

ROOSTING ECOLOGY OF *CORYNORHINUS RAFINESQUII* (RAFINESQUE'S BIG-EARED BAT) AND *MYOTIS AUSTRORIPARIUS* (SOUTHEASTERN MYOTIS) IN TREE CAVITIES FOUND IN A NORTHEASTERN LOUISIANA BOTTOMLAND HARDWOOD FOREST STREAMBED

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ABSTRACT

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ROOSTING ECOLOGY OF *CORYNORHINUS RAFINESQUII* (RAFINESQUE'S BIG-EARED BAT) AND *MYOTIS AUSTRORIPARIUS* (SOUTHEASTERN MYOTIS) IN TREE CAVITIES FOUND IN A NORTHEASTERN LOUISIANA BOTTOMLAND HARDWOOD FOREST STREAMBED

(Major Professor: Kim Marie Tolson, Ph.D.)

Myotis austroriparius and *Corynorhinus rafinesquii* are listed as “species of concern” throughout their range in the southeastern United States. Both species are known to roost in water tupelo (*Nyssa aquatica*) and bald cypress (*Taxodium distichum*) tree cavities. Fifty-seven tree cavities of these two tree species, along with water oak (*Quercus nigra*) and willow oak (*Quercus phellos*), were monitored from May 2007 to March 2009 at the Upper Ouachita National Wildlife Refuge. Water tupelo trees were utilized as roosts by both species, while *C. rafinesquii* were also observed in bald cypress cavities. Characteristics of 26 water tupelo trees revealed cavity height was significantly related to roost tree use by *C. rafinesquii*. Water tupelo cavity trees with chimney openings were identified as winter roost sites for this species. Additional study revealed various structural characteristics of water tupelo trees influenced cavity temperatures, and potentially the selection of roosts by both species.

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LIST OF ABBREVIATIONS

BLH	Bottomland Hardwood
C	Degrees Celsius
cm	Centimeters
DBH	Diameter at Breast Height
DOQQ	Digital Orthophoto Quarter Quadrangle
ft	Foot
g	Gram
GIS	Geographic Information System
GPS	Global Positioning System
h	Hours
ha	Hectare
km	Kilometer
m	Meter
MAV	Mississippi Alluvial Valley
mm	Millimeter
MSA	Kaiser's Measure of Sampling Accuracy
NWR	National Wildlife Refuge
PCA	Principal Components Analysis
SD	Standard Deviation
TCS	Tree Cavity Search
TDL	Temperature Data Logger
TPP	Temperature from 1900 hours the previous day through 0700 hours of the present day

UONWR Upper Ouachita National Wildlife Refuge

U.S. United States of America

USFWS United States Fish and Wildlife Service

INTRODUCTION

Historically, bottomland hardwood (BLH) forests represented the most dominant natural community of forested wetlands in the continental United States, including the region of the Mississippi Alluvial Valley (MAV) (Pashley and Barrow 1993; Twedt and Best 2004). Since the early 1800s, large-scale deforestation has directly contributed to approximately 96% of BLH loss in the MAV (Stanturf and others 2000; Twedt and Best 2004). In addition to deforestation, BLH forests have been devastated by hydrologic alteration, pesticide accumulation, and ecologically damaging timber practices (Dollar and others 1992). Abernathy and Turner (1987) found that these forests comprised only 8% of the total land area in the United States (U.S.), but represented an astonishing 37% of the current forest loss. As a result, BLH forests are now considered one of the most endangered ecosystems in the U.S. (Abernathy and Turner 1987; Stanturf and others 2000).

The losses and alterations of BLH forests have significantly impacted the flora and fauna that constitute them; however, they continue to support the highest number of threatened and endangered species when compared to all other forest types in the U.S. (Dollar and others 1992; Wigley and Roberts 1994). Therefore, it is imperative to preserve the biodiversity that remains, while continuing to focus efforts to protect and re-establish potentially sensitive taxonomic groups, such as bats.

Throughout the world, bats represent the second largest mammalian order behind rodents, consisting of approximately 1200 species (Linzey 2001). Bats are important as

pollinators for plants, predators of human disease vectors and agricultural pests (Anthony and Kunz 1977; Whitaker 1995), and prey for higher-level carnivores (Findley 1993). Their abundance, mobility, and longevity, combined with their sensitivity to pollution and habitat disturbance, make bats well suited as indicators of forest health and environmental conditions (Findley 1993; Fenton 1997; Medellin and others 2000; Hickey and others 2001; Fenton 2003).

The ecology and evolution of bats have been greatly influenced by the conditions and events associated with roosting. This is because roosts provide sites for social interactions, mating, rearing of offspring, hibernation, and protection from predators and changing weather conditions (Kunz 1982). Additionally, the availability of potential roosts may limit the number and distribution of certain species (Humphrey 1975).

More than half of all species of bats use plants exclusively or opportunistically as roosts, of which many prefer the cavities of trees (Kunz 1982). Cavities may form in both live and dead trees by lightning strikes, fire, insect attack, excavation, and decay (Mackowski 1984; Sedgwick and Knopf 1992). The age, diameter, and height directly influence the number and size of cavities that may develop within a particular tree; however, these relationships vary among tree species (Kunz and Lumsden 2003). Cavity formation reaches equilibrium in undisturbed forests (Sedgwick and Knopf 1992), but years of poor land management practices resulted in thinning, harvesting, and pruning of trees that have disrupted this process (Mackowski 1984; Bennett and others 1994).

Many species of bats exhibit a high preference for particular structural characteristics of cavity roost trees (Vonhof and Barclay 1996; Brigham and others 1997, Sedgeley and O'Donnell 1999a, 1999b). Studies have found that trees which are taller

and/or larger in diameter are more often selected as roost sites. It is suggested that these roost trees may provide easier identification and/or minimized predatory risk. The size and shape of a cavity or cavity opening may also directly influence the number of bats that are present, social organization, and/or predation risk (Kunz and Lumsden 2003).

In addition to the above hypotheses, cavity trees may also be selected as roosts for their thermal environments (Vonhof and Barclay 1996; Sedgeley 2001). This is because the thermal environment of a roost considerably influences a bat's energy expenditure (McNab 1982). Bats have high mass-specific metabolic rates due to their large surface area-to-volume ratio, which results in an increased energetic cost to maintain a high body temperature (Speakman and Thomas 2003). Since most species of bats cannot manipulate the physical structure of their roosts (Kunz 1982), it is important that roosts, which provide preferable microclimatic conditions, be selected to enhance reproductive success and survival (Humphrey 1975).

Trees that are tall and/or have large diameters may provide these preferable conditions. Cavities of taller trees are warmer than shorter trees due to their increased exposure to solar radiation (McComb and Noble 1981; Calder and others 1983). Large diameter trunks provide additional cavity insulation than trees with slender trunks (Sluiter and others 1973; Gellman and Zielinski 1996). As the diameter of a tree increases, the cavity wall thickness and thermal inertia of wood also increase (Derby and Gates 1966; Nicolai 1986). Thick cavity walls have been shown to reduce temperature ranges and slow temperature changes as compared to ambient temperatures (Vonhof and Barclay 1997). Additionally, convective heat loss may be reduced as cavity entrance size decreases (Calder and others 1983).

Hamilton and Barclay (1994) suggested that various microclimatic conditions of different roosts may be selected to meet the contrasting thermoregulatory demands of males and females. The selection of different roosts seems to ultimately be attributed to the cost of reproduction endured by reproductively active females (Speakman and Racey 1987; Kurta and others 1990). Warm roosts, that are structured to allow large aggregations of females (maternity colonies) to cluster, are selected to help each individual thermoregulate and conserve energy (Trune and Slobodchikoff 1976). Warm temperatures increase the rate of gestation and postnatal development of their young, which, consequently, improves their chances for survival during the winter (Racey 1982; Kunz 1987; Zahn 1999). Frequent use of torpor by reproductively active females can reduce reproductive success by extending gestation (Tuttle 1976; Tuttle and Stevenson 1982; Barclay and Kurta 2007). In contrast, it has been suggested by a few studies that males and some non-reproductive females induce torpor more frequently than reproductively active females during the winter (Hamilton and Barclay 1994; Grinevitch and others 1995), and as a result may select different roosts (Barclay and Kurta 2007).

Basal cavities sometimes form in the interior of living trees in both tropical and old growth temperate forests. It is suggested that these particular types of cavities are important roost sites for bats because they share similar characteristics with caves. These characteristics include: protection from rain, spacious internal flight space, pronounced light gradients, and stable temperatures and humidity. Additionally, many basal cavities can be found in trees that live for many years, which can provide long-term sites for the bats that occupy them (Kunz and Lumsden 2003).

Water tupelo (*Nyssa aquatica*) and bald cypress (*Taxodium distichum*) are wetland trees found within swamps and floodplains of BLH forests throughout the southeastern United States. Both tree species provide resources that are important to many mammals, fishes, and birds. Bald cypress trees produce seeds that many species of animals consume including: squirrels, evening grosbeaks, wild turkeys, and waterfowl (Martin and others 1951; Brunswig and others 1983). Water tupelo also produces fruit eaten by many species of birds, squirrels, deer, and raccoons (Halls 1977). These trees have the ability to form large basal openings and/or internal cavities that provide a unique habitat for many species of animals including: bears, raccoons, wood rats, chimney swifts, and bats (Gooding and Langford 2004; Shauna Ginger pers. comm.; pers. obs.).

Corynorhinus rafinesquii (Rafinesque's big-eared bat) and *Myotis austroriparius* (Southeastern myotis) are both known to roost within the cavities of these particular trees (Clark 1990; Mirowski 1998; Cochran 1999; Hoffmann 1999; Gooding and Langford 2004; Trousdale and Beckett 2005; Stevenson 2008). Other roosting sites include: caves, old buildings, culverts, cisterns, wells, and bridges (Rice 1957; Barbour and Davis 1969; Jones 1977; Jones and Manning 1989; Trousdale and Beckett 2004; Martin and others 2005). *Corynorhinus rafinesquii* and *M. austroriparius* are both considered rare throughout the southeastern U.S., and are listed as species of concern (NatureServe 2009). A paucity of data exists on natural roosts for both species, especially in caveless regions of the southeastern United States. In Louisiana, very little research has been conducted on either species. In this state, *C. rafinesquii* is listed as S3/S4 (vulnerable/apparently secure) and *M. austroriparius* is listed as S4 (apparently secure) (NatureServe 2009).

Most research on these two species has concentrated on the identification and characterization of roosting sites and surrounding habitat (Clark 1990; Mirowski 1998; Cochran 1999; Hoffmann 1999; Gooding and Langford 2004; Trousdale and Beckett 2005; Stevenson 2008). The purpose of this study was to continue these efforts by focusing on their roosting ecology in relation to water tupelo and bald cypress tree cavities. Data were also collected to better understand how the cavities were utilized as the seasons changed, while attempting to relate these observations to cavity temperature and the thermoregulatory needs of these two bat species.

OBJECTIVES

The objectives of the present investigation were to:

1. Document the occurrence of bat species and their associations with tree cavities.
2. Characterize roost trees used by *C. rafinesquii* and *M. austroriparius*.
3. Examine how *C. rafinesquii* and *M. austroriparius* utilize the internal space of tree cavities as the seasons change.
4. Determine winter roost sites of *C. rafinesquii*.
5. Record cavity temperature change within water tupelo trees to possibly enhance the use of artificial roost sites by *C. rafinesquii*.

MATERIALS & METHODS

Study Site Description

The Upper Ouachita National Wildlife Refuge (UONWR) is located in Union and Morehouse parishes in northeastern Louisiana (Figure 1). The southern boundary of the refuge lies approximately 32.2 km north of Monroe, LA, while the northern boundary borders the Louisiana-Arkansas state line. The UONWR parallels both sides of the Ouachita River, which runs north-south for 22.1 km and extends 25.7 km to the west and 5.3 km to the east (Figure 2). This refuge consists of 17,237 ha of land, with 6,592 ha in Morehouse Parish and 10,645 ha in Union Parish. The refuge was first established in 1978 when the Pennzoil Producing Company sold 8,431 ha to the Department of the Interior, United States Fish and Wildlife Service (USFWS). The Mollicy Unit (6,553 ha) in Morehouse Parish was later purchased from a private landowner between 1997-1999, and an additional 1,999 ha on the western side of the refuge were purchased from Plum Creek Timber Company between 1999-2004 (USFWS 2008).

The UONWR consists of 7,999 ha of bottomland hardwood forest (BLH); 1,837 ha of pine and pine/hardwood mix; 3,738 ha of reforested bottomlands; 478 ha of moist-soil impoundments; 809 ha of scrub-shrub; 1,028 ha of agricultural fields; 276 ha of fallow agricultural fields; and 1,178 ha of open water (USFWS 2008). The BLH forests of the UONWR are classified into three primary habitat types: 1) Sweetgum-Willow Oak; 2) Overcup Oak-Water Hickory; and 3) Bald cypress-Water Tupelo (USFWS 2008).

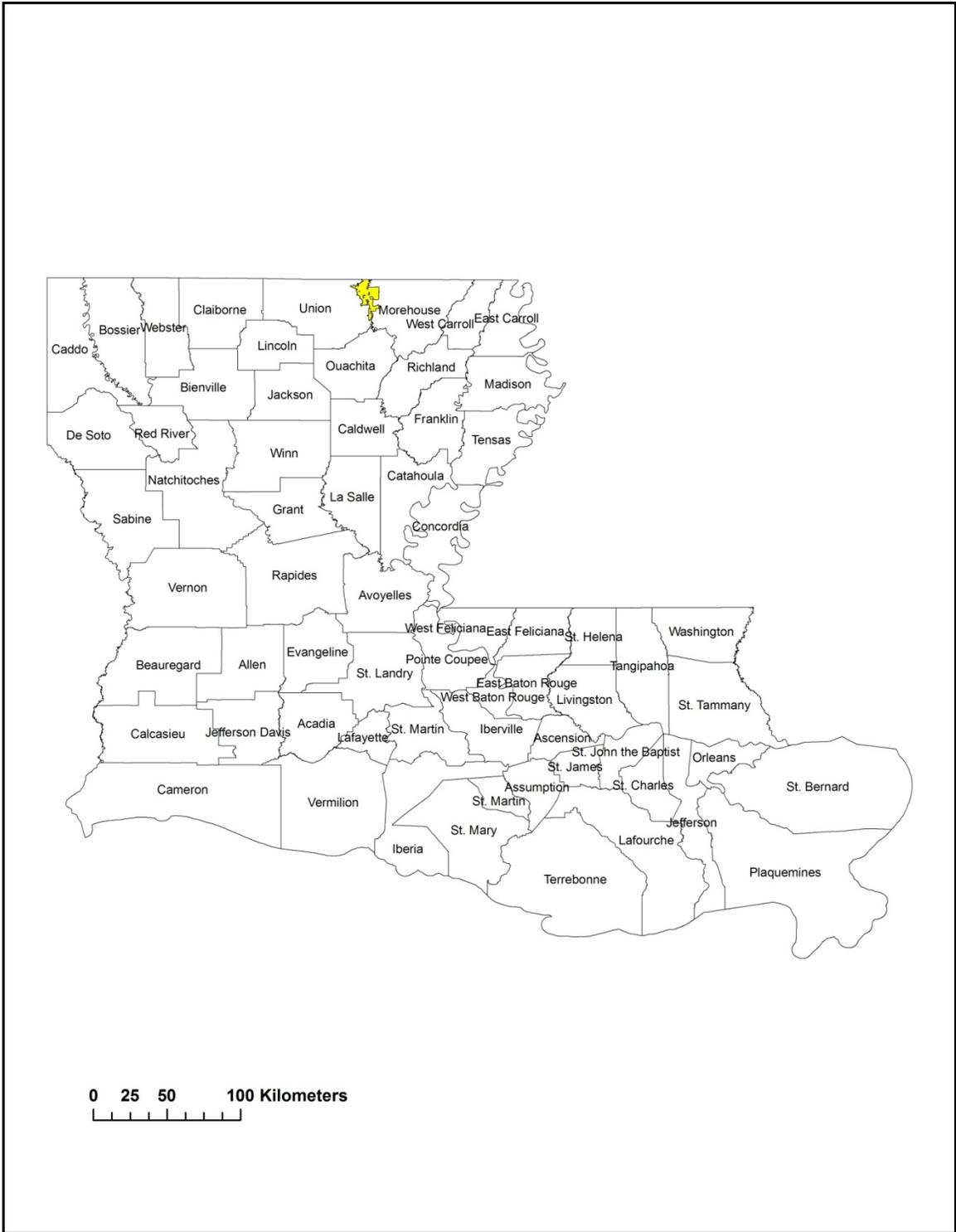


Figure 1 Location of Upper Ouachita NWR within Louisiana

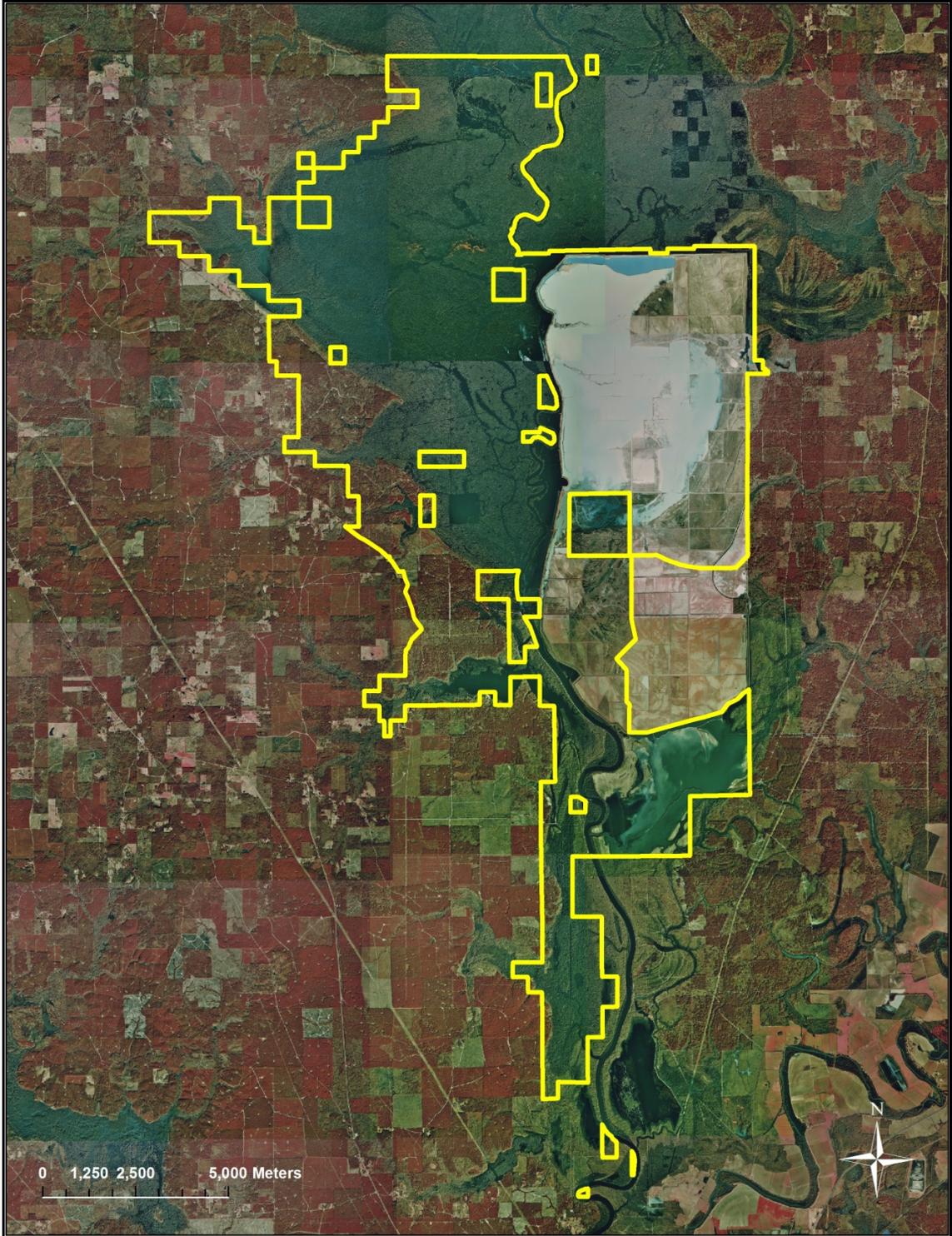


Figure 2 Location of study site in Union Parish, Louisiana with refuge boundary overlaid

Site Selection

The drainage basin of the Ouachita River includes numerous streambeds and channels that wind through the BLH forests of this refuge. One particular unnamed streambed was chosen as the study site due to the presence of water tupelo (*Nyssa aquatica*) and bald cypress (*Taxodium distichum*) trees, which have been reported to be important roost sites for both *Corynorhinus rafinesquii* and *Myotis austroriparius* (Mirowski and Horner 1997, Cochran 1999, Hoffman 1999, Clark 2003, Gooding and Langford 2004, Trousdale and Beckett 2005). In early spring 2007, a 1700 m section of streambed was selected due to the abundance of tree cavities with basal openings. This streambed is located approximately 9.0 km northeast of Marion, LA and 4.8 km south of the Louisiana-Arkansas border (92.187° N, 32.969° W) within the flood plain of the Ouachita River.

Tree Cavity Searches

Tree cavity searches (TCS) were conducted from 24 May 2007 through 7 March 2009 to gain a better understanding of roost site selection among cavity trees inhabited by *C. rafinesquii* and *M. austroriparius*. Every tree located within 10 m of either side of the 1700 m section of streambed that had a basal opening and an internal cavity (> 1 ft, 0.30 m) was numbered in sequential order (1-59). The study sample originally included 50 water tupelo, three bald cypress, three dead-tree snags (unidentified species), two water oak (*Quercus nigra*), and one willow oak (*Quercus phellos*). Two of the water tupelo trees were felled by natural causes during the study. All cavities located were searched during the daytime to determine which (if any) bat species were present. A tree

was considered a “roost tree” if one or more bats were found within the cavity. Basal openings large enough to view the inside of the cavity were searched using a flashlight with a red lens (to minimize disturbance). Openings that were too small to be entered were searched using a mirror and a flashlight with a red lens. Both methods were used to determine bat species present, how many bats occupied the roost (precise values: 1-20; estimated values: 20-50, 50-100, 100-150, and 150+), and the height at which the bats were roosting within the cavity. The height (top or bottom half) was visually estimated for all trees (n = 27) that could be observed with a flashlight. Basal openings were also checked by listening to the vocalizations of roosting bats using an Anabat[®] II system (Titely Electronics, Ballina, Australia) for 60 seconds. This was accomplished by inserting the device into the tree cavity through the basal opening. This method determined species present, and whether there were zero, a few (≤ 10), or many (≥ 11) individuals within the tree cavity. Tree cavities that could be fully observed with a flashlight (n = 27) were checked with this device for 60 seconds in an attempt to identify the species and estimate the number of bats present by sound before entering the cavity. The data recorded using this practice were then compared to the species identified and number of bats that were directly observed with the flashlight within the cavities. This practice allowed for a more accurate assessment of all other tree cavities (n = 30) where basal openings were too small, and/or where bends were present along the tree trunk (could not observe the entire cavity).

Emergence observations were conducted to assess species presence in tree cavities that could not be observed. Trees that required these observations included those

with: small basal openings; chimney openings only; trunk bends; some form of obstruction that denied access.

Roost Tree Characteristics

Roost tree characteristics were obtained for all 57 trees (Type 1 and Type 2) that were used to conduct tree cavity searches and 12 additional trees (Type 3) that were located from winter radio tracking and emergence counts. Ten variables were recorded and that were considered potentially important for the selection of tree cavity roost sites by *C. rafinesquii* and *M. austroriparius*. Data recorded for each cavity tree included: tree species, tree type, inside cavity height (m), tree diameter (cm), and the number of knotholes.

All trees were classified as a particular tree “Type” according to the location of tree cavity openings: Type 1 (basal opening only), Type 2 (basal opening and chimney opening), and Type 3 (chimney opening only). The inside cavity height (m) was measured using a Stanley[®] TLM 100 Fat Max laser measurer. For Type 1 trees, a measurement was recorded from the bottom of the cavity to the highest part of the cavity (also called the ceiling). For Type 2 trees, the measurement was recorded from the bottom of the cavity to the lowest part of the chimney opening (due to the irregular shapes of every chimney opening). For Type 3 trees, since there was no basal opening, an extension ladder was used to climb each tree. A measurement was taken from the lowest part of the chimney opening to the bottom of the cavity. The tree diameter (cm) was recorded for each tree using a retractable measuring tape. For all trees that had a basal swell (characteristic of water tupelo and bald cypress trees), the diameter was

measured 1.4 m above the swell of the tree (Gooding and Langford 2004). The diameter was difficult to measure at this specific height due to the large basal swells of many of the water tupelo and bald cypress trees. To reach above the basal swells, a circular loop was attached to one end of a 3.6 m (12 ft.) pole (pole 1), and a hook to one end of another pole of the same size (pole 2). A measurement was made 1.4 m down from the hook of pole 2 and marked to observe from a distance. The tape measure was strung through the circular loop of pole 1. The hook on the end of the tape measure was then attached to the hook of pole 2. The hook (with the end of the tape measure connected to it) of pole 2 was positioned against the outside of the tree 1.4 m above the basal swell (by placing the marked section at the top of the basal swell). Pole 1 was then walked around the tree to measure the diameter. For all other trees that did not have a basal swell (water oak, willow oak, and dead snags), the measurement was taken at the standard DBH (diameter breast height) of 4'6" (1.4 m). The number of knotholes was counted for each tree. A knothole was classified as a circular hole that penetrated into the cavity of the tree. No records were made of any other holes found anywhere else on the tree that did not penetrate into the cavity. Waypoints were recorded for all 69 trees using a Trimble® GeoXT Global Positioning System (GPS) handheld receiver and mapped using ARC Map (Figure 3). All trees were tagged for identification purposes.

Data were also recorded for all basal openings. A basal opening was classified as any opening (regardless of size) below the swell of the tree that penetrated into the cavity. Data included: height (m), width (cm), circumference (cm), distance from the ground (cm), and cardinal direction of the basal opening. For the height and width, the longest distance between the two relevant points of the basal opening was recorded using a

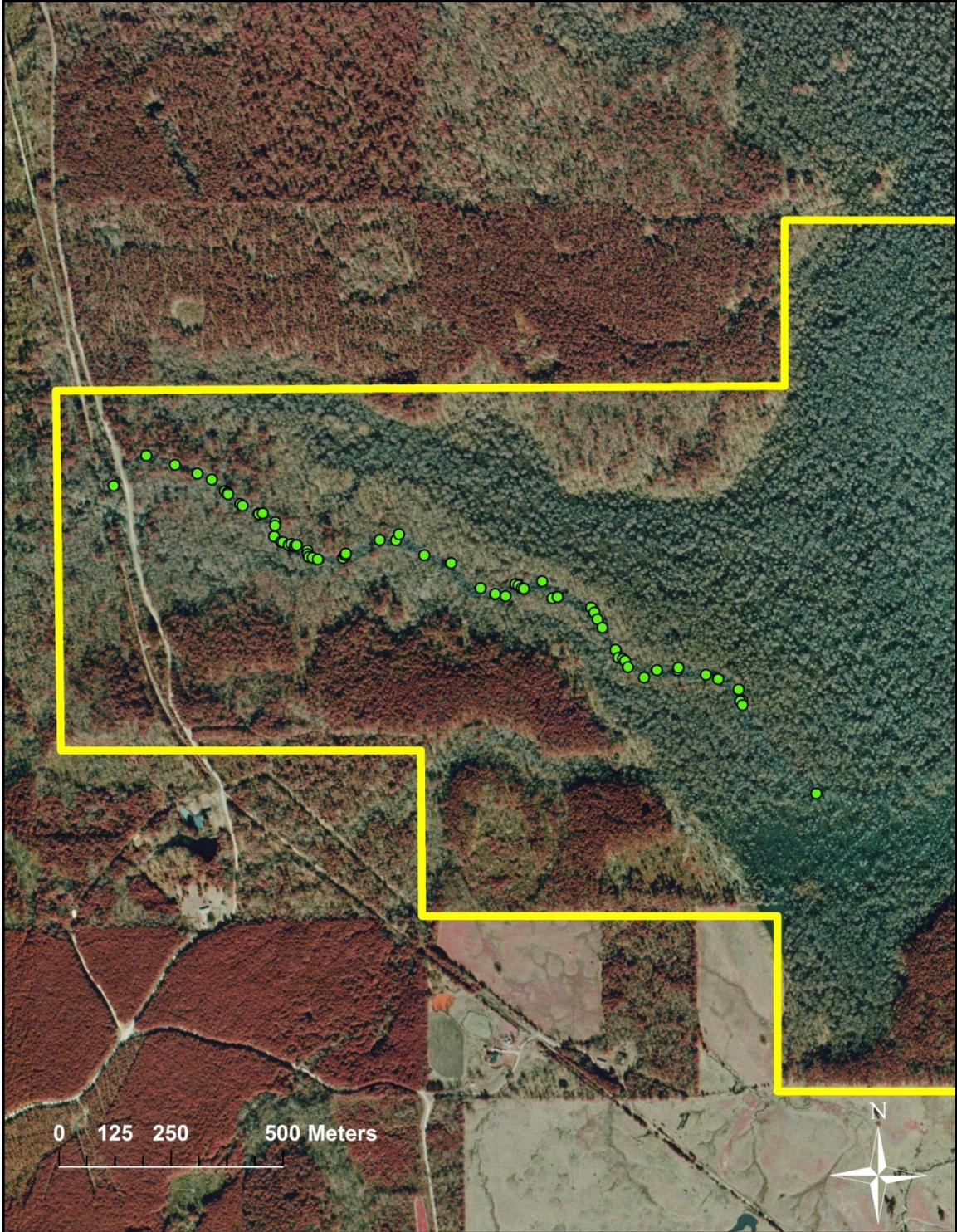


Figure 3 Study site in Upper Ouachita NWR. Green circles indicate roost trees used in this study

retractable measuring tape. The circumference was measured to provide a length that describes the size of the basal opening. This measurement was made by pressing the tape measure around all curves that formed the shape of the basal opening. To record the distance from the ground, the shortest distance was measured from the lowest part of the basal opening to the nearest surface of the ground outside the cavity. A compass was used to record the cardinal direction of the basal opening.

Statistical Analyses

All statistical analyses of roost tree characteristics were performed using SAS 9.1.2 (SAS 2003). A factor analysis (PROC FACTOR) was used to consolidate and group the variables that were highly related with one another. An MSA (Kaiser's Measure of Sampling Adequacy) value was calculated for all correlations between the number of days each roost tree was used and each of the ten variables. The MSA values allowed us to determine if the number of variables could be minimized prior to the principal components analysis (PCA). Principal components were extracted (by repackaging the correlation matrix into eigenvalues) to determine the number of components that accounted for the largest amount of variance. These data were further analyzed using a factor loading matrix to more visually discern the same information. Once it was decided how many components needed to be retained, a PCA was used to assess what variables, if any, exhibited significant correlations with the number of days each species used specific trees cavities (Wuensch 2004). A linear regression analysis (PROC REG) was used to assess variance between tree diameter and cavity height of all 26 water tupelo tree cavities.

Mist Netting

The study site was mist netted from 2 March through 20 September 2007 to determine what bat species were present outside the tree cavities. The 1700 m study site (streambed) was categorized into sequential 100 m sections numbered from 0-17. A 100 m section was randomly chosen throughout the 1700 m streambed on various days to survey the bats within the study site. After a section was surveyed, no mist nets could be placed in that section until the entire study site (sections 0-17) was sampled. Three to four nets of various sizes were placed over water within the streambed and deployed at dusk. Data were recorded for all captured bats including: species, weight (g), gender, and forearm length (mm). The protocol described by the American Society of Mammalogists was used for the handling of all bats that were captured for this study (Gannon and others 2007).

Tree Netting

This method was used to catch bats that were needed to address specific research questions. A mist net was attached to the outside of a tree covering the basal opening. Individuals were captured as they exited the tree after sunset. After the bat was removed from the net, data were recorded including species, weight (g), gender, and forearm length (mm). Bands were attached to all individuals for future identification.

Statistical Analysis

All statistical analyses were performed using SAS 9.1.2 (SAS 2003). Two-sample t-tests, assuming equal variance, were used to assess weight and forearm length data for *C. rafinesquii* and *M. austroriparius*.

Winter Radiotelemetry of *C. rafinesquii*

The USFWS provided 12 radio transmitters (Holohil Systems Ltd., Inc., Ontario, Canada) to locate winter roost sites for *C. rafinesquii*. Data were collected from 15 September through 26 December 2007. Tree cavity searches were conducted during this time to locate both male and female *C. rafinesquii* (determined by the number present in the cavity; solitary bats are usually males and large colonies primarily consist of females). Once a particular gender was potentially identified, the basal opening was netted and data recorded (described in tree netting). The hair along the inter-scapular region was cut close to the skin using surgical scissors. A 0.42 g radio transmitter (model LB-2N) was attached using Torbot[®] bonding cement (Torbot Group, Inc., Rhode Island, USA) by holding the transmitter in place for a minimum of 20 minutes to allow for adhesion. All transmitters weighed < 5% of the bats weight which follows the protocol of Aldridge and Brigham (1988). Once a transmitter was properly attached, the bat was banded and released back into the tree in which it was originally captured to minimize disturbance. The number and waypoint were recorded for all trees that were used to capture bats for this purpose. The high and low temperatures (°C) were recorded from 1900 h of the previous day to 0700 h of the present day that data were collected. A TRX-1000 receiver and 3-element directional antenna (Wildlife Materials, Inc., Illinois, USA) were used to track all bats with transmitters. All telemetry work began the day following transmitter attachment.

Since most transmitters lasted 7-12 days, a new transmitter was placed on a bat every seven days (unless early failure occurred) in an attempt to have at least one working transmitter when all Type 1 and Type 2 trees became uninhabited by

C. rafinesquii. All newly located roost trees were tagged and located using a GPS. All relevant measurements (specified in Roost Tree Characteristics) were recorded depending on tree type.

GIS was used to determine the distance traveled each night as alternate roosts were selected by bats with transmitters. A satellite image of the study site was obtained from the LSU Atlas website (www.Atlas.LSU.edu)—a Digital Orthophoto Quarter Quadrangle (DOQQ) image. ArcView[®] 9 GIS software was used to map roost tree locations.

Water Tupelo Tree Cavity Temperature

Temperature data loggers (LogTag[®] Data Recorders HAXO-8, MicroDAQ, Inc., New Hampshire, USA) were used to measure tree cavity temperature in order to examine how temperature could influence seasonal (summer and winter) roost site selection by *C. rafinesquii* among three tree types. Thirty-six water tupelo trees (12 of each tree type), that were known roosting sites for *C. rafinesquii* were chosen to record the internal cavity temperature during the summer and winter months. This included 12 Type 1 and 12 Type 2 trees that were used to conduct tree cavity searches, and all seven Type 3 trees that were found while winter radio tracking. Five additional Type 3 trees were found and used for this study. Nightly emergences of *C. rafinesquii* were observed at all five of these additional Type 3 trees.

The inside cavity height (explained in Roost Tree Characteristics) was recorded for all 36 trees. It seems plausible to suspect that cavity temperature more closely resembles the ambient temperature near an opening (basal or chimney). The purpose of

this project was to attempt to record cavity temperature only, while avoiding ambient temperature recordings inside the tree cavities. To accomplish this, a selected distance (3 ft. or 0.91 m) was subtracted from the top and bottom of the inside cavity height regardless of tree type and size. The remaining cavity height for each tree was then sectioned into two zones (Zone 1 = bottom half, Zone 2 = top half). Eighteen trees (six of each tree type) were randomly selected to have a temperature data logger (TDL) placed in Zone 1, while the other eighteen trees were selected to have a TDL placed in Zone 2. Once the Zone was selected for all 36 trees, a height was randomly selected within each zone to station one TDL.

For Type 1 trees (basal opening only), ½ in. (1.27 cm) metal electrical conduit poles were used to station the TDL at the selected height. Due to the variations in the size of all basal openings, the poles were cut into 2 ft. (0.61 m) sections and a coupling attached to the end of each one. One TDL was tied to the top of the first pole that was placed into the cavity. Subsequent poles were then attached (one-by-one) inside the cavity by entering the basal opening. Once the data logger reached the desired height, as each section was attached, the last pole was pressed down into the bottom of the cavity for stabilization. All poles were left in the cavities for the duration of each study (summer and winter). The poles were selected because of their small diameter and lack of flexibility. This allowed the pole to lay flush against the side of the cavity to minimize obstruction of the flight path. For Type 3 trees (chimney opening only), a 30 ft. (9.14 m) extension pole (Unger® UNGTF900 Teleplus Extension Pole) was used to lower one TDL into the cavity (through the chimney opening) of all 12 trees using ¼ in. (0.64 cm) nylon rope. To complete this task, a measurement was taken of the distance needed for

the TDL to reach the specified height. The measurement was marked on the rope using fluorescent spray paint to observe the measurement from a distance. The rope was looped over a hook (made from a paint roller) that was attached to the end of the extension pole. The hook was extended over the chimney opening. The TDL was then lowered into the cavity until the marked area of the rope reached the lowest part of the chimney opening. This allowed the researchers to know the TDL had reached the pre-determined height. The rope was pulled tight and tied to two nails that were hammered into the outside of the tree. For Type 2 trees, one of the methods listed above was chosen to station the data logger because of the presence of both basal and chimney openings. Additionally, two TDLs were attached to surrounding vegetation outside the tree cavities to record the ambient temperature (one TDL at each end of the study site).

The TDLs recorded summer temperature (cavity/ambient) every two hours from 23 July through 23 October 2008. The TDLs were extracted from all 36 trees by either detaching the poles, or by raising them through the chimney openings. The summer data were downloaded using BoxCar[®] 3.7 for windows (MicroDaq.com) and batteries replaced. All TDLs were returned to their original trees to record winter data. Since all poles were cut the same length and the ropes were tied to the outside of the corresponding trees, all TDLs were stationed at the exact heights that were used during the summer. Winter data were recorded every two hours from 15 December 2008 through 30 January 2009.

All 36 trees were monitored during the study (summer/winter) by conducting tree cavity searches. Observations of Type 1 and Type 2 trees were compared to previous tree cavity search data to ensure the data loggers did not affect roost tree selection of

C. rafinesquii or *M. austroriparius*. Nightly emergences of *C. rafinesquii* were observed at least twice for all twelve Type 3 trees to ensure tree use.

Statistical Analysis

All statistical analyses of water tupelo tree cavity temperatures were made using SAS 9.1.2 (SAS 2003). An ANOVA, using a general linear model procedure (PROC GENMOD), was used to assess differences in cavity temperature among Type 1, Type 2, and Type 3 trees. This same statistical procedure was also used to assess differences between Zone 1 and Zone 2 of each tree type. A linear regression analysis (PROC REG) was used to assess the relationship between cavity temperature and ambient temperature of each tree type.

RESULTS

Tree Cavity Searches

Species Presence

All 57 trees within the study site were searched 81 times (4,617 TCS) from 24 May 2007 through 8 March 2009. The number of days that a search was conducted each year was as follows: 2007—48, 2008—28, and 2009—5. The greatest number of TCS was conducted in July 2007. In this month all 57 trees were searched a total of 11 days. No tree cavities were searched in February, April, September, and October of 2008. In February 2008, only a portion of the trees ($n = 35$) that were known roosting sites (since May 2007) for *C. rafinesquii* and *M. austroriparius* were searched on two separate trips, because it was apparent that the Type 1 and Type 2 trees had not been recolonized since January 2008. Since all 57 trees were not searched, no data were reported for the month of February. No TCS were reported for April, September, and October 2008 because of high water levels (April) and Hurricanes Ike and Gustav (September, October). TCS were conducted for two or more days in all other months had ≥ 2 (Table 1).

Corynorhinus rafinesquii and *M. austroriparius* were found roosting in 35 (61%) (33-water tupelo, 2-bald cypress) of the 57 trees surveyed during the course of this study. *Corynorhinus rafinesquii* were found roosting in 34 (60%) trees (32-water tupelo, 2-bald cypress), while *M. austroriparius* were observed in eight (14%) water tupelo trees. Both species were observed (≥ 1 occurrence) sharing the same roost in five (9%) water tupelo

Table 1 Total number of days tree cavity searches were conducted by month from 24 May 2007 through 8 March 2009

	2007	2008	2009
January		2	2
February		0	2
March		2	1
April		0	
May	4	3	
June	3	8	
July	11	3	
August	5	2	
September	3	0	
October	6	0	
November	7	4	
December	9	4	
Yearly Total =	48	28	5

Overall Total = 81 days of tree cavity searches

trees. None of the other tree species (1-willow oak, 2-water oak, 3-unidentified snags) within the study site were found to be selected as roost sites by either species (Table 2).

All TCS data were separated into warm (March-October) and cold (November-February) months (Table 2). During the warm months, *C. rafinesquii* were found roosting in 34 (60%) trees (32-water tupelo, 2-bald cypress) of which sixteen (28%) were occupied > 50% of the time. Tree #19 and Tree #23 were used the least (6%) and Tree #45 was used the most (94%) of all 57 trees in these months. In the cold months, *C. rafinesquii* were found roosting in 17 (30%) trees (16-water tupelo, 1-bald cypress) of which none were occupied > 50% of the time. Seven trees (Tree #2, #7, #24, #37, #38, #39, #56) were used little (3%) and Tree #45 was used the most (43%) of all 57 trees in these months.

Combining all of the warm and cold month data, only five trees (9%) were occupied > 50% of the time by *C. rafinesquii* (Table 2). Type 1 and Type 2 trees were occupied the most from May-September (avg. 15-22 roost trees) and the least from October-April (avg. 0-9 roost trees). These tree types were used the most (n = 22) in August 2007 and the least (n = 0) in January 2008 and January 2009. This species gradually decreased its use of Type 1 and Type 2 trees from August 2007 through January 2008 and August 2008 through January 2009. In 2008 and 2009, species presence increased after January (Figure 4).

In the warm months, *M. austroriparius* occupied seven water tupelo trees of which only one tree (Tree #30) was occupied > 50% of the time. Tree #45 was occupied the least (2%) and Tree #30 was occupied the most (96%) of all 57 trees in these months. In the cold months, *M. austroriparius* were found roosting within 7 water tupelo trees of

Table 2 The percentage of the total number of times *C. rafinesquii* and *M. austroriparius* were encountered from 24 May 2007 through 8 March 2009. An encounter means ≥ 1 bat was observed/heard within a tree cavity.

Tree #	Tree Type*	Tree Species	Bat Species	% Tree Use (Warm Months)	% Tree Use (Cold Months)	% Tree Use (Annually)
1	2	NA	--	TF	TF	TF
2	2	NA	CR	22	3	15
3	2	NA	CR	71	0	44
4	2	NA	CR	57	0	36
5	1	NA	CR	88	17	62
6	1	TD	--	0	0	0
7	1	NA	CR	76	3	49
8	1	NA	CR	18	0	11
9	2	NA	--	0	0	0
10	2	NA	CR	80	7	53
11	1	NA	--	0	0	0
12	1	NA	CR	6	0	4
13	1	NA	CR	73	0	46
14	1	NA	--	0	0	0
15	1	NA	--	0	0	0
16	1	NA	CR	61	0	38
			MA	27	17	23
			BOTH	25	0	16
17	1	NA	CR	37	0	23
18	1	NA	CR	53	0	33
19	1	NA	CR	6	0	4
20	1	NA	CR	49	6	33
			MA	29	2	27
			BOTH	16	7	12
21	1	NA	CR	29	0	19
			MA	27	17	23
			BOTH	18	0	11
22	1	NA	CR	24	0	15
23	1	NA	CR	6	0	4
24	2	NA	CR	47	3	31
25	2	NA	CR	67	10	46
26	1	NA	--	0	0	0
27	1	NA	CR	43	40	42
			MA	22	0	14
28	1	NA	CR	61	0	38
			MA	0	3	1

- *Type 1 = Basal opening only
- *Type 2 = Basal and chimney opening
- NA = *Nyssa aquatica* (Water tupelo)
- TD = *Taxodium distichum* (Bald cypress)
- CR = *C. rafinesquii* observed roosting (data includes roosting w/ *M. austroriparius*)
- MA = *M. austroriparius* observed roosting (data includes roosting w/ *C. rafinesquii*)
- BOTH = *C. rafinesquii* and *M. austroriparius* observed roosting together
- Warm Months = All data throughout 2007-09 from March-October
- Cold Months = All data throughout 2007-09 from November-February
- TF = Tree fell during the study and data were not included

Table 2 continued

Tree #	Tree Type*	Tree Species	Bat Species	% Tree Use (Warm Months)	% Tree Use (Cold Months)	% Tree Use (Annually)
29	1	NA	--	0	0	0
30	1	NA	MA	96	40	75
31	1	QP	--	0	0	0
32	2	NA	--	0	0	0
33	2	NA	--	0	0	0
34	2	NA	CR	10	0	6
35	1	NA	--	0	0	0
36	1	QN	--	0	0	0
37	2	NA	CR	14	3	10
38	2	NA	CR	16	3	11
39	1	NA	CR	35	3	23
			MA	20	27	22
			BOTH	4	0	2
40	1	SN	--	0	0	0
41	1	SN	--	0	0	0
42	1	NA	--	0	0	0
43	1	NA	--	0	0	0
44	1	NA	--	0	0	0
45	1	NA	CR	94	43	75
			MA	2	3	2
			BOTH	2	3	2
46	1	NA	--	0	0	0
47	1	NA	--	0	0	0
48	2	NA	--	TF	TF	TF
49	1	SN	--	0	0	0
50	1	QN	--	0	0	0
51	1	NA	--	0	0	0
52	1	NA	CR	55	10	38
53	1	NA	CR	65	33	53
54	2	NA	CR	33	0	21
55	2	TD	CR	73	17	52
56	2	NA	CR	67	3	43
57	2	NA	CR	59	17	43
58	2	NA	CR	47	0	30
59	1	TD	CR	39	0	25

- *Type 1 = Basal opening only
- *Type 2 = Basal and chimney opening
- NA = *Nyssa aquatica* (Water tupelo)
- QP = *Quercus phellos* (Willow oak)
- QN = *Quercus nigra* (Water oak)
- SN = Snag (unidentified tree species)
- TD = *Taxodium distichum* (Bald cypress)
- MA = *M. austroriparius* observed roosting (data includes roosting w/ *C. rafinesquii*)
- CR = *C. rafinesquii* observed roosting (data includes roosting w/ *M. austroriparius*)
- BOTH = *C. rafinesquii* and *M. austroriparius* observed roosting together
- Warm Months = All data throughout 2007-09 from March-October
- Cold Months = All data throughout 2007-09 from November-February
- TF = Tree fell during the study and data were not included

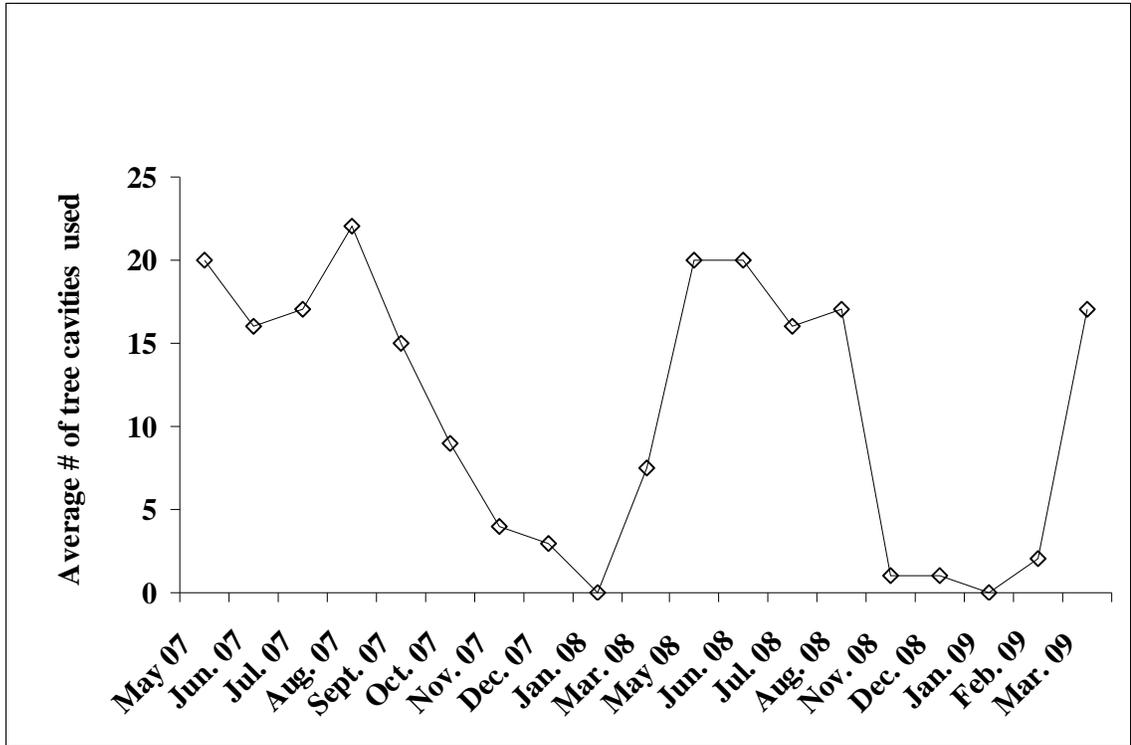


Figure 4 Average number of Type 1 and Type 2 trees used by *C. rafinesquii* each month data were collected.

Type 1 = basal opening only

Type 2 = basal and chimney opening

which none was occupied > 50% of the time. Tree #20 was occupied the least (2%) and Tree #30 was occupied the most (40%) of all 57 trees in these months.

Tree #30 was the only tree occupied > 50% of the time by *M. austroriparius* after combining the warm and cold month data (Table 2). For the duration of this study, Type 1 and Type 2 cavity trees were used the most (avg. = 4.2 times) in the month of August and the least (0 times) in the months of December 2008, January 2008 and 2009, and February 2009. This species decreased its use of Type 1 and Type 2 trees from August 2008 through October 2008 and March 2008 through February 2009. Notable increases in species presence were observed from June 2008 through August 2008 and October 2008 through December 2008 (Figure 5).

Both species were observed roosting together on multiple occasions. Five (9%) different trees (Tree #16, #20, #21, #39, #45) were shared in the warm months and two (4%) trees (Tree #20, #45) were shared in the cold months. During this study (warm and cold months), Tree #39 and Tree #45 were shared the least (2%) and Tree #16 was shared the most (16%) of all co-occupied roosts (Table 2).

Roosting Numbers

Only 27 (26-water tupelo, 1-bald cypress) of the 57 cavity trees were able to be observed fully with a flashlight. *Corynorhinus rafinesquii* were observed in numbers ranging from 1-10 in 26 of these particular cavity trees (25-water tupelo, 1-bald cypress). This range of individuals was encountered a minimum of three (Tree #12) and a maximum of 48 (Tree #45) times. Groups of 11-20 *C. rafinesquii* were observed in seven trees (6-water tupelo, 1-bald cypress) ranging from one (Tree #55) to eleven (Tree #10) separate encounters. Estimated numbers of 20-50 *C. rafinesquii* were observed in 9

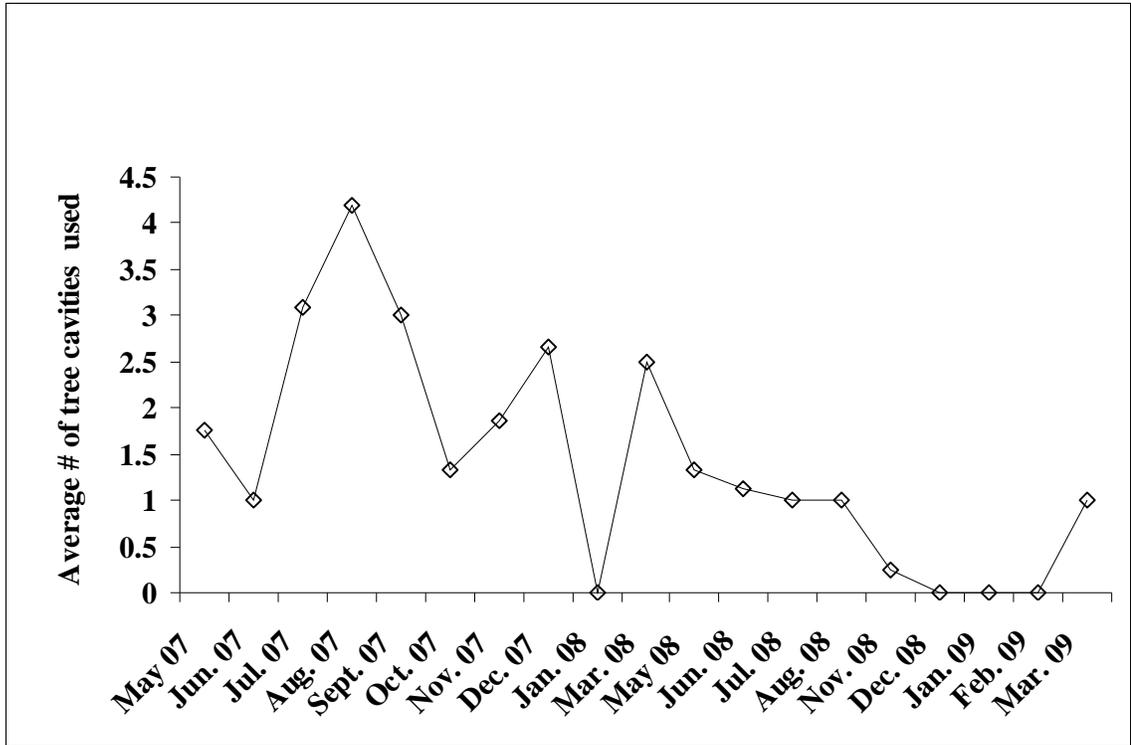


Figure 5 Average number of Type 1 and Type 2 trees used by *M. austroriparius* each month data were collected.

water tupelo trees ranging from one (Tree #7, #24, #25, #56) to 10 (Tree #53) separate encounters. Colonies with an estimate of 50-100 *C. rafinesquii* were observed in 6 water tupelo trees ranging from one (Tree #24, #53, #57) to four (Tree #25) separate encounters. Colonies with an estimate of 100-150 *C. rafinesquii* were observed in 2 water tupelo trees. Colonies this size were observed once in Tree #57 and five times in Tree #53. No colonies of this species were visually estimated to consist of > 150 individuals.

Using the Anabat[®] II system, acoustic estimations of a few (≤ 10) *C. rafinesquii* were encountered in 8 trees (7-water tupelo, 1-bald cypress) on three (Tree #19) to 17 (Tree #54) separate occasions. Acoustic estimations of many (≥ 11) *C. rafinesquii* were only found in Tree #59 on four separate occasions (Table 3).

Myotis austroriparius were visually detected in 7 water tupelo trees. Observations of 1-10 *M. austroriparius* were encountered in six trees. This range of individuals was encountered a minimum of one (Trees #28 and #45) and a maximum of 21 (Tree #20) times. Groups of 11-20 *M. austroriparius* were observed only once in two water tupelo trees (Trees #20 and #39). Colonies with an estimate of 20-50 *M. austroriparius* were observed in two water tupelo trees one time in Tree #28 and two times in Tree #27. Colonies with an estimate of 50-100 *M. austroriparius* were observed in only one water tupelo tree (#27) on nine separate occasions. On one occasion, an estimated 100-150 bats were observed in Tree #45. No colonies of this species were visually estimated to consist of > 150 bats; however, emergence counts revealed > 300 individuals in Tree #30 (cavity could not be observed).

Table 3 The total number of observations and acoustic estimations for *C. rafinesquii* and *M. austroriparius* from 24 May 2007 through 8 March 2009. All observations ≤ 20 were directly counted while all observations > 20 were estimated. Acoustic sounds (Anabat[®] II system) were estimated as zero, few (≤ 10), and many (≥ 11). Acoustic estimation values represent trees that could not be visually observed.

Tree #	Tree Species	Bat Species	Visual						Acoustic	
			Counted		Estimated				Estimated	
			1-10	11-20	20-50	50-100	100-150	150+	Few	Many
1	NA	--	TF	TF	TF	TF	TF	TF	TF	TF
2	NA	CR	0	0	0	0	0	0	12	0
3	NA	CR	33	3	0	0	0	0	0	0
4	NA	CR	29	0	0	0	0	0	0	0
5	NA	CR	50	0	0	0	0	0	0	0
6	TD	--	0	0	0	0	0	0	0	0
7	NA	CR	39	0	1	0	0	0	0	0
8	NA	CR	9	0	0	0	0	0	0	0
9	NA	--	0	0	0	0	0	0	0	0
10	NA	CR	30	11	2	0	0	0	0	0
11	NA	--	0	0	0	0	0	0	0	0
12	NA	CR	3	0	0	0	0	0	0	0
13	NA	CR	37	0	0	0	0	0	0	0
14	NA	--	0	0	0	0	0	0	0	0
15	NA	--	0	0	0	0	0	0	0	0
16	NA	CR	31	0	0	0	0	0	0	0
		MA	19	0	0	0	0	0	0	0
17	NA	CR	19	0	0	0	0	0	0	0
18	NA	CR	27	0	0	0	0	0	0	0
19	NA	CR	0	0	0	0	0	0	3	0
20	NA	CR	27	0	0	0	0	0	0	0
		MA	21	1	0	0	0	0	0	0
21	NA	CR	15	0	0	0	0	0	0	0
		MA	19	0	0	0	0	0	0	0
22	NA	CR	12	0	0	0	0	0	0	0
23	NA	CR	0	0	0	0	0	0	3	0
24	NA	CR	19	4	1	1	0	0	0	0
25	NA	CR	32	0	1	4	0	0	0	0
26	NA	--	0	0	0	0	0	0	0	0
27	NA	CR	34	0	0	0	0	0	0	0
		MA	0	0	2	9	0	0	0	0
28	NA	CR	31	0	0	0	0	0	0	0
		MA	1	0	0	0	0	0	0	0

NA = *Nyssa aquatica* (water tupelo)
 TD = *Taxodium distichum* (bald cypress)
 CR = *Corynorhinus rafinesquii*
 MA = *Myotis austroriparius*
 TF = Tree fell during the study and data were not included

Table 3 continued

Tree #	Tree Species	Bat Species	Visual						Acoustic	
			Counted		Estimated				Estimated	
			1-10	11-20	20-50	50-100	100-150	150+	Few	Many
29	NA	--	0	0	0	0	0	0	0	0
30	NA	MA	0	0	0	0	0	0	6	55
31	QP	--	0	0	0	0	0	0	0	0
32	NA	--	0	0	0	0	0	0	0	0
33	NA	--	0	0	0	0	0	0	0	0
34	NA	CR	0	0	0	0	0	0	5	0
35	NA	--	0	0	0	0	0	0	0	0
36	QN	--	0	0	0	0	0	0	0	0
37	NA	CR	0	0	0	0	0	0	8	0
38	NA	CR	0	0	0	0	0	0	9	0
39	NA	CR	19	0	0	0	0	0	0	0
		MA	16	1	1	0	0	0	0	0
40	SN	--	0	0	0	0	0	0	0	0
41	SN	--	0	0	0	0	0	0	0	0
42	NA	--	0	0	0	0	0	0	0	0
43	NA	--	0	0	0	0	0	0	0	0
44	NA	--	0	0	0	0	0	0	0	0
45	NA	CR	48	4	6	3	0	0	0	0
		MA	1	0	0	0	1	0	0	0
46	NA	--	0	0	0	0	0	0	0	0
47	NA	--	0	0	0	0	0	0	0	0
48	NA	--	TF	TF	TF	TF	TF	TF	TF	TF
49	SN	--	0	0	0	0	0	0	0	0
50	QN	--	0	0	0	0	0	0	0	0
51	NA	--	0	0	0	0	0	0	0	0
52	NA	CR	27	0	2	2	0	0	0	0
53	NA	CR	20	7	10	1	5	0	0	0
54	NA	CR	0	0	0	0	0	0	17	0
55	TD	CR	41	1	0	0	0	0	0	0
56	NA	CR	30	4	1	0	0	0	0	0
57	NA	CR	29	0	4	1	1	0	0	0
58	NA	CR	24	0	0	0	0	0	0	0
59	TD	CR	0	0	0	0	0	0	16	4

NA = *Nyssa aquatica* (water tupelo)
 QP = *Quercus phellos* (willow oak)
 QN = *Quercus nigra* (water oak)
 SN = Snag (unidentified tree species)
 TD = *Taxodium distichum* (bald cypress)
 MA = *Myotis austroriparius*
 CR = *Corynorhinus rafinesquii*
 TF = Tree fell during the study and data were not included

Using the Anabat[®] II system, acoustic estimations of a few (≤ 10) *M. austroriparius* were only heard in Tree #30 on six separate occasions. Acoustic estimations of many (≥ 11) *M. austroriparius* were heard in Tree #30 on 55 separate occasions (Table 3).

Roosting Height

In Table 4 and Table 5, the total percentage of bats observed using the cavity (BOTH) only includes groups of ≥ 2 individuals, since one bat could not roost in both the top and bottom half of a tree cavity. The total percentage of bats observed in either the BOTTOM or TOP includes every individual (1-150) observed in the tree cavities. Hence, when the BOTTOM, TOP, and BOTH percentages are added the combined total does not equal 100%.

During the warm months (March-October), *C. rafinesquii* were encountered on 688 separate occasions. This species was observed roosting 49% of the time within the bottom half and 47% of the time within the top half of tree cavities. Groups of 2-150 individuals were observed roosting in both the top and bottom half only 11% of the time. One *C. rafinesquii* was found roosting by itself 67% of the time of which 47% were observed in the bottom half and 53% in the top half of all tree cavities. When 2-10 *C. rafinesquii* were observed, 49% were located in the bottom half and 38% in the top half of the tree cavities. Smaller groups of 2-10 *C. rafinesquii* were observed roosting in both the top and bottom half of a cavity 13% of the time. Large colonies ranging from 11-150 individuals were observed on 60 (9%) separate occasions of which 68% were located in the bottom half and 28% in the top half of tree cavities. Large colonies (11-150) were

Table 4 The roosting height of *C. rafinesquii* within all tree cavities (n = 27) that could be fully observed with a flashlight from 24 May 2007 through 8 March 2009. A top and bottom half of all internal cavities were visually estimated for all roosting bats.

WARM MONTHS

NUMBER OF BATS	BOTTOM		TOP		BOTH		TOTAL OBSERVATIONS	%
	Total	%	Total	%	Total	%		
1	217	47	241	53	0	0	458	67
2	29	39	32	43	14	19	75	11
3	17	50	11	32	6	18	34	5
4	5	36	6	43	3	21	14	2
5	7	64	4	36	0	0	11	2
6	6	75	2	25	0	0	8	1
7	9	82	2	18	0	0	11	1
8	2	29	5	71	0	0	7	1
9	4	80	1	20	0	0	5	1
10	4	80	1	20	0	0	5	1
TOTAL	83	49	64	38	23	13	170	25
11-20	15	75	4	20	1	5	20	3
20-50	15	63	8	33	1	4	24	4
50-100	2	33	4	67	0	0	6	1
100-150	9	90	1	10	0	0	10	1
TOTAL	41	68	17	28	2	4	60	9
OVERALL	341	49	322	47	25	11	688	

COLD MONTHS

NUMBER OF BATS	BOTTOM		TOP		BOTH		TOTAL OBSERVATIONS	%
	Total	%	Total	%	Total	%		
1	17	43	23	57	0	0	40	66
2	0	0	4	67	2	8	6	33
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	1	100	0	0	1	1
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	1	50	1	50	0	0	2	3
9	0	0	1	100	0	0	1	2
10	0	0	0	0	0	0	0	0
TOTAL	1	10	7	70	2	20	10	16
11-20	0	0	6	50	0	0	6	10
20-50	2	50	2	25	0	0	4	7
50-100	0	0	0	0	0	0	0	0
100-150	1	1	0	0	0	0	1	1
TOTAL	3	27	8	73	0	0	11	18
OVERALL	21	35	38	62	2	10	61	

Warm Months = March-October

Cold Months = November-February

Both = Bats observed in top and bottom half of cavity. Total % only includes ≥ 2 bats.

Table 5 The roosting height of *M. austroriparius* within all tree cavities (n = 27) that could be fully observed with a flashlight from 24 May 2007 through 8 March 2009. A top and bottom half of all internal cavities were visually estimated for all roosting bats.

WARM MONTHS

NUMBER OF BATS	BOTTOM		TOP		BOTH		TOTAL OBSERVATIONS	%
	Total	%	Total	%	Total	%		
1	0	0	45	100	0	0	45	70
2	0	0	1	100	0	0	1	2
3	0	0	3	100	0	0	3	4
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
TOTAL	0	0	4	100	0	0	4	6
11-20	0	0	0	0	0	0	0	0
20-50	0	0	3	100	0	0	3	5
50-100	0	0	2	100	0	0	2	3
100-150	0	0	10	100	0	0	10	16
TOTAL	0	0	15	100	0	0	15	24
OVERALL	0	0	64	100	0	0	64	

COLD MONTHS

NUMBER OF BATS	BOTTOM		TOP		BOTH		TOTAL OBSERVATIONS	%
	Total	%	Total	%	Total	%		
1	0	0	27	0	0	0	27	100
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
TOTAL	0	0	27	100	0	0	27	100
11-20	0	0	0	0	0	0	0	0
20-50	0	0	0	0	0	0	0	0
50-100	0	0	0	0	0	0	0	0
100-150	0	0	0	0	0	0	0	0
TOTAL	0	0	0	0	0	0	0	0
OVERALL	0	0	27	100	0	0	27	

Warm Months = March-October

Cold Months = November-February

Both = Bats observed in top and bottom half of cavity. Total % only includes ≥ 2 bats.

observed roosting in both the top and bottom half of a cavity only 4% of the time (Table 4). Refer to Table 4 for all roosting locations of other numbers observed for this species.

During the cold months, *C. rafinesquii* were encountered on 61 separate occasions. This species was observed roosting 35% of the time within the bottom half 62% of the time within the top half of tree cavities. Groups of 2-150 individuals were observed roosting in both the top and bottom half of a cavity only 10% of the time. One *C. rafinesquii* was found roosting by itself 66% of the time, of which 43% were located in the bottom half and 57% in the top half of all tree cavities. When 2-10 *C. rafinesquii* were observed, 10% were located within the bottom half and 70% in the top half of all tree cavities. Groups of 2-10 *C. rafinesquii* were observed roosting in both the top and bottom half 20% of the time. Large colonies (11-150) were observed roosting within the bottom half of the cavities 27% of the time and within the top half of the cavities 73% of the time. No colonies of ≥ 11 individuals were observed roosting in both the top and bottom half of a cavity during the cold months (Table 4). Refer to Table 4 for all roosting locations of other numbers observed for this species.

During the warm months, *M. austroriparius* were encountered on 64 separate occasions ranging from 1-150 bats. During these months, this species was observed roosting in the top half of the cavities 100% of the time. Observations of 1-10 *M. austroriparius* were encountered 76% of the time, while observations of 20-150 bats were encountered 24% of the time. Refer to Table 5 for all roosting locations of other numbers observed for this species.

During the cold months, *M. austroriparius* were observed roosting on 27 separate occasions. All encounters consisted of only one bat, and in every case (100%) was found to roost in the top half of the cavity (Table 5).

Anabat[®] II Accuracy

The Anabat[®] II system was used 1,236 times for the 27 cavities that could be observed to determine the accuracy of the device in detecting roosting *C. rafinesquii* and *M. austroriparius*. The device was used in 789 cavities during the warm months and 447 cavities during the cold months.

Over the course of the warm months, *C. rafinesquii* were correctly detected 63% of the time. Zero *C. rafinesquii* were correctly detected 97% of the time. When a few (≤ 10) *C. rafinesquii* were detected with the Anabat, correct estimates were made 28% of the time when 1-3 bats were encountered and 69% of the time when 4-10 bats were encountered by observation with a flashlight. Many (≥ 11) *C. rafinesquii* were correctly assumed to be present 82% of the time (Table 6).

During the cold months (November-February), *C. rafinesquii* were correctly detected 90% of the time. Zero *C. rafinesquii* were correctly detected 100% of the time. When a few (≤ 10) *C. rafinesquii* were detected, correct estimates were made 0% of the time when 1-3 bats were encountered and 33% of the time when 4-10 bats were encountered after observing a cavity with a flashlight. Many (≥ 11) *C. rafinesquii* were correctly detected 57% of the time (Table 6).

In the warm months, *M. austroriparius* were correctly detected 95% of the time. Zero *M. austroriparius* were correctly detected 100% of the time. When a few (≤ 10) *M. austroriparius* were detected, correct estimates were made 0% of the time when 1-3 bats

Table 6 Accuracy of the Anabat® II system in determining roost tree use by *C. rafinesquii* during tree cavity searches from 24 May 2007 through 8 March 2009. Data reveals the accuracy of this device for detecting roosting *C. rafinesquii* in all trees (n = 27) that could be fully observed with a flashlight. The device was used for 60 seconds before visually searching a tree cavity.

WARM MONTHS

		ZERO		FEW				MANY		TOTAL	
		0	%	1-3	%	4-10	%	>10	%		%
RIGHT		320	97	101	28	18	69	36	82	475	63
WRONG		11	3	257	72	8	31	8	18	284	37

COLD MONTHS

		ZERO		FEW				MANY		TOTAL	
		0	%	1-3	%	4-10	%	>10	%		%
RIGHT		382	100	0	0	1	33	4	57	387	90
WRONG		0	0	37	100	2	67	3	43	42	10

Warm Months = March-October

Cold Months = November-February

were encountered. Groups of 4-10 *M. austroriparius* were never present within a tree cavity when using this device. Many (≥ 11) *M. austroriparius* were correctly detected within a tree cavity 100% of the time (Table 7).

During the cold months, *M. austroriparius* were correctly detected 96% of the time. Zero *M. austroriparius* were correctly detected 100% of the time. When a few (≤ 10) *M. austroriparius* were detected, correct estimates were made 0% of the time when 1-3 bats were encountered. Groups of 4-10 and > 10 *M. austroriparius* were never present within a tree cavity when using this device (Table 7).

Roost Tree Characteristics

Twenty-six water tupelo trees (Type 1, Type 2) were used to roost tree characteristics that may be selected by *C. rafinesquii* and *M. austroriparius*. These trees were selected for analysis for three reasons: 1) basal openings were large enough to examine the internal tree cavity, 2) the entire length of the cavity could be viewed because no bends were present in the tree trunk, and 3) this was the only tree species used by both *C. rafinesquii* and *M. austroriparius*. Type 3 trees were not used in the analysis, because only five of the ten variables could be obtained due to the lack of basal openings. In addition, no TCS were conducted on Type 3 trees. Although 10 variables were obtained, only nine were used in the analyses because of the lack of multiple tree species.

Roost Tree Characteristics - *C. rafinesquii*

The factor analysis (PROC FACTOR) revealed an MSA value of 0.42 for all nine roost tree variables. Four variables were dropped including: tree “Type”, number of knotholes, distance from the ground, and cardinal direction. The factor analysis of the

Table 7 Accuracy of the Anabat® II system in determining roost tree use by *M. austroriparius* during tree cavity searches from 24 May 2007 through 8 March 2009. Data reveals the accuracy of this device for detecting roosting *M. austroriparius* in all trees (n = 27) that could be fully observed with a flashlight. The device was used for 60 seconds before visually searching a tree cavity.

WARM MONTHS

	ZERO		FEW				MANY		TOTAL	
	0	%	1-3	%	4-10	%	>10	%		%
RIGHT	332	100	0	0	ND	ND	12	100	344	95
WRONG	0	0	18	100	ND	ND	0	0	18	5

COLD MONTHS

	ZERO		FEW				MANY		TOTAL	
	0	%	1-3	%	4-10	%	>10	%		%
RIGHT	382	100	0	0	ND	ND	ND	ND	382	96
WRONG	0	0	16	100	ND	ND	ND	ND	16	4

Warm Months = March-October

Cold Months = November-February

ND = No data were collected

five remaining variables revealed a slightly higher MSA value of 0.45. The five variables were retained including: cavity height, width of basal opening, height of basal opening, circumference of basal opening, and tree diameter. The eigenvalues of the correlation matrix (PROC FACTOR) revealed that two components accounted for 81% of the total variance (Table 8). The loading matrix was plotted and rotated using VARIMAX rotation (PROC FACTOR) to reorder the variables. Tree diameter and cavity height loaded more heavily along component 1, while basal opening width, height, and circumference loaded more heavily along component 2 (Figure 6). All five variables were retained after this analysis. The multiple regression analysis (PROC REG) revealed a significant relationship ($F = 5.56$, $P = 0.0019$) between roost tree use and all five variables ($R^2 = 0.56$). The parameter estimates revealed a significant relationship ($P = 0.0143$) between *C. rafinesquii* roost tree use and cavity height. The other 4 variables were not significantly related ($P > 0.05$) with *C. rafinesquii* roost tree use (Table 9). Table 10 provides the measurements of all five variables (tree diameter, cavity height, basal opening circumference, basal opening width, basal opening height) retained from the analyses.

Roost Tree Characteristics - *M. austroriparius*

The factor analysis (PROC FACTOR) revealed an MSA value of 0.42 for all nine roost tree variables. Three variables were dropped including: number of knotholes, distance from the ground, and cardinal direction. The factor analysis (PROC FACTOR) of the six remaining variables revealed a slightly higher MSA value of 0.46. All six remaining variables were retained including: tree type, cavity height, basal opening width, basal opening height, basal opening circumference, and tree diameter. The

Table 8 Eigenvalues from factor analysis on the correlation matrix for roost tree characteristics selected by *C. rafinesquii*

<u>Component Axis</u>	<u>Eigenvalue</u>	<u>Cumulative Variance</u>
1	2.4863	0.4973
2	1.5656	0.8104
3	0.7428	0.9590
4	0.1854	0.9961
5	0.0197	1.0000

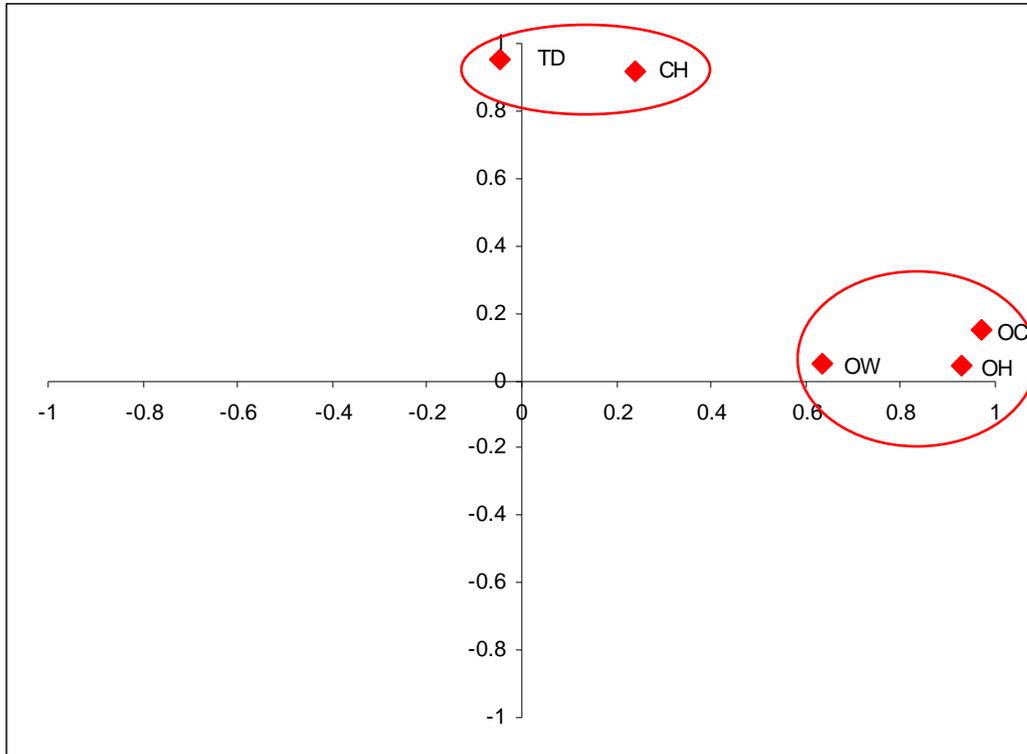


Figure 6 Plot of factor pattern for Factor 1 and Factor 2 (varimax rotation) of roost tree characteristics selected by *C. rafinesquii*

- CH = cavity Height
- OW = basal opening width
- OH = basal opening height
- OC = basal opening circumference
- TD = tree Diameter

Table 9 Parameter estimates from multiple regression analysis of roost tree characteristics selected by *C. rafinesquii*

Variable	DF	Parameter Estimate	Standard Error	t Value	P-Value
Intercept	1	4.02135	8.21368	0.49	0.6293
CH	1	3.28818	1.23580	2.66	0.0143
OW	1	0.23583	0.15566	1.52	0.1440
OH	1	0.20493	0.16558	1.24	0.2289
OC	1	-0.13523	0.08707	-1.55	0.1347
TD	1	0.03384	0.04105	0.82	0.4186

CH = cavity height
OW = basal opening width
OH = basal opening height
OC = basal opening circumference
TD = tree diameter

Table 10 Means \pm SD of variables of roost trees (n = 26) used by *C. rafinesquii*

Tree roost characteristic	Mean \pm SD	Minimum	Maximum
Tree diameter (cm)	81.9 \pm 25.4	25.4	127.3
Cavity height (m)	6.4 \pm 2.8	0.9	12.2
Opening circumference (cm)	259.7 \pm 113.6	119.4	518.2
Opening width (cm)	46.2 \pm 40.3	17.8	223.5
Opening height (cm)	103.6 \pm 54.5	43.2	215.9

eigenvalues of the correlation matrix (PROC FACTOR) revealed that two components accounted for 73% of the total variance (Table 11). The loading matrix was plotted and rotated using VARIMAX rotation (PROC FACTOR) to reorder the variables. Tree diameter, cavity height, and tree type loaded more heavily along component 1, while basal opening width, height, and circumference loaded more heavily along component 2 (Figure 7). All six variables were retained after these analyses. There was no correlation between roost tree use and all six variables combined ($P = 0.64$, $R^2 = 0.17$).

Table 12 shows the means of five of the six variables (tree diameter, cavity height, basal opening circumference, basal opening width, basal opening height) retained from the analyses for all seven water tupelo tree cavities inhabited by *M. austroriparius*. Tree Type was not included because it is a categorical variable; hence, no measurements were recorded. The regression analysis (PROC REG) revealed a significant relationship between tree diameter and cavity height ($P < 0.0001$, $R^2 = 0.60$).

Mist Netting

From 2 March through 20 September 2007, mist nets were deployed within the study site for 18 nights to determine bat species present along the streambed. Four nets were deployed each night for a total of 67 hours. Mist netting efforts resulted in the capture of 112 bats consisting of four species: *C. rafinesquii*, *M. austroriparius*, *Eptesicus fuscus*, and *Lasiurus borealis*. Table 13 lists the total captures for all four individuals.

Table 11 Eigenvalues from factor analysis on the correlation matrix for roost tree characteristics selected by *M. austroriparius*

<u>Component Axis</u>	<u>Eigenvalue</u>	<u>Cumulative Variance</u>
1	2.6596	0.4433
2	1.7319	0.7319
3	0.7830	0.8624
4	0.6248	0.9666
5	0.1842	0.9973
6	0.0164	1.0000

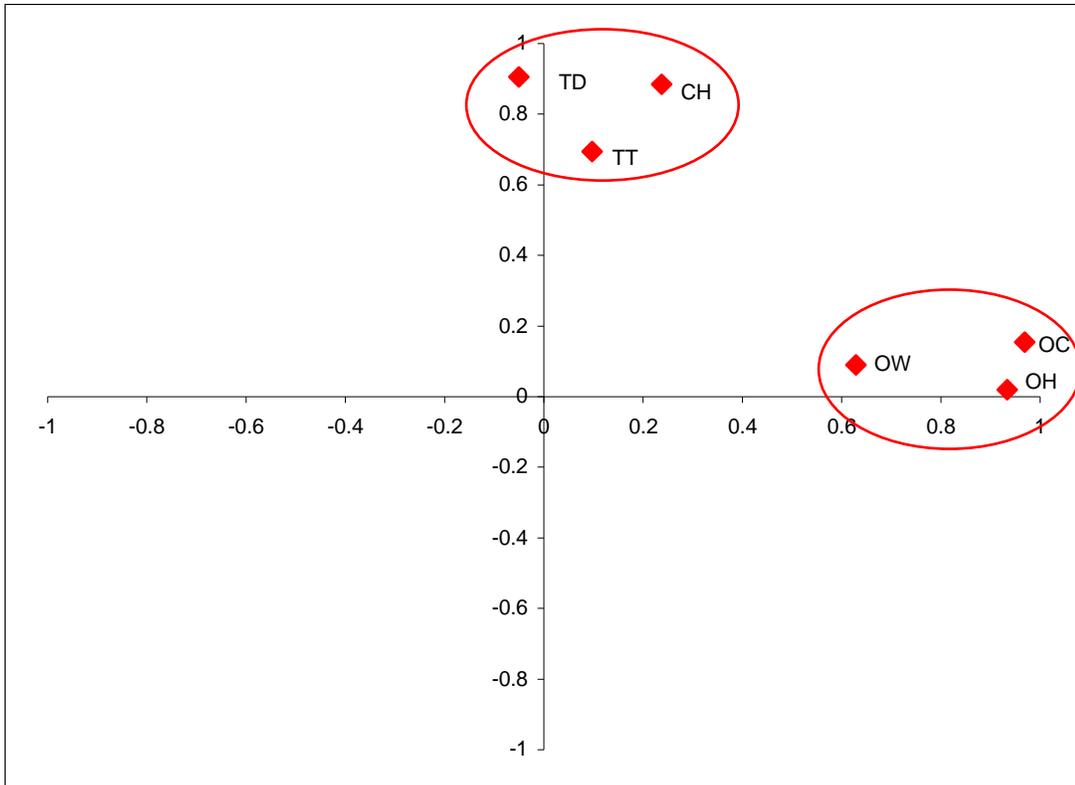


Figure 7 Plot of factor pattern for Factor 1 and Factor 2 (varimax rotation) of roost tree characteristics selected by *M. austroriparius*

CH = cavity height
 TT = tree Type
 OW = basal opening width
 OH = basal opening height
 OC = basal opening circumference
 TD = tree diameter

Table 12 Means \pm SD of variables of roost trees (n = 7) used by *M. austroriparius* that could be fully observed with a flashlight

<u>Tree roost characteristic</u>	<u>Mean \pm SD</u>	<u>Minimum</u>	<u>Maximum</u>
Tree diameter (cm)	95.1 \pm 42.9	57.6	176.3
Cavity height (m)	6.9 \pm 2.9	3.4	11.3
Opening circumference (cm)	269.2 \pm 86.4	167.6	414.0
Opening width (cm)	46.4 \pm 22.8	25.4	81.3
Opening height (cm)	105.2 \pm 59.9	35.6	200.7

Table 13 Total mist net captures of all bat species from 2 March through 20 September 2007

	Male	Female	Total
<i>Corynorhinus rafinesquii</i>	34	22	56
<i>Myotis austroriparius</i>	14	34	48
<i>Eptesicus fuscus</i>	0	1	1
<i>Lasiurus borealis</i>	3	4	7
Total Captures	51	61	112

Body Weight

Table 14 lists the weight (g) of all bats captured. For *C. rafinesquii*, the average weight of females (pregnant and non-pregnant) was higher for all months (March, May, and July) that both sexes were captured. The total captures throughout this study revealed captured females (pregnant and non-pregnant) (n = 22) weighed significantly more ($P < 0.05$) than captured males (n = 34) (Table 15). For *M. austroriparius*, the average weight of females was also higher than the males throughout all months (March and May) both sexes were captured. The weight of all captured females (pregnant and non-pregnant) (n = 34) was significantly higher ($P < 0.05$) than all captured males (n = 15) throughout the study (Table 16).

Forearm Length

Table 17 lists the forearm (mm) of all captured bats. For *C. rafinesquii*, the average length of the forearm was higher for females than males throughout all months (March, May, and July) both sexes were captured. In May, the average forearm length of females (n = 15) was significantly higher ($P < 0.05$) than males (n = 19) captured during this month (Table 18). For *M. austroriparius*, the average forearm length of females was also higher than the males throughout all months (March and May) both sexes were captured (Table 19).

Winter Radiotelemetry of *C. rafinesquii*

Corynorhinus rafinesquii were radio tracked for 51 days between 15 September and 26 December 2007. Transmitters (n = 12; 6 on males, 6 on females) lasted an average of 11.75 (1-20) days. Males inhabited a larger number of roosts (avg. = 2.17)

Table 14 The weight (g) of all mist netted bats collected from 2 March through 20 September 2007

<u>Species</u>	<u>Gender</u>	<u>Reprod. Status</u>	<u>N</u>	<u>Low</u>	<u>High</u>	<u>Mean</u>
<i>Corynorhinus rafinesquii</i>	Females	Pregnant	11	9.75	15.00	12.11
	Females	Non-pregnant	11	8.50	10.75	10.20
	Males	ND	34	8.00	9.75	8.68
<i>Myotis austroriparius</i>	Females	Pregnant	9	9.00	9.50	9.14
	Females	Non-pregnant	24	6.50	8.50	7.80
	Males	ND	15	5.75	8.75	6.80
<i>Eptesicus fuscus</i>	Females	Pregnant	1	16.00	16.00	16.00
	Females	Non-pregnant	0	NC	NC	NC
	Males	ND	0	NC	NC	NC
<i>Lasiurus borealis</i>	Females	Pregnant	4	15.75	17.25	16.63
	Females	Non-pregnant	0	NC	NC	NC
	Males	ND	3	10.00	12.50	11.00

NC = no bats were captured

ND = reproductive status not determined

Table 15 Two sample t-test (assuming equal variance, $\alpha = 0.05$) of *C. rafinesquii* total body weight (g)

Month	Sex	N	Mean (g)	Standard Deviation	t	df	P- Value
March	M	2	9.00	0.45	2.24	5	0.07
	F	5	10.20	0.29			
April	M	5	8.40	0.63	NA	NA	NA
	F	0	NA	NA			
May	M	19	8.80	0.30	6.38	32	0.01
	F	15	11.68	0.34			
July	M	1	8.00	NA	0.83	1	0.56
	F	2	9.63	1.13			
August	M	7	8.57	0.51	NA	NA	NA
	F	0	NA	NA			
Overall	M	34	8.68	0.21	7.56	54	<.0001
	F	22	11.16	0.25			

NA = no data were available

Table 16 Two sample t-test (assuming equal variance, $\alpha = 0.05$) of *M. austroriparius* total body weight (g)

Month	Sex	N	Mean (g)	Standard Deviation	t	df	P- Value
March	M	5	6.50	0.20	6.58	22	0.01
	F	19	7.97	0.10			
April	M	0	NA	NA	NA	NA	NA
	F	7	9.04	0.30			
May	M	9	7.03	0.35	1.98	13	0.07
	F	6	8.13	0.43			
July	M	0	0	NA	NA	NA	NA
	F	2	6.88	0.53			
August	M	1	6.25	NA	NA	NA	NA
	F	0	NA	NA			
Overall	M	15	6.80	0.21	5.46	47	<.0001
	F	34	8.15	0.14			

NA = no data were available

Table 17 Forearm length (mm) of all mist netted bats collected from 2 March through 20 September 2007

		<u>Low</u>	<u>High</u>	<u>Avg.</u>
<i>Corynorhinus rafinesquii</i>	Female	41.90	45.40	43.48
	Male	41.10	44.30	42.51
<i>Myotis austroriparius</i>	Female	35.00	40.30	37.88
	Male	33.70	39.70	36.52
<i>Eptesicus fuscus</i>	Female	36.70	36.70	36.70
	Male	NC	NC	NC
<i>Lasiurus borealis</i>	Female	39.80	45.00	42.18
	Male	37.50	40.00	39.03

NC = no bats were captured

Table 18 Two sample t-test (assuming equal variance, $\alpha = 0.05$) of *C. rafinesquii* forearm length (mm)

Month	Sex	N	Mean (mm)	Standard Deviation	<i>t</i>	df	<i>P</i> - Value
March	M	2	42.25	0.32	2.07	5	0.09
	F	5	43.02	0.20			
April	M	5	42.94	0.94	NA	NA	NA
	F	0	NA	NA			
May	M	19	42.54	0.19	4.33	32	0.01
	F	15	43.79	0.22			
July	M	1	42.00	NA	0.41	1	0.75
	F	2	42.25	0.35			
August	M	7	42.27	0.69	NA	NA	NA
	F	0	NA	NA			
Overall	M	34	42.51	0.14	4.24	54	<.0001
	F	22	43.48	0.18			

NA = no data were available

Table 19 Two sample t-test (assuming equal variance, $\alpha = 0.05$) of *M. austroriparius* forearm length (mm)

Month	Sex	N	Mean (mm)	Standard Deviation	<i>t</i>	df	<i>P</i> - Value
March	M	5	37.28	0.35	1.07	22	0.30
	F	19	37.71	0.18			
April	M	0	NA	NA	NA	NA	NA
	F	7	38.90	1.25			
May	M	9	36.29	0.62	0.51	13	0.62
	F	6	36.78	0.76			
July	M	0	NA	NA	NA	NA	NA
	F	2	39.20	0.28			
August	M	1	34.8	NA	NA	NA	NA
	F	0	NA	NA			
Overall	M	15	36.52	0.36	3.11	47	0.0032
	F	34	37.88	0.24			

NA = no data were available

than females (avg. = 1.67). Roost fidelity was higher for males than females. Females traveled (on average) further distances than males between roosts (Table 20).

On the first day of radio tracking, three (2-female, 1-male) of the 12 *C. rafinesquii* with transmitters selected the roost tree where they were originally captured in the previous day. Those individuals that selected the tree where originally captured continued to use the same roost for 1-2 days. Females were tracked to a total of three Type 1 trees and nine Type 3 trees. After leaving the capture site, females selected one Type 1 tree and nine Type 3 trees. Males were tracked to a total of eight Type 1 trees and six Type 3 trees. After leaving the capture site, males selected seven Type 1 trees and six Type 3 trees (Table 21).

All tracking data were sorted by the high and low temperature from 1900 h the previous day through 0700 h of the present day (TPP). Type 3 trees were used 100% of the time by bats (2-male, 2-female) with transmitters when the high TPP temperature was $\leq 17^{\circ}\text{C}$. When the low TPP temperature was $\leq 8^{\circ}\text{C}$, all females (n = 4) and males (n = 3) were tracked to Type 3 trees. However, one of the males was also tracked to a Type 1 tree on one occasion within this temperature range. Males and females were tracked to Type 1 trees 16% of the time and Type 3 trees 84% of the time. No individuals were tracked to Type 2 trees during the telemetry study. After separating the data by gender, 90% of the females and 79% of the males were tracked to Type 3 trees (Table 21).

Table 20 Winter radio tracking data for *C. rafinesquii*

A. Includes roost trees where bats were originally captured and returned.

B. Does NOT include roost trees where bats were originally captured and Returned.

A.

	<u>Males (n = 6)</u>	<u>Females (n = 6)</u>
Number of roosts (average)	2.17	1.67
Number of days spent/roost tree (average)	4.36	2.83
Distance traveled in m (average)	176.83	291.33
Number of roosts (range)	1-5	1-4
Number of days spent/roost tree (range)	1-11	1-6
Distance traveled in m (range)	0-778	0-1726

B.

	<u>Males (n = 6)</u>	<u>Females (n = 6)</u>
Number of roosts (average)	1.33	1.00
Number of days spent/roost tree (average)	4.43	2.79
Distance traveled in m (average)	126.33	286.12
Number of roosts (range)	1-4	1-3
Number of days spent/roost tree (range)	1-11	1-6
Distance traveled in m (range)	0-282	0-1726

Table 21 The distance traveled, fidelity, and roost tree type for all roosts used by *C. rafinesquii*

Gender	Capture Tree		Movement #1			Movement #2			Movement #3			Movement #4			Movement #5		
	F	TT	D	F	TT	D	F	TT	D	F	TT	D	F	TT	D	F	TT
Female	1	1	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Female	0	1	121	2	3	282	6	3	282	1	3	**	**	**	**	**	**
Female	0	1	89	4	3	**	**	**	**	**	**	**	**	**	**	**	**
Female	2	1	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Female	0	1	212	5	3	**	**	**	**	**	**	**	**	**	**	**	**
Female	0	1	92	1	1	1332	1	3	1726	1	3	1726	3	3	955	4	3
Male	0	1	7	9	3	**	**	**	**	**	**	**	**	**	**	**	**
Male	0	1	162	4	3	162	2	1	**	**	**	**	**	**	**	**	**
Male	0	1	1	3	1	1	1	1	1	11	1	1	5	1	**	**	**
Male	2	1	224	2	3	224	1	1	**	**	**	**	**	**	**	**	**
Male	0	2	335	1	1	89	6	3	**	**	**	**	**	**	**	**	**
Male	0	1	778	1	3	282	7	3	**	**	**	**	**	**	**	**	**

Capture Tree = Tree where bat was captured while exiting. Individual was released inside tree after transmitter attachment

D = Distance traveled from previous roost site

F = Roost fidelity (# of days)

TT = Tree Type (Type 1-basal opening only, Type 2-basal and chimney opening, Type 3-chimney opening only)

** = Signal lost

Water Tupelo Tree Cavity Temperature

During the warm months (23 July 2008 through 23 October 2008), temperature data were collected every two hours for 92 days. Figure 8 shows ambient and tree cavity average temperatures collected during this period. Temperature profiles for all three tree types were found to be equal to one another ($P = 0.062$); however, they were determined to be significantly different from ambient temperatures ($P < 0.001$). Figure 9 illustrates Zone 1 and Zone 2 cavity temperatures among Type 1, Type 2, and Type 3 trees. Zone 1 and Zone 2 cavity temperatures were determined to be significantly different in Type 3 trees ($P = 0.01$) and not significantly different in Type 1 ($P = 0.075$) and Type 2 ($P = 0.077$) trees. Figure 10 shows the linear regression model prediction of ambient temperature effect on cavity temperature of Type 1, Type 2, and Type 3 trees. Internal temperatures of Type 2 trees responded the most and Type 3 trees the least to ambient temperature change during the warm months.

During the cold months (15 December 2008 through 30 January 2009), temperature data were collected every two hours for 47 days. Figure 11 shows ambient and tree cavity average temperatures collected during this period. Temperature profiles of all three tree types were determined to be not equal to one another ($P = 0.004$). The differences of Least Squares Means (PROC GENMOD) are shown in Table 22. Type 1, Type 2, and Type 3 tree cavity temperatures were all determined to be significantly different ($P < 0.001$) from ambient temperatures. Figure 12 illustrates Zone 1 and Zone 2 cavity temperatures for Type 1, Type 2, and Type 3 trees. Zone 1 and Zone 2 cavity temperatures were determined to be significantly different in Type 1 ($P = 0.009$) and Type 2 ($P = 0.001$) trees, but not significantly different in Type 3 ($P = 0.169$) trees.

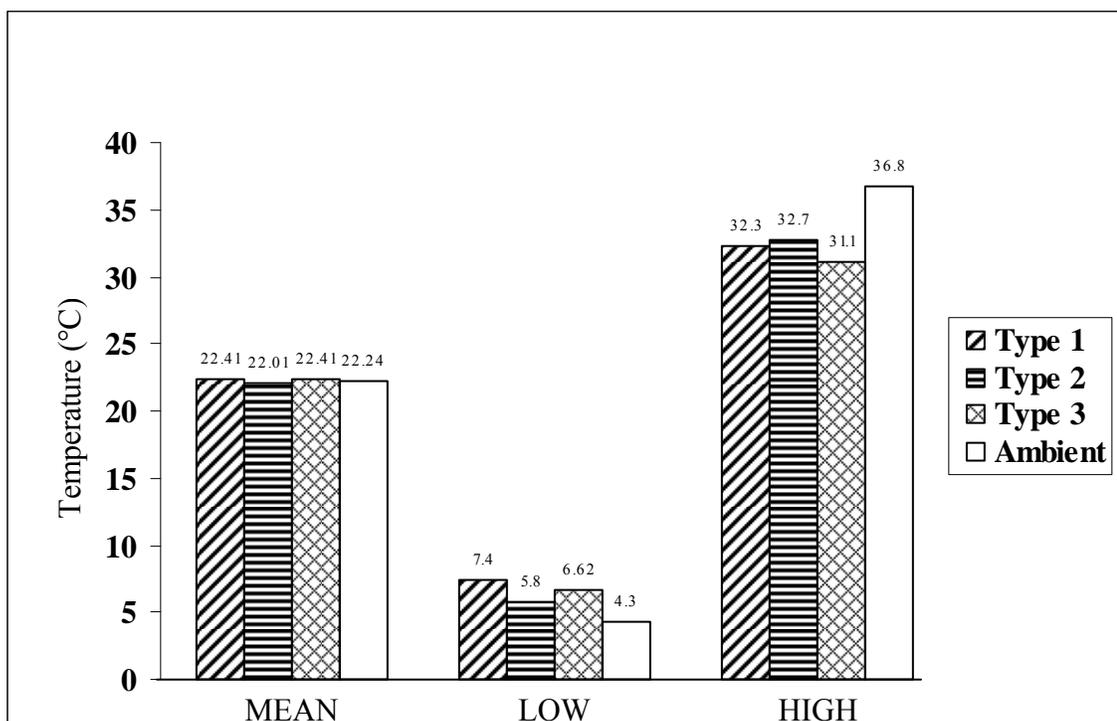


Figure 8 Water tupelo tree cavity (Type 1, Type 2, Type 3) and ambient temperature data (collected 23 July 2008 through 23 October 2008)

Type 1 = basal opening only
 Type 2 = basal and chimney opening
 Type 3 = chimney opening only

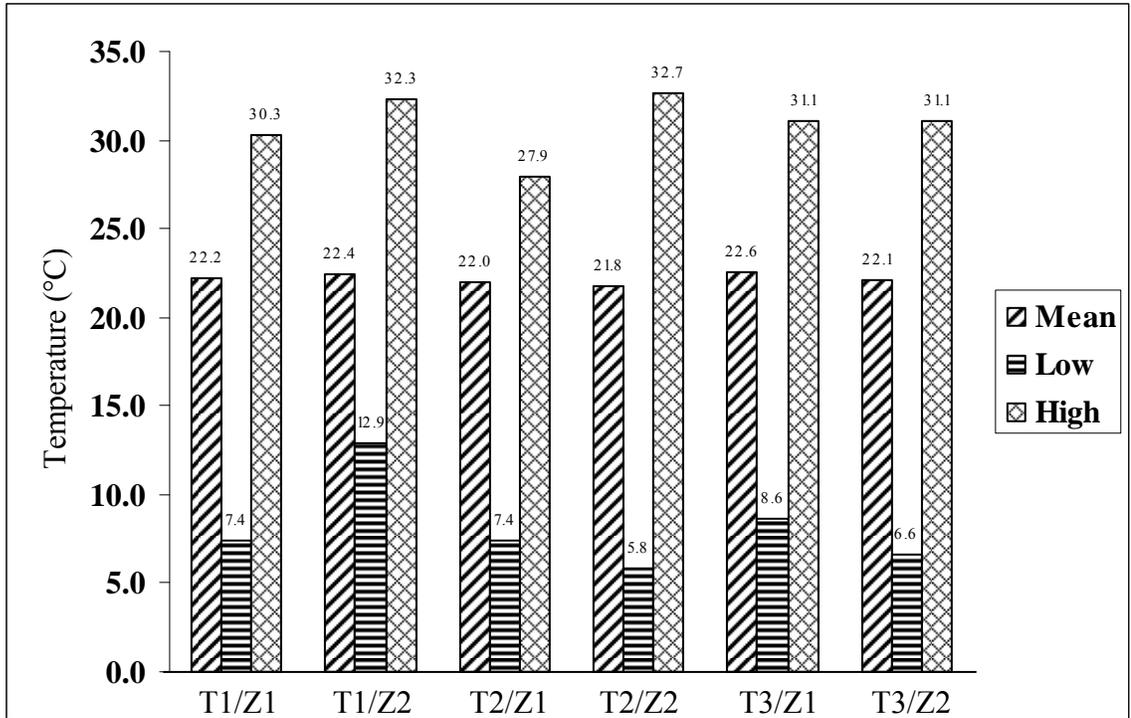


Figure 9 Water tupelo tree cavity (Type 1, Type 2, Type 3) temperature data by Zone 1 and Zone 2 (collected 23 July 2008 through 23 October 2008)

- T1 = Type 1 (basal opening only)
- T2 = Type 2 (basal and chimney opening)
- T3 = Type 3 (chimney opening only)
- Z1 = Zone 1 (bottom half of tree cavity)
- Z2 = Zone 2 (top half of tree cavity)

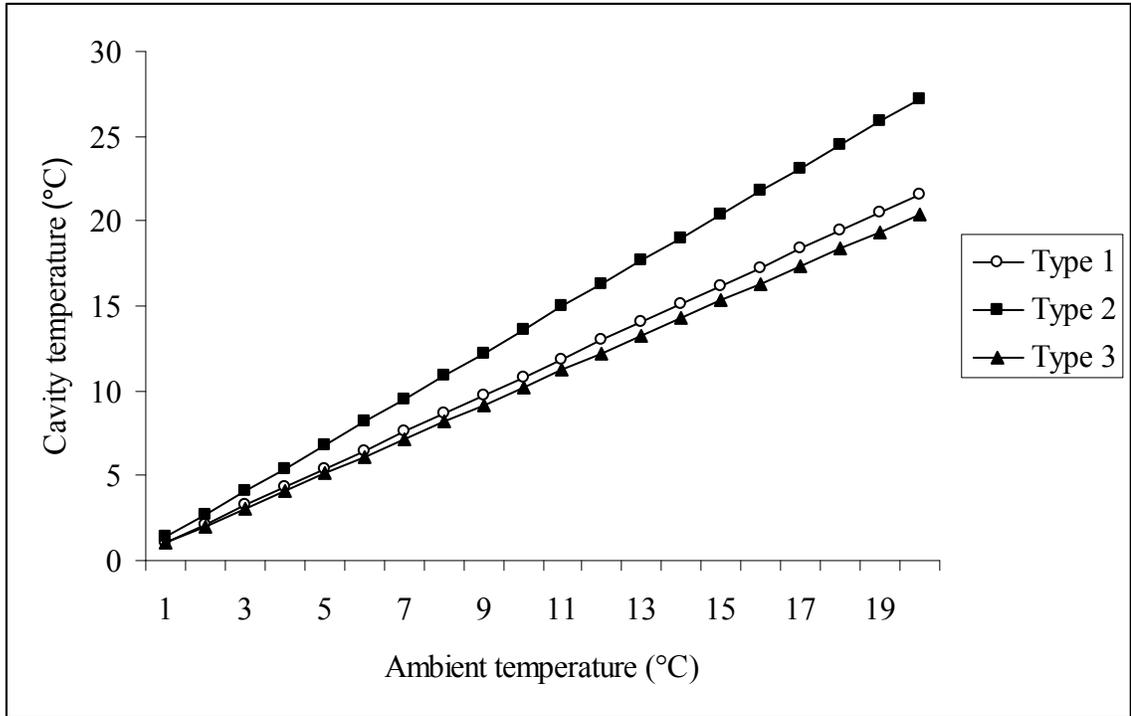


Figure 10 Linear regression model prediction of ambient temperature effect on cavity temperature of Type 1, Type 2, and Type 3 water tupelo trees (collected 23 July 2008 through 23 October 2008)

- Type 1 = basal opening only
- Type 2 = basal and chimney opening
- Type 3 = chimney opening only

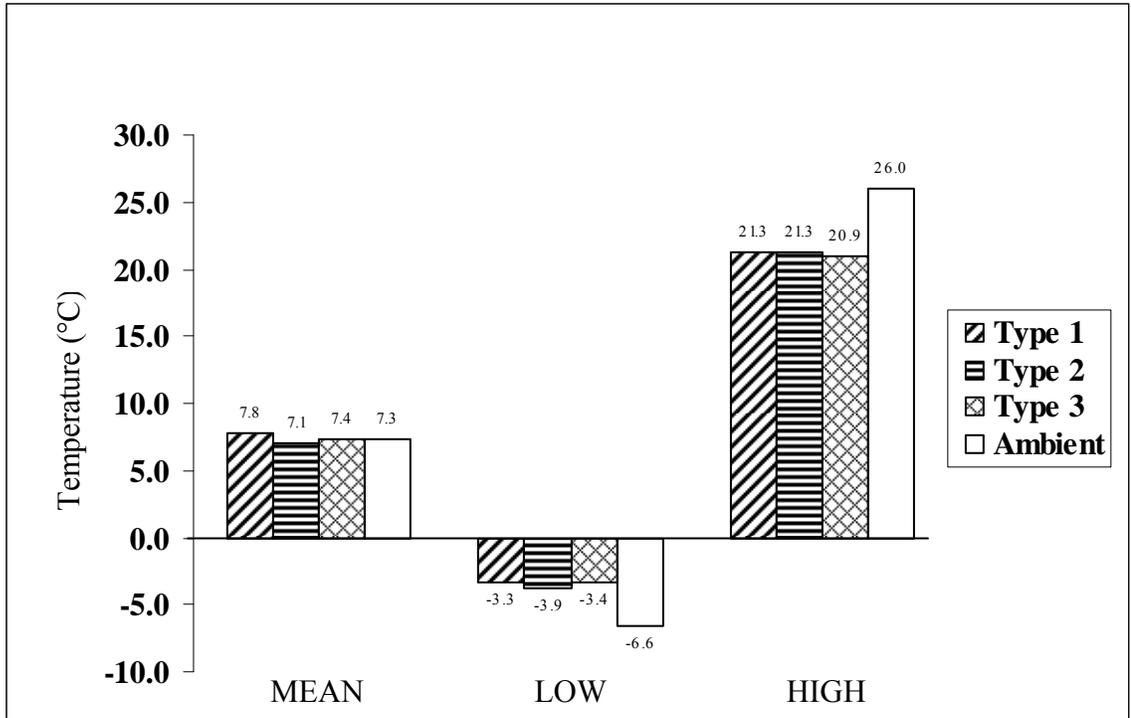


Figure 11 Water tupelo tree cavity (Type 1, Type 2, Type 3) and ambient temperature data (collected 15 December 2008 through 30 January 2009)

Type 1 = basal opening only
 Type 2 = basal and chimney opening
 Type 3 = chimney opening only

Table 22 Differences of least squares means of Type 1, Type 2, and Type 3 water tupelo tree cavity temperatures collected during the winter months.

WINTER

Comparison		Estimate	Standard Error	DF	Chi - Square	P-Value
Type 1	Type 2	0.4009	0.2100	1	3.64	0.0563
Type 1	Type 3	-0.0041	0.0247	1	0.03	0.8671
Type 2	Type 3	-0.4051	0.2311	1	3.07	0.0796

Type 1 = basal opening only

Type 2 = basal and chimney opening

Type 3 = chimney opening only

Winter = 15 December 2008 through 30 January 2009

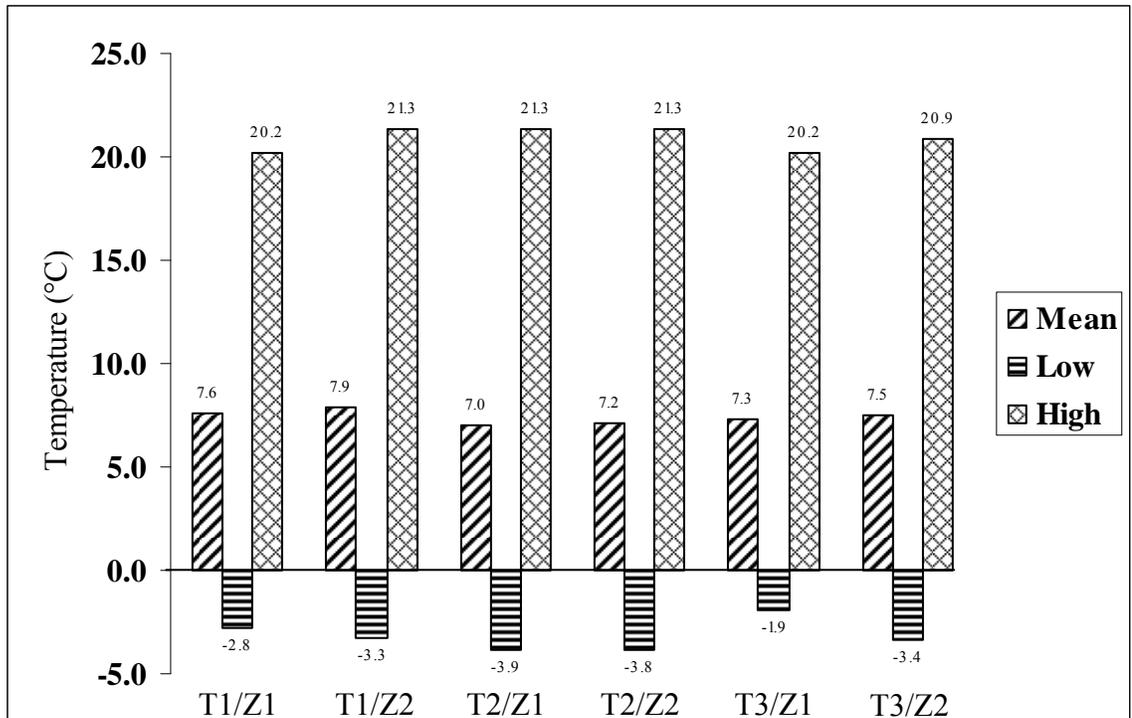


Figure 12 Water tupelo tree cavity (Type 1, Type 2, Type 3) temperature for Zone 1 and Zone 2 (collected 15 December 2008 through 30 January 2009)

- T1 = Type 1 (basal opening only)
- T2 = Type 2 (basal and chimney opening)
- T3 = Type 3 (chimney opening only)
- Z1 = Zone 1 (bottom half of tree cavity)
- Z2 = Zone 2 (top half of tree cavity)

Figure 13 shows the predicted ambient temperature effect on cavity temperature of Type1, Type 2, and Type 3 trees. Type 2 trees responded the most and Type 3 trees the least to ambient temperature change during this period. Figure 14 and Figure 15 show temperature data collected for 72 hours from 22 December through 25 December 2008. The figures compare ambient temperature with internal cavity temperature within Zone 1 (Figure 14) and Zone 2 (Figure 15) of three randomly chosen trees of each tree type.

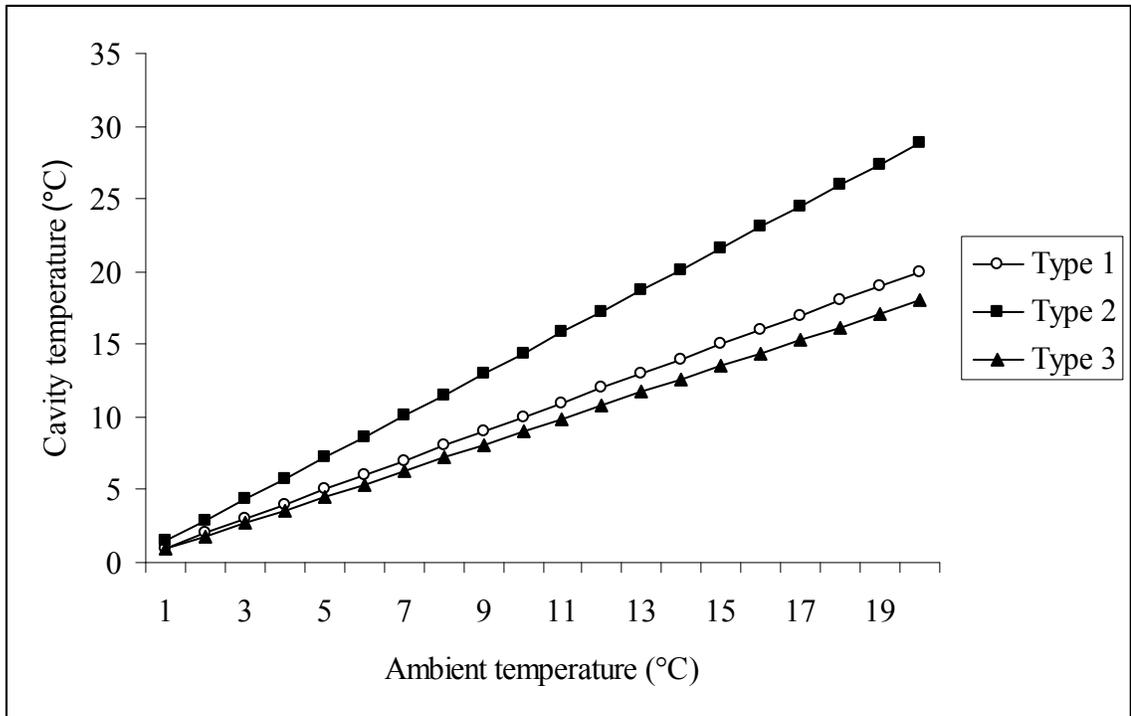


Figure 13 Linear regression model prediction of ambient temperature effect on cavity temperature of Type 1, Type 2, and Type 3 water tupelo trees (collected 15 December 2008 through 30 January 2009)

Type 1 = basal opening only
 Type 2 = basal and chimney opening
 Type 3 = chimney opening only

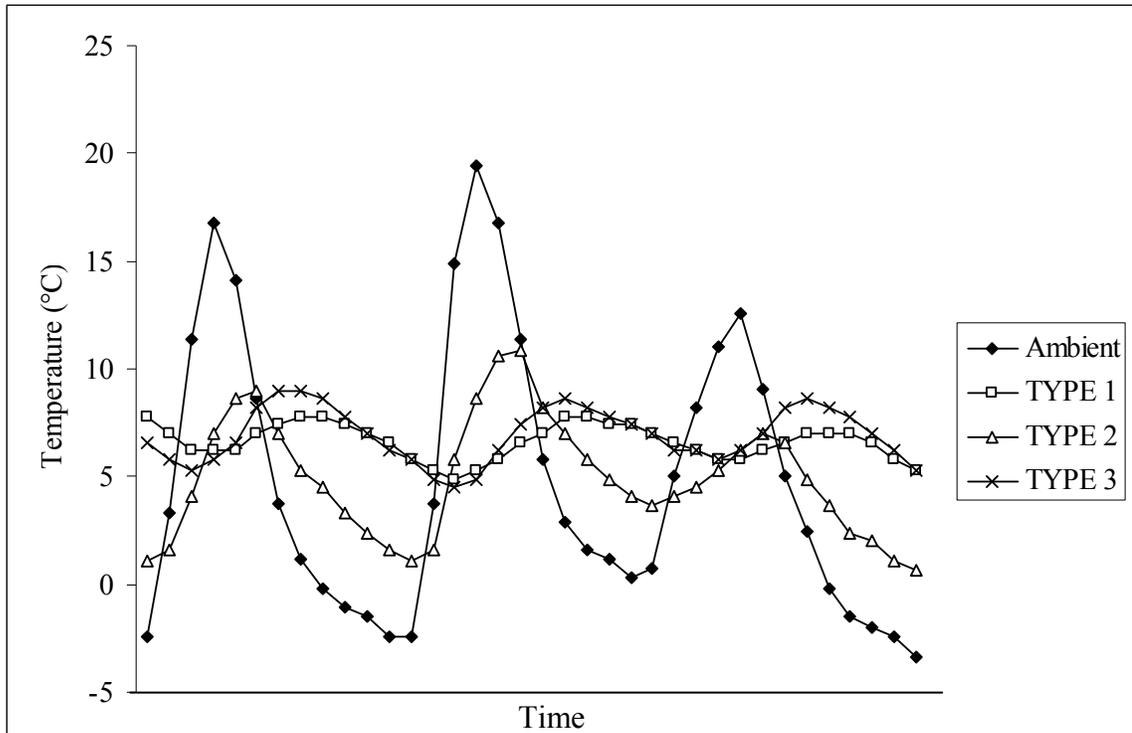


Figure 14 Zone 1 temperature data collected for 72 hours from 22 December through 25 December 2008. Comparison of ambient temperature with internal cavity temperature of three randomly chosen water tupelo trees (Type 1, Type 2, Type 3).

Type 1 = basal opening only
 Type 2 = basal and chimney opening
 Type 3 = chimney opening only
 Zone 1 = bottom half of tree cavity

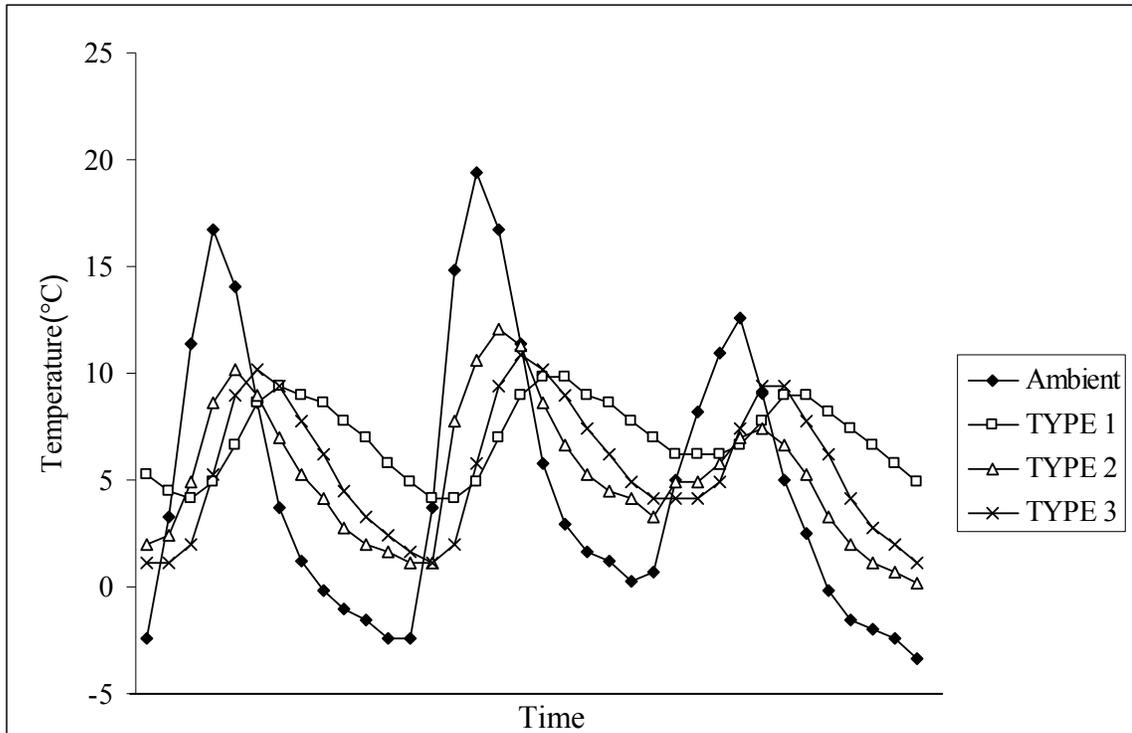


Figure 15 Zone 2 temperature data collected for 72 hours from 22 December through 25 December 2008. Comparison of ambient temperature with internal cavity temperature of three randomly chosen water tupelo trees (Type 1, Type 2, Type 3).

Type 1 = basal opening only
 Type 2 = basal and chimney opening
 Type 3 = chimney opening only
 Zone 2 = top half of tree cavity

DISCUSSION

Tree Cavity Searches

This research was conducted to document bat occurrence collected from repeated, long-term searches of a particular subset of cavity trees inhabited by *C. rafinesquii* and *M. austroriparius*. Many published studies have focused on locating roost sites inhabited by one or both species (Clark 1990; Mirowski and Horner 1997; Hoffman 1999; Gooding and Langford 2004; Trousdale and Beckett 2005; Stevenson 2008). This information is important in identifying the range and location of important maternity roosts; however, by repeatedly observing a fixed set of potential cavity trees it is possible to observe long-term tree use by both species. This study provides the following topics: frequency of tree use, movement between cavities over different information on seasons, and the movement of individual bats, as well as groups. The repeated observations can be related to roost tree characteristics to understand why particular tree cavities were selected over others during the warm and cold months during this study.

The study sample initially included 59 cavity trees of which water tupelo was most abundant. During the 23 months of TCS, two water tupelo trees (Tree #1, Tree #48) fell due to natural causes (Table 2). Both trees were known roosting sites of *C. rafinesquii*, but no data from those particular trees were included in any of the analyses.

Previous studies have reported *C. rafinesquii* and *M. austroriparius* inhabiting cavities of a variety of tree species including water tupelo (Clark 1990; Mirowski and

Horner 1997; Gooding and Langford 2004; Stevenson 2008), bald cypress (Harper 1927; Gooding and Langford 2004; Stevenson 2008), water oak (Stevenson 2008), American beech (*Fagus grandifolia*) (Mirowski and Horner 1997), blackgum (*Nyssa sylvatica*) (Clark 1990; Mirowski and Horner 1997; Stevenson 2008), American sycamore (*Platanus occidentalis*) (Clark 1990; Stevenson 2008), pignut hickory (*Carya glabra*) (Stevenson 2008), eastern cottonwood (*Populus deltoides*) (Stevenson 2008), sweetgum (*Liquidambar styraciflua*), and swamp chestnut oak (*Quercus michauxii*) (Stevenson 2008). *C. rafinesquii* have also been reported roosting in southern magnolia (*Magnolia grandiflora*) (Trousdale and Beckett 2005), shagbark hickory (*Carya ovata*), white oak (*Quercus alba*), cherrybark oak (*Quercus pagoda*), and overcup oak (*Quercus lyrata*) (Stevenson 2008). In addition, *M. austroriparius* have been observed occupying red maple (*Acer rubrum*) (Carver and Ashley 2008) and water hickory (*Carya aquatica*) (Hoffman 1999) tree cavities. In the current study, only water tupelo and bald cypress trees were found to be utilized as roosting sites by either species. Other cavity trees (1 willow oak, 2 water tupelo, 3 unidentified snags) within the study site were not found to be used by either species.

Species Presence/Roosting Numbers - *C. rafinesquii*

Clark and others (1998) suggested that the availability of multiple roosts might be important to *C. rafinesquii*. During both the warm and cold months, *C. rafinesquii* were observed roosting in 60% of all cavity trees (Type 1 and Type 2) at the study site. Many of these trees (Tree #7, #10, #24, #25, #45, #52, #53, #57) were considered primary roosts for large colonies of this species (Table 2). Large colonies ranging from 20-150 estimated individuals were observed within these trees on one or more occasions.

Probably the two most significant trees used by this species were Tree #45 and Tree #53 where large colonies were repeatedly observed.

One or two individuals frequently occupied a few of the 57 trees for many consecutive TCS. The basal openings of these trees were netted to determine the gender of the individuals. All lone individuals were identified as males and banded to determine roost fidelity. Subsequent TCS revealed these individuals continued to occupy the same trees, and occasionally came back to the same roost the following year after abandoning the trees during the cold months.

Large colonies of *C. rafinesquii* were observed throughout the course of study, but there was hardly ever more than one cavity occupied by a large number of individuals on any given day. In addition, the number of roosting individuals varied every time a large colony was encountered. One inference from these observations is that there may have been only one large colony of this species within the study site. Assuming there was only one colony, it appeared that the individuals segregated into smaller groups (20-50) on some days and reformed large colonies (50-150) on other days. This same fission and fusion social organization has been described in numerous bat studies (Kozhurina 1993; Kerth and König 1999; Willis and Brigham 2004). Kerth and König (1999) reported this behavior might suggest that the size of a subgroup is more important than the individual composition of a subgroup. Their study suggested that subgroup formation might be attributed to parasite avoidance, predation, and/or the energetic benefits of social thermoregulation. Due to the structural characteristics of water tupelo trees and the behaviors exhibited by *C. rafinesquii*, researchers who are interested in the social interactions of bats should consider this species as an ideal one to study.

During the warm months, *C. rafinesquii* were observed in twice as many trees as the cold months (Table 2). Not only were there far less encounters during the cold months, but very few colonies were observed consisting of ≥ 20 individuals (Table 3). Only 8% of the total observations of this species over the entire year occurred during the cold months (Table 4). This species is known to “disappear” from trees with basal openings (Type 1 and Type 2) during the winter months (Mirowski and Horner 1997; Gypsy Hanks pers. comm.). The TCS revealed very specific trends for this species that support these observations. During both 2007 and 2008, a steady decline in the average number of trees used by this species was observed from August through January. Conversely, there was a significant increase in the average number of trees occupied by this species from February through May 2008 and from February to March 2009. Type 1 and Type 2 trees were occupied frequently during the warm months; however, as the cold months approached this species gradually decreased its use of these trees. By January of both years, all Type 1 and Type 2 trees were abandoned by this species (Figure 4). Assumptions about these trends are discussed further in “Water Tupelo Tree Cavity Temperature”.

Twenty-six of the 27 Type 1 and Type 2 trees that could be directly observed with a flashlight were utilized by *C. rafinesquii* at some point over the course of this research. A few other roost trees were detected with the Anabat[®] II system, but far more cavities were probably inhabited by this species (Table 2). Although this species was observed in almost every tree ($n = 26$) that could be observed, only a portion of the trees were used on any given day. Gooding and Langford (2004) suggested that any of the large water tupelos within the stand they studied could have been utilized as a roost on

any given day. This should be considered when researchers conduct searches at potential roost sites. Trees should be searched multiple times (≥ 5) to estimate population size and/or the number of roost trees this species utilizes within a given area.

One behavior that was frequently observed by *C. rafinesquii* was the difference in sensitivity to researcher disturbance between males and females. Banded males remained in particular roosts for many consecutive days even though they were disturbed with recurrent cavity examinations. Their ears would sometimes become erect, but the bats rarely ever flew inside or out of the cavities. Single roosting individuals (potentially males) seemed to exhibit high roost fidelity towards specific trees. Researcher disturbance seemed to arouse the bats more as the colony size increased within the tree cavities. Some individuals would fly around inside the cavity, while others seemed to remain calm. When large colonies (≥ 30) (potentially all females) of *C. rafinesquii* were observed, the bats would usually not be present the next day. When large numbers were present, the bats could usually be heard flying inside the cavity even before entering the tree. It was apparent that cavity examination disturbed large colonies of this species to a greater extent than individuals. Sometimes a few individuals were observed exiting the roosts from alternative openings before a researcher entered the cavities. Only a small fraction of bats would be present in a cavity that was used by a large colony the previous day. Fidelity of large colonies of this species was not known because the bats had to be disturbed to estimate population size; however, it is safe to assume that roost fidelity is low for large colonies of this species.

Species Presence/Roosting Numbers - *M. austroriparius*

Hoffman (1999) and Stevenson (2008) both reported that *M. austroriparius* preferred to roost in trees with basal openings at the bottom and ceilings at the top of the cavities (Type 1 trees). In this study, *M. austroriparius* were only observed roosting in Type 1 water tupelo tree cavities. This specific preference for Type 1 trees was much different than the more opportunistic selection of Type 1 and Type 2 trees by *C. rafinesquii*. Combining the warm and cold months, this species was observed roosting in 14% of the 57 trees in this study (Table 2).

Within the study site, *M. austroriparius* primarily roosted in large numbers > 300, determined from numerous emergence counts, within one water tupelo cavity tree (Tree #30). This tree was the largest diameter Type 1 water tupelo tree on the study site. Tree #30 had characteristics that made it stand out from all other cavity trees. It was apparent there was a large ceiling inside this tree, although this could only be assumed from outside the tree. The basal opening was small (81cm wide, 35 cm high) and very close to the ground. This presented a problem because the cavity could never be directly observed with a flashlight due to the small size of this opening. Species identification and number estimates were determined using emergence counts and the Anabat[®] II system. Anytime the water level of the streambed rose, this tree would be one of the first to have its basal opening completely submerged. Sometimes the opening would be under water for days or even months, while basal openings of most of the other Type 1 trees remained above the water level. Most importantly, no other holes were detected anywhere on this tree for the bats to escape. It was perplexing as to why

M. austroriparius selected this particular tree over other Type 1 trees within the study site that had higher basal openings.

On two occasions, large numbers of individuals (possibly those from Tree #30) selected one of two other trees (Tree #27 or Tree #45) with large basal openings when the water level was high. It was possible that all of the individuals came from Tree #30. Special efforts were made to travel to the study site soon after the water level had receded. On both occasions, the tree (Tree #27 or Tree #45) that was previously inhabited had been abandoned. Consequently, on those few occasions it seemed the entire colony of *M. austroriparius* had returned to Tree #30, as numerous individuals could be heard inside the cavity. On two other occasions, when the water level had risen during the daytime, a vast number of the individuals were undoubtedly trapped inside Tree #30. On both occasions, large numbers of this species could be heard inside the tree cavity just minutes before the basal opening became completely submerged. It is unclear whether any bats attempted to escape in the hours prior to the submergence, because the basal opening was not observed during this time. This tree remained under water for several days on both occasions. These observations may reveal how important specific trees are to this species, and/or how costly it may be for the entire colony to move to an alternate roost during the daytime. Other than Tree #30, only Tree #27 was used by large numbers (≥ 20) of this species for three or more days of TCS. Although large colonies of *M. austroriparius* may have been selecting roosts outside the study site, it appeared that roost fidelity was low for every tree other than Tree #30.

In this study, colonies (≥ 2) of *M. austroriparius* consisted of either 2-3 individuals ($n = 4$) or ≥ 20 individuals ($n = 15$). This species was never encountered in

groups of 4-20 individuals. Every other time *M. austroriparius* was observed only one individual (n = 45) was present (Table 5). The basal openings of two of the trees (Tree #16, Tree #21) where one *M. austroriparius* was observed roosting by itself were netted to determine the gender of the individual. All captured bats were male, and were observed roosting by themselves in the same locations for long periods of time (several weeks) after bands were placed on the individuals. All banded individuals eventually disappeared from their roosts. Three *M. austroriparius* were encountered in the same roost for three consecutive TCS days. It appeared an adult female was roosting with two pups. Two smaller individuals were on the back of one large individual that was hanging from the side of the cavity (near the ceiling). One of the smaller individuals was attached to the back of the other smaller individual.

Stevenson (2008) reported *M. austroriparius* did not typically arouse during cavity examination. In this study, single roosting individuals hardly ever aroused from researcher disturbance even if *C. rafinesquii* were flying around the cavity. Conversely, large colonies (≥ 20) appeared to be awake throughout the entire day whether the study site was searched in the morning or afternoon. Large colonies were extremely noisy and could be heard several meters away from their roosts before entering the cavity. Researcher disturbance did not seem to decrease roost fidelity of *M. austroriparius*, whether there was one individual or a large colony.

Myotis austroriparius occupied a total of eight tree cavities over the entire study (Table 2). Although *C. rafinesquii* were observed roosting in a greater number of trees (n = 34) than *M. austroriparius*, both emergence counts and cavity searches revealed *M. austroriparius* might be more abundant than *C. rafinesquii* within the study site. The

cold months were different from the warm months because all individuals were only observed roosting by themselves (Table 5). These individuals remained calm and hardly ever moved or made noise. No large colonies were observed in the 27 cavities that could be observed with a flashlight during the cold months, because Tree #30 was the only tree occupied by large numbers of this species. This tree could only be searched with the Anabat[®] II system. Using this system, the colony of bats in Tree #30 could be heard 40% of the time during the cold months and 96% of the time in the warm months (Table 2). When the weather warmed for a few days after long periods of low temperatures, the colony in this tree usually became active enough to hear without this device. Several emergence counts during the cold months revealed this species would forage when temperatures had warmed up for a few days. Consequently, it was assumed that this tree was used almost everyday during the year even though the bats were not heard on every occasion.

Over the course of the study, *M. austroriparius* was observed roosting (on average) in a larger number of Type 1 trees in 2007 than in 2008-09 (Figure 5). This could have been the result of the higher number of searches that were conducted in 2007 when compared to 2008-09 (Table 1). Four trends are apparent from this data. The first is the steady increase in the average number of roosts (1-4) used by this species from June 2007 through August 2007 (Figure 5). This steady increase was primarily associated with the long-term fidelity of Tree #30 and Tree #27, where large numbers were frequently and consistently observed. In addition, individuals were observed roosting by themselves for many consecutive days in the same trees (Tree #16, #21). There was also a decrease in the number of occupied roosts from August 2007 through

October 2007 (Figure 4). This was primarily due to Tree #16 and Tree #21 not being used as much during this time. The third apparent trend was the increase in the number of occupied roosts in the cold months from October 2007 through December 2007 (Figure 5). Tree #30 was consistently used during this time (Table 2). On numerous occasions, individuals were also observed roosting by themselves as they had done in the warm months. The same two trees (Tree #16, #21) that were used in the warm months were repeatedly used by banded individuals during this time. The last apparent trend that stood out was the steady decrease in the average number of roost trees used by this species from March 2008 through December 2008. Not only were there less encounters than 2007, but there were no spikes or sporadic changes in the data when compared to 2007 (Figure 5). Tree #30 was used throughout this time as it had been in 2007, but there were far fewer encounters of single roosting individuals in the other trees. In addition, Tree #27 was only used for a few days in all of 2008 instead of several weeks as was observed in 2007. This species was not directly observed in January 2008, December 2008, January 2009, or February 2009 (Figure 5).

Roost Sharing - *C. rafinesquii* and *M. austroriparius*

Several studies have reported roost sharing by *C. rafinesquii* and *M. austroriparius* (Mirowski and Horner 1997; Carver and Ashley 2008; Stevenson 2008). Roost sharing behavior was also observed in this study on numerous occasions in only five specific trees (Tree #16, #20, #21, # 39, #45) (Table 2). In three of the trees (Tree #16, #20, #21), both species shared the same roost for many weeks at a time. It was not known if the individuals consistently roosted together since TCS were not conducted every day. Tree #16 was netted to determine the gender and band both

individuals. Both individuals were found to be males, and continued to select the same roost for many more weeks. On multiple occasions during the warm and cold months, both individuals roosted close enough to touch one another as they hung from the ceiling of the cavity. Stevenson (2008) also documented that some individuals that shared a roost were observed clustering together on a few occasions. This location was unusual for *C. rafinesquii*, because this species was observed roosting along the sides of cavities on most every other occasion. Carver and Ashley (2008) suggested that even though both species utilize the same trees on occasion, each may prefer specific site characteristics in particular roost trees. Both species were only observed roosting together in Type 1 trees, but *M. austroriparius* were only found in Type 1 trees in this study (Table 2).

A specific interaction, where both species chose not to share a particular roost, was observed several times during the course of TCS. Tree #27 was frequently used as a roost site by one banded male *C. rafinesquii* for many consecutive days. Tree #27 typically became occupied for long periods of time by a large colony (50-150) of *M. austroriparius*. Anytime the colony of *M. austroriparius* moved into Tree #27, the male *C. rafinesquii* would move to Tree #28. This tree was approximately 1 m from Tree #27. The male *C. rafinesquii* would remain in Tree #28 for the duration of the time that Tree #27 was occupied by the colony of *M. austroriparius*. After Tree #27 was abandoned by this colony, the male *C. rafinesquii* was always found to move back into Tree #27. The male *C. rafinesquii* never chose to share Tree #27 with the colony of *M. austroriparius*. Tree #27 seemed to be a much better cavity tree due to its large internal cavity height and width. The internal cavity of Tree #28 was not even a quarter of the

height and width of Tree #27. The colony of *M. austroriparius* always displaced the lone male *C. rafinesquii* for this tree. This might be attributed to the large numbers of *M. austroriparius* that moved from tree to tree. Large numbers of *M. austroriparius* are noisy and fecal matter accumulates quickly. This may pose a few problems for *C. rafinesquii*. The noise level could possibly inhibit the male *C. rafinesquii* from entering torpor during the daytime. In addition, the quick accumulation of fecal matter usually resulted in an abundance of flying insects within the cavity. Both could possibly deter *C. rafinesquii* from roosting within a cavity with a large colony of *M. austroriparius*. Large colonies of *C. rafinesquii* were also never observed sharing a roost with large colonies of *M. austroriparius*.

Roosting Height - *C. rafinesquii*

The roosting height of all individuals was observed by visually estimating a top and bottom half of all internal cavities. Several studies have reported that *C. rafinesquii* commonly roosts along the sides of internal cavity (Mirowski and Horner 1997; Carver and Ashley 2008; Stevenson 2008). This trend was observed in nearly all encounters with this species. As stated earlier, a few banded males consistently chose to roost from the ceiling of a cavity while sharing a roost with *M. austroriparius*. This behavior was also observed by a few other individuals (gender not determined) that were not roosting with *M. austroriparius*. Other than these few individuals, nearly all TCS revealed *C. rafinesquii* preferred to roost along the sides of cavity chambers.

During the warm months, *C. rafinesquii* seemed to exhibit a preference for the bottom half of the cavity. However, in the cold months the majority of all individuals were observed in the top half of the cavity. During both the warm and cold months, few

observations were made where individuals used both parts of the cavity (Table 4). This evidence suggests *C. rafinesquii* show a preference for a particular height within the cavities as the seasons change. These data may indicate that the temperature is stratified in the cavity, and *C. rafinesquii* selected a height within the cavities where the temperature was most suitable. This is discussed further in “Water Tupelo Tree Cavity Temperature”.

Roosting Height - *M. austroriparius*

Several studies reported that *M. austroriparius* prefers to roost in densely packed clusters at the cavity apex or ceiling (Mirowski and Horner 1996; Carver and Ashley 2008). The findings of this study support these earlier ones as *M. austroriparius* was always observed roosting from the ceilings of roost trees (Table 5). This behavior could potentially limit the number of trees that this species could occupy within a particular site if Type 1 trees are limited compared to other tree types. Forty of the 57 trees (70%) within the study site were Type 1 trees (Table 2). Stevenson (2008) suggested that *M. austroriparius* seemed to exhibit a generalist behavior when selecting roosts. This behavior could be site specific. If Type 1 trees are numerous within a particular site, it can be assumed that this species may exhibit this generalist approach in roost selection. However, if Type 1 trees are limited this generalist approach to selecting roosts may ultimately change. This species was only observed roosting within 24% of all Type 1 water tupelo trees on the study site, and showed a high fidelity to one particular tree (Tree #30) (Table 2). These observations suggest *M. austroriparius* may exhibit a high preference for particular trees. If these trees exist within a particular site, this species may show a high fidelity for those particular trees while ignoring other trees that are not

as suitable. Conversely, in sites where no “high preference” trees exist, this species may exhibit a more generalist selection of many less desirable roost trees.

Anabat[®] II Accuracy

The Anabat[®] II detection system is a common tool for detecting and identifying flying bats within a particular site. This device was an important tool throughout the TCS survey. No other study has documented using this device to conduct TCS. The goal of this study was to enhance the accuracy of future TCS studies where researchers use this device. Only 27 of the 57 tree cavities could be completely observed with a flashlight. In order to justify the estimates for the remaining 30 trees, the device was tested on these particular 27 cavity trees.

Anabat[®] II Accuracy - C. rafinesquii. Over the course of this study, this device was found impractical for detecting 1-3 individuals of this species. One individual hardly ever vocalized before a researcher entered a cavity. This was probably because there was no reason for the bat to communicate, since there were no other individuals present within the roost. Two to three bats could only be detected a small percentage of the time. The Anabat[®] II system was much more effective when there were ≥ 4 bats present. During the cold months, 1-3 bats seemed to never vocalize, as the estimates were wrong 100% of the time. Even though large colonies (≥ 4 bats) were detected somewhat effectively, this species communicated far less as the temperature dropped during the cold months (Table 6). When the temperature was below freezing, this species was never heard. Most of the correct detections were attributed to use on “warm” days during the cold months. As a result, it is not possible to accurately infer whether or not *C. rafinesquii* is present within a particular tree cavity by using this device alone. All

researchers that use this device to conduct TCS should employ caution when reporting presence/absence of this species in trees where the entire cavities cannot be fully observed. However, it is highly recommend that all researchers use the device in conjunction with observations of cavities. On a few occasions this species could be detected with the device, but after entering the cavities they could not be visually detected.

Anabat[®] II Accuracy -*M. austroriparius*. The *Anabat*[®] II system was highly ineffective for detecting 1-3 *M. austroriparius* within a roost, as the estimates were wrong 100% of the time. Four to ten individuals were never observed within a roost. The device was not needed when large numbers (≥ 11) of this species were present during the warm months (Table 7). Colonies of this size could be heard several meters away from the roosts without the device. During the cold months, the only large colony of this species inhabited Tree #30; therefore, the device could not be tested since the cavity could not be entered. The device was used on this tree every time TCS were conducted throughout the study. The data reveal that this species inhabited this tree 40% of the time during the cold months (Table 3). That percentage came primarily from warm temperature days during the “cold” months. The bats hardly ever vocalized on cold temperature days; however, on one particular day the colony could be heard in Tree #30 even though the temperature had been below freezing for several prior days. The *Anabat*[®] II system is probably not needed or sufficient for detecting roosting *M. austroriparius*, because low numbers of roosting individuals were difficult to detect during both the warm and cold months and large colonies could be heard without the device.

Roost Tree Characteristics

Several studies have shown that large diameter trees (particularly the genus *Nyssa*) with triangular basal openings seem to be important in the selection of roosts by *C. rafinesquii* and *M. austroriparius* (Mirowski and Horner 1997; Cochran 1999; Hoffman 1999; Gooding and Langford 2004; Trousdale and Beckett 2005; Carver and Ashley 2008). This study was conducted to further the assessment of tree characteristics that may be potentially important in the selection of roost trees by both species. Other studies have compared use-trees to potential trees (Carver and Ashley 2008), non-use trees (Stevenson 2008), or randomly selected trees (Cochran 1999; Gooding and Langford 2004) to determine selection characteristics. This study was different in that a subset of trees ($n = 57$) was repeatedly monitored for 23 months. This allowed selection characteristics to be analyzed based on the number of days particular trees (entire cavities could be observed) were used or not used by either species.

The only water tupelo tree characteristic that was significantly related with the number of days either species selected particular roosts was cavity height, and this characteristic was only for the trees selected by *C. rafinesquii* (Table 9). It is important to note that this study only focused on the relationship between the tree characteristics and the number of days each tree was occupied by either species. Correlations were not made between tree characteristics of use-trees and non-use trees because *C. rafinesquii* were found in 25 of all 26 trees that were used in the analyses. Instead, the foci of the analyses was to correlate characteristics of trees that were used the most to characteristics of trees that were used the least for both species over the course of the 81 TCS days. This may have affected the analyses for *M. austroriparius*, because this species was only

found in seven of all the 26 trees. All seven trees had very similar characteristics, and they were all occupied about the same number of days. The tree (Tree #30) that was occupied the most (61 days, 75%) of all 57 trees (Table 2) could not be used in the analyses, because the cavity could not be fully observed due to the size of the basal opening. It is possible that significant relationships could have been made if this tree had been included in the analyses.

Although tree diameter was not significant in this study, the regression analysis revealed that tree diameter and cavity height were significantly related with one another. The diameter and height of water tupelo trees were not always indicators of basal opening size (height, width, circumference). Many large trees had small basal openings and, conversely, a few small trees had large basal openings. This may indicate that large internal cavities are more important to both species than the size of the basal openings. One particular large diameter water tupelo tree (Tree #53) with a small basal opening was occupied by large colonies (≥ 20 individuals) of *C. rafinesquii* on several different occasions (Table 3). This was also observed in Tree #30, in which a large colony of *M. austroriparius* was found roosting 75% of all 81 TCS occasions (Table 2). This tree was the largest of all water tupelo trees at the study site, but it had one of the smallest and lowest basal openings. Not only did it appear that the basal opening was difficult to fly through, but it was also one of the first to become submerged by water during flooding events.

Some characteristics of roost trees used by *C. rafinesquii* at UONWR were consistent with other studies. At UONWR, the average diameter of roost trees was 81.9 ± 25.4 cm (Table 10). The average roost tree diameter was 120.1 ± 3.5 cm for 44

roost trees in Louisiana (Gooding and Langford 2004), 79.4 ± 5.1 cm for 14 roost trees in Mississippi (Trousdale and Beckett 2005), 99.8 ± 22.3 cm for 8 roost trees in Texas (Mirowski and Horner 1997), and 124.5 ± 7.5 cm for 24 roost trees in Tennessee (Carver and Ashley 2008). At UONWR, the basal opening average height was 103.6 ± 54.5 cm and the basal opening average width was 46.2 ± 40.3 cm for all roost trees occupied by this species (Table 10). Documented basal opening heights and widths are 120.42 ± 15.31 cm high/ 39.92 ± 5.22 cm wide (Carver and Ashley 2008) and 133.52 ± 10.03 cm high/ 47.90 ± 4.04 cm wide (Gooding and Langford 2004). The average inside cavity height was 6.4 ± 2.8 m among all trees used by *C. rafinesquii* at UONWR (Table 10). Other studies have documented average inside cavity heights of 9.2 ± 0.7 m (Carver and Ashley 2008) and 5.2 ± 2.8 m (Gooding and Langford 2004).

At UONWR, the average diameter of the seven roost trees used by *M. austroriparius* was 95.1 ± 42.9 cm (Table 12). The average diameter of roost trees was 76.4 ± 10.8 cm for eight trees in Tennessee (Carver and Ashley 2008) and 135.1 ± 24.5 cm for two trees in Arkansas (Hoffman 1999). Two other studies reported diameters of 105 cm for one tree in Illinois (Hoffman 1999) and 108 cm for one tree in Louisiana (Gooding and Langford 2004). Reported inside cavity heights are 9.5 m (Gooding and Langford 2004) and 9.6 ± 1.6 m (Carver and Ashley 2008). At UONWR, the average cavity height of all seven trees used by *M. austroriparius* was 6.9 ± 2.9 m (Table 12). Documented basal opening heights and widths include: 60 cm high and 25 cm wide (Hoffman 1999), 191 cm high and 66 cm wide (Gooding and Langford 2004), 105.5 ± 30.4 cm high and 25.9 ± 5.1 cm wide (Carver and Ashley 2008).

Several studies have found that tree diameter is an important factor in the selection of roost trees by many tree-inhabiting bat species (Barclay and others 1988, Lunney and others 1988, Brigham 1991). For *C. rafinesquii*, any water tupelo or bald cypress tree (Type 1, Type 2, Type 3) within the study site that had an internal cavity (> 1 m high) and some form of an external opening could have potentially been occupied on any given day. This was also suggested in the study conducted by Gooding and Langford (2004). As specified earlier, 26 of all 27 trees that could be directly observed with a flashlight were utilized by this species at some point. However, only large diameter trees were selected by colonies of ≥ 30 individuals. This may indicate the cavities selected by maternity colonies must provide different microclimatic conditions than those selected by males and non-reproductive females.

Myotis austroriparius was more specific in the selection of roost trees. Although no significant relationships between roost tree characteristics and use were found, this species only used Type 1 trees within the study site (Table 2). This species may prefer to roost in larger diameter trees as seen by the high fidelity for Tree #30 when compared to other Type 1 trees at the study site.

In the future, researchers may continue to examine similar selection for roost tree characteristics in both species; however, these studies may reveal that the selection behaviors ultimately differ among sites depending on the availability of potential roost trees. For instance, *M. austroriparius* may select trees more opportunistically and for shorter periods of time in areas where no “preferred” roosts exist, and conversely, may select specific trees for longer periods of time in areas where “preferred” roosts exist. It is essential that future researchers use the same methodology to characterize roost trees.

Reported studies have shown how important old-growth cavity trees, particularly the genus *Nyssa*, are to both species. It is apparent that the loss of these trees negatively affects long-term sustainability of bat populations and potentially increases the chance that *C. rafinesquii* and *M. austroriparius* will be listed as endangered species in the future.

Mist Netting

Twelve species of bats inhabit Louisiana annually or during particular months of their migration. These species include: *Myotis septentrionalis* (Northern long-eared bat), *Myotis austroriparius* (Southeastern myotis), *Nycticeius humeralis* (Evening bat), *Pipistrellus subflavus* (Eastern Pipistrelle bat), *Corynorhinus rafinesquii* (Rafinesque's Big-eared bat), *Tadarida brasiliensis* (Brazilian Free-tailed bat), *Eptesicus fuscus* (Big Brown bat), *Lasiurus borealis* (Eastern Red bat), *Lasiurus seminolus* (Seminole bat), *Lasiurus intermedius* (Northern Yellow bat), *Lasiurus cinereus* (Hoary bat), and *Lasionycteris noctivagans* (Silver-haired bat) (NatureServe 2009). Mist nets were deployed during the warm months of 2007 to ascertain species present within the study area other than those that utilize tree cavities. This study was undertaken primarily because no bat surveys have ever been conducted within the UONWR; however, the focus was to target *C. rafinesquii* and *M. austroriparius*.

Using only mist nets to survey the study site, four (33%) of the twelve species of bats found in Louisiana were documented in this study. Since the focus of this study was to capture *C. rafinesquii* and *M. austroriparius*, surveys were only conducted within the study site where both species were frequently observed roosting in tree cavities. Ninety-

three percent of the total captures consisted of these two species (Table 13). This evidence reveals that both species are abundant and possibly out-compete other bat species that fly at low heights along this streambed. The abundance of both species in this particular foraging niche may promote other bat species to higher elevations above the streambed or possibly other areas in the forest.

Body Weight

The average body weight of male and non-pregnant female *C. rafinesquii* recorded during this survey correspond with weights documented from previous studies. Cochran (1999) reported an average male (n = 21) weight of 9.75 g (8.0 to 10.5 g) and 10.43 g (8.0 to 12.5 g) for adult non-pregnant females (n = 11). Mirowski and Horner (1997) reported males (n = 5) averaged 8.0 g (7.8 to 8.5 g) and non-pregnant females (n = 7) averaged 8.5 g (7.5 to 10.0 g). Lowery (1974) reported males (n = 3) averaged 8.13 g (7.9 to 8.0 g) and non-pregnant females (n = 12) averaged 9.1 g (7.9 to 10.2 g). At UONWR, captured males (n = 34) averaged 8.68 g (8.0 to 9.75 g), while non-pregnant females (n = 11) averaged 10.20 g (8.50 to 10.75 g) (Table 14). Mirowski and Horner (1997) documented that females (pregnant and non-pregnant) weighed significantly more than males; however, they were unable to do a monthly analysis due to a lack of captures. Cochran (1999) reported that females (pregnant and non-pregnant) weighed significantly more than males after combining the total captures. At UONWR, both sexes were captured in March, May, and July. The average weight of captured females (pregnant and non-pregnant) was higher than males in all three months. Females (pregnant and non-pregnant) at UONWR also weighed significantly more than males after combining all captures (Table 15).

For *M. austroriparius*, the average body weight of males and non-pregnant females also corresponded with documented weights from other studies. Mirowski and Horner (1997) reported an average male (n = 38) body weight of 6.45 g (5.25 to 8.0 g) and an average non-pregnant female (n = 63) body weight of 7.24 g (6.0 to 9.0 g). Hoffman (1999) reported an average male (n = 95) body weight of 6.90 g (5.75 to 9.0 g) and 7.87 g (6.0 to 10.25 g) for non-pregnant females (n = 167). Lowery (1974) reported males (n = 9) averaged 5.9 g (5.1 to 6.8 g) and non-pregnant females (n = 19) averaged 6.9 g (5.2 to 8.1 g). At UONWR, *M. austroriparius* males (n = 15) averaged 6.8 g (5.75 to 8.75 g) and non-pregnant females (n = 24) averaged 7.80 g (6.5 to 8.5 g). Pregnant females (n = 9) averaged 9.14 g (9.0 to 9.5 g) (Table 14). Hoffman (1999) and Mirowski and Horner (1997) documented that the average weight of females (pregnant and non-pregnant) was more than males in all months data were collected, and females (pregnant and non-pregnant) weighed significantly more than males in for total captures. At UONWR, the average weight of females (pregnant and non-pregnant) was also higher than males during all months both sexes were captured, as well as for total captures (Table 16).

Forearm Length

The forearm lengths of *C. rafinesquii* captures correspond to the lengths documented from other studies. Cochran (1999) reported male (n = 21) forearm lengths averaged 43.3 mm (4.0 to 4.7 mm), while female (n = 34) forearm lengths averaged 43.5 mm (4.05 to 4.58 mm). In Mirowski and Horner's (1997) study, adult males (n = 5) averaged 41.2 mm (41.0 to 42.0 mm) and females (n = 7) averaged 41.6 mm (41.0 to 43.0 mm). Lowery (1974) did not distinguish specific forearm lengths for males and females,

but reported the average forearm length of both males and females was 41.5 mm (38.8 to 43.5 mm). At UONWR, adult male (n = 34) forearm lengths averaged 42.51 mm (41.1 to 44.3 mm) and adult female (n = 22) forearm lengths averaged 43.48 mm (41.9 to 45.4 mm) (Table 17). Cochran (1999) reported that females had a slightly higher average forearm length for all bats captured in their study; however, the length was not significantly longer. At UONWR, the average forearm length for females was higher for all three months that both sexes were captured. Unlike Cochran's (1999) study, the average forearm length of females was significantly higher than males (Table 18).

The forearm lengths of male and female *M. austroriparius* documented in other studies closely resemble the measurements documented here. Lowery (1974) reported the average forearm length of males (n = 18) was 36.0 mm (33.0 to 39.0 mm) and 38.6 mm (33.5 to 40.0 mm) for females (n = 29). Hoffman (1999) reported the average forearm length of males (n = 95) was 37.3 mm (34.8 to 39.8 mm) and females (n = 172) was 38.4 mm (34.1 to 44.0 mm). Mirowski and Horner (1997) documented an average male (n = 38) forearm length of 31.8 mm (31.0 to 40.0 mm) and an average female (n = 70) forearm length of 32.1 mm (33.0 to 41.0 mm). At UONWR, the average forearm length of males (n = 15) was 36.52 mm (33.7 to 39.7 mm) and the average forearm length of females (n = 34) was 37.88 mm (35.0 to 40.3 mm) (Table 17). Hoffman (1999) and Mirowski and Horner (1997) reported the average forearm length was longer for females throughout most months data were collected. Both studies revealed that female forearm lengths were significantly longer than males after combining the total captures. The results both correspond with the forearm length data of *M. austroriparius* collected from UONWR (Table 19).

Winter Radiotelemetry of *C. rafinesquii*

The focus of this study was to locate and characterize winter roost sites occupied by *C. rafinesquii*. In their natural habitat, *C. rafinesquii* are known to roost in Type 1 and Type 2 water tupelo and bald cypress tree cavities (Mirowski and Horner 1997; Cochran 1999; Hoffman 1999; Clark 2003; Gooding and Langford 2004; Trousdale and Beckett 2005); however, it has been observed that these particular types of trees are abandoned during the winter (Gypsy Hanks pers. comm.). It became apparent that this species could not be protected if natural roosting locations were only known for 8 to 10 months out of the year.

Several studies have utilized radio telemetry to track movements of *C. rafinesquii* (Hurst and Lacki 1999; Menzel and others 2001; Gooding and Langford 2004; Trousdale and Beckett 2005). Gooding and Langford (2004) attached radio transmitters to individuals that were netted while exiting roost trees. The individuals were tracked to locate and characterize “preferred” roost trees at D’Arbonne NWR in northeastern Louisiana. Menzel and others (2001) were the first to examine home range size and habitat use by this species in southern upland pine stands. In his study, 4 males were reported to use an average foraging home range size of 160.6 ha (61.6 to 225.3 ha). Hurst and Lacki (1999) tracked the foraging range of five individuals (3-lactating females, 2-scrotal males) captured in a cave within the Cumberland Plateau of Kentucky. These authors found that foraging areas ranged from 61.6 to 225.3 ha, and the distance between these areas and their roosts ranged from 0.12 to 1.22 km. Trousdale and Beckett (2005) tracked 25 individuals (16-females, 9-males) that were captured under eight bridges in Mississippi. In this most recent study it was reported that *C. rafinesquii*

moved short distances (~360 m) between sequential tree roosts, and occupied an average of 5.5 (SD \pm 3.7) different locations. Similar results were found for the distances traveled by *C. rafinesquii* at UONWR. The method used by Gooding and Langford (2004) for capturing individuals was also used in the current research. Besides being an effective technique for capturing a specific individual gender of this species, this method minimized disturbance by placing the transmittered individuals back into the tree cavities they had already selected as roost sites. It also allowed the researcher to know the location of all individuals before tracking commenced.

At UONWR, males utilized a larger number of roost sites for longer periods of time than females (Table 20). Males were expected to exhibit a higher fidelity towards their respective roosts than females, since this behavior had been observed during the previous TCS of the summer months. Surprisingly, males changed roosts (on average) more often than females. This may be a consequence of the time of year that the individuals were tracked, since copulation takes place in the autumn and winter (Jones 1977). Females traveled further distances between roosts than males. The average distance traveled for females was further than the males due to movements by one particular female. This individual moved approximately 1700 m between two roosts on three separate occasions.

Most bats captured in Type 1 and Type 2 trees selected alternate roosts, usually Type 3 trees, after being fitted with a transmitter (Table 20). Some individuals remained in these newly located roosts for the duration of the study, while others eventually went back to their original roost sites. Type 3 trees were selected the majority of the time by both males and females. No bats were ever found to inhabit a Type 2 tree after

transmitter attachment. All transmitted individuals were tracked to a total of 7 different Type 3 trees within or near the study site, of which some were used more than others. There were other Type 3 trees that were never used as roost sites by any of the transmitted individuals; however, emergence counts revealed that all of the Type 3 trees located within the study site were used as roost sites by this species.

At one point during the study, three (2-females, 1-male) *C. rafinesquii* had working transmitters. All three bats were captured from different Type 1 roost trees. The two females selected one particular Type 3 tree as a roost, which was the tallest and most used of all Type 3 trees within the study site. Both females used this tree for a few days. During this time, the transmitted male also selected this particular tree for two consecutive days. This provided evidence that males may abandon their bachelor colonies during the winter months to roost with potentially large colonies of females during the breeding season.

These radio telemetry efforts were initiated for the primary purpose of locating roost sites after all Type 1 and Type 2 trees were abandoned in the winter. Efforts began on 15 September 2007, even though the temperature was relatively warm during this time in Louisiana. It was not known when *C. rafinesquii* would completely abandon Type 1 and Type 2 trees, and whether it would be a gradual or abrupt process. TCS from September through November indicated this species slowly decreased its use of Type 1 and Type 2 trees. By December, very few Type 1 and Type 2 trees were occupied by this species (Figure 4). In the second week of December, the weather forecast indicated that a major cold front was approaching the entire northern half of Louisiana, and the temperature was expected to be below freezing for several days.

Transmitters were attached to two males and one female the night before the cold front arrived. The weather forecast was accurate, as the temperature dropped to -2 °C the first night. All Type 1 and Type 2 trees within the study site were completely abandoned by *C. rafinesquii* after this first night of below freezing weather. All three individuals were located in two different Type 3 trees the following day after the cold front moved into Louisiana. The low temperature remained < 8 °C and the high temperature < 13 °C for several days during this time. For the duration of the cold front, all transmitted bats continued to roost in the same Type 3 trees every day that radio tracking was conducted. In addition, every other Type 1 and Type 2 tree within the study site remained abandoned by this species. The last transmitter ceased working on 26 December 2007. The TCS revealed that all Type 1 and Type 2 trees within the study site remained uninhabited by *C. rafinesquii* for the rest of December 2007 and through the month of January 2008 (Figure 4).

Very little attention was given to Type 3 trees before the radio tracking study in 2007. New questions arose as to why these trees were selected during colder months. At that time, it was not known whether Type 3 trees were only used during the winter, or whether these trees were used throughout the year. Regardless, it remained evident that natural winter roost sites utilized by this species had been identified at UONWR. Future studies may reveal that these particular types of water tupelo trees may be utilized across their range. Justification for the seasonal use of all tree types over the course of a year is further addressed in the following section “Water Tupelo Tree Cavity Temperature”.

Future studies should be directed towards locating winter roost sites of this species in all habitat types. As winter roost sites are located, other questions could be

answered related to the breeding season of this species. It would be interesting to learn if the males alternate between different roosts of large colonies of females, or if they remain with the same colony throughout the winter. If the chimney openings of Type 3 trees could be netted prior to the onset of a major cold front, researchers would have the potential to attach a large number of transmitters to an entire colony of this species. This would allow identification of the ratio of males and females within the winter roosts. Movements of an entire colony could be tracked to better understand how the bats associate with one another in the winter. Particular winter roost trees may be found to be more important than other trees within their range. These suggested studies could provide information to assist in future conservation efforts.

Water Tupelo Tree Cavity Temperature

This phase of the research was conducted at UONWR to better understand the seasonal utilization of roost sites by *C. rafinesquii*. After radio tracking in the winter of 2007, it became apparent that this species was utilizing various water tupelo tree types during different seasons of the year. Type 3 trees had been noticed before the radio tracking study, but attention was focused on TCS of Type 1 and Type 2 trees. Since the TCS were conducted during the daytime, and Type 3 trees did not have basal openings, it was never known whether Type 3 trees were utilized by this species. After the radio tracking study, evening trips were made to the study site to further confirm that Type 3 trees were being used, and Type 1 and Type 2 trees were not being used during the winter months. *Corynorhinus rafinesquii* were observed flying in and out of the chimney openings of Type 3 trees after the radio tracking study during January and February 2008.

After February 2008, Type 1 and Type 2 trees gradually became re-occupied by this species; however, what was most interesting was that Type 3 trees were also being used at this time. Nightly emergence observations of Type 3 trees in the months of April, May, and June 2008 revealed that this particular tree type was important to this species year-round. The driving question of this study was to attempt to understand why Type 1 and Type 2 trees were abandoned during the winter months. It was plausible to suspect that each particular tree type may provide specific, internal microclimatic conditions that are important to this species during different seasons of the year.

A few studies have documented the temperatures of cavities inhabited by this species. Clark (1990) determined that sycamore cavities were more thermally stable than ambient temperatures and temperatures within buildings occupied by *C. rafinesquii*. Mirowski and Horner (1998) reported that the cavity temperature of an occupied water tupelo tree was more thermally stable than ambient temperatures and unoccupied cavity temperatures of water tupelo and beech trees. This was the first study to systematically compare various tree types used by this species. The goal of the present study was not to compare occupied trees to unoccupied trees, but to compare various structural characteristics (Type 1, Type 2, Type 3) of the water tupelo trees that were known roosting sites. This allowed the study to specifically address what temperatures are potentially being selected within natural roost sites as the seasons change.

Determining temperature preferences of this species is important. Vast amounts of money and time have been spent on efforts to build artificial roost structures for this species in areas where natural habitat has been destroyed. Most of these structures have never been colonized by *C. rafinesquii*. The structures that have been successful are only

being used during the warm months of the year, but ultimately become abandoned during the cold months of the year (Mylea Bayless pers. comm.). This same behavior has been repeatedly observed for Type 1 and Type 2 trees (Gypsy Hanks pers. comm.). If seasonal roost selection in their natural habitat is attributed to the internal temperatures of cavity trees, the present study could begin the process of determining seasonal temperature preferences of *C. rafinesquii*. In the future, it may be possible to build structures that mimic the microclimatic conditions of natural roost sites. Ultimately, artificial roost structures could be used over the entire year instead of a portion of the year.

Since there were only a limited number of TDL's to conduct this research, several decisions were made about designing the project to answer the most important questions. To determine if temperature varies within a cavity, the design should have incorporated several TDL's positioned at different heights in the cavities of numerous Type 1, Type 2, and Type 3 trees. Since only 38 TDL's were available, it seemed more important to compare a larger sample size of each type with one TDL present in each, instead of a smaller sample size of each tree type with multiple data loggers present in each. The decision was made to place one TDL in as many trees as possible of each tree type. By positioning a TDL in Zone 1 (lower half) of 18 trees and Zone 2 (upper half) of the other 18 trees, comparisons could be made to determine if future investigation was necessary to assess temperature variation within tree cavities.

If *C. rafinesquii* is seasonally selecting tree types because different cavity temperatures are present in each, these analyses potentially reveal why all three tree types are used during the summer and not during the winter. Since the cavity temperatures of all three tree types were statistically equal during the summer, it makes sense that all

three tree types are used during this season. However, given that the cavity temperatures were statistically not equal during the winter; this could possibly explain one of the factors that drive *C. rafinesquii* to abandon Type 1 and Type 2 trees and only inhabit Type 3 trees during this season.

The cavity temperatures of all three tree types were not significantly different from one another during the winter months; however, cavity temperatures of Type 1 and Type 3 trees were very similar (Table 22). Results indicate that Type 3 tree cavities provided the most stable temperatures in both the summer and winter months, although Type 1 tree cavities offered similar, but slightly less stable conditions. Type 2 tree cavity temperatures were far less stable than the other two tree types (Figures 10 and 13).

Temperatures in Zone 1 and Zone 2 were significantly different in Type 3 trees, but not significantly different in Type 1 and Type 2 trees during the summer. Conversely, in the winter, the temperatures were significantly different between Zone 1 and Zone 2 of Type 1 and Type 2 trees, but not significantly different in Type 3 trees. This is interesting because of the complete reversal in statistical differences of cavity temperatures between summer and winter months. These results suggest that future research should be conducted to determine if variation in temperature exists within cavities of each tree type. Using a design that incorporated a TDL within Zone 1 and Zone 2 of each tree, strong inferences could possibly be made on seasonal tree type selection based on the cavity temperatures.

It is interesting to note the differences in the high and low temperatures not only between the tree types, but also between the zones within each tree type during both the

summer and winter months (Figures 9 and 12). During the summer, the lowest temperature in Zone 2 of Type 1 trees was 4.3 °C higher than any zone of the three tree types (Figure 8). *Myotis austroriparius* were always observed around the ceiling in Zone 2 of Type 1 trees (Table 5). This suggests the possibility that the highly selective behavior of this species for only inhabiting Type 1 trees could be attributed more to temperature preference than structural design (tree type) of a roost tree. The temperatures in Zone 2 of these trees could be warmer because hot air rises and becomes trapped since no openings are present in the top half of these tree types. Figure 9 and Figure 12 further illustrate that temperature differences potentially exist within tree cavities. In addition, these temperature differences may also determine why groups (≥ 2) of *C. rafinesquii* did not scatter throughout the cavity, but usually selected one of the two zones during the TCS (Table 4).

Figure 14 and Figure 15 provide a better indication of how Zone 1 and Zone 2 cavity temperatures of each tree type respond to ambient temperature fluctuation during the winter months. Although each figure shows the zone temperature change from different trees, it is possible to infer similar differences would exist within each tree type. In both figures, it is apparent that ambient temperature affects the cavity temperature of Type 2 trees more extensively than the other two tree types. It is interesting how the cavity temperatures of Type 1 and Type 3 trees respond similarly to ambient temperature fluctuations. For Type 1 and Type 3 trees, the cavity temperatures were more stable in Zone 1 (Figure 14) than Zone 2 (Figure 15). *Corynorhinus rafinesquii* did not use every Type 3 tree within the study site. When *C. rafinesquii* were observed, large colonies were always present in Zone 1 of the trees near the basal swell. This positioning made it

difficult to determine how many were present within the cavities. The bats would always be clustered together very tightly, but the colonies were so large that it appeared as if a blanket of fur was draped over a large portion of the interior wall. Their position in Zone 1 of Type 3 trees during the winter months may be associated with the temperature stability of Zone 1 (Figure 14) as compared to Zone 2 (Figure 15).

Results of this study indicate *C. rafinesquii* may alternate between and within the cavities of different water tupelo tree types in order to take advantage of temperature variation that is important to their survival as the seasons change. If temperature is the driving force in seasonal cavity selection among the tree types, this study may provide evidence why Type 1 and Type 2 trees are abandoned during the winter months. The temperature instability of Type 2 trees could deter occupancy during the winter months. The cavity temperatures of Type 1 and Type 3 trees are not only statistically similar overall (Table 22), but their internal temperatures also respond in a similar way to ambient temperature fluctuations (Figures 14 and 15). The question remains as to why Type 1 trees are not also used during the winter months. Other ecological factors also contribute to tree type selection during this time. The water level at the study site remained high for approximately two months in the late winter and early spring months of 2008. Almost every basal opening was completely submerged during this time. Any bat that did not abandon Type 1 trees before the flood would have been trapped for the duration of high water. Even though their microclimatic conditions may potentially be similar, it is possible that these ecological forces may favor the selection of Type 3 trees over Type 1 trees during the winter months.

Future studies will most certainly determine other factors that contribute to roost tree selection of *C. rafinesquii* and *M. austroriparius*. Unfortunately, their natural habitat will probably continue to decline, which should facilitate an urgent need to build artificial roost structures that can mimic natural roosts for all species of bats. Knowledge that exists on the roosting ecology of *C. rafinesquii* and *M. austroriparius* is still in its early stages; however, technological advances in equipment have and will continue to discover important life history requirements for both species. These data will hopefully initiate long-term, more in-depth studies of their roosting requirements.

CONCLUSIONS

Corynorhinus rafinesquii and *M. austroriparius* are both considered rare across the southeastern U.S, and are listed range wide as species of concern (NatureServe 2009). It is well known that both species roost within the cavities of water tupelo and bald cypress trees (Mirowski and Horner 1997; Cochran 1999; Hoffman 1999; Gooding and Langford 2004; Trousdale and Beckett 2005; Carver and Ashley 2008), which has also been confirmed in this study. The scattered remnants of stands of mature trees has raised concerns about population declines for both *C. rafinesquii* and *M. austroriparius*, and has warranted collaborative efforts from private, state, and federal agencies to obtain an accurate population status throughout their range (Shauna Ginger pers. comm.).

Although *C. rafinesquii* and *M. austroriparius* occupy much of the same habitat throughout their range, it is evident from this study that the species differ dramatically in their selection and utilization of cavity roosts. At UONWR, fifty-nine tree cavities consisting of water tupelo (n = 50), bald cypress (n = 3), water oak (n = 2), willow oak (n = 1), and dead tree snags (n = 3) were monitored on 81 days occasions 24 May 2007 through 7 March 2009. All of the trees were classified according to the location of cavity openings: Type 1 (basal opening only), Type 2 (basal opening and chimney opening). *Corynorhinus rafinesquii* and *M. austroriparius* were found roosting within 35 (61%) (33-water tupelo, 2-bald cypress) of the 57 trees surveyed during the course of this study. *Corynorhinus rafinesquii* seemed to be more opportunistic than *M. austroriparius* in their selection of cavity roosts. *Corynorhinus rafinesquii* were observed in 34 (60%) trees

(32-water tupelo, 2-bald cypress), while *M. austroriparius* were only found in eight (14%) water tupelo trees. Both species were also observed roosting together on occasion.

Roost tree characteristics were measured to better understand why particular trees are selected over others. Several studies have shown that large diameter trees (particularly the genus *Nyssa*) with triangular basal openings seem to be important in the selection of roosts by both species (Mirowski and Horner 1997; Cochran 1999; Hoffman 1999; Gooding and Langford 2004; Trousdale and Beckett 2005; Carver and Ashley 2008). At UONWR, the cavity height of water tupelo trees was the only variable that was significantly related to the number of times roosts were selected, and only for trees selected by *C. rafinesquii*.

The roosting height was recorded to determine how each species utilizes the internal cavities as the seasons change. *Corynorhinus rafinesquii* were observed roosting in both the top and bottom halves of the cavities, while *M. austroriparius* were only found roosting in the top half of the cavities (hanging from or near the ceiling). Although both the top and bottom halves of the cavities were used by *C. rafinesquii*, I found that the bottom halves were used more during the warm months (March-October), while the top halves were used more during the cold months (November-February). It seemed that *C. rafinesquii* may have been selecting different cavity heights as the ambient temperature influenced the cavity temperature.

Before this study began, it was known that *C. rafinesquii* abandoned trees with basal openings during the winter months (Gypsy Hanks pers. comm.). At the end of 2007, radio transmitters were attached to 12 individuals in an attempt to locate winter roost sites. After all the Type 1 and Type 2 trees were abandoned, this species was

located in water tupelo trees that were later classified as Type 3 trees (chimney opening only).

During the next field season, emergence observations at night revealed that Type 3 trees were used throughout the year. This raised question as to why Type 1 and Type 2 trees were abandoned during the winter months. After observing the variation in roosting height by this species, it seemed plausible to suspect that specific temperatures may not only be selected within cavities, but also that cavity temperature in different tree types may influence their selection as the seasons change.

TDLs were used to determine if cavity temperature could influence seasonal roost site selection by *C. rafinesquii* among the three tree types. The analyses revealed that the cavity temperatures of all three tree types were equal in the summer months and not equal in the winter months. Type 1 and Type 3 trees were found to have very similar temperatures when compared to Type 2 trees. Type 3 trees had the most stable temperatures during both the summer and winter months. Additionally, Type 2 trees were found to have the least stable temperatures, and reached warmer temperatures than the other two tree types. This data revealed that temperature could influence seasonal roost site selection for this species; however, future investigation is needed.

Mist nets were deployed during the summer months of 2007 to ascertain species present within the study area other than those that utilize tree cavities. Four of the twelve species of bats found in Louisiana were documented including: *C. rafinesquii*, *M. austroriparius*, *L. borealis*, and *Eptesicus fuscus*. *Corynorhinus rafinesquii* and *M. austroriparius* made up 93% of the total captures. Body weights and forearm lengths of both males and females of both species were consistent with other studies.

There is still a great deal to learn about the roosting ecology of *C. rafinesquii* and *M. austroriparius*. It is apparent that both species are more sensitive to abiotic and biotic factors than previously thought. It may be years or even decades before an accurate population status can be ascertained for both species, due their elusive behavior and the lack of locality knowledge that currently exists. Until then, efforts must continue determine their geographic range, roosting ecology, and life history requirements to ensure both species will be present for years to come.

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Papers Presented

Association of Southeastern Biologists, Birmingham, AL

April 2009

-Cavity temperature of water tupelo (*Nyssa aquatica*) trees as a possible influence on roost site selection by *Corynorhinus rafinesquii* (Rafinesque's big-eared bat). (Presentation) C.L. Rice and K.M. Tolson

-Roosting and habitat use of two Vespertilionid bats (*Myotis austroriparius* and *Corynorhinus rafinesquii*) within a bottomland hardwood forest streambed. (Poster) C.L. Rice and K.M. Tolson

19th Colloquium on Conservation of Mammals in the Southeastern United States,
Jonesboro, AR

February 2009

-Cavity temperature of water tupelo (*Nyssa aquatica*) trees as a possible influence on roost site selection by *Corynorhinus rafinesquii* (Rafinesque's big-eared bat). (Presentation) C.L. Rice and K.M. Tolson

Rafinesque's Big-eared bat Working Group 2nd Annual Meeting, Jonesboro, AR
February 2009

- Cavity temperature of water tupelo (*Nyssa aquatica*) trees as a possible influence on roost site selection by *Corynorhinus rafinesquii* (Rafinesque's big-eared bat). (Presentation) C.L. Rice and K.M. Tolson

Mississippi Bat Working Group 7th Annual Meeting, Jackson, MS
January 2009

- Cavity temperature of water tupelo (*Nyssa aquatica*) trees as a possible influence on roost site selection by *Corynorhinus rafinesquii* (Rafinesque's big-eared bat). (Presentation) C.L. Rice and K.M. Tolson

38th North American Symposium on Bat Research, Scranton, PA
October 2008

- Ambient temperature as a possible effect on roost site selection by *Corynorhinus rafinesquii* (Rafinesque's big-eared bat) in a bottomland hardwood forest streambed. (Presentation) C.L. Rice and K.M. Tolson
- Roost site selection by two Vespertilionid bats (*Myotis austroriparius* and *Corynorhinus rafinesquii*) in a northeast Louisiana bottomland hardwood forest. (Poster) C.L. Rice and K.M. Tolson

Louisiana Association of Professional Biologists, Lafayette, LA
September 2008

- Ambient temperature as a possible effect on roost site selection by *Corynorhinus rafinesquii* (Rafinesque's big-eared bat) in a bottomland hardwood forest streambed. (Presentation) C.L. Rice and K.M. Tolson
- Roost site selection by two Vespertilionid bats (*Myotis austroriparius* and *Corynorhinus rafinesquii*) in a northeast Louisiana bottomland hardwood forest. (Poster) C.L. Rice and K.M. Tolson

Association of Southeastern Biologists, Spartanburg, SC
April 2008

- Ambient temperature as a possible effect on roost site selection by *Corynorhinus rafinesquii* (Rafinesque's big-eared bat) in a bottomland hardwood forest streambed. (Presentation) C.L. Rice and K.M. Tolson
- Roost site selection by two Vespertilionid bats (*Myotis austroriparius* and *Corynorhinus rafinesquii*) in a northeast Louisiana bottomland hardwood forest. (Poster) C.L. Rice and K.M. Tolson

18th Colloquium on Conservation of Mammals in the Southeastern United States,
Blacksburg, VA

February 2008

-Ambient temperature as a possible effect on roost site selection by *Corynorhinus rafinesquii* (Rafinesque's big-eared bat) in a bottomland hardwood forest streambed. (Presentation) C.L. Rice and K.M. Tolson

-Roost site selection by two Vespertilionid bats (*Myotis austroriparius* and *Corynorhinus rafinesquii*) in a northeast Louisiana bottomland hardwood forest. (Poster) C.L. Rice and K.M. Tolson

Rafinesque's Big-eared bat Working Group 2nd Annual Meeting, Blacksburg, VA

February 2008

-Ambient temperature as a possible effect on roost site selection by *Corynorhinus rafinesquii* (Rafinesque's big-eared bat) in a bottomland hardwood forest streambed. (Presentation) C.L. Rice and K.M. Tolson

Mississippi Bat Working Group 6th Annual Meeting, Jackson, MS

January 2008

-Ambient temperature as a possible effect on roost site selection by *Corynorhinus rafinesquii* (Rafinesque's big-eared bat) in a bottomland hardwood forest streambed. (Presentation) C.L. Rice and K.M. Tolson

-Roost site selection by two Vespertilionid bats (*Myotis austroriparius* and *Corynorhinus rafinesquii*) in a northeast Louisiana bottomland hardwood forest. (Poster) C.L. Rice and K.M. Tolson

Louisiana Association of Professional Biologists, Lafayette, LA

September 2007

-Roost site selection by two Vespertilionid bats (*Myotis austroriparius* and *Corynorhinus rafinesquii*) in a northeast Louisiana bottomland hardwood forest. (Poster) C.L. Rice and K.M. Tolson

Honors and Awards

- Travel award for accepted abstract for the Association of Southeastern Biologists Meeting in Birmingham, AL, April 2009
- 1st place for best presentation in the University of Louisiana at Monroe's Student Research Symposium. May 2009
- 2nd place for best poster in the University of Louisiana at Monroe's Student Research Symposium in Monroe, LA, May 2009

- Southeastern Bat Diversity Network Best Student Oral Presentation on Bats Award in Jonesboro, AR, February 2009
- Travel award for accepted abstract for the 38th North American Symposium on Bat Research in Scranton, PA, October 2008
- 1st place for best poster in the Louisiana Association of Professional Biologists Fall Symposium in Lafayette, LA, September 2008
- 1st place for best poster in the University of Louisiana at Monroe's Student Research Symposium in Monroe, LA, May 2008
- 2nd place for best presentation in the University of Louisiana at Monroe's Student Research Symposium in Monroe, LA, May 2008
- Travel award for accepted abstract for the Association of Southeastern Biologists Meeting in Birmingham, AL, April 2008
- Southeastern Bat Diversity Network Outstanding Student Presentation Award in Blacksburg, VA, February 2008

Meetings Attended

- Association of Southeastern Biologists, Birmingham, AL. April 2009
- 19th Colloquium on Conservation of Mammals in the Southeastern United States, Jonesboro, AR. February 2009
- Rafinesque's Big-eared bat Working Group 2nd Annual Meeting, Jonesboro, AR. February 2009
- Mississippi Bat Working Group 7th Annual Meeting, Jackson, MS. January 2009
- 38th North American Symposium on Bat Research, Scranton, PA. October 2008
- Louisiana Association of Professional Biologists, Lafayette, LA. September 2008
- Association of Southeastern Biologists, Spartanburg, SC. April 2008
- 18th Colloquium on Conservation of Mammals in the Southeastern United States, Blacksburg, VA. February 2008
- Rafinesque's Big-eared bat Working Group 2nd Annual Meeting, Blacksburg, VA. February 2008
- Mississippi Bat Working Group 6th Annual Meeting, Jackson, MS. January 2008
- Louisiana Association of Professional Biologists, Lafayette, LA. September 2007

- Association of Southeastern Biologists, Greenville, SC. April 2007
- Mississippi Bat Working Group 5th Annual Meeting, Jackson, MS.
January 2007

