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RADIOTELEMETRIC ASSESSMENT OF MOVEMENT PATTERNS OF THE GRAY BAT *(MYOTIS GRISESCENS)* AT GUNTERSVILLE RESERVOIR, ALABAMA

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We used radiotelemetry to study seasonal variation in movement patterns of gray bats *(Myotis grisescens)* at Guntersville Reservoir, Alabama. Individual gray bats foraged over large areas of Guntersville Reservoir, and there was considerable movement of bats between Blowing Wind and Hambrick caves. Average minimum size of home range of individual gray bats at Guntersville Reservoir was 97 km^2. Bats may have had a greater affinity for foraging areas during and shortly after young became volant, and during the breeding season than later in the active season as time to enter hibernation neared. Bats moved over a broader area when young became volant than later in the active season. Greatest number of days a bat was detected at the same monitoring site, greatest distances traveled by bats, and greatest number of nights a bat was found at the same locality did not vary between sampling periods. During 1991, gray bats were detected more often at about the time young became volant than later in the active season.

The gray bat *(Myotis grisescens)* has a limited distribution in limestone-karst areas of the eastern and southern United States (Hall, 1981; Hall and Wilson, 1966; Rabinowitz and Tuttle, 1980). Primarily because of habitat destruction and molestation by humans (Barbour and Davis, 1969; Tuttle, 1979a, 1979b), the gray bat was listed as an endangered species by the United States Fish and Wildlife Service (Greenwalt, 1976). Large winter colonies of the gray bat hibernate in only nine caves. In early spring, winter colonies disband and leave winter hibernacula. Adult females emerge from hibernation first, followed by yearlings of both sexes, and finally by adult males. Bats move to other caves where they form large transient colonies that occupy caves for several days. Gray bats then form maternity colonies, where females give birth and raise their young, and bachelor colonies, which predominantly contain males and non-reproductive females. After young become volant, sex and age segregation weakens. Young-of-the-year of both sexes remain with females in maternity colonies during July and August. Autumn migration takes place in the same order as spring emergence, with adult females leaving in early September and young-of-the-year remaining behind with the last males to leave, usually by mid-October (Elder and Gunier, 1978; Tuttle, 1976a, 1979a).

Movement patterns among summer caves and between summer caves and hibernacula, are relatively well understood (Elder and Gunier, 1978; Hall and Wilson, 1966; Tuttle, 1976a, 1979a). Gray bats generally occur as discrete populations that occupy a series of summer caves associated with one or a few hibernacula (Elder and Gunier, 1978; Hall and Wilson, 1966; Tuttle, 1976a). However, affiliation between summer caves and winter hibernacula also may involve long-distance movements by a few individuals (Elder and Gunier, 1978; Hall and Wilson, 1966; Tuttle, 1976a) or by whole populations. Gray bats from northwestern Florida, for example, regularly migrate to a winter hibernaculum in northeastern Alabama (Tuttle, 1976a).

During summer months, Blowing Wind and Hambrick caves, located at Guntersville Reservoir in northeastern Alabama, contain the two largest summer colonies of gray bats (Tuttle, 1976a; United States Fish and Wildlife Service, in litt.). The combined populations of gray bats at Blowing Wind and Hambrick caves is ca. 600,000, a doubling of their population during the past 10 years (The Tennessee Valley Authority, in litt.). Blowing Wind Cave (primarily a bachelor colony) and Hambrick Cave (a maternity colony) contain bats that represent a single colony, and almost all of the bats from this association hibernate in nearby Fern Cave. Bats banded in Hambrick Cave have been found hibernating only in Fern Cave, but recoveries of hibernating bats banded at Blowing Wind Cave were more widely distributed. Most hibernated in Fern Cave, but some also hibernated in Tennessee and Missouri. Recoveries of banded bats of all sexes and ages for all times of the year from Blowing Wind Cave indicate movements throughout northern Alabama and middle Tennessee (Tuttle, 1976a).

Although large-scale movement patterns among caves inhabited by single colonies of gray bats are well documented, smaller-scale movement patterns are not well known. During the active season of gray bats, movement patterns associated with foraging require forays from summer caves. At Norris Reservoir, Tennessee, Rabinowitz (1978) found that gray bats foraged at some sites more than others; this foraging pattern may be correlated with abundance of prey species, e.g., mayflies (Ephemeroptera—Rabinowitz, 1978; Rabinowitz and Tuttle, 1982; Tuttle, 1976b). Gray bats may forage 15-35 km from the roost each night, and foraging activities are restricted to the local range of the population, which may be 50 km across (Tuttle, 1976a). Although night-flying, aquatic insects serve as the primary source of food for *M. grisescens,* little is known about foraging and movement patterns of gray bats in Alabama. Guntersville Reservoir is large and supports a variety of aquatic habitats, but not all regions of the reservoir provide equal quantities of acceptable prey species. Gray bats probably use a variety of foraging sites throughout the active season to optimize foraging effort. The only previous study of movement patterns of *M. grisescens* at Guntersville Reservoir was conducted during the 1960s and early 1970s, when the population of gray bats was decreasing (Tuttle, 1975, 1976a, 1976b, 1979a, 1979b).

Historically, various methods have been used to study biology and movement patterns of *M. grisescens.* Banding and recovery has been the method most widely employed (Elder and Gunier, 1978, 1981; Gunier and Elder, 1971; La Val et al., 1977; Stevenson and Tuttle, 1981; Tuttle, 1975, 1976a, 1976b; Tuttle and Robertson, 1969; Tuttle and Stevenson, 1977), but this technique may involve capturing bats several times and it may be critically disturbing to a colony. At times, it has been necessary to use a shotgun to sacrifice bats to recover bands (Tuttle, 1976b). Attached chemiluminescent capsules make dispersing *M. grisescens* more easily detectable, and when observed from a helicopter, the bats can be followed with relative ease (La Val et al., 1977). Observations using night-vision equipment also have been successful (Rabinowitz, 1978). Because they are swift fliers (18-39 km/h—Kennedy and Best, 1972; La Val et al., 1977; Tuttle, 1976a), gray bats can disappear from sight quickly, but radiotelemetry eliminates the need to maintain visual contact with the bats. Technology to monitor movements of small bats by radiotelemetry was not available in the 1960s and 1970s when most studies of *M. grisescens* were conducted in Alabama. Radiotelemetry may provide answers to questions about foraging ecology and movement patterns of this species, and reveal additional information that will be useful in its protection and management. The objective of our study was to use radiotelemetric monitoring to elucidate seasonal variation in movement patterns of individual *M. grisescens* at Guntersville Reservoir.

METHODS AND MATERIALS

This study was conducted at Guntersville Reservoir, a 27,479-ha impoundment of the Tennessee River in northeastern Alabama and southern Tennessee. The reservoir was constructed ca. 50 years ago for commercial navigation, flood control, and hydroelectric generation. It is bounded downstream by Guntersville Dam and upstream by Nickajack Dam in Tennessee. The area surrounding Guntersville Reservoir consists of a mixture of pine-hardwood forests and open pastures. Limestone caves suitable for *M. grisescens* are situated near the reservoir and its tributary systems, and three caves, Blowing Wind, Hambrick, and Nickajack, are used each summer by large colonies of gray bats. Two of these caves, Nickajack (located on Nickajack Reservoir, Tennessee) and Hambrick, open directly onto the water, but Blowing Wind Cave is separated from the reservoir by a distance of ca. 100 m. Entrances of these three caves have been fenced or gated to prevent disturbance of bats by humans.

During summer 1991 (8 July-17 September), gray bats were captured using a harp trap (Tuttle, 1974) as they emerged from Blowing Wind Cave, Jackson Co., Alabama, and in summer 1992 (9 July-14 September) as they emerged from Blowing Wind Cave and Hambrick Cave, Marshall Co., Alabama. Bats were aged as young-of-the-year or adult; young-of-the-year were differentiated by prominent vascularization present at the wrist (Anthony, 1988; Barbour and Davis, 1969). While most females in the population of gray bats at Guntersville Reservoir gave birth and raised their young at Hambrick Cave, a nursery colony containing >2,000 young also was present in Blowing Wind Cave; mothers of these young-of-the-year were the primary focus of research efforts.

Radiotransmitters were attached to 6 adult males and 21 post-lactating, adult females in 1991 and to 34 post-lactating, adult females in 1992. Hair was partially removed from a 1-cm^2 area on the back with scissors, and a radiotransmitter (0.8 g, model BD-2A with reed switch, Holohil Systems Ltd., Carp, Ontario, Canada) was attached using non-toxic, Skin-Bond Cement (Smith and Nephew United, Inc., Largo, FL). Transmission distance for these radiotransmitters is ca. 3-5 km, but may be >10 km over open water with no physical obstructions. No apparent distress was caused to bats by these procedures.

Five teams of two persons each monitored bats throughout the night (1930-0600 h CDT) using TRX-2000S radioreceivers (Wildlife Materials, Inc., Carbondale, IL) and collapsible three and five-element Yagi antennae. When possible, walkie-talkies were used to communicate among teams of observers concerning movements of individual bats. During 1991, bats were monitored from >30 sites, the number and location of which varied throughout summer (Fig. 1; sites 1-12). In 1992, the number of monitoring sites was reduced to seven (Fig. 1; sites 1, 2, 8, 9, 12, 13, and 14), chosen for their wide vantage points and because information gathered in 1991 indicated that these were areas frequently used by bats. Each radiotransmitter frequency usually was monitored on a 1-min rotational basis throughout the night. As in 1991, five teams of two observers each monitored bats throughout the night. The entrance of Blowing Wind Cave was monitored throughout all sampling periods in 1991 and 1992.

Six parameters were used to assess movement patterns, roost fidelity, and home ranges of individual bats. To provide an estimate of how long individual bats remained in the vicinity of Guntersville Reservoir, we examined number of days between receipt of the first and last radiotransmission from a bat and number of successful attempts to locate each bat. To provide an estimate of size of home range, roost-site fidelity, and foraging-site fidelity, we examined total number of sites where each bat was located, number of times each bat was located (i.e., ≥15 min between each time the bat was detected), greatest distance each bat traveled from where the radiotransmitter was attached (measured along a straight line in kilometers), and greatest number of nights each bat was found at the same locality. To assess variation of these parameters within years, we divided each year into early and late-season sampling periods (8 July-5 August and 19 August-3 September in 1991, 9 July-7 August and 21 August-4 September in 1992, respectively). The early season sampling period generally corresponded to when young became volant and to the premigratory time for adult females, and the late-season period generally corresponded to when adult females began to migrate to hibernacula, the time of copulation, and to the premigratory time for young-of-the-year and adult males (Tuttle, 1975, 1976a, 1976b). One-way analysis of variance was used to assess differences between sexes and sampling periods. To provide an estimate of minimum size of home range of individual bats, we plotted localities where bats with radiotransmitters were detected, connected the points with straight lines, measured the greatest length and width (90° to length) of home range, and overlaid a grid to estimate minimum area of the home range. All statistical analyses were conducted using SPSS/PC+ (Norŭsis, 1990).

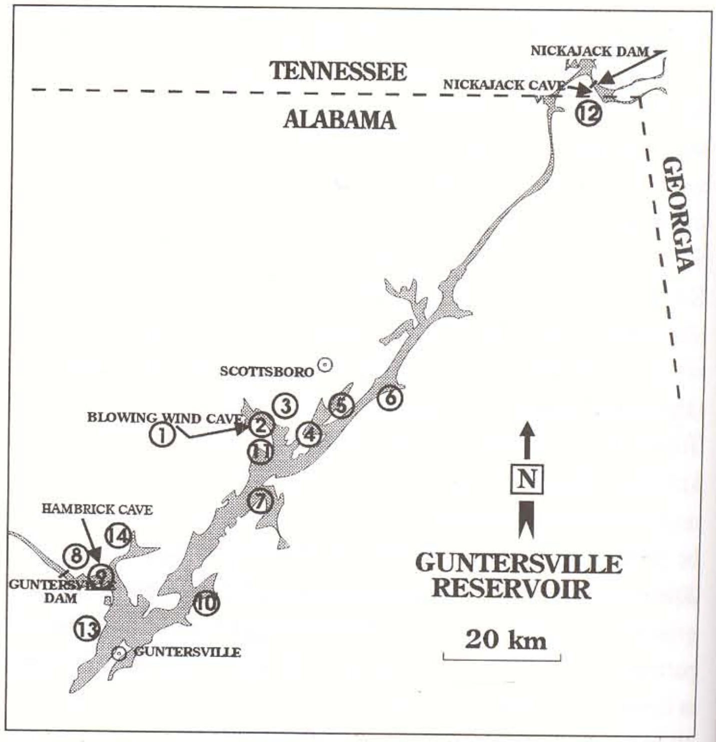

Fig. 1.—Sites monitored for gray bats *(Myotis grisescens)* at Guntersville Reservoir, Alabama, and Nickajack Reservoir, Tennessee: 1) Blowing Wind Cave; 2) Jackson County Highway 114 (south of US Highway 72); 3) Island in North Sauta Creek; 4) Goose Pond Colony (boat ramp); 5) Jackson County Sportsman's Club (boat ramp); 6) B. B. Comer Bridge (boat ramp); 7) South Sauta Creek (boat ramp); 8) Guntersville Dam; 9) Hambrick Cave; 10) Guntersville State Park; 11) Mink Cove; 12) Nickajack Cave; 13) Brown's Creek; 14) Honeycomb Creek Campground. In addition, 16 other sites were monitored at irregular intervals.

RESULTS

During 1991, 38,771 attempts (81,452 min) were made to locate the 27 bats with radiotransmitters attached to them (Table 1). Unknown electrical sources near monitoring sites interfered with radiotransmissions at some lower frequencies (150.000-150.300 KHz). Consequently, data for 11 bats were omitted from analyses. Of the remaining 16 bats, radiotransmissions were received from 10 of them (three males, seven females), and six (three males, three females) were not located after release. Activity areas of bats generally were near Blowing Wind and Hambrick caves. Of the 10 bats detected after release, six remained within 10 km of Blowing Wind Cave, one (150.578) was located ca. 20 km downstream at Guntersville State Park, and three (150.370, 150.418, 150.517) were located in the Hambrick Cave-Guntersville

Table 1.—*Gender of gray bats* (Myotis grisescens), *frequency of radiotransmitter (KHz), date radiotransmitter was attached, date of receipt of last radiotransmission, total number of attempts to locate the bat, number of minutes spent attempting to locate the bat, and number of minutes the bat was located at Guntersville Reservoir, Alabama, 1991-1992. Radiotransmitters were attached to bats at Hambrick (indicated by an asterisk) and Blowing Wind caves.*

Year	Gender of bat	Transmitter frequency	Begin date	End date	Number of attempts	Minutes attempted	Minutes located
1991	F	150.458	8 Jul	10 Jul	225	1,068	40
	F	150.016	9 Jul	N/A	3,176	9,590	N/A
	F	150.038	22 Jul	N/A	2,101	4,925	N/A
	F	150.418	22 Jul	14 Aug	1,927	5,212	43
	F	150.138	22 Jul	N/A	2,103	4,972	N/A
	F	150.080	23 Jul	N/A	2,047	4,997	N/A
	F	150.157	19 Aug	N/A	714	1,359	N/A
	F	150.178	5 Aug	N/A	1,396	2,836	N/A
	F	150.057	5 Aug	N/A	1,428	2,892	N/A
	F	150.247	5 Aug	N/A	1,490	3,061	N/A
	F	150.266	5 Aug	N/A	1,469	3,062	N/A
	F	150.308	5 Aug	N/A	2,234	6,499	N/A
	F	150.370	5 Aug	14 Aug	2,322	4,167	4
	F	150.220	19 Aug	N/A	844	1,636	N/A
	F	150.349	19 Aug	19 Aug	1,809	2,889	0
	M	150.756	19 Aug	19 Aug	1,657	2,669	0
	M	150.398	19 Aug	23 Aug	1,687	2,728	8
	M	150.439	19 Aug	19 Aug	677	1,341	0
	F	150.328	23 Aug	23 Aug	592	1,912	0
	F	150.497	3 Sep	3 Sep	1,413	2,284	1
	F	150.517	3 Sep	6 Sep	1,365	2,040	14
	F	150.578	3 Sep	7 Sep	1,417	2,289	1
	F	150.657	3 Sep	4 Sep	1,368	2,016	9
	F	150.697	3 Sep	3 Sep	1,368	2,036	0
	M	150.738	3 Sep	18 Sep	1,403	2,109	10
	M	150.637	17 Sep	17 Sep	270	431	0
	M	150.537	17 Sep	18 Sep	269	432	2
Total					38,771	81,452	132

Dam area, ca. 30 km from the release site (Thomas, 1994).

In 1991, four bats with radiotransmitters were detected on two or more occasions at the same monitoring site (Table 2), indicating that bats may have areas where they regularly forage (i.e., an individual home range). Data obtained in 1991 indicated that average home range of individual bats was ca. 4 by 17 km and covered an area of ca. 50 km^2 (Table 2). Generally, home ranges of the

Table 1.—*continued*

Year	Gender of bat	Transmitter frequency	Begin date	End date	Number of attempts	Minutes attempted	Minutes located
1992	F	172.650	9 Jul	15 Jul	3,978	8,080	54
	F	172.550	9 Jul	15 Jul	3,949	8,048	25
	F	172.950	9 Jul	14 Jul	3,931	8,195	22
	F	172.888	9 Jul	15 Jul	3,902	7,997	5
	F*	172.849	11 Jul	27 Jul	3,162	3,468	88
	F	172.969	24 Jul	24 Jul	2,883	3,404	0
	F	172.770	24 Jul	9 Aug	2,267	2,790	40
	F	172.591	24 Jul	8 Aug	2,878	3,403	10
	F	172.691	24 Jul	29 Jul	2,221	2,744	26
	F	172.729	24 Jul	12 Aug	2,132	2,689	2
	F	172.809	24 Jul	7 Aug	2,898	7,177	5
	F	172.830	24 Jul	8 Aug	2,139	2,696	13
	F*	172.572	6 Aug	11 Aug	2,147	2,952	1
	F*	172.631	6 Aug	9 Aug	3,178	4,344	12
	F*	172.872	6 Aug	12 Aug	2,154	2,737	14
	F*	172.909	6 Aug	12 Aug	2,146	2,783	7
	F	172.927	7 Aug	7 Aug	1,955	2,735	0
	F	172.671	7 Aug	8 Aug	1,956	2,510	1
	F	172.791	7 Aug	9 Aug	1,878	2,431	9
	F	172.989	7 Aug	9 Aug	1,971	2,524	0
	F	172.382	21 Aug	21 Aug	1,636	1,895	0
	F	172.020	21 Aug	21 Aug	1,705	2,191	0
	F	172.109	21 Aug	21 Aug	1,719	2,199	0
	F	172.259	21 Aug	21 Aug	1,635	1,894	0
	F	172.540	21 Aug	21 Aug	1,636	1,899	0
	F	172.710	21 Aug	21 Aug	1,696	2,004	0
	F	172.751	21 Aug	21 Aug	1,701	2,015	0
	F	172.168	4 Sep	4 Sep	776	776	0
	F	172.211	4 Sep	4 Sep	442	442	0
	F	172.304	4 Sep	4 Sep	722	724	0
	F	172.353	4 Sep	4 Sep	722	722	0
	F	172.431	4 Sep	4 Sep	724	739	0
	F	172.501	4 Sep	4 Sep	876	876	0
	F	172.640	4 Sep	10 Sep	1,068	1,133	80
Total					67,885	103,216	414

four bats that showed greatest movement from Blowing Wind Cave coincided with the area between Blowing Wind and Hambrick caves and reflected movements between the two caves. Limited observations of these four bats indicated one-way movements from Blowing Wind Cave to Hambrick Cave and Guntersville State Park; none of these bats returned to Blowing Wind Cave (Thomas, 1994).

During 1992, 67,885 attempts (103,216 min) were made to locate the 34 bats with radiotransmitters (all females). Sixteen of these bats were not detected after release, but radiotransmissions were received from 18 of

Table 2.—*Number of times gray bats* (Myotis grisescens) *were located after release (≥15 min between each time of location), number of sites where they were located after release (does not include site of release), and estimates of minimum size of home range at Guntersville Reservoir, Alabama, 1991-1992.*

Year	Frequency of transmitter	Number of locations	Number of sites	Minimum size of home range		
				Length (km)	Width (km)	Area (km^2)
1991	150.370	2	2	29	3	44
	150.398	1	2	3	3	5
	150.418	12	6[a]	29	9	193
	150.458	3	7[a]	7	4	15
	150.497	1	1			
	150.517	5	3[a]	29	5	73
	150.537	1	1			
	150.578	1	1	22		
	150.657	3	3	5	1	3
	150.738	4	3[a]	11	2	11
Average		3.3	2.9	17.3	3.9	49.1
1992	172.550	9	2[a]	22		
	172.572	1	1			
	172.591	4	2	31	9	140
	172.631	8	2[a]	15	9	68
	172.640	15	1[a]	22		
	172.650	13	2[a]	22		
	172.671	1	1	28		
	172.691	5	2[a]	89	5	223
	172.729	2	1[a]	28		
	172.770	25	3[a]	31	16	248
	172.791	3	1[a]	22		
	172.809	5	2[a]	31	16	248
	172.830	10	3[a]	31	9	140
	172.849	3	2[a]	15	9	68
	172.872	8	3[a]	15	9	68
	172.888	5	1[a]			
	172.909	5	1[a]	15		
	172.950	5	3[a]	29	7	102
Average		7.1	1.8	27.8	9.1	134.6
Overall average		5.7	2.2	24.2	6.9	97.2

[a]Radiotransmissions received at the same site ≥2 nights.

them at least once after release (Table 1). Excluding the release site, no individual bat was located at more than three monitoring sites (Table 2). Greatest activity of bats occurred near Blowing Wind Cave, Hambrick Cave, and Guntersville State Park, with 15 of the 18 bats being found two or more times at the same monitoring site (Table 2). A functioning radiotransmitter, which had been placed on a bat at Blowing Wind Cave 2 days previously, was recovered from a cave in Guntersville State Park, indicating the bats used roost sites other than Blowing Wind and Hambrick caves.

Of the 13 bats found after they were released at Blowing Wind Cave in 1992, one (172.888) was detected only at Blowing Wind Cave, two (172.550 and 172.650) traveled to Guntersville State Park (ca. 20 km) and returned, and one (172.950) went to Guntersville State Park, back to Blowing Wind Cave, then to Brown's Creek and Guntersville State Park (Thomas, 1994). Once they left Blowing Wind Cave, none of the remaining nine bats with radiotransmitters were detected there again; two bats (172.591 and 172.770) went to Guntersville State Park and Brown's Creek, one (172.830) moved between Brown's Creek, Guntersville State Park, and Hambrick Cave, two (172.640 and 172.791) went to Guntersville State Park, two (172.671 and 172.729) went to Brown's Creek, one (172.809) went to Guntersville State Park, Brown's Creek, and Hambrick Cave, and one (172.691) that was released at Blowing Wind Cave on 24 July was located at Brown's Creek on 26 July and outside Nickajack Cave, Tennessee, on 28 and 29 July, ca. 75 km upriver from the capture site and >100 km from Brown's Creek (Fig. 1; Thomas, 1994). The five bats with radiotransmitters attached to them at Hambrick Cave were found only at the release site, Brown's Creek, and Guntersville State Park (Table 2; Thomas, 1994). Data obtained in 1992 indicated the average home range was ca. 9 by 28 km and covered an area of ca. 135 km^2. When combined with 1991 data, average minimum size of home range of gray bats at Guntersville Reservoir was ca. 7 by 24 km and covered an area of ca. 97 km^2 (Table 2).

When amount of effort made to locate bats in 1991 was examined statistically, there was no significant difference between the sampling periods of 8 July-5 August and 19 August-3 September for number of attempts to locate bats (F-value = 0.575, $d.f.$ = 1,14, P = 0.461; 8 July-5 August, n = 3, $\bar{x}$ = 1,491 attempts/bat, range = 225-2,322; 19 August-3 September, n = 13, $\bar{x}$ = 1,177 attempts/bat, range = 269-1,809), but there was a significant difference between sampling periods for number of minutes spent attempting to locate bats in 1991 (F-value = 4.927, $d.f.$ = 1,14, P = 0.044; 8 July-5 August, n = 3, $\bar{x}$ = 3,482 min attempted/bat, range = 1,068-5,212; 19 August-3 September, n = 13, $\bar{x}$ = 1,937 min attempted/bat, range = 432-2,889). For 1992, there were significant differences between sampling periods for number of attempts to locate bats (F-value = 40.202, $d.f.$ = 1,32, $P \leq$ 0.001; 9 July-7 August, n = 20, $\bar{x}$ = 2,686 attempts/bat, range = 1,955-3,978; 21 August-4 September, n = 14, $\bar{x}$ = 1,218 attempts/bat, range = 442-1,719) and number of minutes spent attempting to locate bats (F-value = 20.143, $d.f.$ = 1,32, $P \leq$ 0.001; 9 July-7 August, n = 20, $\bar{x}$ = 4,185 min attempted/bat, range = 2,431-8,195; 21 August-4 September, n = 14, $\bar{x}$ = 1,394 min attempted/bat, range = 442-2,199). Thus, subsequent analyses of the six parameters used to assess movement patterns were conducted after data recorded for each bat were divided by number of minutes we attempted to locate the bat, then multiplied by 100.

Statistical analyses of number of days between receipt of first and last radiotransmission indicated no significant differences between sexes or between sampling periods during 1991. However, in 1992, number of days that radiotransmissions were received was significantly greater in the 9 July-12 August sampling period than in the 21 August-10 September period (Table 3). Thus, bats remained in the vicinity of monitoring sites for more days in the sampling period of 9 July-12 August than 21 August-10 September 1992. These bats may have a greater affinity for foraging areas during and shortly after the time young become volant and during the breeding season than later in the active season as time to enter hibernation nears.

In 1991, number of successful attempts to locate a bat did not differ between sexes, but a significant difference was present between sampling periods; there was a greater number of successful attempts to locate bats for 8 July-14 August than for 19 August-18 September (Table 3). There was no significant difference between sampling periods in 1992. Thus, during 1991, bats were found more often at about the time young became volant than later in the active season. Bats tended to lose affinity for foraging areas after young become volant.

Number of sites where a bat was detected after release did not differ between sexes, but in 1991 and 1992, there were significant differences between sampling periods (Table 3). In 1991 and 1992, bats were

Table 3.—*Results of one-way analysis of variance between sexes and times radiotransmitters were attached for variables examined in a radiotelemetric assessment of foraging patterns of gray bats* (Myotis grisescens) *at Guntersville Reservoir, Alabama, 1991-1992. One asterisk indicates* $P \leq 0.05$ *and two asterisks indicate* $P \leq 0.001$.

Variable and date		n	$\bar{x}$	range	Results of ANOVA		
					d.f.	*F*	*P*
Number of days between receipt of first and last radiotransmission/number of minutes attempted X 100							
1991							
	Males	6	0.234	0-0.759			
	Females	10	0.150	0-0.461	1,14	0.525	0.481ns
	8 July-14 August	3	0.327	0.240-0.461			
	19 August-18 September	13	0.148	0-0.759	1,14	1.661	0.218ns
1992							
	9 July-12 August	20	0.240	0-0.744			
	21 August-10 September	14	0.044	0-0.618	1,32	7.893	0.008*
Number of successful attempts to locate each bat/number of minutes attempted X 100							
1991							
	Males	6	0.205	0-0.474			
	Females	10	0.589	0-3.745	1,14	0.633	0.439ns
	8 July-14 August	3	1.555	0.096-3.745			
	19 August-18 September	13	0.189	0-0.686	1,14	7.781	0.015*
1992							
	9 July-12 August	20	0.450	0-2.538			
	21 August-10 September	14	0.504	0-7.061	1,32	0.015	0.904ns
Total number of sites where each bat was located/number of minutes attempted X 100							
1991							
	Males	6	0.075	0-0.232			
	Females	10	0.120	0-0.655	1,14	0.279	0.606ns
	8 July-14 August	3	0.273	0.048-0.655			
	19 August-18 September	13	0.064	0-0.231	1,14	5.043	0.041*

Table 3.—*continued*

Variable and date		n	$\bar{x}$	range	Results of ANOVA *d.f.*	*F*	*P*
1992							
	9 July-12 August	20	0.044	0-0.111			
	21 August-10 September	14	0.006	0-0.088	1,32	12.770	0.001**
Number of times each bat was located/number of minutes attempted X 100							
1991							
	Males	6	0.077	0-0.232			
	Females	10	0.104	0-0.281	1,14	0.238	0.633ns
	8 July-14 August	3	0.186	0.048-0.281			
	19 August-18 September	13	0.072	0-0.245	1,14	3.181	0.096ns
1992							
	9 July-12 August	20	0.152	0-0.896			
	21 August-10 September	14	0.097	0-1.324	1,32	0.370	0.548ns
Greatest distance (km) each bat traveled from where radiotransmitter was attached/number of minutes attempted X 100							
1991							
	Males	3	0.211	0-0.522			
	Females	7	0.648	0-1.422	1,8	2.236	0.173ns
	8 July-14 August	3	0.636	0.556-0.696			
	19 August-18 September	7	0.466	0-1.422	1,8	0.271	0.617ns
1992							
	9 July-12 August	17	0.746	0-3.243			
	21 August-10 September	1	1.942	—	1,16	2.414	0.140ns
Greatest number of nights each bat was found at the same locality/number of minutes attempted X 100							
1991							
	Males	6	0.107	0-0.463			
	Females	10	0.045	0-0.098	1,14	1.112	0.310ns
	8 July-14 August	3	0.071	0.024-0.096			
	19 August-18 September	13	0.068	0-0.463	1,14	0.003	0.961ns
1992							
	9 July-12 August	20	0.074	0-0.219			
	21 August-10 September	14	0.025	0-0.353	1,32	3.300	0.079ns

more likely to be detected in the sampling periods of 8 July-14 August and 9 July-12 August, than in the sampling periods of 19 August-18 September and 21 August-10 September, respectively. In 1991, seven bats were detected beginning 19 August, but average number of sites was less than that for the three bats detected in the earlier sampling period (Table 3). Beginning 21 August 1992, only one bat was located after it was released (172.640). This bat was flying over the reservoir north (average direction from observers = 335°, range = 250-40°, where north = 360 and 0°) of the hotel facilities at Guntersville State Park and was detected at varying intervals during 0350-0440 h 7 September, 2013-2344 h 7 September, 0206-0448 h 8 September, 1945-2357 h, 2004-2126 h, and 2326-2400 h 9 September, and 2405-0308 h 10 September (Thomas, 1994). Thus, bats moved among more sites when young became volant than later in the active season. Bats moved over a broader area around the reservoir during earlier sampling periods.

There was no difference in number of times a bat was located after release, in greatest distance a bat traveled from where a radiotransmitter was attached, or in greatest number of nights a bat was found at the same locality, between sexes or between sampling periods during 1991 or 1992 (Table 3). Thus, number of times detected, greatest distances traveled, and greatest number of nights a bat was found at the same locality were similar throughout sampling periods.

DISCUSSION

It generally is assumed that addition of a radiotransmitter weighing 4-10% of body mass has a negligible effect on movement patterns of bats. Aldridge and Brigham (1988) demonstrated, however, that maneuverability decreased proportionally to increase in mass of radiotransmitter and recommended radiotransmitters ≤5% of body mass with animals <70 g. Because body mass of pregnant bats may increase >30%, an absolute upper limit of 30% was suggested, but this upper limit should be used only when food is abundant. Although the bat can forage with this load, its behavior will be modified (Aldridge and Brigham, 1988). Because body mass of gray bats we studied was 8-11 g, radiotransmitters (0.8 g) were ≤10% of body mass. Judging from distances bats traveled and length of time that radiotransmissions were received, bats apparently were unaffected by the radiotransmitters.

Based on earlier studies, the foraging range of *M. grisescens* was assumed to be <35 km (Tuttle, 1976a), and the majority of forays to be <12 km (range 1-35 km—La Val et al., 1977). Accordingly, monitoring sites were established around North Sauta Creek, a large, shallow-water tributary of Guntersville Reservoir, near the roost at Blowing Wind Cave (Fig. 1). Our initial plan was to maintain radiocontact among observers using walkie-talkies and attempt to triangulate locations of any bats detected, but this was not successful. During summer months, Blowing Wind Cave was home to 200,000-300,000 *M. grisescens* (The Tennessee Valley Authority, in litt.). Upon emergence from the roost, these bats dispersed in several directions, quickly moving out of sight and outside the range of radioreceivers. While many *M. grisescens* were observed foraging in the area of North Sauta Creek, a population density of this magnitude required many of the bats to forage in areas beyond the region of the reservoir being monitored. When an attempt was made to reconcile the situation by moving some of the monitoring sites farther away from the roost, we lost the ability to maintain radiocommunications with each other. The great distance between monitoring sites made attempts to triangulate the location of bats impossible.

M. D. Tuttle (in litt.) suggested that bats with radiotransmitters be followed by boat directly from the roost and observed with night-vision scopes to determine location and exact size of their territories, but this was not feasible. Blowing Wind Cave has two entrances, and neither opens directly onto the water. While most bats emerged from the largest entrance and went directly to North Sauta Creek, the nearest water, many bats flew overland at great heights for a distance of several kilometers to, presumably, broader expanses of Guntersville Reservoir. It would be nearly impossible to locate a specific bat at the cave entrance and follow it to its foraging territory, because bats frequently alternate between land and water in route to their destinations.

Most bats initially captured at Blowing Wind Cave remained in the vicinity of the cave in 1991 (Thomas, 1994). Gray bats tended to be transient, however, and more than one bat was detected near the Guntersville Dam-Hambrick Cave area, ca. 30 km away from Blowing Wind Cave. One bat was located near Guntersville State Park, ≥20 km from the capture site. There also is reason to believe that some bats traveled farther than shown by our data. During 1991, several bats with radiotransmitters were detected at Nickajack Cave, Tennessee, but because portions of the data became suspect when we discovered that false readings were being obtained on some of the lower radiofrequencies, the information was disregarded. Apparently, Tuttle (1976a) did not include Nickajack Cave, Tennessee, in his study of large-scale movement patterns of gray bats. However, our data indicate that Nickajack Cave probably is within the local range of the population that inhabits Blowing Wind and Hambrick caves, and most bats from Nickajack Cave likely hibernate in Fern Cave with other members of this population. Although bats from Nickajack Cave possibly hibernate elsewhere, none of 43 banded at Nickajack Cave, was recovered in the hibernating colony in Coach-James Cave, Edmonson Co., Kentucky (Hall and Wilson, 1966).

In addition to early or late migration, a few bats, most often yearlings or adults without young, may make lengthy trips to other places within their summer home range (Tuttle, 1976a). Gray bats apparently used alternate roost sites (Table 2). A monitoring team always was stationed at the capture site (i.e., Blowing Wind Cave), and we initially expected that bats with radiotransmitters would return to this site on a regular basis. However, they returned only sporadically or not at all. One bat from Blowing Wind Cave was recorded at Brown's Creek and at Nickajack Cave, Tennessee (ca. 75 km from the capture site and >100 km from Brown's Creek—Fig. 1; Thomas, 1994). This long-range movement pattern is consistent with other studies. An adult female *M. grisescens* from a colony in Tennessee was found 205 km distant on 7 August, at a cave outside the home range of the colony, and returned to the original colony site within 4 nights (Tuttle, 1976a), and bats in Kentucky also are known to travel ≤75 km between summer caves (Hall and Wilson, 1966).

There was further evidence that gray bats were using roost sites other than those where bats originally were captured. A radiotransmitter, which had been used in our study, was found in a cave at Guntersville State Park during summer of 1992. Tuttle (United States Fish and Wildlife Service, 1982, in litt.) suggested that gray bats were territorial, and depending on abundance of prey, foraging territories may be occupied by 1-15 bats. He also suggested that females in reproductive condition seemed to control these territories, which are located in the same places and used by the same bats year after year. If this assumption is true, *M. grisescens* probably is most territorial at critical times of the year, e.g., when it is caring for its young. During our study, which was conducted after young became volant each year, some bats repeatedly returned to the same foraging sites suggesting that gray bats have large individual home ranges (Table 2).

La Val et al. (1977) observed gray bats from a helicopter in Missouri and found that bats flew rapidly and directly to foraging areas. In most instances, the flight path of bats that flew cross-country took them over water again within a few minutes. Bats foraged over water, with brief forays into riparian vegetation. Gray bats they observed tended to be in groups of two or three adjacent to heavily wooded bluffs and hillsides. When subsequent passes were made along the river in the helicopter, foraging bats, assumed to be the same individuals, often were observed in the same places as on the previous pass (La Val et al., 1977). In Tennessee, Rabinowitz and Tuttle (1982) reported that gray bats sometimes fed continuously at feeding territories for several hours before returning to their roosts. Like La Val et al. (1982), we also found that bats tended to be concentrated in groups in foraging areas, but groups or individual bats rarely stayed >1 h before leaving. Based upon our radiotelemetry data, none of the bats continuously fed in any location for several hours. We suspect that Rabinowitz and Tuttle (1982) and La Val et al. (1982) observed different individuals or groups of bats that were passing through a foraging area instead of the same bats remaining for long periods to time. Qualitative observations of bats in foraging areas indicated that several bats foraged over the water followed by times when no bats were present. Our observations of short-term foraging times at particular sites by individuals or small groups of bats also are supported by observations of La Val et al. (1982) in Missouri. They reported that one female was followed by helicopter for 63 min on 19 May. During this time, she foraged continuously above the water along a 0.5-km section of the river. Occasional forays were made into riverbank trees, but these were of brief duration. She foraged from just above the water to treetop level, but most commonly remained 2-10 m above water. At the end of the observation period, she returned to the cave from which she had been released. Another female on 18 May was observed foraging for 21 min during which she flew at a height <2 m over water for much of the time, within a 0.6-km section of the river (La Val et al., 1977). We do not believe that individual bats returned to roost sites after short foraging forays, but we believe that foraging bats move on to foraging sites their predecessors have vacated. Because we never detected a bat in any foraging area for a long period of time in the same night, we believe that foraging areas were visited at irregular intervals throughout the night by different individuals or groups of bats. Further, individual bats may return to the same foraging site on subsequent nights and often at about the same time.

We have ascertained that 1) individual gray bats foraged over large areas of Guntersville Reservoir, 2) there was considerable movement of bats between Blowing Wind and Hambrick caves, 3) average minimum size of home range of individual gray bats at Guntersville Reservoir was ca. 7 by 24 km and covered an area of ca. 97 km^2, 4) bats may have a greater affinity for foraging areas during and shortly after young become volant and during the breeding season than later in the active season as time to enter hibernation nears, 5) during 1991, bats were found more often at about the time young became volant than later in the active season, 6) bats moved over a broader area during the time young became volant than later in the active season, and 7) greatest number of days at the same monitoring site, greatest distances traveled, and greatest number of nights a bat was found at the same locality did not vary between sampling periods. Further studies are needed to determine precise microhabitats that are most important to *M. grisescens* at Guntersville Reservoir. Data acquisition in our radiotelemetric study was limited because of great distances traveled by gray bats and inability to determine which microhabitats the bats were foraging over. Use of alternate techniques of study or modification of our radiotelemetric techniques, e.g., radiotelemetric monitoring with the aid of aircraft or satellites, or developing methods to quantify rates of visitation by bats to specific microhabitats, might prove to be more precise in determining specific microhabitats used by gray bats during their nightly forays.

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