, with emphasis on the endangered species *Myotis grisescens* and *Myotis sodalis*. Journal of Mammalogy, 58:592-599.

Lacki, M. J., L. S. Burford, and J. O. Whitaker, Jr. 1995. Food habits of gray bats in Kentucky. Journal of Mammalogy, 76:1256-1259.

Rabinowitz, A. R. 1978. Habitat use and prey selection by the endangered gray bat, *Myotis grisescens*, in East Tennessee. M.S. thesis, University of Tennessee, Knoxville, 56 pp.

Thomas, D. P. 1994. A radiotelemetric assessment of the foraging ecology of the gray bat (*Myotis grisescens*) at Guntersville Reservoir, Alabama. M.S. thesis, Auburn University, Alabama, 78 pp.

Thomas, D. P., and T. L. Best. In press. Radiotelemetric assessment of movement patterns of the gray bat (*Myotis grisescens*) at Guntersville Reservoir, Alabama. Special Publications, North Carolina State Museum of Natural History, Raleigh.

Timmerman, L., and V. R. McDaniel. 1992. A maternity colony of gray bats in a non-cave site. Proceedings of the Arkansas Academy of Science, 46:108-109.

Tuttle, M. D. 1974. An improved trap for bats. Journal of Mammalogy, 55:475-477.

Tuttle, M. D. 1976*a*. Population ecology of the gray bat (*Myotis grisescens*): philopatry, timing and patterns of movement, weight loss during migration, and seasonal adaptive strategies. Occasional Papers of the Museum of Natural History, The University of Kansas, 54:1-38.

Tuttle, M. D. 1976*b*. Population ecology of the gray bat (*Myotis grisescens*): factors influencing growth and survival of newly volant young. Ecology, 57:587-595.

Tuttle, M. D. 1979. Status, causes of decline, and management of endangered gray bats. The Journal of Wildlife Management, 43:1-17.