RAFINESQUE'S BIG-EARED BAT (*CORYNORHINUS RAFINESQUII*) IN MISSISSIPPI: DISTRIBUTION, CURRENT STATUS, AND CONSERVATION NEEDS

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Abstract—Rafinesque's big-eared bat (*Corynorhinus rafinesquii*) is a "Species of Greatest Conservation Need" in Mississippi that is potentially negatively affected by habitat changes resulting from natural and anthropogenic events. Historical records and recent investigations indicate that the species is widespread in Mississippi, but surveys and monitoring sufficient to ascertain status of its populations have been limited in spatial and temporal scope. To date, big-eared bats have been documented in 27 counties. The species is typically associated with mature bottomland hardwood forests but also occurs in upland mixed woodlands, and several maternity roosts have been found in abandoned houses in upland pine (*Pinus* spp.) forests. Most studies in Mississippi have yielded data on current distribution and extent that artificial structures serve as maternity roosts. There is a need to further investigate use of natural roosts using radiotelemetry in certain forest types, e.g., bottomlands within the floodplain of large rivers and mixed woodlands of the Loess Hills. Studies of winter roosts and foraging habitat also are needed to gain a more complete understanding of ecology of the species. Management should include identification and protection of natural and artificial roosts, location and protection of wells and cisterns that potentially serve as winter roosts, selective management for appropriate cavity-producing trees, and improved coordination and cooperation among government agencies and private landowners.

INTRODUCTION

Rafinesque's big-eared bat (*Corynorhinus rafinesquii*) occurs throughout the Southeastern United States but is considered uncommon over most of its range, including Mississippi (Harvey and others 1999). The species is State-listed as endangered, threatened, or of special concern in all States where it occurs, and it is listed as a "Species of Greatest Conservation Need" in Mississippi (Mississippi Museum of Natural Science 2005). Prior to the early 1990s, Rafinesque's big-eared bats had been reported only from scattered localities from 12 counties in Mississippi, but recent surveys throughout portions of the State have documented their occurrence in 15 additional counties (fig. 1). Although several recent big-eared bat studies conducted in Mississippi have been published in professional journals (e.g., Trousdale and Beckett 2002, 2004, 2005; Trousdale and others 2008), results of most field studies are currently available only in unpublished theses (Sherman 2004, Stevenson 2008, Wilf 2004) and agency reports (e.g., Martin and others 2007, 2008; McCartney 2007). Thus, we identified a need to examine recent published and unpublished studies and consolidate information on this species for Mississippi. This was necessary to provide researchers and managers the most up-to-date information for assessing species status and making management decisions. Herein, we describe distribution of known populations, status of roost sites and maternity colonies, management practices implemented to conserve the species and provide roosting habitat, and conservation needs for Rafinesque's big-eared bats in Mississippi.

DISTRIBUTION AND STATUS

Historical records of Rafinesque's big-eared bats in Mississippi indicated that the species was uncommon in the State. Big-eared bats catalogued in the Mississippi Museum of Natural Science (MMNS) Natural Heritage Database during 1894 to 1941 consisted of specimens collected in Hinds, Pearl River, Rankin, Simpson, Washington, Wayne, and Yazoo Counties (fig. 1). No additional specimens were deposited in the museum until 1990. Wolfe (1971) stated that although not common, big-eared bats were distributed throughout the State and had been reported from buildings, caves (usually near the entrance), and hollow bald cypress (*Taxodium distichum*) trees. At that time populations were known to occur in eight counties, five of which were

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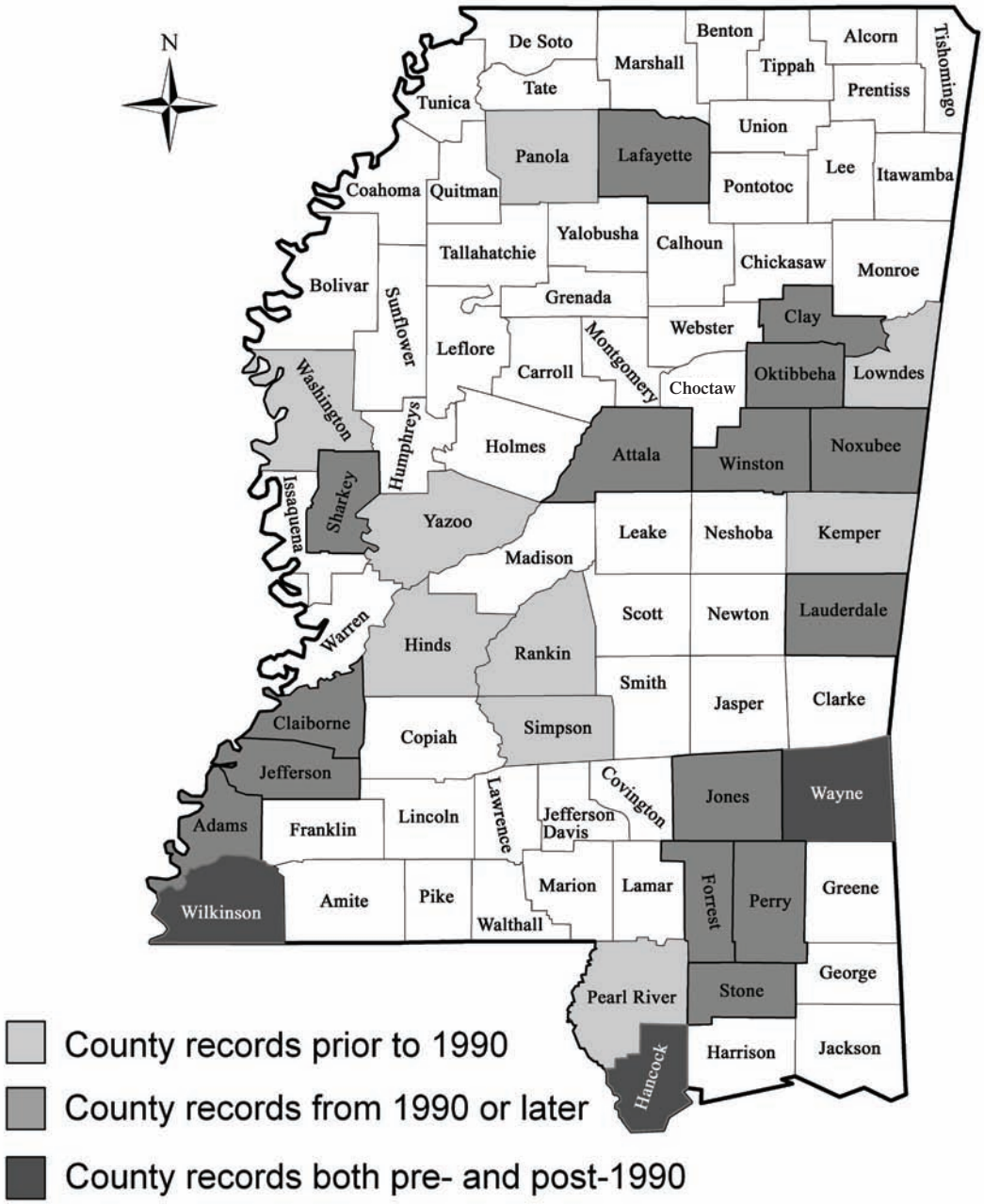

Figure 1—Known distribution of Rafinesque's big-eared bat based on early museum and literature records (pre-1990) and recent surveys (1998 to 2009).

represented by specimens in the MMNS and three of which were reported in the literature. These included counties in the northeastern (Oktibbeha and Lowndes), northern (Panola), westcentral (Yazoo and Rankin), southwestern (Wilkinson), and southern (Wayne, Pearl River, and Hancock) parts of the State. Kennedy and others (1974) listed records from the following nine counties, all of which were derived from the literature: Hancock, Kemper, Lowndes, Panola, Pearl River, Rankin, Wayne, Wilkinson, and Yazoo. Jones and Carter (1989) stated that the species was statewide in occurrence, with the subspecies *C. r. rafinesquii* along the northern edge of the State and *C. r. macrotis* throughout the rest of Mississippi. Specimens catalogued in the MMNS during 1990 to 2001 were collected in Clay, Hancock, Perry, and Wayne Counties.

Recent studies have revealed Rafinesque's big-eared bats in several additional areas in Mississippi. Trousdale and Beckett (2002, 2004) conducted surveys in southern Mississippi and located colonies beneath bridges in five counties (Jones, Perry, Stone, Wayne, and Wilkinson). Most bridges surveyed were within or near the DeSoto or Bienville National

Forests (NF). Terrain consisted of a mosaic of habitat types including upland and lowland mixed hardwood-pine (*Pinus* spp.) forest, upland mesic hardwood forest, bottomland hardwoods, and bald cypress/tupelo *(Nyssa* spp.) swamps. Other locations in southern Mississippi include several sites on Camp Shelby Army National Guard Training Site, now referred to as the Camp Shelby Joint Forces Training Center (JFTC) in Forrest and Perry Counties. Sites on Camp Shelby where big-eared bats were captured with mist nets primarily were narrow riparian corridors adjacent to pine-hardwood forests (Martin and others 2007).

Several studies also have documented occurrence in western and southwestern counties. Wilf (2004) captured a single male in a mist net on Delta NF in Sharkey County. Sherman (2004) examined maternity colonies roosting in abandoned houses on St. Catherine Creek National Wildlife Refuge (NWR) in Adams County. One of the colonies was reported to contain 60 individuals in 1990 (Sherman 2004). St. Catherine Creek NWR consisted of a mixture of bottomland hardwoods, upland mixed hardwoods, and open water areas managed primarily for waterfowl. Big-eared bats also have been documented using bridges as roosts at crossings along tributaries of Bayou Pierre in Claiborne County. One of the bridges supports a maternity colony of about 30 individuals (Wolters and Martin 2000, 2011); the surrounding area was primarily recently harvested hardwood forest. In August 2009, a large population consisting of about 150 individuals was located in an abandoned building in Jefferson County.[1] This represents the largest known maternity colony of Rafinesque's big-eared bats in Mississippi.

Limited surveys for big-eared bats have been conducted in northcentral and eastern counties, except for studies of roosting habitat in bottomland hardwood areas on the Noxubee NWR (Richardson 2007, Stevenson 2008). Several colonies have been located in hollow bald cypress and American sycamore (*Platanus occidentalis*) trees on this refuge in Oktibbeha, Winston, and Noxubee Counties. An abandoned house in Clay County has served as a maternity roost since 1988. A maternity colony recently discovered in an abandoned seismograph building in Lafayette County in northcentral Mississippi was reported to contain 85 to 100 individuals during summer 2008.[2] We confirmed that this structure contained about 70 hibernating Rafinesque's big-eared bats on March 3, 2009. Big-eared bats were documented from Lauderdale County in eastern Mississippi when five individuals were observed roosting in an elongated airstrip culvert on Naval Air Station (NAS) Meridian on October 11, 2000 (Martin and others 2005). Finally, one specimen was captured during a mist net survey conducted by the Mississippi Bat Working Group (MBWG) in Attala County in July 2007.

ROOST SITES

Rafinesque's big-eared bats roost in natural sites and a variety of humanmade structures throughout their range (Bennett and others 2008, Clark 1990, Gooding and Langford 2004, Jones 1977, Lance and others 2001, Trousdale and Beckett 2004, Trousdale and others 2008). Although Wolfe (1971) indicated that big-eared bats were known from sites near openings of caves in Mississippi, use of caves in Mississippi has not been documented during more recent surveys. McCartney (2007) surveyed 22 caves in Mississippi (primarily on private property) in 11 counties during 2005 to 2007 and found no evidence of big-eared bats. Trousdale and Beckett (2002) surveyed five of these caves and three additional caves in two counties and likewise did not observe big-eared bats.

In Mississippi, big-eared bats have been documented using a variety of roosts including tree cavities, bridges, culverts, wells, cisterns, abandoned structures, and specially designed artificial roosts. They were observed in 18 hollow trees and 3 abandoned buildings on Noxubee NWR (Stevenson 2008); 14 trees, 16 bridges, and 3 abandoned houses on DeSoto NF (Trousdale and Beckett 2005, Trousdale and others 2008); 6 additional bridge sites, an abandoned house, and a well in southwestern Mississippi (Claiborne and Jefferson Counties); 5 abandoned buildings on St. Catherine Creek NWR (Sherman 2004); an abandoned house, an old well, and a bald cypress tree on the Delta NF in western Mississippi (Wilf 2004); old bunkers and the digester tank of an abandoned water treatment plant on Camp Shelby JFTC in southern Mississippi (Martin and others 2007); and cinder block artificial roosts on St. Catherine Creek NWR (McCartney 2007) and DeSoto NF.[3] Big-eared bats once were observed roosting in elongated airstrip culverts in eastern Mississippi (Martin and others 2005).

Studies of natural roosts of big-eared bats in Mississippi have only been conducted on DeSoto NF (Trousdale and Beckett 2005) and Noxubee NWR (Richardson 2007, Stevenson 2008). Trees used as roosts on DeSoto NF were hollow tupelo and southern magnolia (*Magnolia grandiflora*), most of which were alive, relatively large (mean d.b.h. = 79.4 cm), and possessed openings to cavities located well above the base of the tree. Roosts were in 14 trees, all of which were within bottomland hardwood or loblolly pine

[1] Personal communication. 2009. Lann M. Wilf, Deer Program Biologist, Mississippi Department of Wildlife, Fisheries and Parks, 30095 Peacely Ferry Road, Aberdeen, MS 39730.

[2] Personal communication. 2009. Edmund Keiser, Professor (retired), University of Mississippi, Biology Department, 211 Saint Andrews Circle, Oxford, MS 38655.

[3] Personal communication. 2010. Stephanie Steele, Wildlife Biologist, U.S. Forest Service, Chickasawhay Ranger District, 968 Highway 15 South, Laurel, MS 39443.

(*P. taeda*)-hardwood stands. Stevenson (2008) documented relative abundance of cavities in trees and their use by big-eared bats within bottomland hardwood forests. Large hollow trees (mean d.b.h. = 100 cm) were used most often as roosts, but some bats used cavities in trees as small as 41 cm d.b.h. Rafinesque's big-eared bats most often selected roosts in cavities of bald cypress, black tupelo (*N. sylvatica*), American sycamore, pignut hickory (*Carya glabra*), and two oak (*Quercus* spp.) species—swamp chestnut oak (*Q. michauxii*) and water oak (*Q. nigra*). Other species that provided roost sites were sweetgum (*Liquidambar styraciflua*), American beech (*Fagus grandifolia*), overcup oak (*Q. lyrata*), shagbark hickory (*C. ovata*), cherrybark oak (*P. pagoda*), eastern cottonwood (*Populus deltoides*), willow oak (*Q. phellos*), and white oak (*Q. alba*) (Stevenson 2008).

Maternity Roosts

Most investigations of Rafinesque's big-eared bat roost sites in Mississippi have focused on maternity roosts (herein defined as a roost site occupied by multiple females and where birthing apparently has taken place) in artificial structures (table 1). However, few studies of maternity colonies in natural roosts have been conducted and these data should be viewed only as estimates. Maternity roosts in tree cavities have only been documented on DeSoto NF (Trousdale and Beckett 2005, Trousdale and others 2008) and Noxubee NWR (Stevenson 2008). Seven tupelo and southern magnolia trees on DeSoto NF were used by multiple individuals and considered to be maternity roosts (Trousdale and Beckett 2005). Stevenson (2008) located maternity roosts in four relict bald cypress

Table 1—County and status of recently surveyed maternity roosts of Rafinesque's big-eared bats in Mississippi[a]

Location	Type of roost	Bats	Date of last survey	Source
		no.		
Adams County	3 artificial roosts[b]	70	July 2007	McCartney (2007)
Claiborne County	Concrete bridge	30+	June 2009	Wolters (unpub. data)
Clay County	Abandoned house	75–90	2008	Richardson (unpub. data)
George County	1 concrete bridge	11	July 2001	Trousdale (2008)
Jefferson County	Abandoned stone building	150	Aug 2009	Wilf (pers. commun.)
Jones County (West locality[c])	2 concrete bridges	30+	July 2005	Trousdale (2008)
Lafayette County	Abandoned stone building	85–100	June 2008	Keiser (pers. commun.)
Perry County (Benndale[c])	3 concrete bridges	30	July 2004	Trousdale (2008)
Perry County (Cypress Creek[c])	1 concrete bridge	4	July 2004	Trousdale (unpub. data)
Perry County (Leaf River WMA[c])	2 concrete bridges	8	July 2004	Trousdale (2008)
Wayne County (East locality[c])	2 concrete bridges	6	May 2005	Trousdale (2008)
Wayne County (North locality[c])	2 concrete bridges	12	June 2004	Trousdale (2008)
Wayne County (Hollis Creek[c])	2 concrete bridges	10	July 2005	Trousdale (2008)
Wayne County (Thompson Creek[c])	2 concrete bridges	6	June 2004	Trousdale (2008)
DeSoto National Forest	14 tree roosts	33	Aug 2004	Trousdale (pers. commun.)
Noxubee National Wildlife Refuge	4 tree roosts	160	2007	Stevenson (pers. commun.)

WMA = Wildlife Management Area.

Numbers of bats associated with bridges represent values recorded on the most recent survey when bats were present; most bridges were surveyed multiple times over at least a 3-year period and numbers were quite variable.

[a] Number of bats includes adult females and young at highest count made during the latest survey.

[b] Previously in abandoned house.

[c] Locality [see Trousdale (2008) for description].

Figure 2—Concrete girder bridge in Claiborne County, MS, used as a maternity roost by > 30 Rafinesque's big-eared bats in 2009. (Photo by Monica Wolters)

trees (d.b.h. > 127.0 cm) with top openings on Noxubee NWR. The maximum number of bats in the 4 trees combined was estimated at 160, with 50 bats being the largest number estimated in a single roost at one time.[4]

Trousdale and Beckett (2002) surveyed 99 bridges in southern Mississippi and identified 6 bridges in 5 counties inhabited by big-eared bats. Repeated visits to these sites and other locations revealed that 36 bridges located on or near DeSoto NF were used at least once during 2002 to 2004, with 1 to 25 bats observed (Trousdale and Beckett 2004). All bridges used by bats were made of concrete and had rectangular compartments or girders on the underside. Additionally, Trousdale (2008) radio tracked big-eared bats to 25 roost structures in his study area. Besides the previously noted tree roosts, 11 were humanmade (8 bridges, 2 abandoned houses, and 1 empty oil storage tank). Maternity roosts were documented beneath 20 bridges, in 1 house, and in an oil tank (Trousdale and Beckett 2004). Populations roosting in bridges also have been documented in westcentral Mississippi. A maternity roost with 32 big-eared bats was discovered in April 2000 beneath a bridge over a tributary of Bayou Pierre in Claiborne County about 1 km from the Mississippi River (Wolters and Martin 2000, 2011). The bridge was a concrete girder structure with multiple compartments on each side (fig. 2). Surveys of this bridge, four other bridges, and an abandoned house with an adjacent well were conducted during 2000 to 2009.[5] The maternity colony has fluctuated considerably since first observed (32 bats in 2000), with an estimate of 20 in 2001 to 30 in 2009. The other bridges surveyed did not support maternity colonies but commonly were used as day roosts by individual or small numbers of bats. Surveys on Camp Shelby JFTC in southcentral Mississippi documented big-eared bats roosting in seven cement structures, including observation point bunkers, an abandoned building, the digester tank of an old wastewater treatment plant, and two bridges. The bridges on Camp Shelby supported about 11 and 25 bats in 1999 (Trousdale and Beckett 2002). The digester tank historically supported a maternity population of 45 big-eared bats, but recent surveys have documented only a few individuals using the structure (Martin and others 2007). Small maternity colonies presently occur beneath two concrete bridges on secondary roads on the installation. Surveys of bridges in other regions of Mississippi have revealed little use by big-eared bats. No bats were roosting beneath 42 bridges examined on Noxubee NWR and vicinity in 2007 to 2008 (Stevenson 2008), 24 bridges on Theodore Roosevelt NWR in 2008, and 15 bridges in southeastern Mississippi along the Pascagoula River Basin in 2009 (McCartney 2010).

[4] Personal communication. 2010. Candice Stevenson, Refuge Operations Specialist, U.S. Fish and Wildlife Service, Merritt Island National Wildlife Refuge, P.O. Box 2683, Titusville, FL 32781.

[5] Personal observation. M. Wolters and C.O. Martin.

Figure 3—Abandoned house on St. Catherine Creek National Wildlife Refuge that historically served as a maternity roost for 40 to 60 Rafinesque's big-eared bats. (Photo by Alison McCartney)

Sherman (2004) examined artificial roosts used by Rafinesque's big-eared bats on St. Catherine Creek NWR and vicinity in southwestern Mississippi. Big-eared bats were observed using seven abandoned buildings, three of which were confirmed maternity colonies. Three of the sites were in bottomland hardwood swamp forest, two in upland mixed hardwood forest, and one in upland mixed hardwood-pine forest (McCartney 2007). The primary structure was a multilevel abandoned house that was historically a maternity roost containing 40 to 60 bats (fig. 3). This population declined substantially in the 1990s as the building deteriorated. The house contained 50 individuals in May 2002 (McCartney 2007). However, concrete culvert towers designed to mimic hollow trees were later installed on the refuge, and 70 big-eared bats were observed using the roosts in July 2007 (fig. 4). We observed another large maternity colony in 2008 in an abandoned house on private property in Clay County with numbers of bats ranging from 75 to 90. The MBWG attempted unsuccessfully to obtain permission to adopt the house and make minor structural improvements to ensure protection of the roost in 2007, but the request was declined by the property owner. The large colonies in abandoned buildings in Lafayette and Jefferson Counties likely represent maternity roosts but data on these sites are incomplete. We visited the Jefferson County site on May 21, 2010 and counted 147 big-eared bats in what appeared to be a maternity colony (fig. 5). However, no pups were present at that time and we were not able to return later to verify it as a maternity roost.

Figure 4—Concrete culvert tower roost installed on St. Catherine Creek National Wildlife Refuge. Seventy big-eared bats were observed using three of the structures in July 2007. (Photo by Alison McCartney)

Figure 5—Abandoned building in Jefferson County, MS, recently discovered as a roost site for > 150 Rafinesque's big-eared bats. (Photo by Chester Martin)

Winter Roosts

Winter roosts of big-eared bats in Mississippi are relatively unknown. Searches on Noxubee NWR revealed only a few large, old bald cypress trees that were used as winter roosts (Stevenson 2008). We observed about 200 wintering big-eared bats in a tree on Noxubee NWR in 2009. Several bridges checked by Trousdale (2008) on DeSoto NF were used as roosts by bats in torpor during winter. Big-eared bats hibernate in cisterns and wells in the northern part of their range (Harvey and Saugey 2001, Harvey and others 1999), but only limited surveys of these structures have been conducted in Mississippi. We observed clusters of 12 to 25 individuals during November through January 2001 to 2004 in a dilapidated well adjacent to an abandoned house in Claiborne County. We also observed big-eared bats during winter in a partially covered well in Winston County. Big-eared bats were not observed in any of 10 cisterns surveyed in southwestern Mississippi (McCartney 2007, Sherman 2004). However, big-eared bats have been documented from cisterns in other States (Harvey and Saugey 2001) and potentially occur in these structures in Mississippi. Single individuals were observed occasionally during winter in houses on St. Catherine Creek NWR in 2002 to 2003, and one big-eared bat was in a culvert on private land adjacent to the refuge in February 2003 (Sherman 2004). As previously noted, Rafinesque's big-eared bats have been observed hibernating in an abandoned concrete structure in northcentral Mississippi (fig. 6).

MANAGEMENT

Most management efforts for Rafinesque's big-eared bats in Mississippi have focused on provision and improvement of artificial roosts. In 2002, an alternative bat house with a shed design was constructed by personnel of St. Catherine Creek NWR near the original known primary roost site.

Figure 6—Cluster of Rafinesque's big-eared bats hibernating in a concrete structure in northcentral Mississippi. (Photo by Barry Moss)

This structure was not accepted by the bats as a roost site, so three additional roosts constructed of triple-stacked circular concrete culvert blocks were erected near the site in 2004. All three of the roosts have been occupied by big-eared bats and two appear to have served as alternative maternity roosts (McCartney 2007). Artificial roosts installed on DeSoto NF include 4 cinder block structures, 4 tall wooden roosts, and 18 plastic culvert roosts. To date, only solitary occurrences of big-eared bats have been observed in the cinder block roosts, and none have been observed in the wooden or plastic roosts. However, most of the structures have not been checked consistently since their construction (see footnote 3). Also, the U.S. Army Corps of Engineers at Sardis Lake project office has developed plans to construct a cinder block tower roost near the abandoned seismograph building in Lafayette County. The building is showing signs of decay and the proposed structure is intended to provide an alternate roost site for big-eared bats. The U.S. Fish and Wildlife Service is experimenting with a variety of designs on Noxubee NWR. A structure recently installed on the refuge consists of a 9.1-m tall by 76.2-cm diameter steel culvert with a wooden top and a 76.2- by 122-cm opening at the bottom, which is used during spring and autumn by 1 to 12 big-eared bats.

Although bridge roosting populations have been documented in several regions of Mississippi, few attempts have been made to protect these sites except on some Federal lands. The two bridges occupied by big-eared bats on Camp Shelby JFTC have been identified as protected sites, and one of the bridges recently was rebuilt using the "Choctaw style," a modification of the concrete girder T-beam design. Additionally, the U.S. Forest Service has developed specifications for replacement of bridges on secondary roads within the National Forests in Mississippi. The U.S. Forest Service and Mississippi Department of Transportation (MDOT) currently are collaborating on replacement guidelines for bridges using bat-friendly designs in southern Mississippi.

The U.S. Fish and Wildlife Service, in collaboration with Mississippi State University, has conducted studies of roosting habitat of big-eared bats and management needs in bottomland hardwood forests on Noxubee NWR (Stevenson 2008). About 650 randomly selected hollow trees were inspected during the study; it was determined that American beech and sweetgum have a high tendency to produce cavities, whereas this is not the case for oaks (Richardson 2007, Stevenson 2008). This research was used to provide recommendations for reforestation and silviculture that can be incorporated into land management practices for conserving big-eared bats and their habitat. Richardson (2007) also reported an experiment for increasing use of hollow trees without openings by cutting portals to allow access by bats to these chambers; this technique potentially provides an opportunity to increase naturally occurring roost sites where suitable trees are rare or when entrances are too small for big-eared bats.

An important aspect of big-eared bat management in Mississippi has been development of outreach programs. The MBWG was formed in 2001 with the primary goal of promoting conservation of bats in the State through research, habitat management, and education. MBWG includes an ad hoc committee on education and outreach, and members routinely make presentations to local groups and civic organizations. Information on big-eared bat conservation and management is generally included in these presentations. Additionally, updates on big-eared bat research and management efforts are included in presentations at the MBWG annual meeting and professional conferences.

CONSERVATION NEEDS

A major threat to populations of Rafinesque's big-eared bats in Mississippi is loss of habitat, especially mature forest stands used for roosting. The documented association of big-eared bats with mature bottomland forest (Clark 1990, Cochran 1999, Gooding and Langford 2004, Lance and others 2001, Rice 2009) suggests that declines of this forest type have negatively affected the species. Historical records indicate that in the Mississippi Alluvial Valley (MAV) approximately 78 percent of forested wetlands (mostly bottomland hardwoods) had been converted to other land uses by the mid-1970s (MacDonald and others 1979), and bottomland hardwoods along the lower Mississippi River were being cleared for agriculture in tracts as large as 12,000 ha during the 1980s (Gosselink and Lee 1989). By the mid-1980s, the MAV forested landscape had been reduced to a highly fragmented 20 percent of its historical extent (Haynes 2004, Wilson and others 2007). Currently, about 19 percent of Mississippi's forest land is composed of bottomland hardwoods, and forested area in the Mississippi Delta has increased by 12 percent since 1994 (King and others 2006, Oswalt and others 2009). Additionally recent Natural Resource Conservation Service (NRCS) data shows that, under the Wetland Reserve Program (WRP), there are 68,623 ha of land under WRP contract in Mississippi, including 52,672 ha restored to bottomland hardwoods (Miller and others 2011). However, forests containing large-diameter trees suitable as Rafinesque's big-eared bat roost sites likely will not be available for decades since Rafinesque's big-eared bats appear to prefer to roost in large (> 50 cm d.b.h.) trees within bottomland hardwood forests (Stevenson 2008, Trousdale 2011). Significant populations of big-eared bats also have been documented from upland mixed forests, and males have been found foraging in sapling-stage pines (Menzel and others 2001). It is worthwhile to note that three of the four largest known roost sites in Mississippi are located in abandoned buildings in upland pine forests. Thus, other forest types

may also be important, and further work is needed to fully understand habitat needs for this species.

Conservation of natural roosts is critical for conservation efforts to be effective. Hollow, large-diameter trees often are rare on the landscape due to management practices and natural events, e.g., tornadoes and hurricanes. For example, 14 percent of live trees in Mississippi's southern forest survey unit experienced wind-related damage during Hurricane Katrina in 2005 (Oswalt and others 2009). These included mature hardwood trees blown down on DeSoto NF and Camp Shelby, some of which had been documented previously as roosts. Therefore, known and potential roost trees should be protected, and forest management prescriptions should ensure a future supply of large trees, especially in lowland areas near water (fig. 7). Efforts should consider retention of bald cypress, water tupelo, blackgum, sweetgum, American beech, southern magnolia, and American sycamore which have the propensity to develop cavities used by big-eared bats.

Additional surveys are needed to locate natural roosts and roosts in artificial structures. Although extensive studies have been conducted on national forests (DeSoto and Delta), national wildlife refuges (St. Catherine Creek, Noxubee, and Theodore Roosevelt), U.S. Department of Defense installations (Camp Shelby, Camp McCain, NAS Meridian), one national park (Vicksburg National Military Park), and several State wildlife management areas in the Pascagoula River Basin, many areas of the State have never been surveyed. Also, traditional surveys have not proven suitable for determining roost habitat by big-eared bats, and few studies, except those conducted on DeSoto NF (Trousdale and Beckett 2004, 2005; Trousdale and others 2008), have attempted to locate roosts using radiotelemetry. There is also a need to conduct studies of foraging habitat in different areas of the State. Further, an apparent continuum of populations along the Loess Hills corridor in western Mississippi needs to be more extensively surveyed. Little information is available on ecology of Rafinesque's big-eared bats in winter, except for the study by Rice (2009) in bottomland hardwoods of northeastern Louisiana. Similar studies need to be conducted in Mississippi to provide information useful to identify forest management practices that benefit big-eared bats.

Management should include identification and protection of natural and artificial roosts. Roost switching has been well documented in Rafinesque's big-eared bats (Gooding and Langford 2004, Lance and others 2001, Trousdale and Beckett 2005), and populations use a combination of natural and artificial roost sites. Trousdale and others

Figure 7—Forest management prescriptions in Mississippi should ensure a future supply of large trees that have the propensity to develop cavities used by Rafines que's big-eared bats. Preferred species include bald cypress, water tupelo, blackgum, American beech, southern magnolia, sweetgum, and American sycamore. (Photo by Candice Stevenson)

(2008) also demonstrated that roost fidelity of a population of big-eared bats in southeastern Mississippi varied with habitat type and recommended that conservation and roost monitoring programs include this flexibility with regard to potential movements among roosts within relatively short periods. Lance and others (2001) determined that amount of mature forest surrounding a bridge was a primary factor in determining occupancy by big-eared bats. Use of bridges may also be associated with tendency of the species to switch roosts frequently with bridges, abandoned buildings, and hollow trees serving as alternate roosts (Trousdale and Beckett 2004). Roosting in bridges may also result from limited availability of natural roosts. Bridges commonly were used by big-eared bats on the DeSoto NF where suitable roost trees were deficient (Trousdale and Beckett 2005) and in an area dominated by recently harvested forest stands along Bayou Pierre and its tributaries in westcentral Mississippi (Wolters and Martin 2000, 2011). Conversely, big-eared bats were never observed using bridges in more naturally forested areas with extensive stands of mature hardwoods in Noxubee NWR, Theodore Roosevelt NWR, and at sites along the Pascagoula River.

The largest maternity colonies documented in Mississippi occur in abandoned structures on private lands. These sites degrade through time and ultimately become unsuitable as roosting habitat. Wooden structures especially are subject to degradation and collapse, and remote buildings often are vandalized. A worthwhile effort would be to obtain permission to protect and stabilize important roost sites. However, landowners may be suspicious of actions that in their view cede control over their property to government agencies or conservation organizations, as was the case with the house in Clay County. Nevertheless, more effective interaction is needed among conservation organizations and private landowners regarding protection and management of bat habitat, especially as most (78 percent) Mississippi timberlands are privately owned (Oswalt and others 2009) and given that Miller and others (2011) calculated that there currently are approximately 19,900 ha of potential big-eared bat roosting habitat in Mississippi, with most potential suitable habitat (12,600 ha) on private land. There needs to be greater involvement with organizations such as Bat Conservation International when developing projects to protect roosts. Additionally, there needs to be more effective coordination with State offices and MDOT regarding protection of bridge roosting sites and use of bat-friendly designs when new bridges are constructed. Finally, both Federal and State agencies should acknowledge the need to protect and manage Rafinesque's big-eared bats by providing funding for research and habitat management. Conservation of the species ultimately will be tied to landscape-level management of forests.

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