Appendix A. Gray Bat, *Myotis grisescens*, Literature Review

Review of Gray Bat Papers

2019 Sasse

Gray Bat Day Roosts in Concrete Barriers on Bridges during Migration

Sasse (2019) reports a novel roost type, used by gray bats in Arkansas during spring and fall migration. From 2013–2018, Sasse (2019) did daytime visual surveys for bats in vertical crevices between concrete barriers on 164 bridges and grouped bridges by season (spring = March 1–May 31, summer = June 1–August 15, fall = August16–November 30), as "no attempt was made to standardize survey effort across seasons or bridges." He also measured the width of the concrete barrier crevices. If Sasse found bats in crevices between barriers, he captured them by hand and recorded species, sex, age (based on epiphyseal gap), reproductive status, and applied a forearm band (Sasse, 2019). The Arkansas Department of Environmental Quality's stream classification layer (October 16, 2014 version) was used by Sasse (2019) to determine stream order at bridge sites. Sasse used a chi-square test to assess differences in crevice width and stream order of bridges occupied by bats and bridges unoccupied by bats (Sasse, 2019).

From 2013–2018, Sasse (2019) performed 1270 bridge surveys (range of 94–520) and observed gray bats using crevices between concrete barriers on 38 different surveys (range of 2–19). Sasse (2019) observed 74 gray bats total, 72 of which were alive (62 males and 10 females). One of the dead bats was discarded without necropsy, while the other was found desiccated in a crevice near two live male gray bats. Most (75%) of gray bat observations involved a single gray bat (Sasse, 2019). Gray bats occupied 21/164 bridges surveyed in Franklin, Izard, Johnson, Lawrence, Madison, Newton, Randolph, Sharp, and Washington counties (Sasse, 2019). Bats used bridges over all stream orders (1st–6th order), with no difference in bridge use by stream order, but 67% of gray bats were found in bridges over 3rd and 4th order streams. Additionally, most (67%) of gray bats were in 12.7 mm-wide crevices, but there was no difference in use across available crevice widths (range of 6.35–19.1 mm; Sasse, 2019).

2019 Sasse et al.

Morphological Discrimination of Gray Bats and Southeastern Bats

Sasse et al. (2019) studied gray bats and southeastern bats (*Myotis austroriparius*) in Arkansas that were live-captured (2005–2018 for gray bats, 2014–2017 for southeastern bats) and specimens from museum exhibits to determine morphological differences. Their (Sasse et al.) goal was to clarify the conflicting information available on identification of gray bats and southeastern bats in areas where both species' ranges overlap. Sasse et al. (2019) compared length of toe hairs, point of wing attachment at foot/ankle, forearm length, and presence/absence of notches in claws.

Nearly all (99%) of the 162 gray bats had notches in their claws, while none of the 121 southeastern bats had notches in their claws (Sasse et al., 2019). Average forearm length of 148 gray bats was 43.0 mm (range of 40.0–46.0 mm), significantly larger than the average forearm length of 388 southeastern bats, which was 37.3 mm (range of 30.5–41.2 mm; $P < 0.001$; Sasse et al., 2019).

2018 Thalken et al.

Shifts in Assemblage of Foraging Bats at Mammoth Cave National Park Following Arrival of WhiteNose Syndrome

Thalken et al. (2018) used pre- and post-WNS mist-net capture data to examine temporal changes in bat assemblages in Mammoth Cave National Park, KY (~212 km^2). From

2009–2016 (except 2012), Thalken et al. (2018) conducted bat surveys on 78 nights at 25 sites (1–3 times/site/year, except 2 ephemeral ponds that were surveyed 5–6 times in 2016), using 6–18 m length and 6–9 m height nets. A comparison was done using chi-square test of independence on data from 6/25 sites that were sampled pre- (n=9 nights) and post-WNS (n=33 nights), these sites were considered "focal" sites (Thalken et al., 2018). Another comparison was done using capture data from all 25 sites and a single-factor ANOVA, followed by a Fisher's LSD multiple-comparison procedure (Thalken et al., 2018).

From 2009–2011 (pre-WNS), capture rates at the 6 focal sites were 1.7 bats/night while post-WNS (2014–2016) capture rates at the same sites were 1.54 bats/night (Thalken et al., 2018). Bat declines from pre- to post-WNS at the 6 focal sites were significant ($P < 0.001$), with 87.2% of the total chi-square score resulting from declines in northern long-eared bat (*Myotis septentrionalis*) captures (Thalken et al., 2018). In contrast, gray bat captures increased from 0 bats pre-WNS to > 30 bats post-WNS (Thalken et al., 2018). Because gray bats were not captured during the pre-WNS period, this species was not included in the modeling analysis. When Thalken et al. (2018) compared all 25 sites, general linear model analyses of the effect of year on capture rates indicated significant declines in Rafinesque's big-eared bats (*Corynorhinus rafinesquii*; $P < 0.0003$) and northern long-eared bats ($P < 0.0001$). Overall, northern long-eared bats were negatively impacted by WNS, while evening (*Nycticeius humeralis*), big brown (*Eptesicus fuscus*), and eastern red (*Lasiurus borealis*) bats may be increasing in abundance.

2017 Bernard & McCracken

Winter Behavior of Bats and the Progression of White-Nose Syndrome in the Southeastern United States

Bernard & McCracken (2017) measured activity patterns of bats outside of three winter hibernacula from January–May 2012 (year 1) and five hibernacula from October–May 2012–2014 (years 2 and 3), all hibernacula were in Tennessee. Their (Bernard & McCracken) goal was to determine how time, temperature, bat species, body condition, and WNS status affected bat activity (defined as the number of ≥ 2 echolocation pulses/24-hr period; recorded in years 1, 2, and 3; Bernard & McCracken, 2017). In years 2 and 3, bats were captured using mist-nets (6–12 m length, 2.6 m height) and processed to determine species, reproductive condition, forearm length, weight, and wing damage index score (WDI; Bernard & McCracken, 2017). Bernard & McCracken (2017) opened mist-nets 30 minutes before sunset to five hours after sunset, until 30 bats were captured, or until temperatures were less than 0 °C.

Bernard & McCracken (2017) collected "useable" acoustic data on 2,091 of 2,366 detector nights (566, 000 total bat passes), with bat activity occurring on 1,695 days. Bat activity was significantly correlated with mean daily temperature ($R^2 = 0.2879$, $F_{1,1450} = 586.2$, $P < 0.0001$), and bat activity was recorded at temperatures ≥ -13 °C (Bernard and McCracken, 2017). Bernard & McCracken (2017) documented the greatest acoustic activity at caves that were negative for *P. destructans*, the fungus that causes WNS, during the first year of monitoring. In total, 947 (648 males, 297 females, 2 unknown) individual bats from 10 species were captured; 5 *Corynorhinus rafinesquii*, 19 *Eptesicus fuscus*, 3 *Lasiurus borealis*, 3 *Lasionycteris noctivagans*, 182 *Myotis grisescens*, 51 *Myotis leibii*, 19 *Myotis lucifugus*, 56 *Myotis septentrionalis*, 45 *Myotis sodalis*, and 33 *Perimyotis subflavus* (Bernard and McCracken, 2017). Bernard & McCracken (2017) noted that body condition varied across species, capture sessions, seasons, and in relation to how long a hibernaculum was *P. destructans* positive.

2017 Hammerson et al.

<u>Strong Geographic and Temporal Patterns in Conservation Status of North American Bats</u>

Hammerson et al. (2017) performed a comprehensive conservation status assessment of 45 bat species occurring in North American north of Mexico, including the gray bat. Hammerson et al. (2017) used the NatureServe method, which “combines information on rarity (e.g., range extent, population size), trends, and threats to produce a global conservation status rank (G rank): G1 = Critically Imperiled; G2 = Imperiled; G3 = Vulnerable; G4 = Apparently Secure; G5 = Secure.” Rankings G1–G3 are considered “at risk” and rankings G4–G5 are “more secure” (Hammerson et al., 2017). Hammerson et al. (2017) also determined a “threat impact”, determined by scoring threat severity toward a species.

From 1985–2000, Hammerson et al. (2017) noted a slight improvement in the status of all 45 bat species, driven by improvement in the status of gray bats and Indiana bats (*Myotis sodalis*). While data from 2000–2015 showed an overall decline in status for all 45 bat species, gray bats improved in status (Hammerson et al., 2017). While threat impact data for only gray bats is not available, threat impact projections indicate that 22 species of the North American bat fauna faces substantial threats, 64% of which are considered high to medium-high threats (Hammerson et al., 2017). Highest projected threats included invasive species and disease, energy production and mining, human intrusion/disturbance, and biological resource use (e.g., wood cutting; Hammerson et al., 2017).

2017 Moore et al.

Habitat Use of Female Gray Bats Assessed Using Aerial Telemetry

Moore et al. (2017) studied the habitat use of female gray bats in Arkansas, using aerial telemetry. During calibration trials, the largest error was 1.2 km between actual and estimated transmitter locations. Bats were captured at Bone Cave and Neward storm drain in 2014, and at Crystal, Logan, and Cave Springs caves in 2015 (14 June–1 July for both years; Moore et al., 2017). Moore et al. (2017) recorded mass, forearm length, reproductive condition, and health of captured bats. Fifty lactating gray bats were radio tagged in 2014 and 62 post-lactating gray bats were radio tagged in 2015 (Moore et al., 2017). Radio-tagged bats were tracked using radio telemetry via 4-element Yagi antenna attached to a Cessna 182 Skylane single-engine prop plane and R4500 scanner-receiver.

The home ranges for gray bats in 2014 (362.2 ± 24.9 km^2) were larger than the home ranges recorded in 2015 (57.9 ± 8.6 km^2) (Moore et al., 2017). The mean farthest distance a female gray bat traveled from the maternity colony was 21 ± 2.9 km^2 in 2014 and 9 ± 0.7 km^2 in 2015 (Moore et al., 2017). The average home range size was 159 km^2 (~39,300 acres; Moore et al., 2017). Difference in home range size may have been due to changes in colony size, insect abundance, or habitat continuity/fragmentation (Moore et al., 2017). Gray bats used open water for foraging and commuting more than all other available land types (Moore et al., 2017). Rivers served as the main foraging and commuting areas, but the bats also used lakes, streams, and ponds (Moore et al., 2017).

2016 Cervone et al.

Bats Under an Indiana Bridge

Cervone et al. (2016) surveyed > 200 bridges and culverts in southwest Indiana from 2004–2005 for a highway study. They found a single bridge containing roosting Indiana (*Myotis sodalis*), gray, big brown (*Eptesicus fuscus*), little brown (*Myotis lucifugus*), and tri-colored bats (*Perimyotis subflavus*). No other surveyed bridges contained bats. From 13 October 2006 to 3 April 2011, formal bridge inspections were performed, which included determining the number of bats by species, locations of bats, and behaviors of bats (Cervone et al., 2016). Air temperature, substrate temperature, relative humidity, lighting, and sound levels were measured at the gray bat occupied bridge (Cervone et al., 2016). Cervone et al. (2016) banded 224 bats (60 Indiana bats, 154 little brown bats, 6 big brown bats, and 4 tri-colored bats).

Over 118 visits to the bat occupied bridge, only two gray bats were observed in the bridge, but 6,887 little brown bats, 878 Indiana bats, 774 big brown bats, and 29 tri-colored bats were seen (Cervone et al., 2016). Individual gray bats were documented 13 April 2007 and September 2012 (Cervone et al., 2016), but they are considered outliers, as their known range in Indiana borders the Ohio River to the southeast. Sound levels above the bridge were 81.4–84.6 dBA and sound levels below the bridge were 84.1–85.0 dBA (Cervone et al., 2016). On 26 October 2007, Cervone et al. (2016) documented daytime light readings of ≤ 162 lux units (lx) under the bridge and ≥ 9,688 lx above the bridge. During surveys, air temperatures ranged from 5–32° C (spring), 5–29° C (fall), and 25–33° C (summer; Cervone et al., 2016). Average relative humidity under the bridge ranged from 48–83% (spring), 39–80% (fall), 43–76% (summer), and 50–79% (winter).

2016 Gerdes

Gray Bat Migration in Missouri

Gerdes (2016) completed a Master's Thesis studying gray bat migration in Missouri using acoustical data. Anabat I and II bat detectors, deployed 3–20 January and 30 April–12 May 2015 were used to record bat acoustics (Gerdes, 2016). Seven detectors were deployed across Missouri, one of which was deployed at a winter hibernaculum, one at a transient cave, and the remaining five were deployed at known maternity colony locations (Gerdes, 2016). Acoustic files were classified by Bat Call Identification Software (BCID), using the default Missouri species list and a minimum of five call pulses for identification (Gerdes, 2016).

Gray bat activity at 4 maternity caves began as early as March (Gerdes, 2016). By the beginning of May, the majority of bat activity at the hibernacula was gone (Gerdes, 2016). There was no apparent effect of distance between the maternity caves to the hibernacula and the rate/timing of gray bat migration, though the sample size was too small for statistical analysis (Gerdes, 2016). Using acoustic activity data, Gerdes (2016) observed a roughly logistic growth pattern for the arrival of bats to the 4 maternity caves, with the pattern beginning early in the year (Gerdes, 2016).

2016 Powers et al.

Monitoring the Status of Gray Bats (*Myotis grisescens*) in Virginia, 2009–2014, and Potential Impacts of White-Nose Syndrome

Powers et al. (2016) goal was to measure effects of WNS on summer colonies of gray bats in southwestern Virginia. Powers et al. (2016) conducted yearly gray bat surveys (late August–early September, 2009–2014) at a single maternity colony in a culvert spanning Washington County, VA and Sullivan County, TN and up to four bachelor colonies per year at caves in Lee, Scott, and Russell counties, VA. Bats were captured using harp traps, single-high mist-nets, and hand capture techniques for 1–3 hours after sunset (traps opened at sunset). All gray bats were weighed, had forearm measurements taken, and banded. Powers et al. (2016) began documenting age from 2010–2014 by examining backlit photographs of wings. They also calculated body mass index (BMI) across years and sites and examined BMI changes across years using a generalized linear mixed model (GLMM).

From 2009–2014, Powers et al. (2016) captured 2949 gray bats (range of 366–591 bats/year), with males comprising 69.2% of all captures. They estimate the colony in the culvert is 2500–9000 bats. A bridge roost in the Clinch River watershed is estimated to contain 1500 bats. The GLMM did not detect significant changes in BMI across sites or years, but comparing the juvenile to adult ratio decreased from 2010–2014 (Powers et al., 2016). Powers et al. (2016) indicate that gray bats are still in an early response stage to WNS and suggest continued monitoring of gray bat colonies.

2013 Lindsay & Jung

<u>Novel microsatellite loci to investigate population structure in the endangered gray bat (*Myotis grisescens*)</u>

Lindsay & Jung (2013) isolated and characterized 16 polymorphic microsatellite loci in the gray bat, which can be used to investigate genetic patterns across gray bat colonies. Described in the article are all 16 novel microsatellite loci developed for gray bats, including forward and reverse primer sequences, annealing temperatures (temperature required for primers to bind to DNA), and repeat motifs (short, recurring patterns in DNA). This article may be important for future gray bat studies that involve genetic analyses of gray bat colonies; thus, it was included in this review.

2012 Gore et al.

Decline in the Winter Population of Gray Bats (*Myotis grisescens*) in Florida

Gore et al. (2012) used literature from 1988–2011 to estimate the number of gray bats wintering in caves in Florida. Only data from Old Indian Cave (located in Florida Caverns State Park) and Dugong Cave (< 100 m south of Florida Caverns State Park) were used, as these are the only known gray bat hibernacula. Twenty counts were made at Old Indian Cave from 1988–2011 and seven counts were made at Dugong Cave from 1997–2011 (Gore et al., 2012). Gore et al. (2012) did not standardize their methods of estimating gray bat numbers in early years, therefore only direct count data from 1990–2011 was used in the analysis (Spearman-rank correlation).

The number of gray bats hibernating in Old Indian Cave decreased from approximately 600 bats in 1988 to three bats in 2011, which Gore et al. (2012) attributes to human disturbance, vandalism, and installation of a gate made of steel bars (possibly impeding airflow and bat flight). The number of gray bats in Dugong Cave decreased from 60 bats in 1997 to 0 bats in 2011 (Gore et al., 2012), but the cause is unknown. From 1990–2011, direct count data were negatively correlated with year (Spearman p = -0.08, P < 0.001; Gore et al., 2012).

2007 Martin

Assessment of the Population Status of the Gray Bat (*Myotis grisescens*)

Martin (2007) is a 106 page status review by the US Army Corps of Engineers on the gray bat. The review includes gray bat natural history, population threats, habitat requirements, behavior, gray bats on military instillations, 2005–2007 hibernacula surveys, and DOD/Army initiatives. To summarize the review, gray bat maternity colonies were documented at seven army installations in five states (Alabama, Indiana, Kentucky, Missouri, and Tennessee), with a priority-two (according to the Gray Bat Recovery Plan) gray bat maternity colony in Woods Reservoir Dam at Arnold Air Force Base in Tennessee (Martin, 2007). Gray bat maternity colonies (25,000–50,000 bats) were documented in four states (Alabama, Kentucky, Missouri, and Tennessee; Martin, 2007). Martin (2007) estimate the number of gray bats in hibernacula in Alabama (1 cave with 842,300 bats), Tennessee (3 caves with 798,496 bats), Arkansas (1 cave with 148,750 bats), Kentucky (1 cave with 75,150 bats), and Missouri (3 caves with 718,000 bats). The estimated number of gray bats in 11 priority hibernacula surveyed from 2005–2007 was 2,511,042 (range of 27,600–561,300) gray bats (Martin, 2007).

2007 Sasse

Status of Populations of the Endangered Gray Bat in the Western Portion of its Range

Sasse (2007) monitored 48 gray bat maternity colonies in Missouri, Arkansas, and Oklahoma from 1978–2002. Various techniques were used to estimate colony sizes, including measuring of guano piles, visual counts, and estimates of ceiling area covered by bats. Sasse (2007) used a Mann-Kendall test to account for the considerably variation in accuracy of survey methods.

The number of gray bats in maternity colonies ranged from 0–136,000 bats, and analyses by Sasse (2007) determined that 79% of the surveyed colonies were stable or increasing in number of gray bats. This suggests that the endangered species recovery plan used by US Fish and Wildlife Service for gray bats is effective.

2006 Brack & LaVal

Diet of the Gray Myotis (*Myotis grisescens*): Variability and Consistency, Opportunism, and Selectivity

Brack & LaVal (2006) investigated food habits of the gray bat to compare diet to insect prey availability. From 1978–1979, Brack & LaVal (2006) collected 10,736 fecal pellets from 1,225 gray bats of known age, capture location, reproductive condition, and sex at five maternity caves and two dispersal caves in Missouri. Insect availability was determined via light-traps and sticky-traps in 1978 and only light-traps in 1979; traps were used concurrently when taking bat fecal samples (Brack and LaVal, 2006). Brack & LaVal (2006) captured bats with mist-nets and harp traps.

The most common insect orders in the gray bat diet were Trichoptera (present in 90% of samples; composed ≥ 50% in 31% of samples), Coleoptera (93% of samples; ≥ 50% in 17% of samples), Lepidoptera (76% of samples), Plecoptera (76% of samples), Ephemeroptera (46% of samples), and Diptera (39% of samples; Brack & LaVal, 2006). Hymenopterans, homopteran, and heuropteran remains were present, but occurred rarely or in small quantities (Brack and LaVal, 2006). Meanwhile, light-trap samples were often dominated by coleopterans and lepidopterans (Brack and LaVal, 2006). In summary, gray bat diet varied spatially, temporally, and among bats by sex, age, and reproductive condition. Brack & LaVal (2006) go on to suggest that gray bats use a combination of selective and opportunistic feeding.

2006 Sherman & Martin

Rediscovery of the Gray Bat (*Myotis grisescens*) in Northeastern Mississippi

Sherman & Martin (2006) document the finding of a male gray bat discovered on private property in Tishomingo County, Mississippi on 20 September 2004. The bat had been given to the Mississippi Health Department for rabies testing on 21 September 2004, where it was identified as a gray bat, the bat tested negative for rabies (Sherman and Martin, 2006). This finding is of note because gray bats had been documented at a nearby chalk mine from 1939–1967, but had not been detected since. This 2004 observation marks the first detection of a gray bat in Mississippi in 37 years (Sherman and Martin, 2006).

2005 Harvey et al.

Endangered Bats of Arkansas: Distribution, Status, and Ecology (2004–2005)

Harvey et al. (2005) is an annual report (2004–2005) to Arkansas Game and Fish Commission about the endangered bat species of Arkansas. Information regarding gray bats can be found on pages 4–6 (species accounts) and 13–15 (status of the gray bat in Arkansas). Harvey et al. (2005) surveyed caves throughout the year and estimated bat numbers via direct observation, measurement of fresh guano deposits, and roost/cave emergence counts.

Harvey et al. (2005) estimate that > 180,000 gray bats occupy ~20 caves in Arkansas during the summer, though they estimate > 350,000 gray bats hibernate in just five caves during winter. They determined that, of the three endangered species in Arkansas, gray bats have the most secure status, with populations remaining stable/increasing. Three Arkansas caves important to gray bats—Bonanza Cave, Blanchard Springs Cavern, and Cave Mountain Cave—were surveyed (all three are also mentioned in Harvey, 1994). Bonanza Cave was not checked winter 2004–2005, but the population was increasing from ~55,000 gray bats in 2002 to ~107,710 gray bats in 2003–2004 (Harvey et al., 2005). Similarly, winter gray bat numbers for Blanchard Springs Cavern increased from 33 gray bats in the 1980s to 116,620 in 2004–2005 (Harvey et al., 2005). In winter 1981–1982, Cave Mountain Cave contained ~50 gray bats, which increased to ~127,500 gray bats in 2004–2005 (an all-time high of 320,450 gray bats was documented in winter 2003–2004; Harvey et al., 2005). The summer gray bat count for eight sites in 2005 was 128,660 gray bats (Harvey et al., 2005). Of the three important gray bat caves, Harvey et al. (2005) only give summer 2005 gray bat count results for Blanchard Springs Cavern (2870 bats).

2005 Webster

Additional Records of the Gray Bat, *Myotis Grisescens* (Chiroptera: Vespertilionidae), from North Carolina

Webster (2005) is a brief review of three separate records of gray bats in North Carolina. Webster (2005) first mentions that "only one published record of *Myotis grisescens* from North Carolina exists" at the time of writing. He is referring to an article from 1969 by Tuttle and Robertson, published in the Journal of Mammalogy with the title, The gray bat, *Myotis grisescens*, east of the Appalachians. In the aforementioned article, a single adult female was recovered on 1 October 1968 in Asheville, NC, from the grill of an automobile. This bat had been previously tagged in Rhea County, TN, 200 km west of Asheville. Webster (2005) notes two adult male gray bats were submitted to the Buncombe County Health Center for rabies testing in 2000 and 2001. The third record details gray bat acoustic documentation during the summer along Pigeon River (Haywood County) and near Tapoco (Swain County). Webster (2005) argues that these records indicate that gray bats are more common in western NC than previously thought.

2002 Johnson et al.

Gray Bat Night-Roosting Under Bridges

Johnson et al. (2002) studied gray bats night roosting under bridges. Of the 37 bridges examined in this study, the authors found gray bats roosting at 2 of them (Johnson et al., 2002). However, gray bat echolocation calls were recorded at 15 of these 37 bridges (Johnson et al., 2002). The authors found 20–30 gray bats roosting at a two lane paved bridge over West Chickamauga Creek at 0240 hours in Catoosa County, Georgia (Johnson et al., 2002). The bats at this bridge clung to the concrete ceiling at the middle and east end of the bridge (Johnson et al., 2002). The authors also found 20–30 gray bats at 0140 hours under the north end of the US Route 27 expressway bridge that crosses West Chickamauga Creek in Walker County (Johnson et al., 2002). Night roost activity was concentrated around the middle and end portions of the I-beam construction bridges (Johnson et al., 2002).

2001 Murray et al.

Variation in Search-Phase Calls of Bats

Murray et al. (2001) examined levels of intraspecific variation in search-phase calls of seven Vespertilionid bat species (including gray bats) using Anabat II detectors and the Analook software. Five parameters; duration, maximum frequency, minimum frequency, frequency of the body, and slope of the body, were used in the analyses (Murray et al., 2001). Bats were captured using harp traps and mist-nets across Missouri, Kansas, Indiana, Kentucky, Tennessee, North Carolina, and Michigan (Murray et al., 2001). Murray et al. (2001) attached chemiluminescent tags to captured bats and released them at locations with low bat activity (determined by acoustic detectors), before releasing and recording the echolocation calls of the aforementioned bats.

According to the analyses used by Murray et al. (2001), all seven bat species showed significant variation among individuals and among geographic locations, the exception being frequency of the call body in gray bats. Across areas, mean gray bat call duration ranged from 5.3–5.8 ms, maximum frequency ranged from 64.8–68.4 kHz, minimum frequency ranged from 44.1–44.8 kHz, frequency of the body ranged from 46.4–46.5 kHz, and slope of the body ranged from 44.1–54.3 octaves/s (Murray et al., 2001).

2000 Thomas & Best

Radiotelemetric Assessment of Movement Patterns of the Gray Bat (*Myotis grisescens*) at Guntersville Reservoir, Alabama

Thomas and Best (2000) studied the movement patterns of gray bats in Alabama. Bats were captured via harp trap during summer 1991 and 1992 as they emerged from caves (Thomas and Best, 2000). Captured bats were radio-tagged (6 adult males in 1991, 21 post-lactating females in 1991, and 34 post-lactating females in 1992) to determine roosting patterns, home range, roost-site fidelity, and foraging-site fidelity.

Of the 27 gray bats radio-tagged in 1991, 10 were detected after release (3 males, 7 females). Of these 10 bats, 6 stayed within 10 km of Blowing Wind Cave, 1 was found 20 km downstream in Guntersville State Park, and 3 were found 30 km away from the release site at Hambrick Cave-Guntersville Dam area (Thomas and Best, 2000). Four of the gray bats were detected two or more times at the same monitoring areas, suggesting that these areas where they regularly forage may be part of an individual home range (Thomas and Best, 2000). Of the 34 gray bats radio-tagged in 1992, 18 were detected after release, with minimum home ranges of 3–248 km^2 (Thomas and Best, 2000). The average home range size for these bats between the two study years, 1991 and 1992, was 97 km^2 (~24,000 acres; Thomas & Best, 2000). They seemed to move over a larger area after the young had become volant.

1998 Mitchell

Species Profile: Gray Bat (*Myotis grisescens*) on Military Installations in the Southeastern United States

Mitchell (1998) is a profile on gray bats at military installations in the southeastern United States, written by the US Army Corps of Engineers. The document contains general information about the gray bat, including: physical descriptions, status, distribution, life history and ecology, habitat requirements, impacts and causes of decline, monitoring efforts, and management efforts.

1998 Whitaker & Hamilton

Mammals of the Eastern United States

Whitaker and Hamilton (1998) provide a general account for the gray bat touching on subjects like habitat, distribution, food/feeding, as well as reproduction and development. Gray bats are highly migratory, moving up to 525 km between summer and winter caves (Whitaker and Hamilton, 1998). At the time of writing, gray bats were only known to use caves as roosting habitat (Whitaker and Hamilton, 1998). Maternity colonies generally form in warm caves usually no more than 1 km from a water source (Whitaker and Hamilton, 1998). Most foraging occurs within 11 km of the maternity cave (Whitaker and Hamilton, 1998). Adult females occupy the maternity caves, while males and yearlings occupy separate but nearby caves (Whitaker and Hamilton, 1998). Female gray bats typically have a single pup each year, which is born in an altricial state, but capable of independence at three weeks post-parturition (Whitaker and Hamilton, 1998).

1997 Best et al.

<u>Variation in Diet of the Gray Bat (*Myotis grisescens*)</u>

During spring and summer 1991, Best et al. (1997) collected 1,476 fresh guano pellets from gray bats at Blowing Wind Cave, Jackson County, Alabama. To do so, they spread two cloth bed sheets (cleaned everyone 1–2 hours) on the ground at the lower cave opening from 1930–0630 for 1–3 nights during 11 sampling sessions between 19 April–20 September (Best et al., 1997). Each guano pellet was teased apart, and its contents were inspected under magnification and put onto a slide for insect identification (Best et al., 1997). To quantify available insect prey, Best et al. (1997) collected 384 samples from four sites (one terrestrial and three aquatic) within 2 km of Blowing Wind Cave with a hand-held sweep net. Analysis of variance, Student-Newman-Keuls a posteriori test, Spearman-rank correlation, and sequential Bonferroni adjustment were used to analyze the data (Best et al., 1997).

Best et al. (1997) discovered the remains of 14 orders of Insecta, two orders of Arachnida, eye-like structures from an unknown organism, and gray bat hair in the guano pellets. Lepidoptera, Diptera, and Coleoptera (in decreasing order of presence) were the most common taxa in guano, accounting for ≥ 48.5% of all samples (Best et al., 1997). Available prey included one order of Arachnida (Araneae), 10 insect orders, and unidentified insects (Best et al., 1997). Best et al. (1997) identified significant variation in insects consumed by sampling sessions, night, and hour. However, there was no significant correlation between potential prey and prey found in guano pellets (Best et al., 1997).

1996 Best & Hudson

Movements of Gray Bats (*Myotis grisescens*) Between Roost Sites and Foraging Areas

Best and Hudson (1996) studied the movement patterns of gray bats between their roosts and foraging habitats in Alabama. Bats were captured and radio-tagged (only post-lactating bats) in summer 1994 using a modified harp trap at two Indian Cave and Blowing Spring Cave (Best and Hudson, 1996). Ten observers (five teams of two), equipped with radio receivers and three-element Yagi antennae monitored gray bat foraging behavior for 10 consecutive nights (at each of the capture sites; Best and Hudson, 1996).

When the young became volant, adults did not always return to the roost that they left from, suggesting that these gray bats use alternate roost sites during the summer (Best and Hudson, 1996). The gray bats studied primarily used tributaries and larger waterways as foraging areas and as commuting routes to access open water habitats (Best and Hudson, 1996). Gray bats monitored at Indiana Cave were never detected upstream from the capture site after ten nights of monitoring (Best and Hudson, 1996), rather they were detected between Indian Cave and Wheeler Reservoir. All gray bats that were detected were found between Indian Cave and Wheeler reservoir to the south (Best and Hudson, 1996).

1995 Decher & Choate

Myotis grisescens

This article by Decher and Choate (1995) is a mammalian species account that summarizes information about the gray bat, including fossil record data, characteristics of gray bats, gray bat form and function, distribution, ontogeny and reproduction, ecology, behavior, and genetics. Gray bats can survive up to 16.5 years of age (Decher and Choate, 1995). In 1975, the total population of gray bats was estimated to contain ~2,275,000 individuals (based on estimates by M. D. Tuttle; Decher and Choate, 1995). Pictures of a gray bat bachelor colony roosting in a storm sewer in Kansas (Fig. 4) indicates that gray bats were known to use some artificial structures (Decher and Choate, 1995). However, no mention is made about artificial structure use by gray bats in this article, as the storm sewer is referred to as a "summer cave" (Decher and Choate, 1995).

1995 Lacki et al.

Food Habits of Gray Bats in Kentucky

Lacki et al. (1995) report the food habits, including abundance of insect prey items, of gray bats in riparian habitat in central Kentucky. Mist-nets were used on four different nights at each of four sites along Jessamine Creek (Jessamine County, KY) from 25 May–19 August 1993 (Lacki et al., 1995). Nets were placed across the stream and open from dusk–midnight (Lacki et al., 1995). Lacki et al. (1995) collected guano from captured gray bats, which were marked to prevent resampling of previously captured bats. Insects were captured via black-light traps, placed "out of sight from mist nets" and compared to insects found in guano (Lacki et al., 1995).

Lacki et al. (1995) collected 58 guano samples from 94 bats, with guano samples containing insects from 11 families and nine orders. Gray bats primarily ate Coleoptera (beetles;

58.3–100.0% frequency in guano from May–August), except in May when Trichopterans (caddisflies; 0–70.8% frequency in guano from May–August) were the primary prey consumed (Lacki et al., 1995). Lacki et al. (1995) note that gray bats also ate large numbers of Diptera (flies; 1.3–16.7% frequency in guano) and Lepidoptera (moths; 25.0–66.7% frequency in guano). Gray bat diet was most diverse in May (followed closely by July), and type of insect consumed was correlated with abundance of insect type in May and July, but not August; there were too few fecal samples in June (Lacki et al., 1995). Lacki et al. (1995) suggest that gray bats feed opportunistically.

1995 Sabol & Hudson

Technique Using Thermal Infrared-Imaging for Estimating Populations of Gray Bats

Sabol and Hudson (1995) is an article detailing the use of thermal infrared (IR) imaging to estimate gray bat populations at Blowing Wind Cave (4 August 1993) and Cave Springs Cave (5 August 1993) in Alabama. A skilled observer performed “skip-minute” exit counts at caves (count the number of emerging bats for one minute, spend a minute writing, return to counting), while a thermal IR scanning radiometer (set at 25 frames/s) recorded emerging bats (Sabol and Hudson, 1995). Values recorded by the skip-minute method and IR scope were then compared.

Due to technical complications, only data from Cave Springs Cave met the requirements to properly estimate the number of emerging gray bats. Total gray bat emergence estimate via the skip-minute method was 49,000 bats, while the IR estimate was 46,950 bats (Sabol and Hudson, 1995). Sabol and Hudson (1995) detail a way to estimate the number of bats emerging from a cave, while decreasing the possibility of error due to human subjectivity.

1994 Harvey

Status of the Endangered Gray Bat (*Myotis grisescens*) Hibernating Populations in Arkansas

Harvey (1994) wrote this report on the status of gray bat populations in Arkansas from 1978–1994. At the time of writing, Harvey (1994) estimated that 222,000 gray bats primarily occupied four Arkansas caves—Bonanza Cave, a small cave near (~1 km away) Bonanza Cave, Blanchard Springs Caverns, and Cave Mountain Cove. In February 1994, Bonanza Cave housed an estimated 165,000 hibernating gray bats, though the previous estimate (no date given) was 250,000 bats (Harvey, 1994). The cave near Bonanza Cave housed an estimated 25,000 gray bats in February 1994, but was not known to contain gray bats in previous survey years (1991–1992; Harvey, 1994). The hibernating gray bat population at Blanchard Springs Caverns increased from 33 gray bats in the winter of 1985–1986 to an estimated 20,000 gray bats February 1994. Harvey (1994) attributes this change to a decrease in human disturbance at the caverns, per U.S. Forest Service protocols. Cave Mountain Cave housed ~ 700 gray bats in winter 1980–1981, decreasing to ~50 gray bats in the following winter (1981–1982), and then increasing to an estimated 11,700 gray bats in February 1994. Again, Harvey (1994) attributes the increase in number of hibernating gray bats to a decrease in human disturbance, as Cave Mountain Cave was fenced during summer 1982. Overall, Harvey (1994) indicates that hibernating gray bat colony sizes remained stable throughout the reporting period.

1992 Timmerman & McDaniel

Maternity Colony of Gray Bats in A Non-Cave Site

In 1988, a maternity colony of approximately 8000 gray bats was found in a storm drain in Newmark, Independence County, Arkansas (Timmerman and McDaniel, 1992). The western inlet of the storm drain was located at the intersection of Front and Main streets, the entrance was 7m across and 1.7m high (Timmerman and McDaniel, 1992). The drain itself was 160m long (Timmerman and McDaniel, 1992). The maximum height within the drain was 1.9 m above the gravel and 1.45 m above the water's surface (Timmerman and McDaniel, 1992). Water was present in the drain year round (Timmerman and McDaniel, 1992). The maternity colony was located 50–65 m in at the point of maximum height and width, with the colony sitting in a rectangular ceiling dome that serves as a heat trap (Timmerman and McDaniel, 1992). This maternity colony was located 3 km from the nearest body of water (Timmerman and McDaniel, 1992).

1984 Brack, Mumford, & Holmes

The Gray Bat (*Myotis grisescens*) in Indiana

In 1982 netting was conducted on Muddy Fork Creek in Clarke County, Indiana from 1–7 July (Brack et al., 1984). Eleven *Myotis grisescens* were captured—7 lactating females and 4 adult males (Brack et al., 1984). On 5 July 5 1982, a colony of gray bats was located in a limestone quarry 6 km from Muddy Fork Creek (Brack et al., 1984). The quarry was described as being large with 6 major openings and several smaller openings (Brack et al., 1984). The quarry was flooded with several feet of water, and the ceiling was approximately 5 to 7 meters above the surface (Brack et al., 1984). An exit count was conducted and the approximate number of individuals was 400 (Brack et al., 1984).

1981 Elder & Grunier

Dynamics of a Gray Bat Population (*Myotis grisescens*) in Missouri

Elder & Grunier (1981) studied a population of gray bats in Marvel Cave, Stone County, Missouri 1968–1978. Five banding trips were made each winter for the first two years (10 total banding trips), and a total of 18,627 gray bats were banded (Elder and Gunier, 1981). Gray bats were hand captured from cave walls each winter to be sexed and so that each bat's band number (if present) could be recorded (Elder and Gunier, 1981). The goal of this research was to better understand survivorship and mortality factors of gray bats.

When assessing survival, Elder & Grunier (1981) made the following assumptions: banded bats were evenly distributed among the entire population, banded bats returned to the cave in the same proportion as unbanded bats, and mortality rates after year one were equal for banded and unbanded bats. Elder & Grunier (1981) concluded that gray bat survival rate for the 9 years sampled was 69.5% per year for males and 73.1% for females. Elder & Grunier (1981) suggest that if mortality rates remained constant, some gray bats in the Marvel Cave colony would survive to age 18. Regarding bat mortality, Elder & Grunier (1981) identified three primary causes of bat mortality: direct influence by humans (e.g., burning hibernating clusters with torches or placing strings of fireworks among torpid colonies, and mass removal for lab studies), indirect influence by humans (e.g., noise and light pollution due to construction), and natural predation.

1980 Grigsby

The Gray Bat, *Myotis grisescens*, in the Southwest Portion of the Ozark Plateau: Movement Patterns, Maternity Colonies, Hibernacula and Philopatry

Grigsby (1980) completed a doctoral dissertation on the movement patterns, maternity colonies, hibernacula, and philopatry of gray bats in the southwest portion of the Ozark Plateau, a physiographic region at the junction of Missouri, Oklahoma, and Arkansas. Gray bats were observed moving to feeding grounds in northeastern Oklahoma in late March/early April (Grigsby, 1980). Bats moved into maternity caves in early May (Grigsby, 1980). Adult males were not encountered during the maternity period (Grigsby, 1980). Gray bats began to move between caves after the young became volant (Grigsby, 1980). The gray bats that formed maternity colonies in northeastern Oklahoma used two hibernacula—one in Missouri and one in Arkansas (Grigsby, 1980). Cave 6, a maternity cave, was 130 km from the Missouri hibernacula and 194 km from the Arkansas hibernacula (Grigsby, 1980). Four maternity caves were observed during this study (Caves 2, 4, 6, and 7) (Grigsby, 1980). Caves 4, 6, and 7 were within 1 km of a major/large body of water (Grigsby, 1980), while Cave 2 was 1.5 km from the Illinois River (Grigsby, 1980). Maternity colonies were observed in domes of caves, which serve as heat traps (Grigsby, 1980).

1980 Rabinowitz & Tuttle

Status of Summer Colonies of the Endangered Gray Bat in Kentucky

Rabinowitz and Tuttle (1980) studied the status of gray bat summer colony populations in the Kentucky area. Maximum past population estimates of gray bats in 20 Kentucky caves was 515,400 (Rabinowitz and Tuttle, 1980). This estimate is based on a method of comparing areas of a roost covered with old guano/staining to areas of a roost with new guano/lack of staining. By 1979, population estimates had fallen to 61,000, an 89% decline (Rabinowitz and Tuttle, 1980). Of the 20 caves surveyed, 4 could be put into the least disturbed category (one human disturbance/month; Rabinowitz and Tuttle, 1980). Of the caves that experienced the most disturbance (≥5 human disturbances/month), 9 of 13 had 100% population declines (Rabinowitz and Tuttle, 1980). Of the 8 colonies surveyed, 7 abandoned their original roost locations (Rabinowitz and Tuttle, 1980). Roost sites that had been abandoned the longest were often those nearest to main entrances or routes frequently used by cavers (Rabinowitz and Tuttle, 1980).

1979 Tuttle

Status, Causes of Decline, and Management of Endangered Gray Bats

Tuttle (1979) surveyed 22 summer gray bat colonies in Alabama and Tennessee in 1968–1970 and 1976. Tuttle (1979) estimated the number of square meters covered by roosting bats and multiplied that number by an assumed mean clustering density of bats (1,828/m^2; per previous work by Tuttle in 1975). Additionally, Tuttle (1979) estimated disturbance of gray bat colonies by humans via a combination of landowner, caver, and personal observations.

From 1968 to 1976, Tuttle (1979) conservatively estimated a 54% decline in the number of gray bats, and a 76% decline from known past maximum population levels. There was a strong association between gray bat decline and human disturbance, with some colonies completely dispersing from 1968–1976 (Tuttle, 1979). Tuttle (1979) recommended immediate protection of the most important caves used by gray bats in summer and winter.

1978 Elder & Gunier

Sex Ratios and Seasonal Movements of Gray Bats (*Myotis grisescens*) in Southwestern Missouri and Adjacent States

Elder and Gunier (1978) studied the seasonal movements of gray bats in southwestern Missouri and surrounding areas. Over three winters (1968–1971), Elder and Gunier (1978) banded 18,768 gray bats. For five years after banding, a yearly random "grab" sample was taken by 3–5 workers, who grabbed 200–300 bats (Elder and Gunier, 1978). These bats were sexed and band numbers (if present) were recorded. The results of this study are based on recapture data at 26 recapture sites across Arkansas, Oklahoma, Kansas, Missouri, and Illinois.

Data collected from Marvel Cave suggests that the gray bats disperse widely in all directions after hibernation, excepting the southeast (Elder and Gunier, 1978). The relatively small number of tagged gray bats found at Marvel Cave in the summer suggest that there are many alternate cave roosts that these bats go to for the summer (Elder and Gunier, 1978). Sex ratio data shows that males and females were never in complete isolation from each other during the summer; there were always some adult males present in summer colonies (Elder and Gunier, 1978). Sex ratio varied greatly from year to year at hibernacula, even with large sample sizes (Elder and Gunier, 1978).

1978 Saugey

Reproductive Biology of the Gray Bat, *Myotis grisescens*, in Northcentral Arkansas

Saugey (1978) studied the reproductive biology of gray bats in five counties (Independence, Newton, Searcy, Sharp, and Stone) in Arkansas from spring 1975–spring 1976. In the summer, bats were captured using 12-meter mist nets set up at cave openings, while winter specimens were collected via hand removal and nets (Saugey, 1978). To establish a timetable of reproductive cycling and to monitor juvenile development, bats were sacrificed after capture. The author removed fetal bats in-utero from pregnant females and took forearm and body measurements (Saugey, 1978). For captured juvenile gray bats, Saugey (1978) measured forearms measured, recorded weight and sex, and analyzed stomach contents. Saugey (1978) sacrificed all adult specimens in order to study the reproductive tissues (uteri, ovaries, testes, and epididymides).

During the study, 306 adult and juvenile gray bats were examined. Male and female gray bat reproductive cycles were asynchronous (Saugey, 1978). Saugey (1978) determined that the gray bat spermatogenic cycle lasted from late-summer to mid-September and copulation occurred in fall, winter, and spring. Female gray bat ovulation occurred in spring during emergence from hibernacula (Saugey, 1978). All maternity colonies were found in cave rooms with high ceilings that were dry and devoid of speleothems (Saugey, 1978). The median gray bat parturition date was 7 June (range of 1–14 June) and gestation lasted 60–70 days, with significant growth and development occurring in the final 35 days (Saugey, 1978). Gray bat pups were born with their eyes closed, but achieved near-adult size within one month following parturition, though juvenile weight was still less than that of adults (Saugey, 1978).

1977 LaVal, Clawson, LaVal, & Caire

Foraging Behavior and Nocturnal Activity Patterns of Missouri Bats, With Emphasis on the Endangered Species *Myotis grisescens* and *Myotis sodalis*

LaVal et al. (1977) studied the foraging behavior and activity patterns of gray bats and Indiana bats in Missouri. The gray bats in this study generally foraged over water and nearby riparian vegetation (LaVal et al., 1977). Gray bats normally foraged below treetop height and down to 2 meters above ground (LaVal et al., 1977). Gray bats generally flew downstream towards wider sections of the stream, seeming to prefer these areas as opposed to the narrow upstream sections (LaVal et al., 1977). All gray bats were observed foraging over water, only entering riparian vegetation for short periods of time (LaVal et al., 1977).

1977 Tuttle & Stevenson

An Analysis of Migration as a Mortality Factor in the Gray Bat Based on Public Recoveries of Banded Bats

Tuttle and Stevenson (1977) studied the impacts of migration as a mortality factor for gray bats by banding bats at 50 caves. From 1960–1971, 40,182 gray bats were trapped or hand-netted, before being banded (Tuttle and Stevenson, 1977). The authors then analyzed recoveries of bands made by the public at locations other than caves through December 1974; most of the 71 bats recovered were dead or injured, though eight bats were released alive.

Peak recoveries of banded gray bats were in April (15 bats) and September (18 bats) coinciding with migration (Tuttle and Stevenson, 1977). During the months of May and June, 5 males and only 1 female were recovered (Tuttle and Stevenson, 1977). Around 90% of bats recovered were found near major bodies of water (Tuttle and Stevenson, 1977).The data collected supports the hypothesis that migration may be a major source of stress and mortality for gray bats (Tuttle and Stevenson, 1977).

1976 Tuttle

Population Ecology of the Gray Bat (*Myotis grisescens*): Philopatry, Timing and Patterns of Movement, Weight Loss During Migration, and Seasonal Adaptive Strategies

Tuttle (1976b) includes information on recovery from 1973–1974 of 19,691 banded gray bats (40,182 originally banded in 1960, 1961, 1968–1971) at 120 locations (including sites in Florida, Virginia, Tennessee, and Alabama). This work indicates that gray bats show strong site philopatry. Gray bats were found to emerge from and return to hibernation in the following order: adult females emerged in early April and returned in early September, young of the year of both sexes were next, and adult males were last (Tuttle, 1976b). Tuttle (1976b) determined that adult females would occupy a single maternity cave, while adult males and yearlings occupied other caves. Clusters of gray bats in summer caves contained an average 1,828 bats/m^2 (range of 999–2575 bats/m^2; Tuttle, 1976b).

1976 Tuttle

Population Ecology of the Gray Bat (*Myotis grisescens*): Factors Influencing Growth and Survival of Newly Volant Young

Tuttle (1976a) observed five gray bat colonies in the Tennessee River drainage system of Alabama and Tennessee. In 1968 and 1969, Tuttle (1976a) followed columns of bats emerging from five limestone caves to determine foraging distance. Bats were also trapped and hand-net captured at roosts, weighed, had their forearms measured, and banded. Tuttle (1976a) also analyzed post-flight growth and development of gray bat young at four of the colonies from June–October 1970.

From 25 June–12 October 1970, Tuttle (1976a) captured and processed 1,148 newly volant, juvenile gray bats. Additionally, 5,626 juvenile gray bats were banded “during the first four maternity cave visits of 1969 and 1970” (Tuttle, 1976a). Juvenile gray bats at the four sampled colonies first became volant 20–25 June, with nearly all juvenile bats flying by 15 July (Tuttle, 1976a). Distance to water was an important factor when determining mean weight of young bats, as bat weights were lower at caves farthest from water when compared to bats in caves close to water ($p < 0.005$; Tuttle, 1976a). However, when bats in caves farthest from water transferred to caves close to water, the difference in mean weight was no longer significant. Tuttle (1976a) suggests that these results are due to the energetic cost of long flights. Rates of survival across the gray bat colonies were difficult to assess due to potential differences in opportunistic scavengers, which could have provided false lows in the count of dead individuals (Tuttle, 1976a).

1975 Tuttle

Population Ecology of the Gray Bat (*Myotis grisescens*): Factors Influencing Early Growth and Development

Tuttle (1975) studied the relationship between ambient temperature, bat population size, and growth and development of juveniles in six gray bat maternity caves in Tennessee and Alabama. Caves selected for this study housed 7,000–50,000 gray bat adults prior to the beginning of the study, but Tuttle's research activities disturbed the colonies, and this reduced the numbers to 1,000–28,400 adults during the observation period. In 1970, Tuttle (1975) visited the caves at 10-day intervals from April through early August and then at longer intervals until October. Tuttle (1975) took temperature measurements underneath gray bat clusters and 10 m away from the cluster; however, bats generally avoided probes he hung from the ceiling where they normally clustered. Tuttle (1975) also caught bats at the cave entrances, taking data on weight, reproductive condition, and sex ratios for adults. He removed pups from the cave ceiling to measure forearm lengths and body mass; he used these data to assess growth rates.

A major finding of this study was that a gray bat maternity colony can modify the temperature within the space occupied by a cluster, elevating the microclimate to 10 °C higher than the surrounding cave temperature. This “social thermoregulation” could allow adults and pups to remain normothermic (not in torpor) during most of the time they are occupying the cave, which should facilitate pup growth. However, temperatures dropped at night while females were out foraging. Juvenile birth weights averaged 2.9 grams (n = 94 bats). Banded juveniles gained an average of 0.25 grams/day, though this varied across caves. Juveniles were able to fly at 24–33 days of age (determined for two caves). Tuttle (1975) noted that heat retention and thus pup development will be affected by the choice of roost site within the cave, the size of the maternal colony, and the degree of clustering by the colony.

1971 Gunier & Elder

Experimental Homing of Gray Bats to a Maternity Colony in a Missouri Barn

Gunier & Elder (1971) studied a gray bat colony living in a barn in central Missouri in 1967; they estimated 15,000–20,000 gray bats occupied the barn. The barn was scheduled to be dismantled. On 14–15 July 1967, Gunier & Elder (1971) captured and banded 437 bats. The captured gray bats were then released 38 miles south (225 bats) and 75 miles northwest of the barn (212 bats).

In total from both release sites, 46 gray bats returned to the barn while it was being dismantled (Gunier and Elder, 1971). The major takeaway from this study is that gray bats will use artificial structures as roosts and show philopatry to said roosts.

1969 Tuttle & Robertson

The Gray Bat, *Myotis grisescens*, East of the Appalachians

Tuttle and Robertson (1969) describes a non-reproductive female gray bat (band number 6-83169). Originally captured at Grassy Creek Cave in Rhea County, Tennessee, on 12 June 1968, this bat was recaptured on 1 October 1968 in Asheville, North Carolina. This article documents the first known record of a gray bat in North Carolina, suggesting that the Appalachian Mountains do not completely hinder gray bat movements (Tuttle and Robertson, 1969).

1966 Hall & Wilson

Seasonal Populations and Movements of Gray Bat in the Kentucky Area

Hall and Wilson (1966) researched the seasonal movements of populations of gray bats in Kentucky, Tennessee, Indiana, and Illinois. Hall and Wilson (1966) banded 3,072 gray bats in the winters of 1958–1961 and 1,622 gray bats in the summers of 1958–1961. Gray bat movements were determined by recovery or recapture of banded individuals.

Gray bat populations showed a tendency to aggregate in the winter and tended to be more dispersed in the summer (Hall and Wilson, 1966). Most of the summer colonies of gray bats from the surrounding areas aggregated to Coach-James Cave in Kentucky for the winter (Hall and Wilson, 1966). This cave is approximately in the center of all of the summer colonies that migrated there (Hall and Wilson, 1966). There is some movement of bats between caves for hibernation (Hall and Wilson, 1966). The area of movement of this population of gray bats to Coach-James Cave and to their respective summer colonies constitutes roughly 7% of the total species range (Hall and Wilson, 1966).

1966 Ubelaker

Parasites of the Gray Bat, *Myotis grisescens*, in Kansas

Ubelaker (1966) collected 54 gray bat specimens in Kansas 1962–1964 and examined them for parasites, identifying nine new parasite-host records. Additionally, 37 bats were sacrificed and tested for endoparasites (Ubelaker, 1966). Parasites from the order Acari, Siphonaptera, and Diptera were identified, as well as trematodes, nematodes, and cestodes (Ubelaker, 1966).

1964 Hays & Bingman

A Colony of Gray Bats in Southeastern Kansas

Hays and Bingman (1964) is a short description of a breeding colony of gray bats that were using a storm sewer in Pittsburg, Kansas. The colony consisted of ~400 gray bats, some of which were banded. Two banded bats were taken from the colony November 1961; the bats were originally banded in Missouri in 1959 by Dr. Richard F. Myers (Hays and Bingman, 1964). Another banded bat (also banded by Dr. Myers in Missouri), was captured via mist net on 1 June 1960 by Dr. T. M. Sperry (Hays and Bingman, 1964). At the time of writing, this was the only reported gray bat colony in Kansas (Hays and Bingman, 1964).

1954 Smith & Parmalee

Notes on Distribution and Habits of Some Bats from Illinois

Smith and Parmalee (1954) is a short account of distributional data and observations gathered in Illinois in 1953. Five gray bat specimens (two males and three females) were found alive in Pike County, Illinois (October 1, 1953)—200 miles northwest of the previous northernmost documentation in Illinois (Smith and Parmalee, 1954). Gray bats were not discovered at the Pike County location during two subsequent surveys in December. Average forearm length of the five gray bats was 42.4 mm and ranged from 41–44 mm (Smith and Parmalee, 1954). A single specimen perished after five weeks in captivity, though no documentation regarding reproductive condition or sex of the captive individual was mentioned (Smith and Parmalee, 1954).

1933 Guthrie

Notes on the Seasonal Movements and Habits of Some Cave Bats

Guthrie (1933a) captured bats at Rocheport and Hunter's Caves in Missouri, from 1 April 1931–1 July 1932 in order to learn more about bat habits and movement. Bats were captured with hands, standard nets, "bat snatcher" (a pair of forceps attached to the end of a bamboo pole and operated by a wire), and occasionally shot out of the air (Guthrie, 1933a). The primary goal of the research was to collect cytological samples (see Guthrie, 1933b); thus, many of the captured bats were taken to the lab for dissection (Guthrie, 1933a).

The author documented six species (*Myotis grisescens*, *M. lucifugus*, *M. septentrionalis*, *M. sodalis*, *Eptesicus fuscus*, and *Perimyotis subflavus*) in the two surveyed caves (Guthrie, 1933a). Guthrie (1933a) noted an incident where an injured lactating female gray bat attracted other bats (several dozen) upon crying out, though the attracted bats quickly dispersed when the cries stopped. Guthrie (1933a) was able to reproduce these results multiple times, attracting bats each time the injured gray bat cried out. Gray bats were generally found clustering in caves, sometimes in groups of 500–600 individuals (Guthrie, 1933a). Gray bats were found with young in the summer, though adults would quickly abandon their offspring when placed in cages, showing a weak "maternal instinct" (Guthrie, 1933a). Furthermore, Guthrie (1933a) captured many lactating gray bats (specific numbers not given), but none of them were carrying pups. Guthrie (1933a) noted segregation of sexes in gray bats, where lactating and pregnant bats would roost together, while males and most of the non-reproductive females roosted together in a different location.

1933 Guthrie

The Reproductive Cycles of Some Cave Bats

From 1 April 1931–1 July 1932, Guthrie (1933b) studied the reproductive cycle of 148 female gray bats. Bats were collected from Rocheport Cave and Hunter's Cave in Missouri before eventually being sacrificed. Guthrie (1933b) observed degree of tooth wear, amount of subcutaneous fat, amount of fat surrounding reproductive organs/tissues, and weighed and measured reproductive organs/tissues. A subset of living bats (no specific number given) had their vaginal contents removed and examined so that insemination could be detected (Guthrie, 1933b). Guthrie (1933b) also examined the spermatozoa of eight male gray bats.

Guthrie (1933b) suggests that gray bats exhibit considerable variation in date of parturition, as young bats that were collected had head–tail lengths ranging from 27–40 mm and forearm lengths from 13–26 mm. Conspicuous tooth wear was noted in females collected on 19, 24, and 25 June 1932 (Guthrie, 1933b). Most female gray bats (no specific value was given) had reduced mammary glands (indicative of post-lactation) by the end of July (Guthrie, 1933b). Guthrie (1933b) detected sperm in the uteri of two females in September, four in October, one in November, and one in December. Guthrie (1933b) also suggests that gray bats differ from the other species studied (*Myotis lucifugus*, *Myotis sodalis*, *Myotis septentrionalis*, *Eptesicus fuscus*, and *Perimyotis subflavus*) in their time to sexual maturity, as some gray bats captured in April to 1 May were immature (little or no follicular growth). Additionally, the gestation period of captured gray bats appeared to range from 1 May–1 July (Guthrie, 1933b).

1928 Miller & Allen

The American Bats of the Genera *Myotis* and *Pizonyx*

Miller and Allen (1928) is a book about American bats and includes some early information about gray bats. Notable information includes gray bat distribution, physical characteristics (“Diagnosis”), measurements, specimens, and habits. Distinct from other *Myotis*, the dorsal fur on gray bats is essentially the same tint from base to tip. Gray bats are recognized as primarily cave users in summer, unlike *Myotis lucifugus* and *M. keenii septentrionalis* (Miller and Allen, 1928). As of 1928, gray bats had been documented in southern Indiana, Illinois, Tennessee, Georgia, Alabama, Missouri, and Arkansas and were thought to also occur in Kentucky (Miller and Allen, 1928). Gray bats are slightly bigger than *M. lucifugus*, with similar proportions and forearms generally > 40 mm in length (Miller and Allen, 1928). Miller and Allen (1928) examined 258 gray bat specimens from five states: Alabama, Arkansas, Illinois, Missouri, and Tennessee. Miller and Allen (1928) noted that breeding female gray bats segregate from males until August, at which point males and females can be found in the same colony.

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