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Bats of the Savannah River Site and Vicinity

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W. Mark Ford, Timothy C. Carter, and John W. Edwards

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Cover photos:

Clockwise from top left: big brown bats (photo by John MacGregor); Rafinesque's big-eared bat (photo by John MacGregor); eastern red bat (photo by John MacGregor); and eastern red bat (photo by Julie Roberge).

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Abstract

The U.S. Department of Energy's Savannah River Site supports a diverse bat community. Nine species occur there regularly, including the eastern pipistrelle (*Pipistrellus subflavus*), southeastern myotis (*Myotis austroriparius*), evening bat (*Nycticeius humeralis*), Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), silver-haired bat (*Lasionycteris noctivagans*), eastern red bat (*Lasiurus borealis*), Seminole bat (*L. seminolus*), hoary bat (*L. cinereus*), and big brown bat (*Eptesicus fuscus*). There are extralimital capture records for two additional species: little brown bat (*M. lucifigus*) and northern yellow bat (*Lasiurus intermedius*). Acoustical sampling has documented the presence of Brazilian free-tailed bats (*Tadarida brasiliensis*), but none has been captured. Among those species common to the Site, the southeastern myotis and Rafinesque's big-eared bat are listed in South Carolina as threatened and endangered, respectively. The presence of those two species, and a growing concern for the conservation of forest-dwelling bats, led to extensive and focused research on the Savannah River Site between 1996 and 2002. Summarizing this and other bat research, we provide species accounts that discuss morphology and distribution, roosting and foraging behaviors, home range characteristics, habitat relations, and reproductive biology. We also present information on conservation needs and rabies issues; and, finally, identification keys that may be useful wherever the bat species we describe are found.

Keywords: Bats, foraging, habitat use, rabies, roosting, Savannah River Site.

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Introduction

The Savannah River Site supports a diverse bat community. Nine species occur there regularly. Another three may use the Site occasionally. These three, the northern yellow bat (*Lasiurus intermedius* Allen), little brown bat (*Myotis lucifugus* LeConte), and Brazilian free-tailed bat (*Tadarida brasiliensis* I. Geof. St.-Hilaire), have been documented on the Site but probably occur there only occasionally.

Relative to other mammalian orders, the size of these 12 species varies little. Total body length ranges from 84 mm to 132 mm, and wing length ranges from 98 mm to 183 mm (see tables 1 and 2 and tables accompanying each species account). In terms of mass, the largest bat known to occur on the Site, the hoary bat (*Lasiurus cinereus* Beauvois), is only four times larger than the smallest bat found there, the eastern pipistrelle (*Pipistrellus subflavus* F. Cuvier) (table 1). By comparison, the largest rodent there, the beaver (*Castor canadensis* Kuhl), is 200 times larger than the smallest rodent, the eastern harvest mouse (*Reithrodontomys humulis* Audubon and Bachman), and the largest carnivore, the black bear (*Ursus americanus* Palla), is more than 900 times larger than the smallest carnivore, the long-tailed weasel (*Mustela frenata* Lichtenstein) (Cothran and others 1991).

Distributions of most temperate zone bats are strongly influenced by the availability of roost structures (Findley 1993, Humphrey 1975). The roosting habits of bats in South Carolina are diverse (table 3), resulting in variations in the diversity of bat communities across the State. The least diverse bat community occurs in the Piedmont (6 species), whereas the most diverse occur in the Blue Ridge and lower Coastal Plain (12 species) (Menzel and others 2003). Nine of the fourteen species that occur in South Carolina (Menzel and others 2003) typically roost in caves or mines during

Table 1—Comparison of average mass, total length, and forearm length of bats of the Savannah River Site

Species	Mass	Total length	Forearm
	g	mm	
Eastern pipistrelle	5.4 fg	83.6 h	34.3 g
Southeastern myotis	5.7 efg	86.6 gh	37.1 fg
Little brown bat	6.5 defg	87.4 gh	37.0 fg
Evening bat	8.0 cdefg	86.8 gh	36.2 fg
Rafinesque's big-eared bat	8.6 cdef	96.1 ef	43.4 cd
Silver-haired bat	9.3 cde	99.5 def	41.6 de
Eastern red bat	10.0 cd	101.8 de	39.5 ef
Seminole bat	10.1 c	103.9 d	41.5 de
Northern yellow bat	20.0 a	127.6 b	51.7 b
Hoary bat	21.2 a	132.5 a	55.2 a
Big brown bat	15.3 b	111.6 c	45.9 c
Brazilian free-tailed bat[a]	11.5 c	93.1 fg	43.4 cd

Means followed by the same letter within a column are not significantly different ($P \leq 0.05$).
[a] Although the Brazilian free-tailed bat has not been captured on the Savannah River Site, it is likely this species occasionally occurs onsite.

Table 2—Average body mass, wing length, wing-aspect ratio index, and wing-loading index of bats of the Savannah River Site

Species	Mass	Wing length	Wing-aspect ratio index[a]	Wing loading index[b]
	g	*mm*		
Eastern pipistrelle	5.4	97.7	2.27	1.28
Southeastern myotis	5.7	115.0	2.30	0.99
Little brown bat	6.5	107.7	2.23	1.26
Evening bat	8.0	114.0	2.43	1.49
Rafinesque's big-eared bat	8.6	127.0	2.27	1.21
Silver-haired bat	9.3	128.3	2.57	1.45
Eastern red bat	10.0	138.0	2.64	1.39
Seminole bat	10.1	138.3	2.66	1.59
Northern yellow bat	20.0	158.3	2.58	2.06
Hoary bat	21.2	183.0	2.94	1.88
Big brown bat	15.3	138.3	2.47	1.97
Brazilian free-tailed bat[c]	11.5	133.0	3.05	2.02

[a] Wing length/length of fifth phalyx; higher numbers indicate longer, narrower wings.
[b] [Mass/(wing length x length of fifth phalyx)] x 1,000; higher numbers indicate higher body mass per unit of wing area.
[c] Although the Brazilian free-tailed bat has not been captured on the Savannah River Site, it is likely this species occasionally occurs onsite.

Table 3—Typical roosting habitats of the 14 species of bats that occur in South Carolina

Species	Foliage	Bark/ cavity	Artificial structure	Cave/ mine	Rock crevices
Eastern pipistrelle	S	S	S	WS	
Southeastern myotis		S	S	WS	
Little brown bat		S	S	WS	
Small-footed myotis[a]			S	W	S
Northern long-eared myotis[a]		S	WS	W	
Evening bat	S	S	S		
Rafinesque's big-eared bat		WS	WS	WS	
Silver-haired bat		WS	W	W	S
Eastern red bat	WS				
Seminole bat	WS				
Northern yellow bat	WS				
Hoary bat	WS				
Big brown bat		WS	WS	WS	
Brazilian free-tailed bat[a]		WS	WS	WS	

W = winter roost; S = summer roost.
[a] Species that have not been captured on Savannah River Site.

part of the year (table 3). Three species roost in mines or caves, but only during the winter (table 3). In addition to suitable foliage and cavity roost sites, the Blue Ridge also contains mines and crevices in vertical rock faces, resulting in the greatest diversity of roost structures in the State. Thus diversity in the bat community on the Savannah River Site may be somewhat limited simply by its physiographic position.

In the last 10 years many studies have focused on the distribution and natural history of bats in the Southeastern United States. Over half the total published literature about the natural history of bats in South Carolina and Georgia was published in that period, and research has proceeded as fast in other Southeastern States. Although many aspects of their behavior and natural history in the Southeast remain poorly understood, much is known about bat species' roosting requirements, foraging behavior, diet, home range, and reproduction. Making land management decisions without regard for the effects they may have on bat communities no longer can be justified by claims that too little is known about habitat requirements of this diverse mammalian order.

Many recent studies of bat habitat requirements were conducted on the Site. Similar studies elsewhere in the Southeast also provided useful information about the natural history of bats known to occur there. This report summarizes information about the distribution, roosting ecology, foraging behavior, diet, home range, and reproduction of bats that occur on and near the Site. Information contained herein should aid land managers in assessing how their management decisions may affect bat species.

Major Vegetation Types of the Savannah River Site

The Savannah River Site is a former nuclear weapons material production facility operated by the U.S. Department of Energy (DOE). It borders the Savannah River in west-central South Carolina in the upper Coastal Plain physiographic province and occupies 78 000 ha (fig. 1). It is located in parts of Aiken, Barnwell, and Allendale Counties. When the DOE acquired the land in 1950, about 33 percent of it was cropland or pasture, and the remainder was forested (see Workman and McLeod 1990 for a detailed description of vegetation communities). In 1952 the USDA Forest Service began managing timber on the Site, and 20 years later it was designated the Nation's first National Environmental Research Park (Workman and McLeod 1990). The Site has a temperate climate characterized by mild winters and long summers with average air temperatures of 9 and 27 °C, respectively (Workman and McLeod 1990). The frost-free period lasts roughly 240 days, and the average annual rainfall is 120 cm. Most rain falls in March (13.1 cm) and the least in November (5.9 cm) (Workman and McLeod 1990).

Using Workman and McLeod (1990) and Imm and McLeod (in press), we identified seven major vegetation types on the Site (fig. 2). These include loblolly-slash pine (*Pinus taeda* L., *P. elliottii* Engelm.) (32 461 ha), longleaf pine (*P. palustris* Mill.) (17 008 ha), mixed pine-hardwood (4569 ha), upland hardwood (2738 ha), and bottomland hardwood (16 462 ha) forests; lakes/ponds/marshes (1672 ha), and grass-brush (5214 ha).

Pine forests dominate the Savannah River Site landscape, and pine canopies there tend to be dominated by a single species. Because of their age and management on the Site, longleaf pine stands tend to have lower densities and

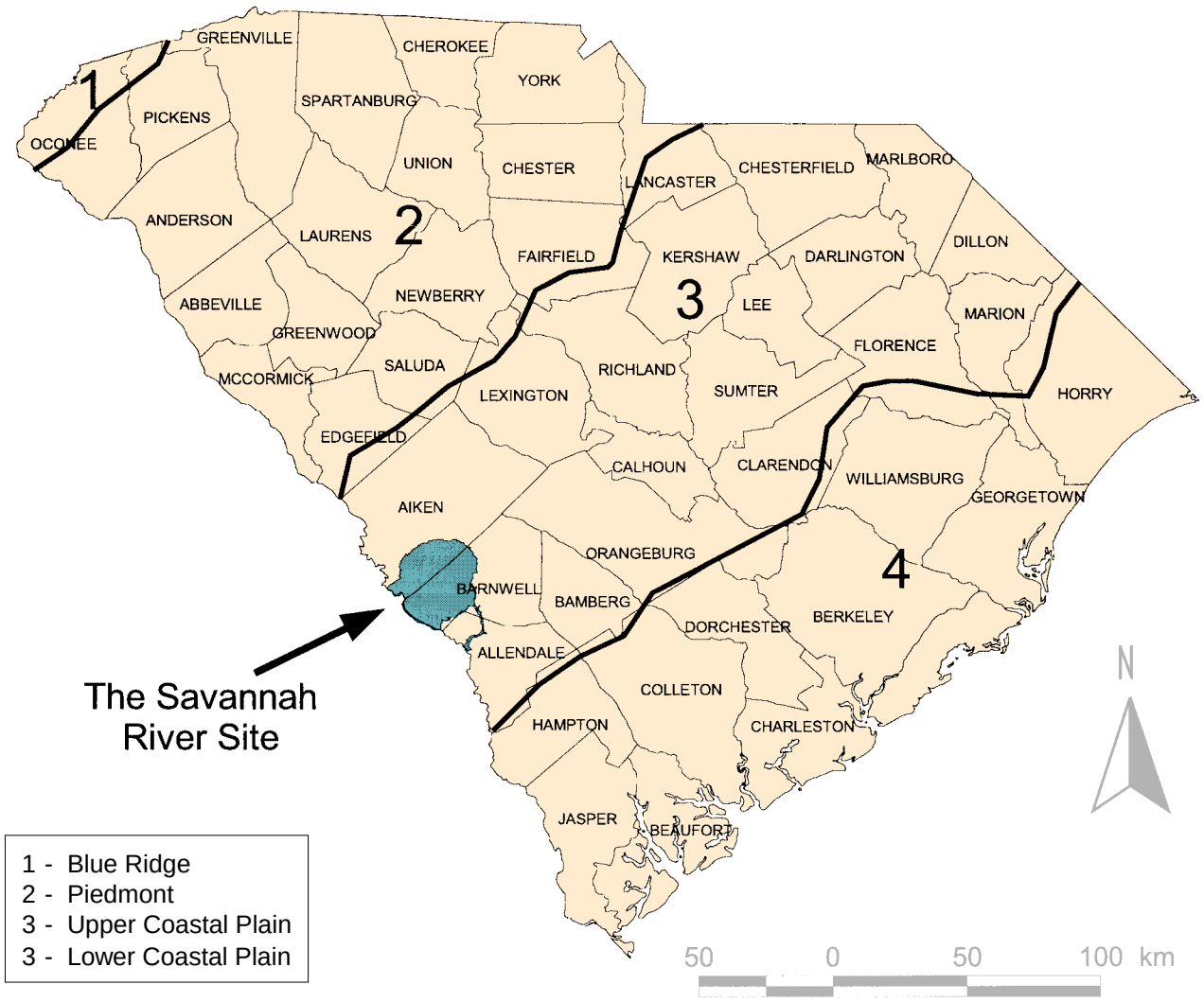


Figure 1—Location of South Carolina's four physiographic provinces and the Savannah River Site.

basal areas than loblolly and slash pine forests. Because vegetation density is a primary factor affecting bat foraging activity (Owen and others, in press), we treated longleaf forest separately (fig. 2). Both forest types are managed for timber production on the Site within the constraints of red-cockaded woodpecker (*Picoides borealis* Vieillot) habitat management guidelines.[1] See Blake (in press) for a detailed discussion of forest management practices there. Although the rotation length for pines there is relatively long for managed forests in the Southeast (50 to 120 years), many age classes are found in the region. Clearcut harvesting is used to convert slash pine to species better suited for site-specific conditions, i.e., longleaf, loblolly pine. Young pine plantations constitute most early successional habitat on the Site. Managers there use prescribed fire on a 3- to 5-year rotation to treat areas of pine forest.

Mixed pine-hardwood forests occupy much of the Savannah River Site, ranging from the dry and infertile sandhills, which are remnant beach dunes from the Cretaceous shoreline, to moist, rich bottomland sites, which are subject to periodic inundation. Tree species occurring in sandhill communities include longleaf pine, turkey oak (*Quercus laevis* Walt.), scrub post oak (*Q. margaretta* Sarg.), bluejack oak (*Q. incana* Bartr.), blackjack oak (*Q. marilandica* Muenchh.), blackgum (*Nyssa sylvatica* Marsh.), sand hickory [*Carya pallida* (Ashe) Engl. & Graebn.], mockernut hickory [*C. tomentosa* (Poir.) Nutt.], sassafras [*Sassafras albidum* (Nutt.) Nees], and sparkleberry (*Vaccinium arboreum* Marsh.) (Workman and McLeod 1990). On more mesic upland and bottomland sites, loblolly pine forms mixed stands with the hardwood species typical of such sites.

Upland hardwood communities on the Site are dominated by oaks and hickories and are located on the flats of the Aiken Plateau, on stream bluffs,

[1] Edwards, J.W.; Smathers, W.M., Jr.; Lemaster, E.T.; Jarvis, W.L. 2000. Savannah River Site red-cockaded woodpecker management plan. 66 p. On file with: USDA Forest Service-Savannah River, P.O. Box 700, New Ellenton, SC 29809.

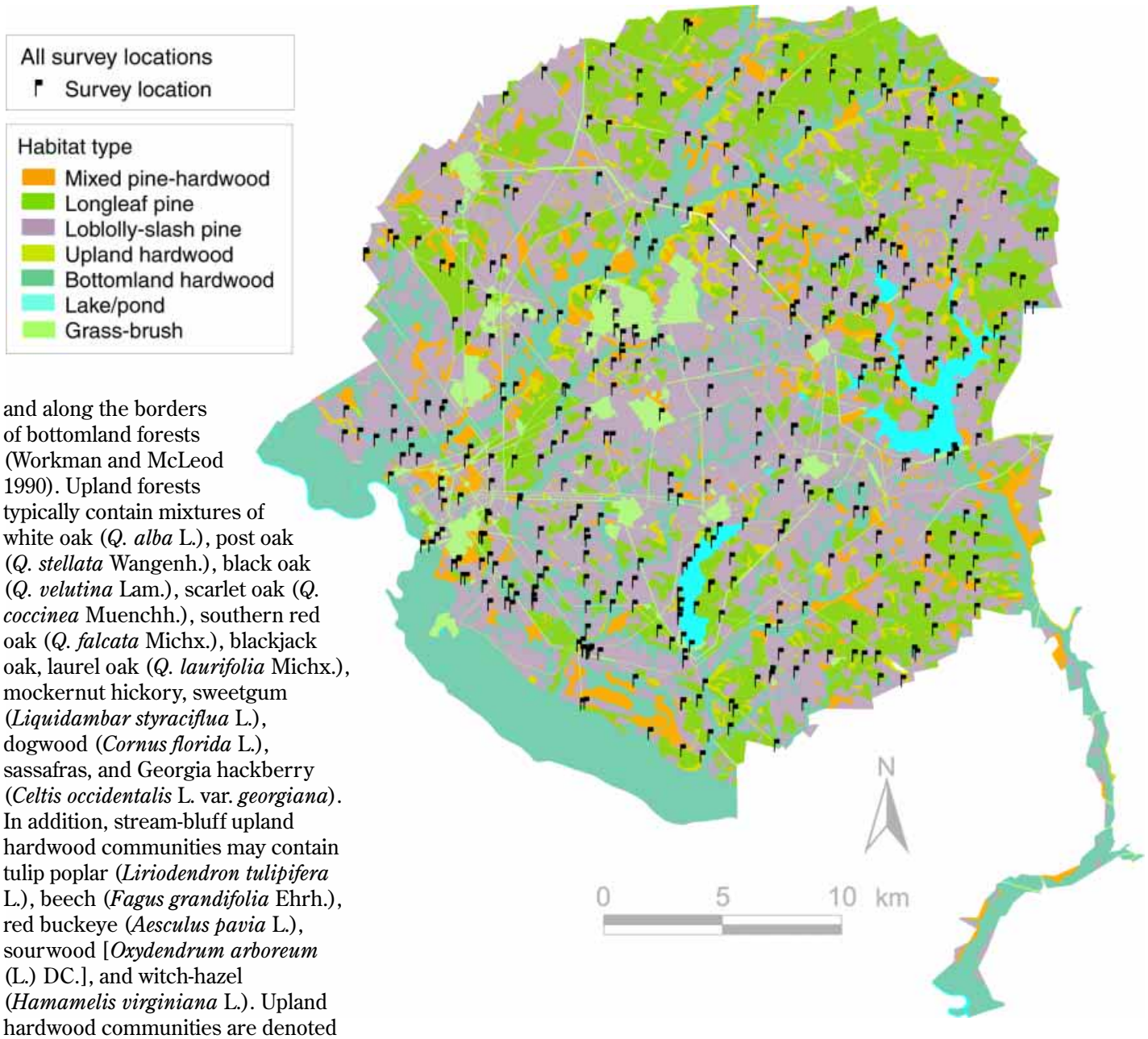


Figure 2—The 449 locations where AnaBat surveys were conducted during summer 2001, and the distribution of 7 habitat types across the Savannah River Site.

and along the borders of bottomland forests (Workman and McLeod 1990). Upland forests typically contain mixtures of white oak (*Q. alba* L.), post oak (*Q. stellata* Wangenh.), black oak (*Q. velutina* Lam.), scarlet oak (*Q. coccinea* Muenchh.), southern red oak (*Q. falcata* Michx.), blackjack oak, laurel oak (*Q. laurifolia* Michx.), mockernut hickory, sweetgum (*Liquidambar styraciflua* L.), dogwood (*Cornus florida* L.), sassafras, and Georgia hackberry (*Celtis occidentalis* L. var. *georgiana*). In addition, stream-bluff upland hardwood communities may contain tulip poplar (*Liriodendron tulipifera* L.), beech (*Fagus grandifolia* Ehrh.), red buckeye (*Aesculus pavia* L.), sourwood [*Oxydendrum arboreum* (L.) DC.], and witch-hazel (*Hamamelis virginiana* L.). Upland hardwood communities are denoted as upland hardwoods on the forest habitat maps included in each species account (fig. 2).

Bottomland hardwood forests on the Site are typical of the mesic mixed-hardwood forests of the southeastern Coastal Plain (Workman and McLeod 1990). Bottomland hardwood communities occur in the lowlands at elevations between 25 and 90 m and commonly are flooded during high-water periods in late winter and early spring (Workman and McLeod 1990). Most hardwoods on the Site were selectively harvested in the late 1800s and early 1900s. They remained relatively undisturbed during the last three-quarters of the 20th century (Workman and McLeod 1990). Common tree species in the bottomland forests include sweetgum, red maple (*Acer rubrum* L.), swamp chestnut oak (*Q. michauxii* Nutt.), cherrybark oak (*Q. falcata* var. *pagodifolia* Ell.), water oak (*Q. nigra* L.), laurel oak, willow oak (*Q. phellos* L.), overcup oak (*Q. lyrata* Walt.), green ash (*Fraxinus pennsylvanica* Marsh.), and blackgum. Because the structure of most swamp forests on the Site—occurring primarily along the Savannah River (Whipple and others 1981)—is similar to the structure found in bottomland hardwood forests, we displayed them as bottomland hardwoods on the forest habitat maps included with each species (fig. 2), and we otherwise included them with bottomland hardwood communities. Swamp forests occur at elevations between 25 and 35 m and commonly are inundated during a portion of the year (Workman and McLeod 1990). Approximately half of the swamp

forests on the Site are second-growth bald cypress [*Taxodium distichum* (L.) Rich. var. *distichum*])-water tupelo (*N. aquatica* L.) swamp, and the other half is composed of ridges and hardwood islands (Jensen and others 1984). Common tree species in swamp forest areas include bald cypress, water tupelo, water ash (*F. caroliniana* Mill.), green ash, American elm (*Ulmus americana* L.), and sycamore (*Platanus occidentalis* L.).

Most of the acreage in lakes, ponds, and marshes is in the reservoirs of Par Pond and L Lake, which the DOE constructed for use in cooling reactor. Although not extensive, an important habitat included in this category is Carolina bays. Carolina bays are natural shallow elliptically shaped wetlands whose depths range from zero to a few meters (Schalles and others 1989). Although they occur from Florida to Virginia, most Carolina bays are in North and South Carolina. Typically they are oriented northwest to southeast. Approximately 500,000 Carolina bays occur on the Coastal Plain, and about 300 are on the Savannah River Site (Kirkman and others 1996). Most Carolina bays are surrounded by upland pine-mixed hardwood forest. Bat activity commonly is concentrated over the wetland habitat that Carolina bays provide, because overstory vegetation is sparse and aquatic insects congregate around them (Menzel and others 2003). Because Carolina bays are small and occur in patchy distribution across the landscape, it is hard to map the patterns of bat activity relative to them (see figure 3 for the location of Carolina bays). To simplify the forest-habitat maps included with each species account, we did not identify Carolina bays, although we did include them in the figures that compare bat activity levels among the habitat types.

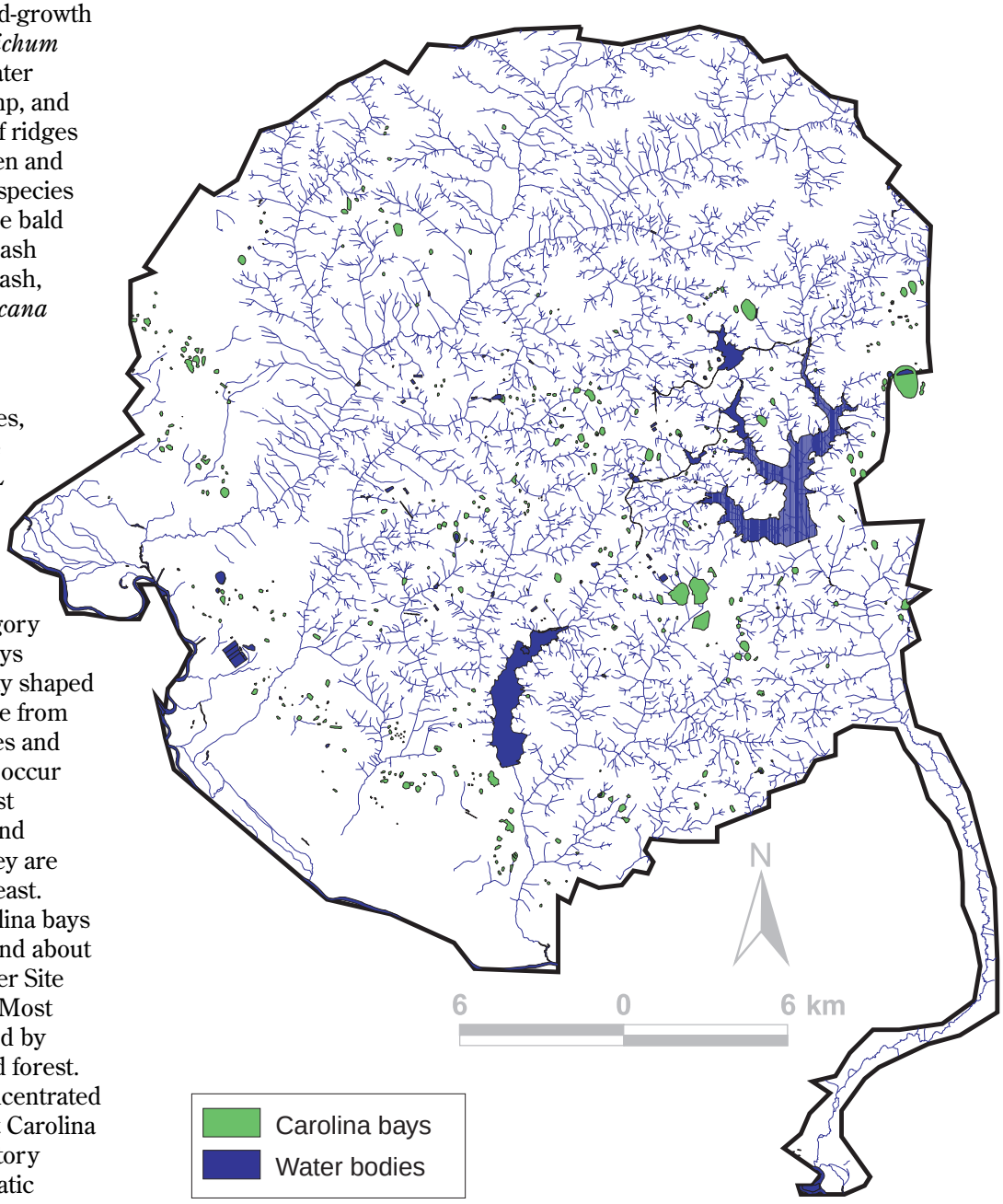


Figure 3—Location of streams and Carolina bays on the Savannah River Site.

Grass-brush habitats include roads, railroad and utility rights-of-way, and lawns around the Site's facilities areas. The facilities themselves are shown on the vegetation maps. Such grassy areas constitute the only permanently maintained early successional habitat on the Site. Typically, the rights-of-way are dominated by a mix of broomsedge (*Andropogon* spp.), blackberry (*Rubus* spp.), Japanese honeysuckle (*Lonicera japonica*), and various grasses.

Because of their importance to foraging bats, we delineated separately the sampling points located within canopy gaps (regardless of vegetation type) and included them on maps displaying the Carolina bays and seven vegetation types.

The Sitewide Bat Survey

In preparing the species accounts, we relied heavily on a survey conducted during summer 2001. In that survey we sampled 449 points across the Site, covering areas representative of most site habitats (fig. 2). We conducted the surveys between sunset and 02:30 from late May to early August 2001 [see Menzel (2003) for a detailed description of the methods]. At each sampling point, we censused bat activity for 20 minutes using an AnaBat II bat detection system (Titley Electronics, Ltd., Ballina, New South Wales, Australia) (Murray and others 2001). We identified calls using both qualitative and quantitative techniques (Menzel 1998, O'Farrell and others 1999) and a call library, which we created by recording the calls of hand-released bats captured in the Southeast. Figures 4 and 5 are illustrations generated using AnaLook software (4.8i), and they represent typical search phase calls of the nine bat species occurring regularly on or around the Site. Menzel (2003) was not able to discriminate between the calls of eastern red (*Lasiurus borealis*) and Seminole (*L. seminolus*) bats based on the calls recorded, so both species are included in a group termed "eastern red/Seminole bat." We determined the age and vegetation type of the stand around each survey point using 1985 Forest Inventory and Analysis data provided by the USDA Forest Service.

The following results are condensed from Menzel (2003). Trends in bat activity were relatively consistent among habitat types. The activity level (number of calls per 20-minute survey) of the eastern red/Seminole bat group was highest, followed by eastern pipistrelles, evening bats, big brown and hoary bats, and southeastern myotis (in order of decreasing activity) (fig. 6). Because of the highly variable nature of bat activity across the Site, we found few differences in the levels of activity among species within each habitat type (table 4). Overall, we

Table 4—Comparison of flight activity (number of calls per 20-minute survey) among 6 bat species in 10 habitat types on the Savannah River Site during summer 2001

Habitat type	Survey locations	Eastern red/ Seminole bats		Eastern pipistrelles		Evening bats		Big brown bats		Hoary bats		Southeastern myotis			
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	*F*	*P*
	no.														
Lakes and ponds	16	3.3A	1.11	2.7AB	1.45	0.6BC	0.24	0.8BC	0.47	0.4BC	0.26	0.1C	0.09	2.93	0.017
Carolina bays	35	6.1A	2.25	0.8B	0.23	1.7B	0.61	0.5B	0.25	0.1B	0.06	0.4B	0.15	5.64	0.001
Bottomland hardwoods	66	4.0A	0.94	2.0AB	0.97	1.2B	0.50	0.6B	0.28	1.3B	1.20	0.4B	0.15	2.89	0.014
Forest gaps	38	3.5A	1.11	1.1B	0.56	0.6B	0.27	0.1B	0.09	0.0B	0.03	0.8B	0.29	5.74	0.001
Grass-brush	59	5.7A	1.69	2.1B	0.71	2.4B	1.05	0.8B	0.42	0.1B	0.07	0.1B	0.06	5.73	0.001
Upland hardwoods	11	2.0A	1.03	0.5B	0.45	0.5B	0.31	0.0B	0.	0.0B	0.	0.1B	0.09	2.56	0.036
Pine hardwoods	14	4.4A	1.72	0.6B	0.34	0.1B	0.10	0.1B	0.07	0.0B	0.	0.1B	0.14	5.83	0.001
Loblolly-slash pines	140	2.0A	0.41	0.5B	0.20	0.2B	0.06	0.1B	0.03	0.1B	0.03	0.4B	0.17	13.22	0.001
Longleaf pines	70	3.0A	0.96	0.3B	0.23	0.6B	0.17	0.2B	0.11	0.0B	0.03	0.1B	0.07	7.75	0.001

Means followed by the same letter within a column are not significantly different ($P \le 0.05$).

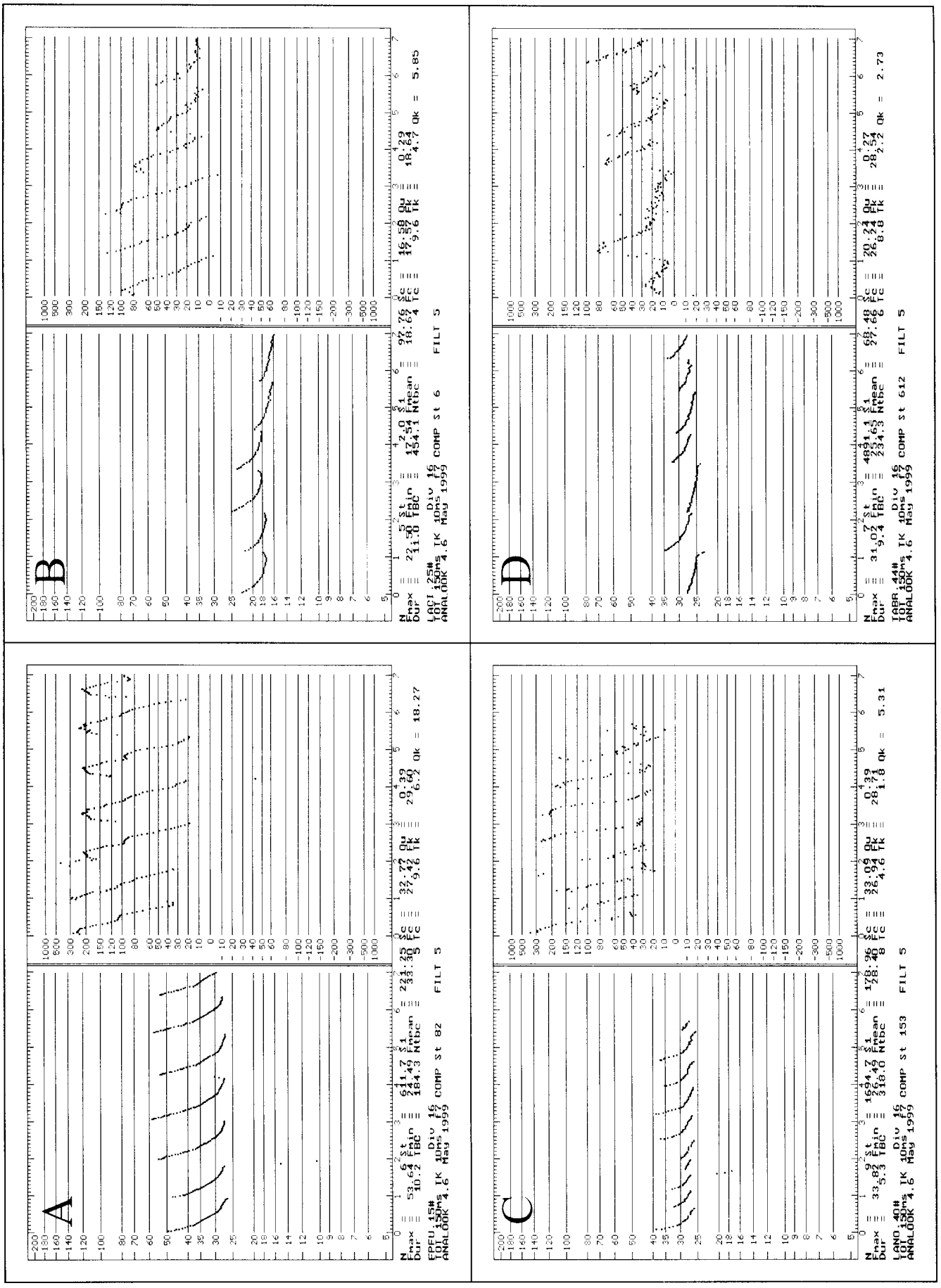


Figure 4—Illustrations generated using AnaLook software (4.8i) of typical search-phase calls of four low-frequency bat species that occur on or around the Savannah River Site: (A) big brown bat, (B) hoary bat, (C) silver-haired bat, and (D) Brazilian free-tailed bat.

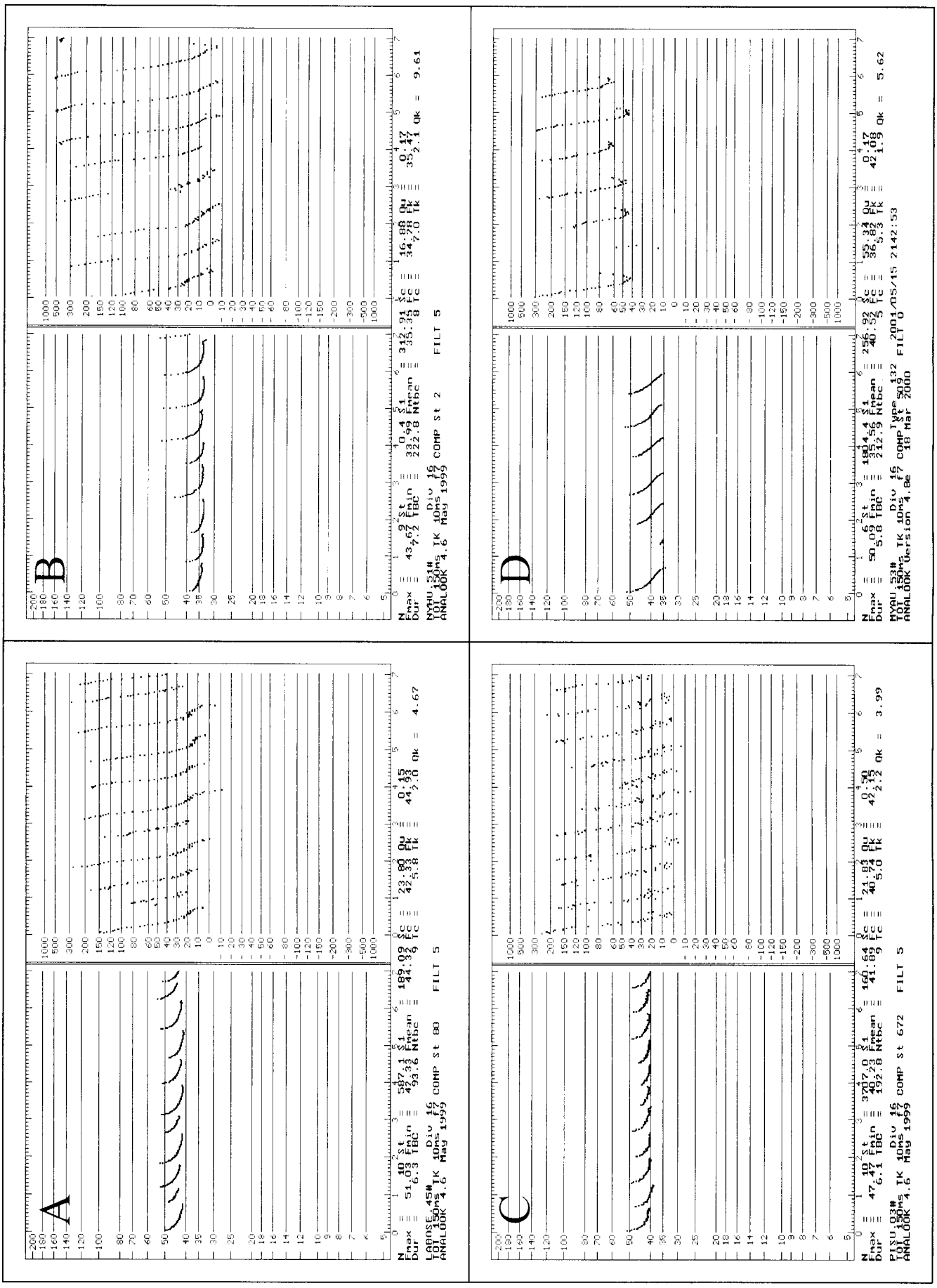


Figure 5—Illustrations generated using AnaLook software (4.8i) of typical search-phase calls of four high-frequency bat species that occur on or around the Savannah River Site: (A) eastern red/Seminole bat, (B) evening bat, (C) eastern pipistrelles, and (D) southeastern myotis.

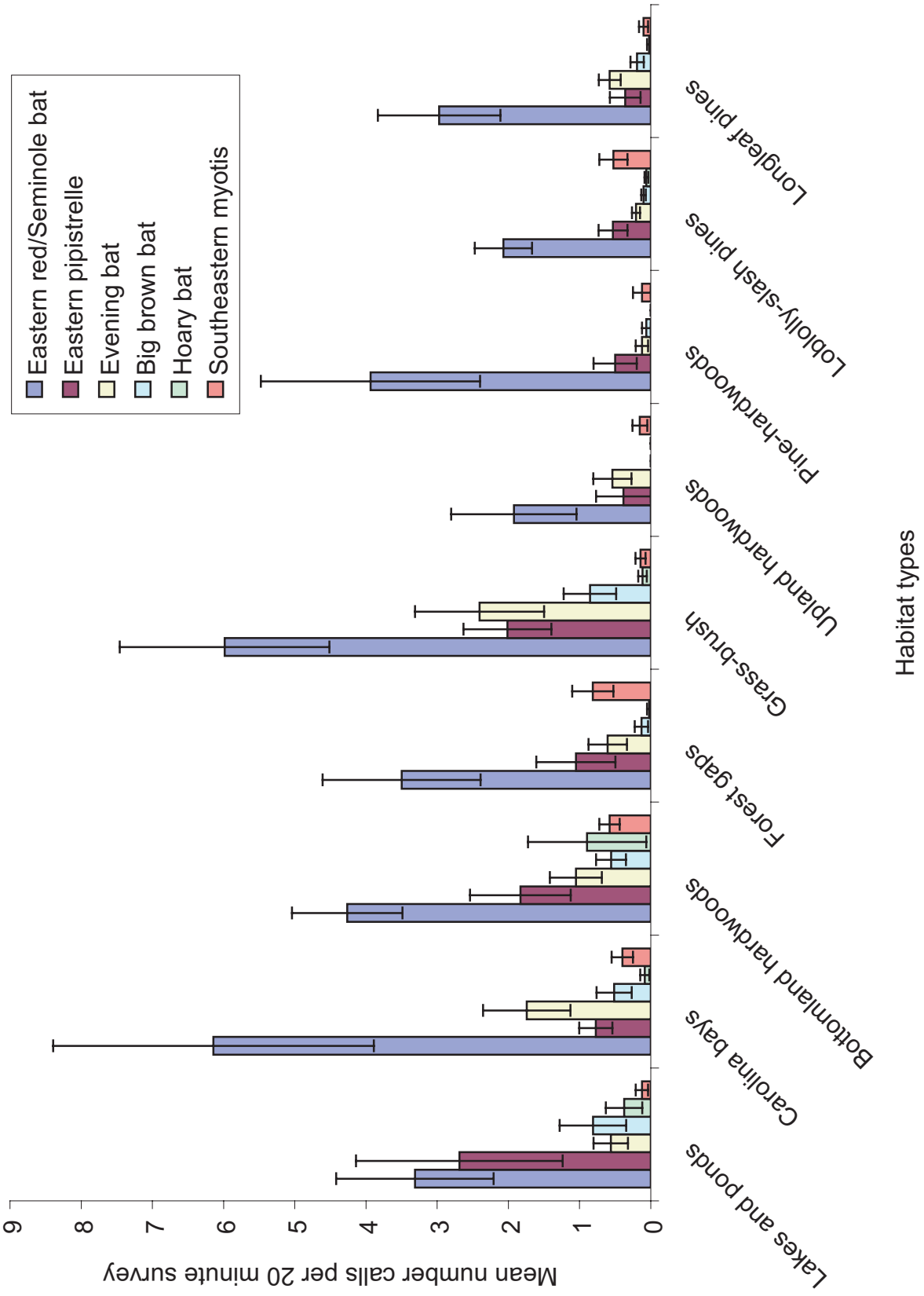


Figure 6—Effect of habitat type on the flight activity of six bat species on the Savannah River Site.

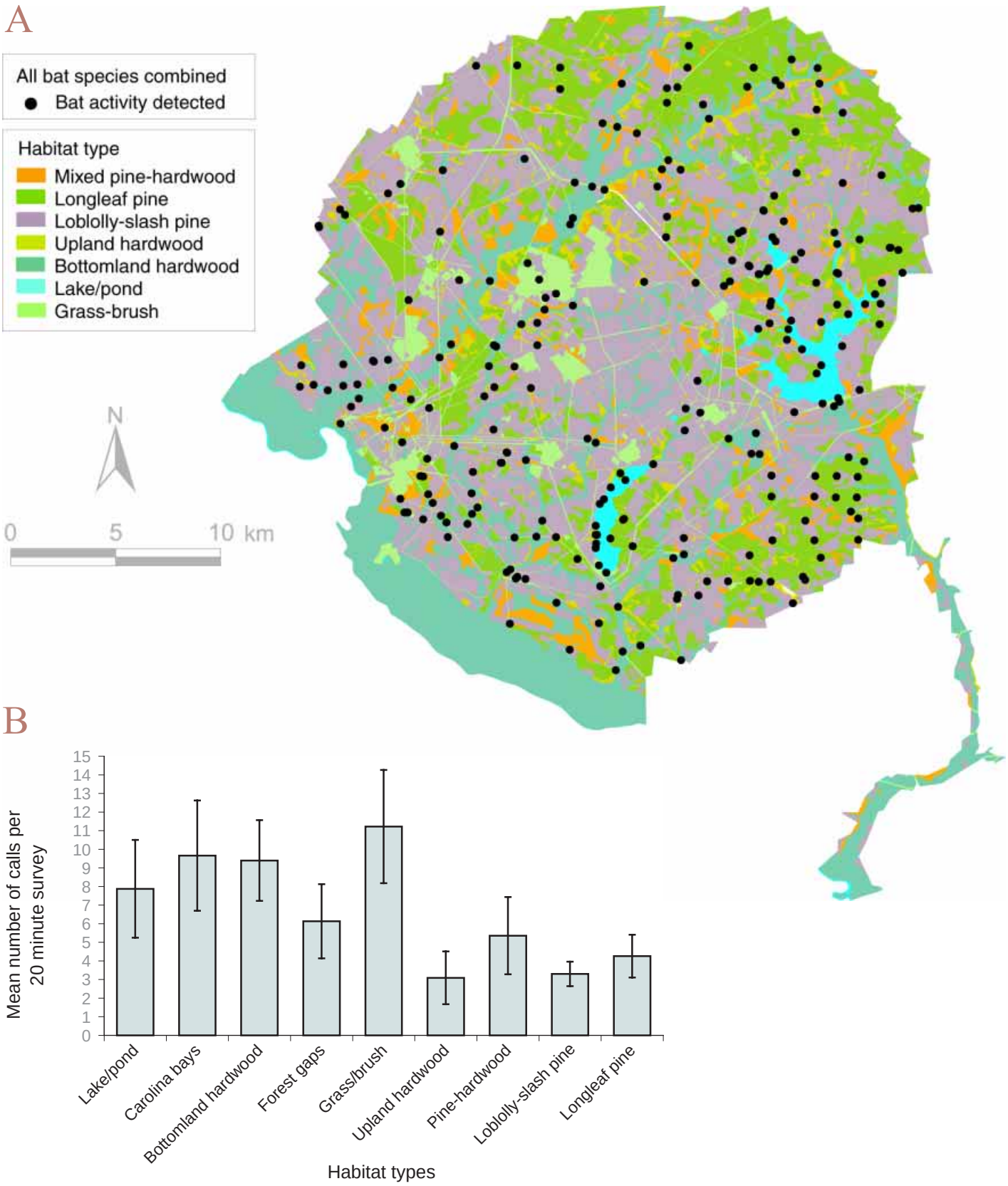


Figure 7—(A) AnaBat survey locations where bat activity was detected in surveys conducted during summer 2001 and (B) a comparison of bat flight activity among vegetation community types on the Savannah River Site.

detected bat activity on 87.5 percent of the lake and pond survey points, 80.0 percent of the Carolina bay survey points, 66.7 percent of the bottomland survey points, 71.1 percent of the forest gap survey locations, 74.6 percent of the grass-brush survey points, 63.6 percent of the upland hardwood points, 57.1 percent of the pine-hardwood points, 48.6 percent of the loblolly-slash survey points, and 58.6 percent of the longleaf survey locations. Sitewide, we recorded bat activity at 62.6 percent of all survey locations (fig. 7). For all species combined, activity was highest in grass-brush and bottomland hardwoods and over lakes, ponds, and Carolina bays. Levels of activity tended to be low in upland hardwood and pine-hardwood and on sites with pine-dominated canopies (fig. 7).

In all forest age classes except clearcut, bat activity levels also differed among the species (table 5). This trend was consistent among age classes other than clearcut. The level of activity of the eastern red/Seminole bat group was highest, followed by eastern pipistrelles, evening bats, big brown and hoary bats, and southeastern myotis (table 5). For all species combined, activity was highest in clearcuts, moderate in stands aged 4 to 20 years and > 60 years, and lowest in stands aged 21 to 60 years (fig. 8). This trend corresponds with the typical density of vegetation in stands in these age classes. In clearcuts, bat foraging activity is not impeded by forest clutter. The area above newly regenerating stands (4 to 20 years) provides excellent foraging habitat. Stands aged 21 to 60 years often are stocked so densely that there is little room for bats to forage. After stands reach > 60 years, their canopies begin to open—either through natural stand attrition or as a result of thinning treatments—and these openings provide foraging areas.

Table 5—Comparison of flight activity (number of calls per 20-minute survey) among six bat species in five stand-age classes on the Savannah River Site during summer 2001

Age class	Survey locations	Eastern red/ Seminole bats		Eastern pipistrelles		Evening bats		Big brown bats		Hoary bats		Southeastern myotis		*F*	*P*
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE		
	no.														
Clearcut	6	5.3	2.55	3.3	3.33	2.0	0.93	0.8	0.65	0.	0.	0.2	0.17	5.30	0.001
4–20	135	3.7A	0.84	1.3B	0.36	1.2B	0.47	0.5B	0.20	0.1B	0.04	0.3B	0.12	9.61	0.001
21–40	36	3.0A	1.04	0.4B	0.22	0.4B	0.21	0.1B	0.07	0.0B	0.03	1.0B	0.49	22.27	0.001
41–60	190	3.5A	0.63	0.5B	0.17	0.6B	0.14	0.2B	0.06	0.0B	0.02	0.2B	0.07	2.47	0.032
> 60	66	3.4A	0.70	1.7AB	0.94	1.1B	0.50	0.4B	0.24	1.3B	1.20	0.3B	0.15	1.37	0.264

Means followed by the same letter within a column are not significantly different ($P \leq 0.05$).

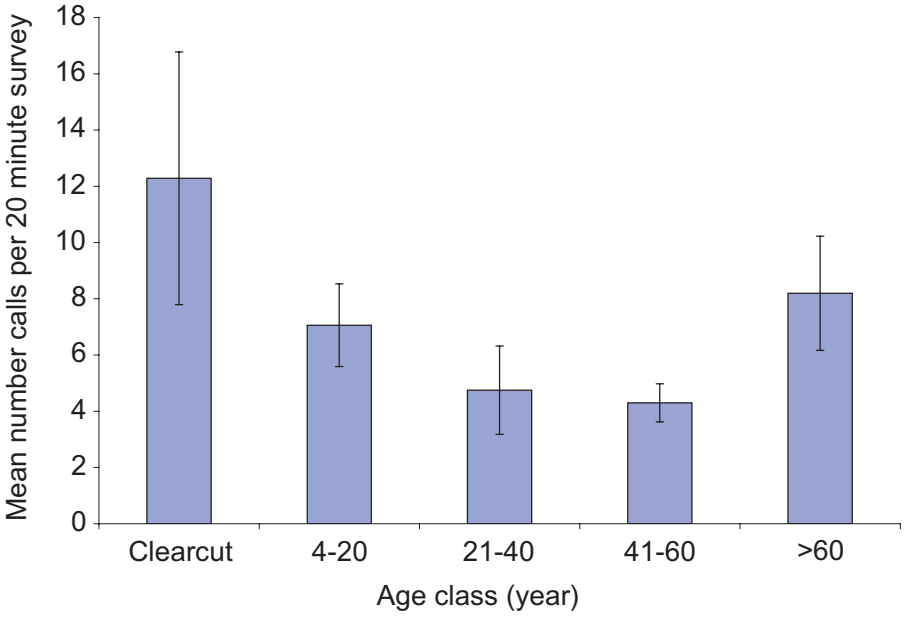


Figure 8—Effect of stand age on bat flight activity on the Savannah River Site.

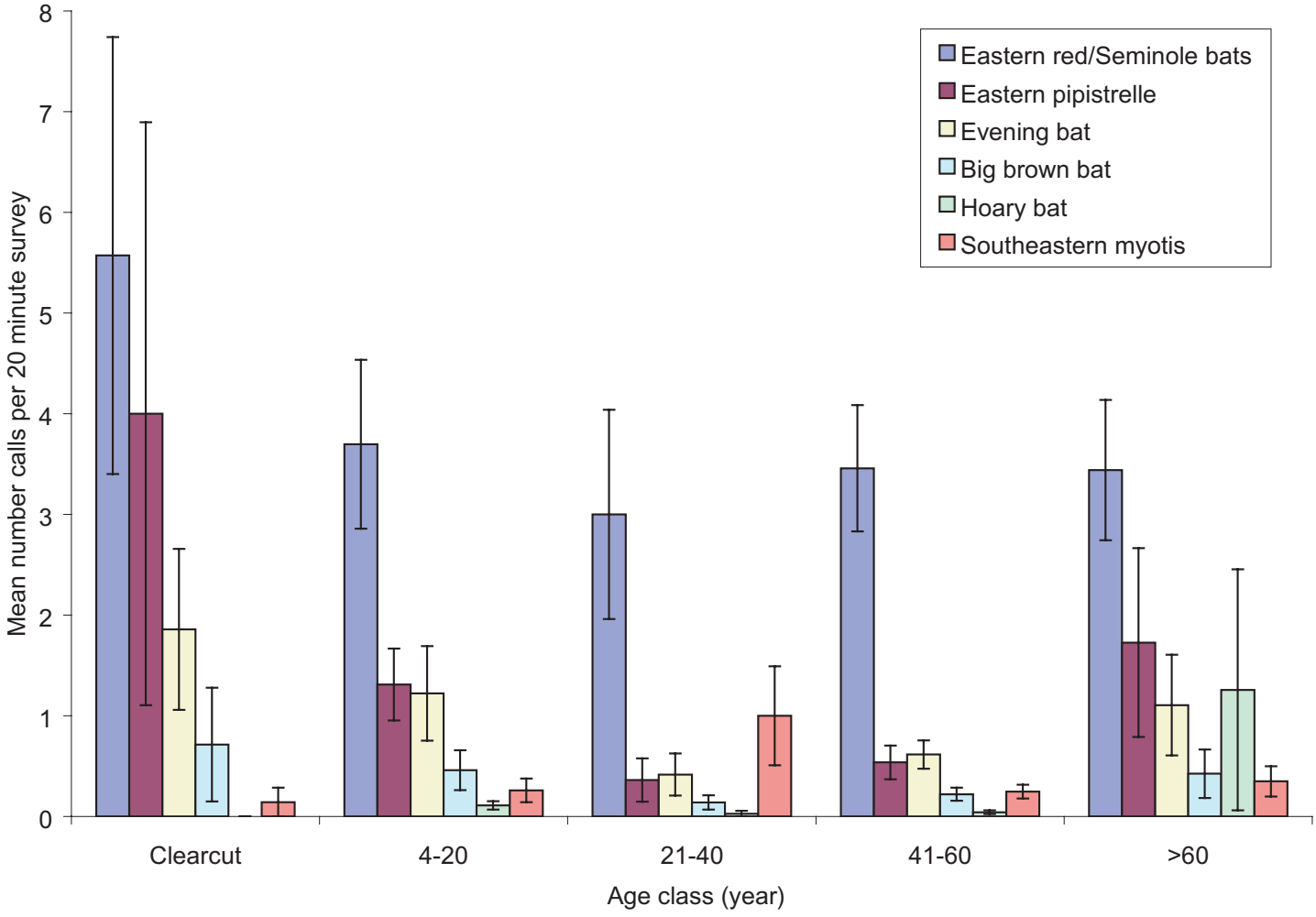


Figure 9—Effect of stand age on the flight activity of six bat species on the Savannah River Site.

The foraging activity patterns of two species did not correspond to the activity pattern of all species combined (fig. 9). Hoary bat activity was highest in stands aged > 60 years, and no hoary bat calls were detected in clearcuts (fig. 9). Southeastern myotis activity was highest in stands 21 to 40 years old and lowest in the youngest and oldest stands.

Accounts of Species

Species accounts are organized into two major sections, "Bats of the Savannah River Site" and "Bats of South Carolina in Areas Neighboring the Savannah River Site." Twelve bat species have been documented on the Site, but not all occur there regularly. To determine those species that do, we examined the range of each of the 14 bat species found in South Carolina (Menzel and others 2003), reviewed museum records for specimens captured on the Site itself, and reviewed capture records maintained for bat surveys taken there. In summarizing previous capture and collection records, we reviewed museum records listed in Menzel and others (2003) for specimens captured on the Site; recorded unpublished survey records from 1999 to 2001 for one of the authors;[2] recorded capture records reported by Carter (1998), Menzel (1998), and Childs and Buchler (cited in Cothran and others 1991); reviewed records maintained by public health personnel in South Carolina, as reported by DiSalvo and others (2002); and reviewed records maintained by the South Carolina Department of Natural Resources. Based on our review, some species captured on the Site probably do not occur there regularly and should be of little concern to Site managers, e.g., the northern yellow bat (*L. intermedius*) and the little brown bat (*M. lucifugus*). In addition, although the Brazilian free-tailed bat (*T. brasiliensis*) has not been captured, it has been detected on call surveys, so it occurs occasionally.

Within each species account, we tried to synthesize all information collected in South Carolina about roosting ecology, foraging behavior, diet, home range, and reproduction. We used information from published studies, faunal surveys of specific regions within the State (Cothran and others 1991, Golley 1966, Penney 1950, Sanders 1978), unpublished master's theses (Carter 1998, Menzel 1998), and unpublished museum records. Because aspects of the natural history of some bat species found on the Site have not been studied anywhere in South Carolina, we supplemented information in each species account with information collected from other regions. Where information collected from other regions was used, we noted it in the individual species accounts.

In each species account, we included the following subsections—Morphology and Distribution, Roosting, Foraging and Home Range, Effect of Stand Age and Habitat Type on Flight Activity, and Reproduction. Morphology and Distribution describes the species' general physical characteristics, subspecies that occur on the Site, and species distribution. That section includes a picture of the species and a table providing its average body measurements. Data provided in the body measurement table were collected from specimens captured or collected in the Southeast (primarily Georgia). If the average body measurements differed significantly (t-test, alpha < 0.05) between males and females, we provided a separate table for each sex. Each Morphology and Distribution section references a map illustrating distribution of the species in South Carolina, adapted from Menzel and others (2003).

The Roosting section includes information about a species' summer and winter roosting habits. Information about the general roosting habits of each species also is provided. In addition, specific information concerning roosting habits in South Carolina or on the Site is provided for seven of the nine bat species that regularly occur on-site.

The Foraging and Home Range section includes information about emergence time, foraging habitats, specific foraging characteristics, e.g., foraging height, whether the species has ever been documented foraging in groups, and diet. When data were available, we included information about selective foraging. Also where available, we included information about the spatial attributes and size of the species' home range. We defined home range as the spatial extent an individual traveled during 3 to 15 nights. All reported home ranges were based on > 25 telemetry points and most were based on > 30 points.

In each species account, we discuss habitat types on the Site in which a species' foraging activity was concentrated and the habitat types it seemed to use less. This information is based largely on the sitewide surveys conducted during summer 2001. We used survey data to prepare maps showing the general distribution of each species' foraging activity across the Site. We also prepared figures for each species or species group, i.e., eastern red/Seminole bat, that show the average level of call activity in each vegetation type.

We conclude each account with a brief discussion of the species' reproductive habits. Because little work has been done with regard to bat reproductive habits in South Carolina, most of this information came from studies conducted in other regions of the United States. Information included in this section includes the time of year mating occurs, whether delayed fertilization occurs, when the young are born, and the average number of young per litter.

[2] Menzel, M.A. Unpublished data. On file with: West Virginia University, Division of Forestry, Percival Hall, Morgantown, WV 26506.

Bats of the Savannah River Site

Family Vespertilionidae

Vespertilionidae is the largest family of bats, consisting of 42 genera and 355 species (Nowak 1994). Family distribution is cosmopolitan, and members are found on every continent except Antarctica. Its members are found in habitats ranging from desert to tropical forest. Because members of this group lack noseleafs and have simple, unmodified lips and nostrils, they are commonly called the plain-faced bats. The tragus usually is well developed, and the tail is not free from the uropatagium.

Nine genera and thirty-one species of vespertilionids occur in the United States. Of these, 8 genera and 13 species occur in South Carolina. All nine bat species that commonly occur on the Savannah River Site are members of the family Vespertilionidae.

Eastern pipistrelle (*Pipistrellus subflavus*)

Morphology and Distribution

The eastern pipistrelle is the second smallest bat found in South Carolina and the smallest bat on the Site (fig. 10). One of four recognized subspecies, *P. s. subflavus,* occurs in the State (Fujita and Kunz 1984). Mass ranges from 3.3 to 8.0 g, and average total length is 85.1 mm (Whitaker and Hamilton 1998). See table 6 for average body measurements of individuals collected in the Southeast.

The eastern pipistrelle is common throughout much of the eastern half of North and Central America. In the United States, its range extends west from Maine to Minnesota and south through much of east Texas (Fujita and Kunz 1984). Thirty-nine eastern pipistrelles from South Carolina are preserved in collections, and 23 have been live-captured in the State (Menzel and others 2003). The eastern pipistrelle occurs in all of South Carolina's physiographic provinces and is common throughout the State (fig. 11) (Menzel and others 2003).

Photo courtesy of John MacGregor

Figure 10—Eastern pipistrelle.

Eastern pipistrelles were captured in late June and late August during survey work conducted by Childs and Buchler in 1979 (Anon. 1980, Cothran and others 1991). Between 1996 and 2001, we captured one female and five male eastern pipistrelles on the Site (table 7). Based on the regional distribution of this species, it is likely that while it is not abundant on the Site, the eastern pipistrelle is a common resident there.

Roosting

Eastern pipistrelle hibernacula have been found in culverts (Moore 1949), storm sewers (Goehring 1954), tunnels (Mohr 1942), caves (Davis 1966, Hahn

1908, Raesly and Gates 1987, Swanson and Evans 1936), and mines (Menzel and others 1997, Sealander and Heidt 1990, Whitaker and Rissler 1992). No studies have quantitatively examined its winter roosting habits in South Carolina, although Golley (1966) collected a male eastern pipistrelle roosting under a house in Berkeley County, SC, during the winter. Golley (1966) also found a large colony of eastern pipistrelles roosting in caves near Parler in Orangeburg County, SC, during the winter and spring. The winter roosting habits of this species on the Savannah River Site are unknown.

The eastern pipistrelle's summer roosting habits also are poorly known. Maternity roosts usually are found in human-made structures such as barns (Lane 1946, Poole 1938) or houses (Allen 1921). Menzel and others (1996) captured a female and her nonvolant young in a pitfall trap set near a basal cavity in a large sweetgum, which suggests that basal cavities may serve as maternity roosts for the species. A few individuals also have been found roosting in tree canopies (Findley 1954) and Spanish moss (*Tillandsia usneoides*) during the summer (Jennings 1958, Menzel and others 1999). In summer 1997, Carter and others (1999b) located an eastern pipistrelle roosting in swamp chestnut oak, sweetgum, and laurel oak in a bottomland hardwood stand on the Site.

Table 6—Body measurements of the eastern pipistrelle bat in the Southeastern United States

Measurement	Number[a]	Mean	SD	CV	Range
			mm		
Female					
Total	15	86.3	5.96	6.90	77.0 – 99.0
Tail	15	39.0	3.16	8.11	34.0 – 45.0
Foot	15	7.8	1.21	15.48	6.0 – 10.0
Ear	15	12.8	1.56	12.16	10.0 – 14.5
Tragus	14	4.7	1.37	28.98	3.5 – 7.5
Forearm	15	34.6	1.12	3.24	33.0 – 36.0
			g		
Mass	14	5.7	1.03	18.06	4.3 – 8.0
			mm		
Male					
Total	26	82.1	5.74	6.99	71.0 – 95.0
Tail	26	36.9	2.95	7.98	30.0 – 41.0
Foot	26	8.3	1.28	15.47	6.5 – 11.0
Ear	26	12.5	1.09	8.71	10.5 – 14.0
Tragus	22	4.7	1.48	31.12	3.0 – 8.0
Forearm	24	34.2	1.96	5.75	30.0 – 39.0
			g		
Mass	24	5.2	1.16	22.50	3.3 – 8.0

Measures that differed significantly between the sexes ($P \leq 0.05$).
[a] Number of individuals measured.

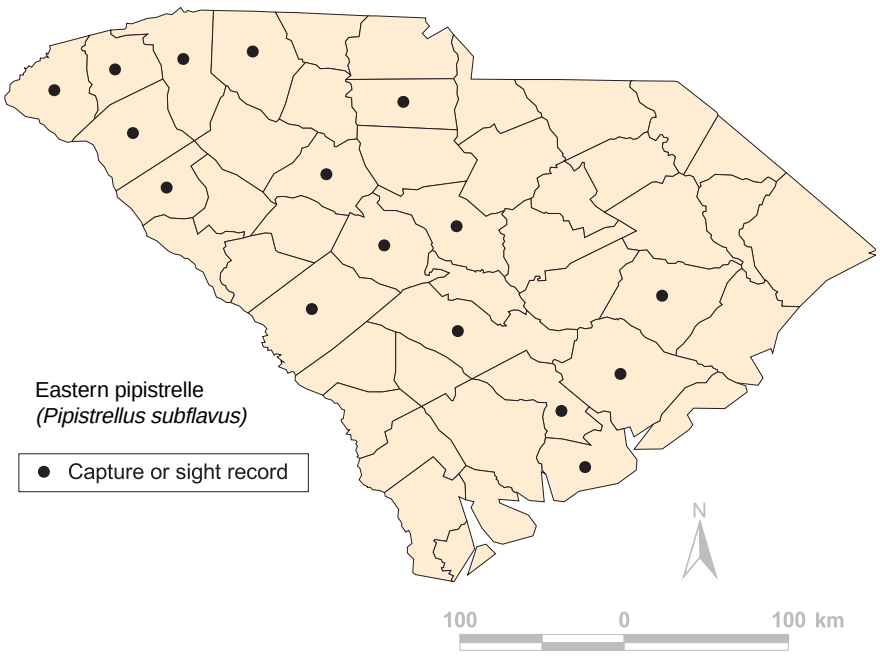


Figure 11—Distribution of the eastern pipistrelle in South Carolina (Menzel and others 2003). Symbols denote counties for which records exist.

Table 7—Number of bats captured on the Savannah River Site, 1996 to 2000

Species	Sex	Age	
		Adults	Juveniles
Eastern pipistrelle (n = 7)	F	1	0
	M	5	0
Southeastern myotis (n = 2)	F	0	0
	M	1	0
Little brown bat (n = 1)	F	1	0
	M	0	0
Evening bat (n = 67)	F	27	13
	M	21	6
Rafinesque's big-eared bat (n = 9)	F	7	0
	M	1	0
Eastern red bat (n = 56)	F	30	11
	M	8	5
Seminole bat (n = 22)	F	6	6
	M	7	3
Hoary bat (n = 3)	F	2	0
	M	0	0
Big brown bat (n = 6)	F	2	1
	M	3	0
Total (n = 173)	F	70	31
	M	52	14

n = total number captured (the difference between n and sum of age and sex data is because age and sex were not recorded for all individuals captured);
F = female; M = male.

Foraging and Home Range

Eastern pipistrelles commonly forage over waterways and along field edges (Fujita and Kunz 1984, Whitaker and Hamilton 1998). Harper (1927) found them foraging over fields and cypress bays and in pine barrens of the Okefenokee Swamp. On the Savannah River Site, Carter and others (1999b) documented foraging among bottomland hardwoods and in pine stands. Their diet includes insects in the orders Coleoptera, Homoptera, Diptera, Hymenoptera, and Lepidoptera (Ross 1961, Sherman 1939, Whitaker 1972). They also forage on trichopterans and hemipterans (Carter and others 1999b).

Little is known about this species' home range, although Krishon and others (1997) documented the home range of one eastern pipistrelle on Sapelo Island, GA. It was 389.2 ha and concentrated in high marsh (47 percent), oak (24 percent), and slash-loblolly pine (17 percent) habitats. The average distance from the roost area to a foraging location was 1137 m. Carter and others (1999b) documented an eastern pipistrelle's home range on the Site at 395.5 ha, concentrated in bottomland hardwood and upland pine stands.

Effect of Habitat Type and Stand Age on Flight Activity

We recorded eastern pipistrelles at 37.5 percent of the lake and pond survey points, 28.6 percent of the Carolina bay survey points, 18.2 percent of the bottomland hardwood survey points, 18.4 percent of the forest gap survey locations, 23.7 percent of the grass-brush survey points, 9.1 percent of the upland hardwood points, 21.4 percent of the pine-hardwood points, 12.1 percent of the loblolly-slash survey points, and 7.1 percent of the longleaf survey locations. Overall, we recorded the eastern pipistrelle's call at 16.7 percent of the survey locations (fig. 12). Although variable, its activity was greatest around lakes and ponds, bottomland hardwood forests, and grass-brush (fig. 12). In bottomland hardwoods, we recorded a call approximately every 10 minutes. The figures comparing bat activity among vegetation community types are arranged with hydric communities on the left, mesic communities in the center, and xeric communities on the right. Eastern pipistrelle activity was concentrated in hydric and mesic communities (table 4).

Eastern pipistrelle activity also differed among stands of different ages (fig. 9). We recorded most in clearcuts (fig. 9) or areas devoid of vegetation, e.g., roads, open water habitats (fig .12). We recorded moderate levels of activity in stands aged 4 to 20 years and > 60 years (fig. 9). The species' activity was low in stands 21 to 60 years old (table 5).

Reproduction

Eastern pipistrelles mate in autumn and spring (LaVal and LaVal 1980) and parturition occurs in May and June (Jennings 1958, LaVal and LaVal 1980). The sexes segregate into bachelor and maternity colonies in the spring. No information is available concerning the parturition times for this species in South Carolina, but on the Savannah River Site it probably occurs in May and June.

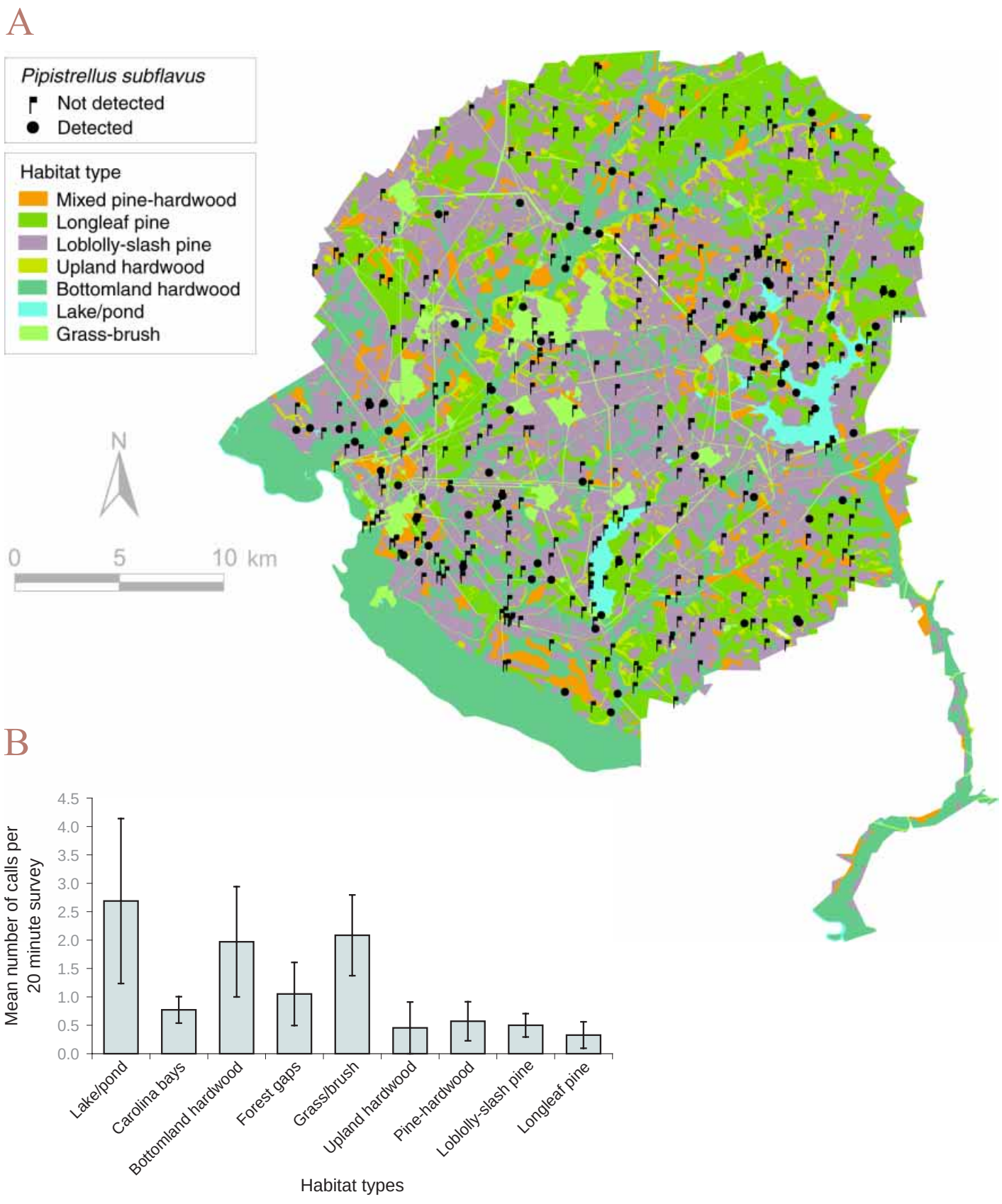


Figure 12—(A) AnaBat survey locations where eastern pipistrelles were detected in surveys conducted during summer 2001 and (B) a comparison of flight activity levels of eastern pipistrelles among vegetation community types on the Savannah River Site.

Photo courtesy of John MacGregor.

Figure 13—Southeastern myotis.

Southeastern myotis (*Myotis austroriparius*)

Morphology and Distribution

The southeastern myotis is a small brown bat with wooly pelage and a calcar that lacks a keel (fig. 13) (Jones and Manning 1989). Of the three subspecies of southeastern myotis now recognized, only *M. a. austroriparius* occurs in South Carolina (Hoffmeister 1989). The mass of the southeastern myotis ranges from 5 to 12 g, and total length averages 91.5 mm (Whitaker and Hamilton 1998). See table 8 for average body measurements of individuals collected in the Southeast.

The southeastern myotis' range extends from Louisiana and east Texas up the Mississippi Alluvial Valley into southern Indiana and Illinois, and east along the coast of Georgia and the Carolinas (Jones and Manning 1989). Four southeastern myotis from South Carolina are in museum collections, and 18 have been live-captured. Distribution in South Carolina is limited to the upper and lower Coastal Plain (fig. 14). Because of its rarity there, the State has listed the species as threatened (South Carolina Department of Natural Resources 2001) (table 9).

Only two southeastern myotis have been captured on the Site, one male and one sex undetermined, captured in 1997 and 2000, respectively (table 7). None was captured during the 1979 surveys. The Site is on the northern edge of the species' range, and although the two documented records

Table 8—Body measurements of the southeastern myotis bat in the Southeastern United States

Measurement	Number[a]	Mean	SD	CV	Range
		----------	*mm*	----------	
Total	14	86.6	5.24	6.05	77.0 – 95.0
Tail	14	36.9	2.14	5.81	34.0 – 42.0
Foot	14	9.6	1.08	11.22	7.0 – 11.0
Ear	14	13.9	0.53	3.86	13.0 – 15.0
Tragus	4	6.7	1.50	22.22	5.0 – 8.0
Forearm	14	37.1	1.98	5.34	32.0 – 40.0
		----------	*g*	----------	
Mass	12	5.7	0.79	13.91	4.3 – 7.0

[a] Number of individuals measured.

probably are not extralimital, it appears to be rare on the Site.

Roosting

Southeastern myotis roost in caves (Mumford and Whitaker 1982, Rice 1957), mines (Sealander 1979), trees (Lowery 1974, Sealander 1979), and buildings (Lowery 1974, Mumford and Whitaker 1982, Sealander 1979). Davis and Rippy (1968) banded a colony of 300 individuals roosting in a fertilizer plant in Georgia. Only Clark and others (1998) have investigated the roosting habits of southeastern myotis in South Carolina. Roosts were found in cavities of live tupelo gum trees in a closed-canopy forest on the Francis Beidler Forest (Clark and others 1998). Based on this information and the species' roosting habits in other areas of its range, we believe it probably roosts in tree cavities in bottomland hardwood and swamp forests on the Site.

Foraging and Home Range

Southeastern myotis typically forage near water (Barbour and Davis 1969). In the winter they prey on arthropods in the orders Coleoptera and Lepidoptera and in the family Culicidae (Zinn 1977). During the summer months they consume primarily Coleoptera and Lepidoptera (Zinn 1977). Clark and others (1998) surveyed too few foraging locations to determine home-range size, but all foraging points were in swamp forests. We know little about the size of the species' home range or habitat use on the Site. However, based on the known home range of other myotids with similar morphological characteristics, we surmise the southeastern myotis' home range is between 100 and 500 ha. Data collected during the 2001 AnaBat surveys suggest that foraging activity on the Site is concentrated in swamp forest bordering the Savannah River (fig. 15).

Effect of Habitat Type and Stand Age on Flight Activity

Southeastern myotis were recorded at 12.5 percent of the lake and pond survey points, 22.9 percent of the

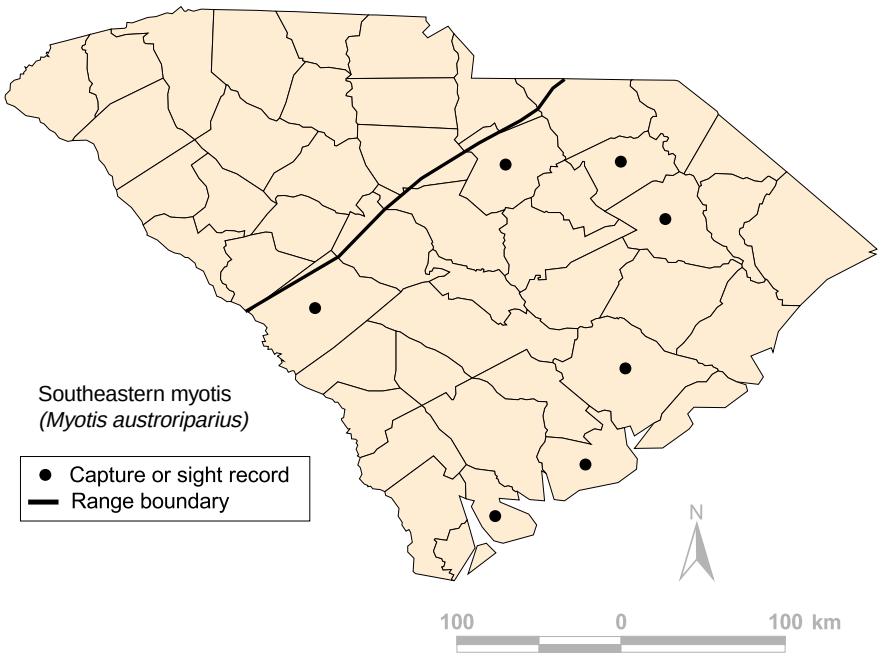


Figure 14—Distribution of the southeastern myotis in South Carolina (Menzel and others 2003). Symbols denote counties for which records exist. Typical summer distribution is south of the range line.

Table 9—Protection status of the bats of the Savannah River Site[a]

Species	South Carolina		
	State ranking	Protection status	Abundance
Eastern pipistrelle			Common
Southeastern myotis	S1	ST	Rare
Little brown myotis	S3	SC	Uncommon
Small-footed myotis[b]	S1	ST	Rare
Northern long-eared myotis[b]	S4	SC	Common
Evening bat			Common
Rafinesque's big-eared bat	S2	SE	Rare
Silver-haired bat			Uncommon
Eastern red bat			Common
Seminole bat			Common
Northern yellow bat	SU	SC	Rare
Hoary bat	SU	SC	Uncommon
Big brown bat			Common
Brazilian free-tailed bat[b]			Common

S1 = critically imperiled in State; S2 = imperiled in State; S3 = rare or uncommon; S4 = apparently secure in State; SU = status undetermined; ST = State threatened; SC = of concern, State; SE = State endangered.

[a] Only species of concern are assigned rankings and protection status.

[b] Species not captured on the Savannah River Site.

Source: South Carolina Department of Natural Resources (2001).

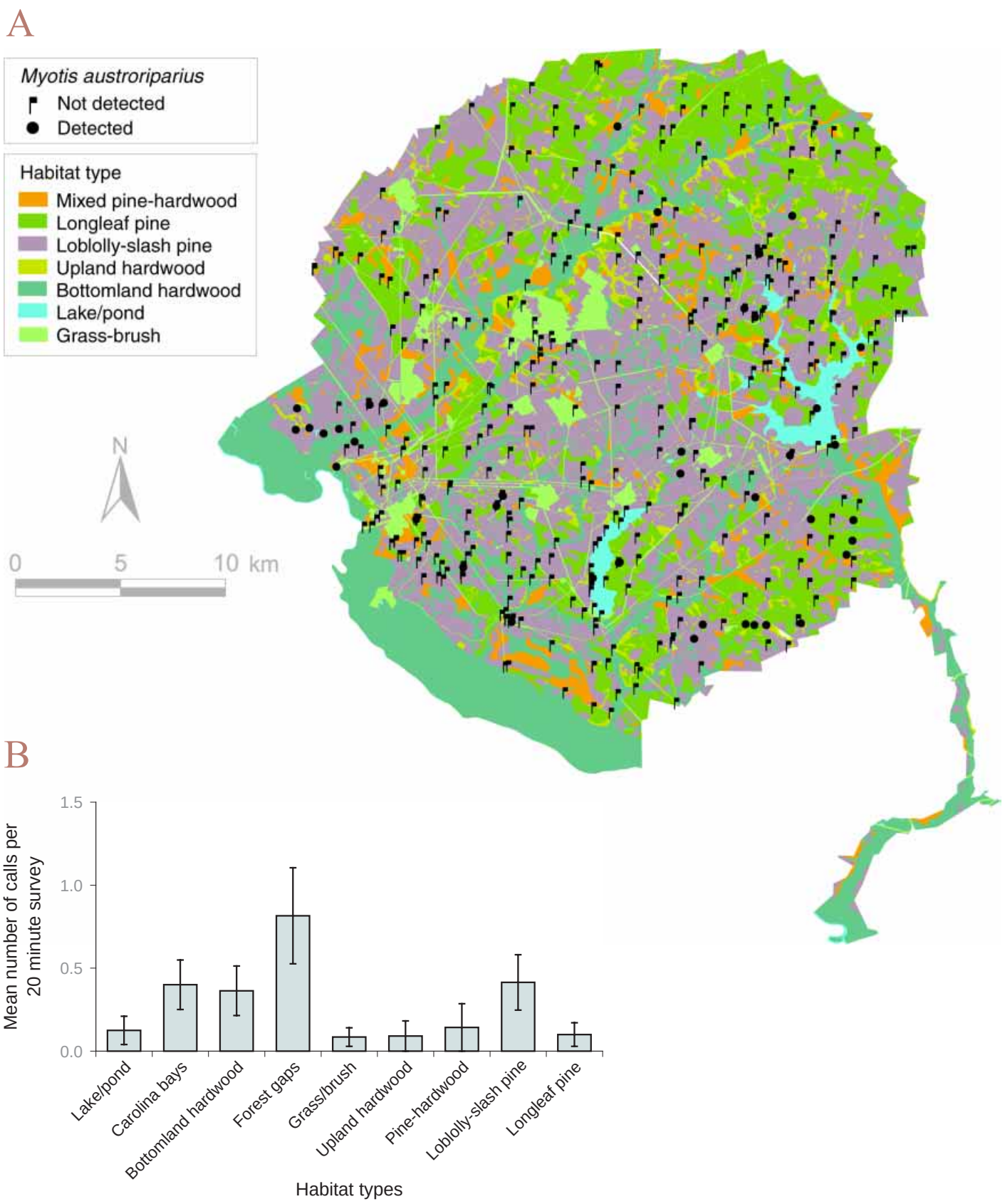


Figure 15—(A) AnaBat survey locations where southeastern myotis were detected in surveys conducted during summer 2001 and (B) a comparison of flight activity levels of southeastern myotis among vegetation community types on the Savannah River Site.

Photo courtesy of John MacGregor

Figure 16—Evening bat.

Carolina bay survey points, 13.6 percent of the bottomland hardwood survey points, 26.3 percent of the forest gap survey locations, 5.1 percent of the grass-brush survey points, 9.1 percent of the upland hardwood points, 7.1 percent of the pine-hardwood points, 7.1 percent of the loblolly-slash survey points, and 2.9 percent of the longleaf survey locations. Overall, we recorded this species at 10.2 percent of the survey locations (fig. 15). Its on-site foraging activity was low (table 4). The mean number of calls recorded was less than one per 20-minute survey in all habitat types (fig. 15). Activity was highest in Carolina bays, bottomland hardwood forests, and forest gaps; and the survey points where southeastern myotis were detected were concentrated near swamp forests along the Savannah River (fig. 15).

Southeastern myotis' foraging activity varied among stands of different ages (fig. 9). Unlike the eastern pipistrelle's, most of this species' activity was in stands aged 21 to 40 years (table 5).

Reproduction

Southeastern myotis mate in autumn; fertilization and parturition occur in spring (Lowery 1974). In Florida, Rice (1957) found that the species entered maternity roosts around mid-March. Most maternity roosts were in caves and contained between 2,000 and 90,000 individuals at average densities of 1,600 bats per m^2. Young were born from late April to mid-May. The southeastern myotis is the only myotid in South Carolina that typically gives birth to twins (Barbour and Davis 1969). Although no maternity colonies have been studied in South Carolina, parturition probably occurs in May and early June on the Savannah River Site.

Evening bat (*Nyticeius humeralis*)

Morphology and Distribution

The evening bat is a small brown bat that occurs throughout the Southeastern United States (fig. 16). Of the three recognized subspecies, only one, *N. h. humeralis,* occurs in South Carolina. Weight ranges from 5 to 14 g, and average total length is 92.7 mm (Whitaker and Hamilton 1998). See table 10 for average body measurements of individuals collected in the Southeastern United States.

The evening bat's range extends north from the Texas-Mexico border to Nebraska, and east through Pennsylvania (Watkins 1972). Museum collections include 172 specimens from South Carolina; 93 have been live-captured in the State. The evening bat occurs in all physiographic provinces of South Carolina and is common statewide (fig. 17) (Watkins 1972).

Table 10—Body measurements of the evening bat in the Southeastern United States

Measurement	Number[a]	Mean	SD	CV	Range
			mm		
Total	20	86.8	6.28	7.23	77.0 –102.0
Tail	20	33.8	4.07	12.04	26.0 – 39.0
Foot	20	7.9	1.34	16.97	6.0 – 11.0
Ear	19	11.9	2.02	16.96	6.5 – 14.5
Tragus	20	3.9	1.38	35.14	2.5 – 7.0
Forearm	18	36.2	1.81	4.99	33.0 – 39.0
			g		
Mass	18	8.0	2.04	25.57	4.3 – 12.4

[a] Number of individuals measured.

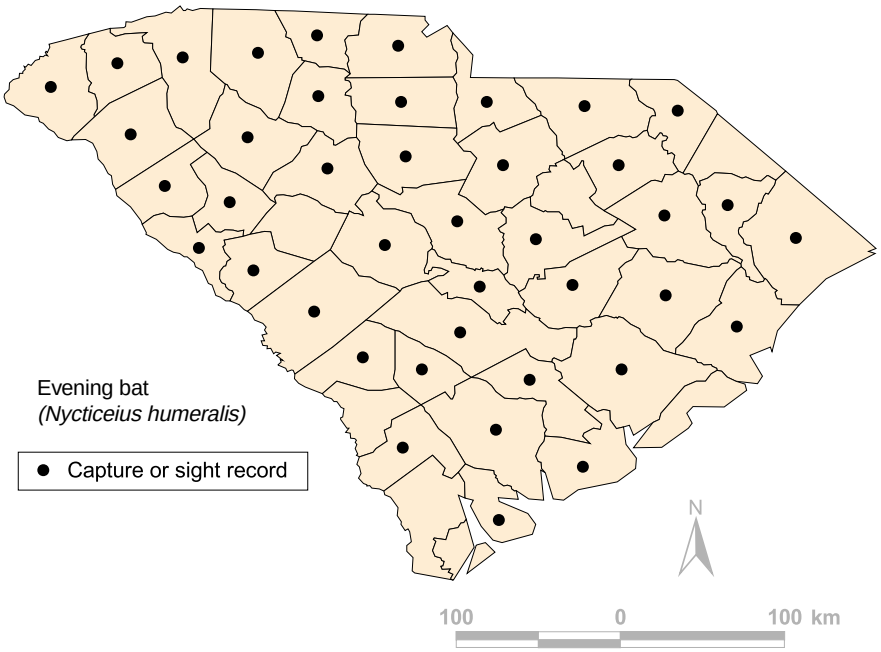


Figure 17—Distribution of the evening bat in South Carolina (Menzel and others 2003). Symbols denote counties for which records exist.

Evening bats were captured during the 1979 survey on the Site (Anon. 1980, Cothran and others 1991). In on-site surveys conducted from 1996 to 2001, it was the most commonly captured species; we captured 27 adult females, 21 adult males, 13 juvenile females, and 6 juvenile males (table 7).

Roosting

No studies have quantitatively examined winter roosting habits of evening bats in South Carolina, and little is known about their winter roosting habits anywhere. There are, however, anecdotal accounts of evening bats roosting in attics in Legareville, Charleston County, SC, during the winter.

Menzel and others (2000b) found 61 evening bat summer roost trees on the Site. The most common tree species was longleaf pine, but conifer snags in beaver ponds also were common (Menzel and others 2000b). Evening bats roosted either in cavities or under exfoliating bark. Roosts were in areas with fewer overstory and understory trees, greater average canopy height, lower understory richness and diversity, lower overstory richness, less-dense canopies, and greater snag abundance than in random plots (Menzel and others 2000b). Evening bat maternity colonies used roosts in mature longleaf pine in stands where the height of the overstory, density of the canopy, and proportion of the basal area composed of conifers were greater than in areas surrounding roost trees used by solitary evening bats (Menzel and others 2001a). Summer roosts have been found elsewhere in Spanish moss (Jennings 1958), under exfoliating bark (Bailey 1933, Barbour and Davis 1969, Chapman and Chapman 1990), and in tree cavities (Barbour and Davis 1969, Harper 1927). There is one record of this species roosting in caves (Easterla 1965). Maternity roosts have been found in buildings (Cope and others 1961, Watkins and Shump 1981) and tree cavities (Menzel and others 2001a). In the upper and lower Coastal Plain of Georgia, the species often shares maternity roosts in buildings with *T. brasiliensis*.[3]

Foraging and Home Range

Evening bats begin foraging in late twilight (Lowery 1974). At first emergence, they forage 13 to 25 m above the ground, but later in the night they forage lower (Harper 1927, Lowery 1974). Harper (1927) reported that in the Okefenokee Swamp area of Georgia, evening bats foraged in pine barrens and over fields. Krishon and others (1997) found that 76 percent of the bats' foraging area on Sapelo Island, GA, was over slash-loblolly pine habitat. Evening bats feed on insects in the orders Hemiptera, Hymenoptera, Coleoptera, and Lepidoptera (Mumford and Whitaker 1982, Ross 1961). Carter (1998) found that on the Site they fed primarily on Coleoptera and Hymenoptera during early and midsummer. In late summer, the species fed on a wider variety of insect taxa, including Hemiptera, Homoptera, Coleoptera, and Hymenoptera (in order of decreasing volume) (Carter 1998).

The home range of one juvenile and five adult evening bats tracked on the Site ranged from 38.7 to 761.0 ha and averaged 285.3 ha (Carter 1998). Habitat types contained within the home ranges included pine forests (59 percent) and bottomland hardwoods (37 percent) (Carter 1998). Habitat types were used in the same proportion as they were available. The 761.0-ha home range of the juvenile was much larger than that of the other five. On Sapelo Island, GA, the species' home range was within a 15.1-ha slash-loblolly pine stand (Krishon and others 1997).

Effect of Habitat Type and Stand Age on Flight Activity

We recorded evening bats at 31.3 percent of the lake and pond survey points, 42.9 percent of the Carolina bay survey points, 31.8 percent of the bottomland hardwood survey points, 31.6 percent of the forest gap survey locations, 40.7 percent of the grass-brush survey points, 27.3 percent of the upland hardwood points, 14.3 percent of the pine-hardwood points, 10.7 percent of the loblolly-slash survey points, and 21.4 percent of the longleaf survey locations. Overall, they were present on 24.9 percent of all survey locations (fig. 18). Most bat activity was within grassy areas, among bottomland hardwoods, and over Carolina bays (fig. 18). Whereas eastern pipistrelle activity was highest over lakes and ponds, evening bat activity was highest over Carolina bays. Unlike the southeastern myotis, evening bat activity was widespread throughout the Site.

Stand age also influenced evening bat activity (table 5). As with the eastern pipistrelle, activity was highest in clearcuts and young stands (fig. 9). Moderate activity occurred in stands > 60 years old, but was low in 21- to 60-year-old stands (fig. 9).

Reproduction

In the Southeastern United States, evening bats give birth in May and June. In the Northeast, parturition may occur in July (Harper 1927, Watkins 1972). Evening bats arrive at nursery roosts around the second week of April (Golley 1966) in South Carolina. In May, Golley (1966) captured several pregnant females in the State. Most bats leave their nursery colonies by late August (Baker 1965). Young bats become volant about 20 days after birth (Schmidly 1991). Menzel and others (2000b) found many evening bat maternity colonies and captured many juvenile evening bats on the Savannah River Site.

[3] Personal communication. 1999. Jim Ozier, Senior Wildlife Biologist, Georgia Department of Natural Resources, Wildlife Resources Division Nongame-Endangered Wildlife Program, 116 Rum Creek Drive, Forsythe, GA 31029-6518.

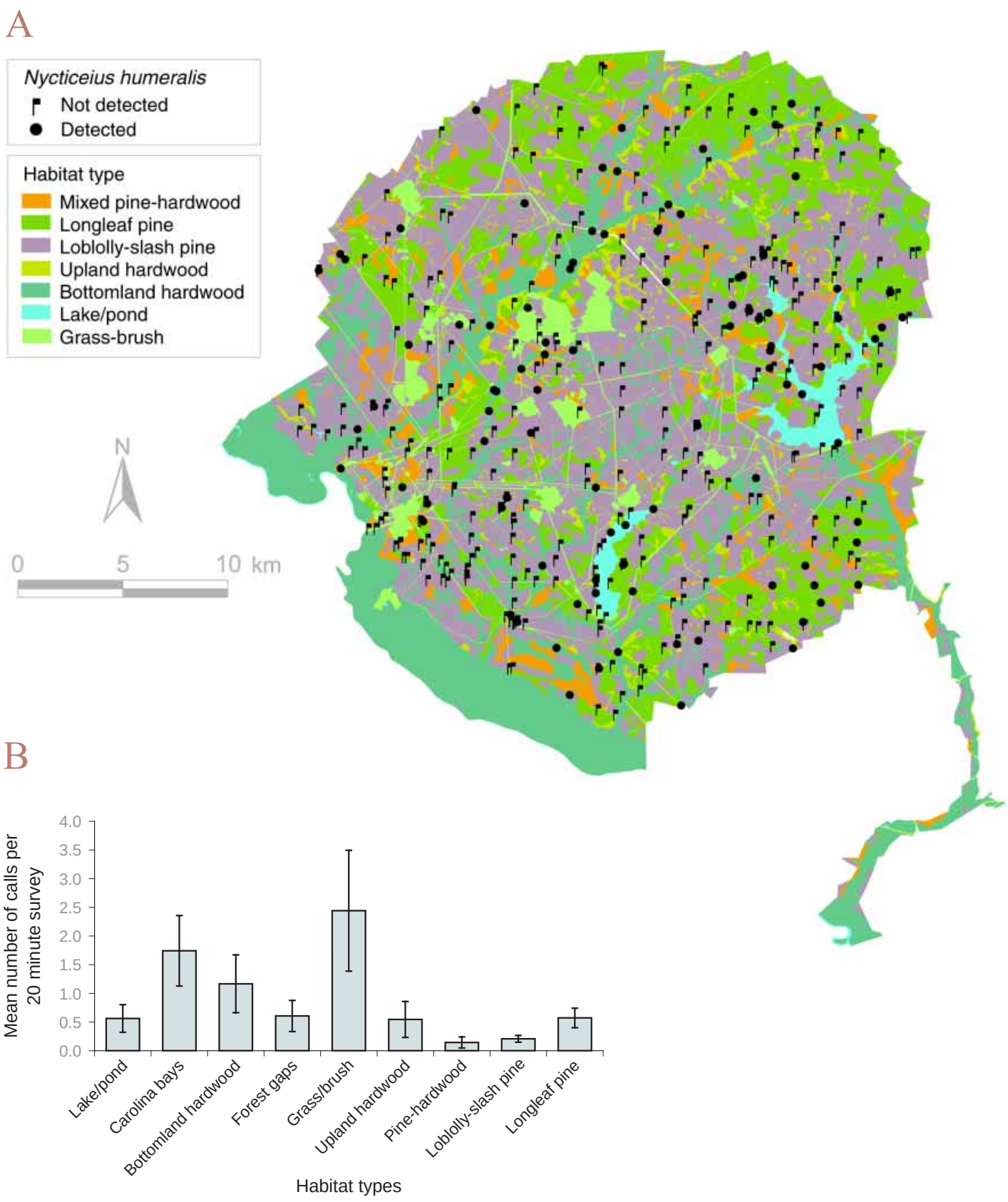


Figure 18—(A) AnaBat survey locations where evening bats were detected in surveys conducted during summer 2001 and (B) a comparison of flight activity levels of evening bats among vegetation community types on the Savannah River Site.

Photo courtesy of John MacGregor

Figure 19—Rafinesque's big-eared bat.

Rafinesque's big-eared bat (*Corynorhinus rafinesquii*)

Morphology and Distribution

Rafinesque's big-eared bat is small, and its most obvious attribute is its extremely large ears (fig. 19). Both subspecies of Rafinesque's big-eared bat (*C. rafinesquii rafinesquii* and *C. r. macrotis*) occur in South Carolina (Jones 1977). Weight ranges from 7 to 10 g, and average total length is 99.5 mm (Whitaker and Hamilton 1998). See table 11 for average body measurements of individuals collected in the Southeastern United States.

Rafinesque's big-eared bat is found throughout the Southeast. Its range extends south from southern Virginia, along the Atlantic Coast into Florida, and west into Oklahoma and east Texas (Jones 1977). Museum collections include 65 specimens from South Carolina; 30 individuals have been live-captured in the State. Its distribution in the South extends through the upper and lower Coastal Plain and the Blue Ridge (fig. 20). It is listed as endangered in South Carolina (table 9) (South Carolina Department of Natural Resources 2001).

Two Rafinesque's big-eared bats collected on the Site are reposited in the University of Georgia Museum of Natural History (Cothran and others 1991). Between 1996 and 2000, we captured seven adult females and one adult male (table 7).

Table 11—Body measurements of Rafinesque's big–eared bat in the Southeastern United States

Measurement	Number[a]	Mean	SD	CV	Range
			mm		
Total	12	96.1	4.54	4.73	90.0 –104.0
Tail	12	46.4	3.11	6.72	43.0 – 53.0
Foot	11	11.8	2.40	20.40	9.0 – 18.0
Ear	11	32.2	2.60	8.08	28.0 – 35.0
Tragus	5	12.7	2.39	18.80	10.0 – 15.0
Forearm	10	43.4	1.33	3.08	41.0 – 46.0
			g		
Mass	11	8.6	1.05	12.15	7.5 – 11.1

[a] Number of individuals measured.

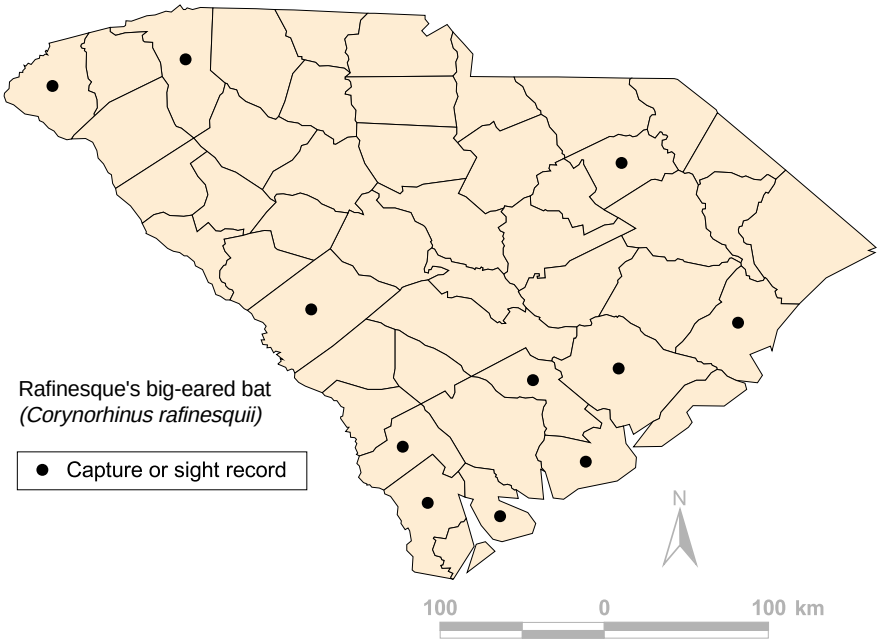


Figure 20—Distribution of the Rafinesque's big-eared bat in South Carolina (Menzel and others 2003). Symbols denote counties for which records exist.

Roosting

The Rafinesque's big-eared bat's winter roosting habits are not well known. It has been found roosting in abandoned buildings throughout the year (Clark 1990). Winter roosts also have been found near cave entrances (Barbour and Davis 1969).

During the summer, Rafinesque's big-eared bats roost in abandoned buildings, hollow trees, and under bark (Barbour and Davis 1969, Hall 1963, Jones 1977, Lowery 1974, Menzel and others 2001b). Typically, summer roosts are located in the twilight zone of caves and mines or in dimly lit sections of buildings (Whitaker and Hamilton 1998). Menzel and others (2001b) found male big-eared bats roosting in abandoned houses in Aiken County, SC, approximately 8 km northwest of the Savannah River Site. We have found some of them roosting in an abandoned barn on the Site. They probably roost under bridges, in tree cavities, and in abandoned structures near bottomland and swamp forests on the Site. Clark (1990) described roosting sites in North Carolina as "predominately frame, one-story [abandoned] homes with plaster walls and large attics." Lance and others (2001) found them roosting under 32 girder-type bridges in Louisiana. Bridges probably are an important component of the species' roosting habitat in South Carolina. Future surveys should determine which bridges on the Site serve as roosts for this species. Lance and others (2001) found big-eared bats roosting in hollow blackgum trees. Based on unpublished museum records, several hundred were reported roosting in a house on Belle Isle in Georgetown County, SC. Clark and others (1998) found some roosting in tree cavities of water tupelo in the Francis Beidler Forest in South Carolina. Most roosts were within basal cavities. They also found a 1-night roost in a dead bald cypress.

Foraging and Home Range

We know little about the foraging habits of Rafinesque's big-eared bats. They do not begin to forage until after dark and are agile fliers (Schmidly 1991). In a study conducted in Aiken County, SC, the home-range size of male big-eared bats ranged from 23.9 to 260.5 ha and averaged 93.2 ha (Menzel and others 2001b). They selectively foraged there in sapling-stage pine stands (Menzel and others 2001b). The results of this study stand in stark contrast to the results of a study conducted by Clark and others (1998) on the Francis Beidler Forest in central South Carolina, where the home range of three individuals was between 64 and 89 ha, primarily in swamp forests. On-site, this bat probably forages in a wide variety of habitats. However, foraging activity may be concentrated in mature bottomland hardwood and swamp forests, brushy communities, and 3- to 5-year-old pine plantations.

Fecal pellet analyses in South Carolina indicated the primary taxa consumed by Rafinesque's big-eared bats was Lepidoptera (Menzel and others 2002b). Ellis (1993) collected fecal pellets from the roost of a maternity colony in North Carolina and found that the diet was exclusively composed of Lepidopterans (67 percent) and Dipterans (33 percent). Most of the flies eaten (94 percent) were tabanids (family Tabanidae).

Effect of Habitat Type and Stand Age on Flight Activity

Because of the low intensity of the echolocation calls produced, activity patterns of the Rafinesque's big-eared bat cannot be monitored reliably with bat detectors. We did not attempt to determine the effect of habitat type or stand age on the flight activity of this species.

Reproduction

Rafinesque's big-eared bats seem to mate in autumn (Hoffmeister and Goodpaster 1963). Animals with swollen testes have been found in August (Hall 1963), and reproductively active males were captured in areas around the Site in September (Menzel and others 2001b). Females enter maternity roosts in May. Each of two maternity colonies found after parturition by Hall (1963) contained about 50 individuals. The species' typical litter size is one. Young are born in late May and early June (Barbour and Davis 1969, Hall 1963).

Photo courtesy of John MacGregor

Figure 21—Silver-haired bat.

In South Carolina, maternity colonies have been found in abandoned buildings. Parturition probably occurs in May and June on the Savannah River Site.

Silver-haired bat (*Lasionycteris noctivagans*)

Morphology and Distribution

The silver-haired bat is a small bat with silvery-white frosting, and it occurs throughout southern Canada and most of the United States (fig. 21). Weight ranges from 7 to 16 g, and average total length is 99.7 mm (Whitaker and Hamilton 1998). See table 12 for average body measurements of individuals collected in the Southeastern United States.

The silver-haired bat reaches the southern limit of its range in the Southeast (Kunz 1982). Museum collections include 26 silver-haired bats from South Carolina. The species is distributed statewide (fig. 22), and individuals have been captured in all four of South Carolina's physiographic provinces. However, its distribution in the State probably differs among seasons, and many of the individuals may have been captured while migrating.

Although one individual collected on the Site is reposited in the University of Georgia Museum of Natural History, none was captured during the 1979 or 1996 to 2001 surveys. The species is migratory (Barclay 1984a, Kunz 1982). Silver-haired bats probably are rare on the Site between late autumn and early spring and may not occur there in the summer.

Roosting

Roosting habits of the silver-haired bat in South Carolina are unknown. In other States, they are known to hibernate in mines (Baker 1965, Layne 1958, Pearson 1962), caves (Baker 1965, Beer 1956, Turner 1974), rock crevices (Frum 1953), buildings (Clark 1993, Frum 1953), and trees (Cowan 1933, Jackson 1961). Summer roosts have been found in tree cavities and under bark (Betts 1996, Mattson and others 1996, Parsons and others 1986, Vonhof 1996). Because it is unlikely that silver-haired bats are on-site during the summer, the limited knowledge of the species' summer roosting habits in the Southeast is of little concern.

Foraging and Home Range

Jones and others (1973) and Kunz (1973) found that silver-haired bats typically have two peaks of foraging activity per night—3 and 7 hours after sunset. Barclay (1984b) found that they forage throughout the night, typically in coniferous or mixed deciduous forests that are near water (Jones 1965, 1966; Kunz 1973). They fly slowly and erratically when foraging (Hayward and Davis 1964, van Zyll de Jong 1985). Food items include Lepidopterans, Homopterans, Dipterans, Hemipterans, Hymenopterans, Coleopterans, and Neuropterans

Table 12—Body measurements of the silver-haired bat in the Southeastern United States

Measurement	Number[a]	Mean	SD	CV	Range
		mm			
Female					
Total	3	109.0	1.73	1.59	108.0 –111.0
Tail	3	41.0	4.00	9.76	37.0 – 45.0
Foot	3	8.7	2.08	24.02	7.0 – 11.0
Ear	3	15.0	2.65	17.64	12.0 – 17.0
Tragus	2	5.2	2.47	47.14	3.5 – 7.0
Forearm	3	43.0	1.00	2.33	42.0 – 44.0
		g			
Mass	3	10.4	0.85	8.20	9.5 – 11.2
		mm			
Male					
Total	8	95.8	6.84	7.14	81.0 –102.0
Tail	8	39.5	2.20	5.58	35.0 – 42.0
Foot	8	7.31	0.88	12.09	7.0 – 9.5
Ear	8	14.6	1.53	10.46	11.0 – 16.0
Tragus	8	4.0	0.89	22.16	3.0 – 6.0
Forearm	8	40.9	10.9	2.68	43.0 – 40.0
		g			
Mass	7	8.6	1.58	18.39	5.2 – 9.9

Measures that differed significantly between the sexes ($P \leq 0.05$).
[a]Number of individuals measured.

(Black 1974; Whitaker and others 1977, 1981). The species' foraging habits in South Carolina are not known. Because silver-haired bats probably do not reside on-site during the summer, the limited knowledge about its foraging behavior in the Southeast is of little concern.

Effect of Habitat Type and Stand Age on Flight Activity

We did not record any calls of silver-haired bats during the 2001 AnaBat survey. Although they may occur on-site during the winter months, it is unlikely that they are summer residents there.

Reproduction

The reproductive habits of silver-haired bats are not well known. Similar to other vespertilionid bats, they probably mate in the autumn (van Zyll de Jong 1985). Ovulation occurs in April and May (Druecker 1972). They give birth to one or two young in June or July (Easterla and Watkins 1970, Kunz 1971, Merriam 1884). It is unlikely that parturition occurs on the Savannah River Site.

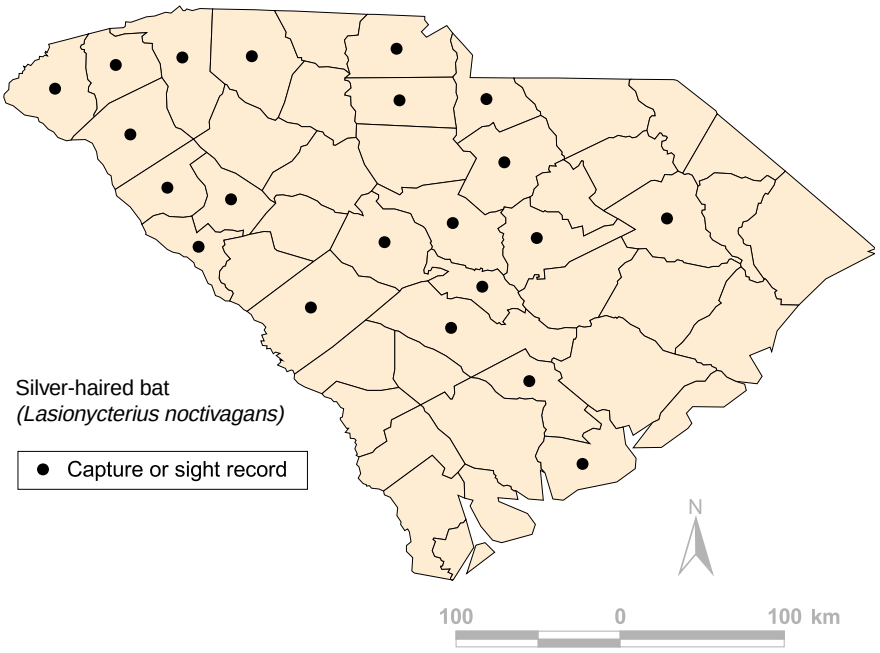


Figure 22—Distribution of the silver-haired bat in South Carolina (Menzel and others 2003). Symbols denote counties for which records exist.

Photo courtesy of John MacGregor

Figure 23—Eastern red bat.

Eastern red bat (*Lasiurus borealis*)

Morphology and Distribution

The eastern red bat is medium sized and brick red (males) or brick red with white frosting (females); it occurs throughout forested regions of the Eastern United States (fig. 23) (Shump and Shump 1982a). Of the three recognized subspecies of eastern red bats, only one, *L. b. borealis*, occurs in South Carolina. Its mass ranges from 9.5 to 16 g, and its average total length is 112.3 mm (Whitaker and Hamilton 1998). See table 13 for average body measurements of individuals collected in the Southeast.

The range of the eastern red bat extends south from southern Canada into Argentina and Chile (Shump and Shump 1982a). Museum collections include 108 specimens from South Carolina; 145 have been live-captured in the State. The species is abundant in all four physiographic provinces of South Carolina and is common throughout the State (fig. 24).

One eastern red bat was captured at Rainbow Bay during the 1979 survey (Anon. 1980). Between 1996 and 2001, we captured 30 adult females, 8 adult males, 11 juvenile females, and 5 juvenile males (table 7). Based on our capture data, the eastern red bat is the second most abundant bat species on the Site.

Roosting

Eastern red bats migrate to the Southern United States to hibernate. Generally, winter roosts include tree branches and leaf clusters (Barbour and Davis 1969). The species is well adapted for winter survival outside of caves and may become active on warm winter nights (Barbour and Davis 1969). Winter roosting habits in South Carolina have not been determined. As with the other species, we know little of the relative abundance of eastern red bats on the Savannah River Site during the winter or of its winter roosting habits.

In the summer, eastern red bats most commonly are found roosting on small branches and leaf petioles in the crowns of deciduous trees (Barbour and Davis 1969), but they also have been found in woodpecker cavities (Fassler 1975) and caves (Myers 1960). Menzel and others (1998) found 64 eastern red bat roost trees on the Savannah River Site. Roosts typically were in hardwood trees larger in diameter at breast height (d.b.h.) and taller than surrounding trees. The roost trees were in areas with greater overstory tree height and basal area, denser overstory canopies, and greater overstory and understory diversity than random plots (Menzel and others 2000b). Twenty tree species were used as roosts on the Site, but sweetgum and red maple were the most common (Menzel and others 2000b). The eastern red bat moves to new roost trees often, spending an average of 1.2 nights at each (Menzel and others 1998). Each individual we tracked selected roost trees from a small area of their foraging range (average roost selection area = 2.6 ha).

Table 13—Body measurements of the eastern red bat in the Southeastern United States

Measurement	Number[a]	Mean	SD	CV	Range
			mm		
Total	36	101.8	7.46	7.33	88.0 –117.0
Tail	36	45.8	4.59	10.01	36.0 – 56.0
Foot	36	7.9	1.36	17.19	6.0 – 10.0
Ear	32	11.3	1.28	11.28	8.0 – 14.0
Tragus	26	4.3	1.29	29.94	3.0 – 8.0
Forearm	33	39.5	2.31	5.85	34.0 – 44.0
			g		
Mass	27	10.0	1.52	15.15	8.0 – 13.0

[a] Number of individuals measured.

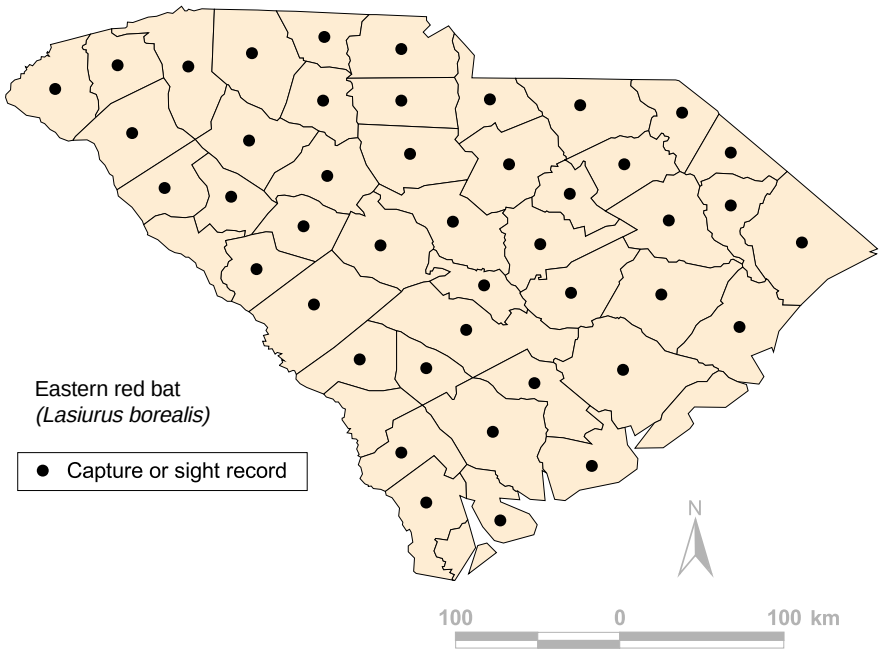


Figure 24—Distribution of the eastern red bat in South Carolina (Menzel and others 2003). Symbols denote counties for which records exist.

Foraging and Home Range

Eastern red bats typically begin foraging 1 to 2 hours after sunset, although some individuals may begin earlier and continue foraging throughout the night (Kunz 1973). There is some evidence suggesting they exhibit bimodal foraging activity patterns (Carter and others 1999a). The species forages at temperatures as low as 7 °C (LaVal and LaVal 1979). In South Carolina, eastern red bats feed mostly on Coleoptera and Hemiptera during early summer (Carter 1998), but in mid- and late summer they feed on a more diverse assemblage of taxa, including Coleoptera, Hemidoptera, Lepidoptera, Homoptera, and Hymenoptera (Carter 1998). Elsewhere, remains of Lepidoptera, Homoptera, Coleoptera, Hymenoptera, and Diptera have been found in the stomachs of eastern red bats (Mumford 1973, Ross 1967, Whitaker 1972).

The home range of five eastern red bats tracked on-site ranged from 125.8 to 878.5 ha and averaged 453.2 ha (Carter 1998). Habitat types within its home range included bottomland hardwoods (55 percent), pine stands (40 percent), and upland hardwoods (5 percent) (Carter 1998). This species did not appear to forage selectively in specific habitat types; they used each in proportion to its availability.

Effect of Habitat Type and Stand Age on Flight Activity

Because it is difficult to differentiate calls of eastern red and Seminole bats, we included both calls in a single category. Although data collected in previous studies suggest eastern red bats are more likely to forage in bottomland forests than Seminole bats (Menzel 1998), pooling the calls made it impossible to distinguish foraging habitat use of the two. We recorded calls at 56.3 percent of the lake and pond survey points, 71.4 percent of the Carolina bay survey points, 45.5 percent of the bottomland hardwood survey points, 68.4 percent of the forest gap survey locations, 62.7 percent of the grass-brush survey points, 45.5 percent of the upland

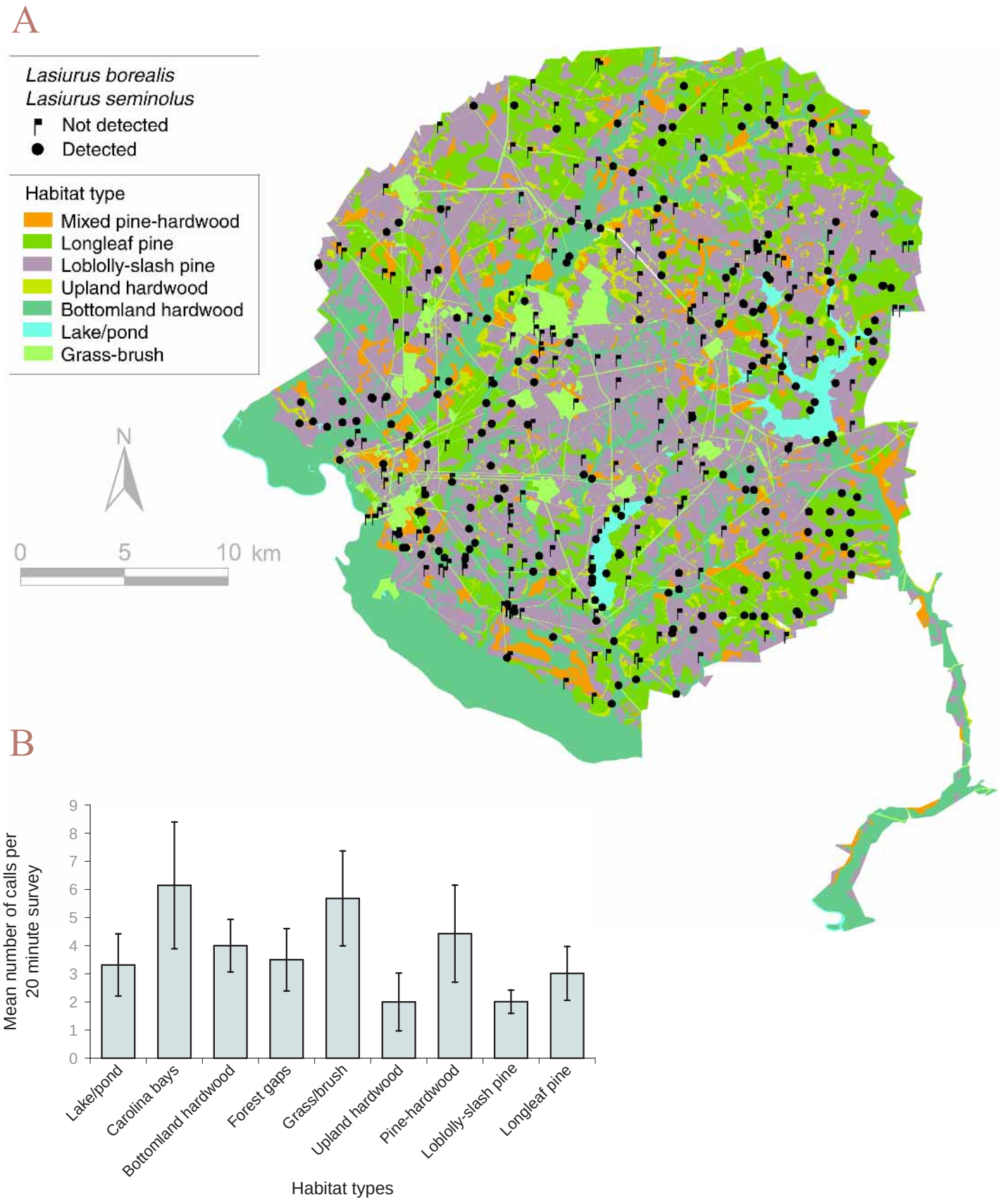


Figure 25—(A) AnaBat survey locations where eastern red/Seminole bats were detected in surveys conducted during summer 2001, and (B) a comparison of flight activity levels of eastern red/Seminole bats among vegetation community types on the Savannah River Site.

hardwood points, 50.0 percent of the pine-hardwood points, 36.4 percent of the loblolly-slash survey points, and 47.1 percent of the longleaf survey locations. Overall, the species group was present on 49.7 percent of the survey locations (fig. 25). The group's wide distribution across habitat types and their high occurrence rate probably resulted from our inclusion of both species. The effect of pooling would have an even greater effect on these metrics if they commonly foraged in different habitats. If Seminole bats usually roost and forage in upland habitats and eastern red bats in bottomland forests, such pooling would result in a group common to both upland and bottomland communities. Also, because the eastern red and Seminole bats are the second and third most common species on the Site, respectively, it is not surprising that this group was detected on half of all 449 survey locations.

In addition to being commonly detected, the group's activity levels were relatively high in all habitat types (fig. 25). Most activity was detected over Carolina bays and grass-brush habitat (table 4).

Eastern red and Seminole bat activity also seemed to be less affected by stand age than that of other species (fig. 9). Although activity was greatest within clearcuts, it was relatively constant among stands aged 4 years or older (table 5).

Reproduction

Eastern red bats undergo delayed fertilization. Mating occurs in August and September, and fertilization in spring (Glass 1966, Whitaker and Hamilton 1998). Copulation sometimes occurs in flight (Stuewer 1948). Estimated gestation is between 80 and 90 days (Jackson 1961). Its young are born in late May and June (Lowery 1974), and lactation lasts about 38 days (Kunz 1971). The average embryo count is 3.2 (Shump and Shump 1982a). Members of the genus *Lasiurus* are the only bats that regularly give birth to more than two progeny (Nowak 1994). Although no one has studied the reproductive habits of eastern red bats in South Carolina, we have captured juveniles on the Site, and it is likely that they commonly raise their young on-site.

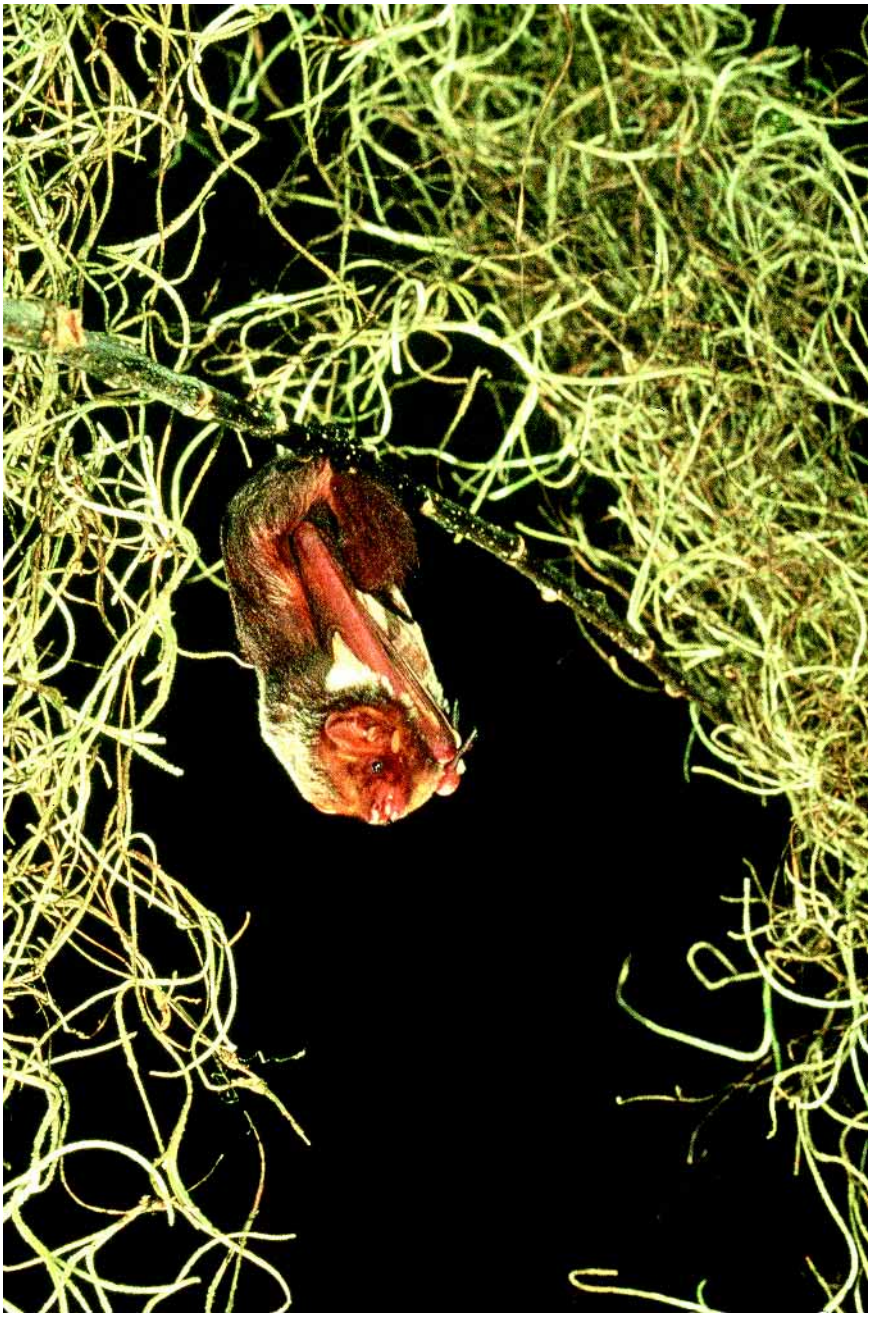


Photo courtesy of J. Scott Altenbach

Figure 26—Seminole bat.

Seminole bat (*Lasiurus seminolus*)

Morphology and Distribution

The Seminole bat is a medium sized, mahogany colored bat common throughout the Deep South (fig. 26). The Seminole bat is monotypic. Its mass ranges from 9 to 14 g, and its average total length is 111 mm (Whitaker and Hamilton 1998). See table 14 for average body measurements of individuals collected in the Southeast.

Although a few "wandering" individuals have been captured in New York (Layne 1955) and Pennsylvania (Poole 1949), this species typically is found south from the southeastern tip of Virginia to Florida, and west along

Table 14—Body measurements of the Seminole bat in the Southeastern United States

Measurement	Number[a]	Mean	SD	CV	Range
			mm		
Female					
Total	16	106.1	6.65	6.27	89.0 –116.0
Tail	16	43.7	3.91	8.95	38.0 – 53.0
Foot	16	8.6	0.81	9.51	6.0 – 9.0
Ear	15	12.2	0.98	8.01	11.0 – 14.0
Tragus	14	6.5	1.57	24.09	4.0 – 9.0
Forearm	16	42.3	0.94	2.23	41.0 – 45.0
			g		
Mass	14	12.7	1.80	14.15	8.5 – 15.0
			mm		
Male					
Total	18	101.8	5.59	5.49	93.0 –115.0
Tail	18	43.9	3.89	8.85	38.0 – 52.0
Foot	17	8.1	1.25	15.49	5.0 – 9.0
Ear	16	12.0	1.15	9.62	10.0 – 14.0
Tragus	17	6.1	1.49	24.44	3.0 – 8.0
Forearm	18	40.5	1.40	3.45	38.0 – 43.5
			g		
Mass	12	9.8	1.18	12.09	7.8 – 11.0

Measures that differed significantly between the sexes ($P \leq 0.05$).
[a] Number of individuals measured.

Roosting

In the winter, Seminole bat roosts commonly are found in oak hammock communities in Spanish moss (Constantine 1958), but the species' winter roosting habits in South Carolina are not known.

Seminole bats also commonly roost in Spanish moss during the summer months (Barbour and Davis 1969). Although one summer roost was located under loose bark, this species typically does not use bark roosts (Sealander 1979). On the Savannah River Site, summer roosts usually are in the terminal branches of pine limbs in communities dominated by pines (Menzel and others 1998). Although 10 tree species were used as roosts, most (86 percent) were pines, primarily loblolly (Menzel and others 2000b). Roosts tended to be in taller, larger diameter trees than the surrounding overstory (Menzel and others 2000b). Roosts were found in areas with higher basal area, lower understory species richness, and less Spanish moss than random plots (Menzel and others 2000b). On-site, Seminole bats move

the Gulf Coast into east Texas (Wilkins 1987). Museum collections include 42 Seminole bats from South Carolina; 58 have been live-captured in the State. Distribution of the Seminole bat in South Carolina includes the upper and lower Coastal Plain (fig. 27). They have been captured in the Piedmont and Blue Ridge, but their distribution in surrounding States suggests they rarely occur above the fall line.

The Seminole bat was one of the most commonly captured bat species during the 1979 survey (Anon. 1980). In surveys conducted between 1996 and 2001, we captured six adult females, seven adult males, six juvenile females, and three juvenile males (table 7). Based on surveys conducted on the Site, the Seminole bat is the third most common species, exceeded in abundance only by evening and eastern red bats.

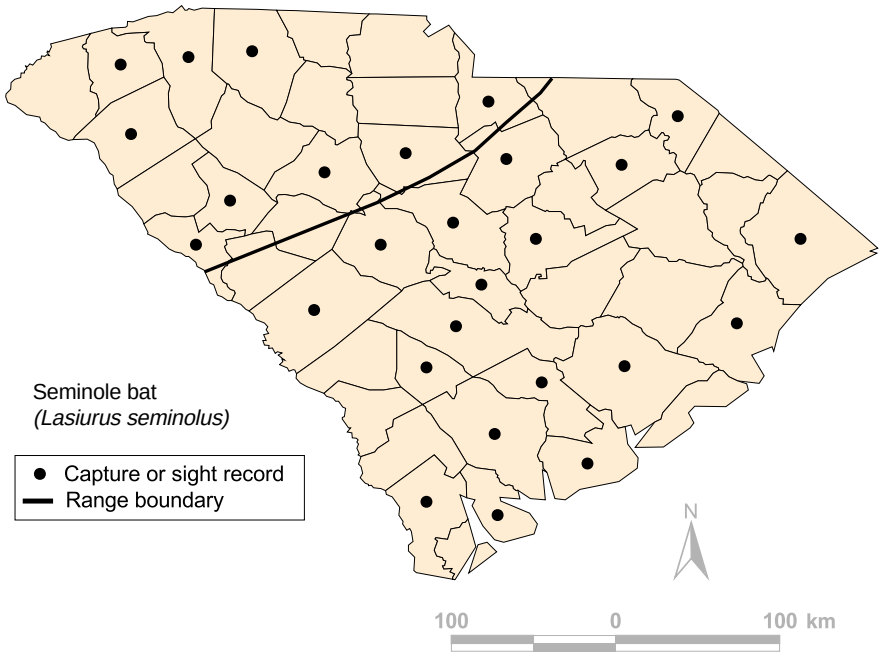


Figure 27—Distribution of the Seminole bat in South Carolina (Menzel and others 2003). Symbols denote counties for which records exist. Typical summer distribution is south of the range line.

Photo courtesy of John MacGregor

Figure 28—Hoary bat.

to new roost trees often, spending an average of 1.7 days in each. On average, they select new roost trees within about a 0.25-ha portion of their home range.

Foraging and Home Range

Although Seminole bats commonly forage at treetop level (Barbour and Davis 1969), two reports document the species gleaning prey from leaf surfaces (Barbour and Davis 1969, Sherman 1935). Sherman (1939) found the remains of Homopterans (Jassidae), Dipterans (Dolichopodidae, Muscidae), and Coleopterans (Scolytidae) in a single stomach. Zinn (1977) reported that Coleoptera, Odonata, and Hymenoptera were important food items. Carter (1998) found that Seminole bats fed primarily on Hymenoptera, Coleoptera, and Lepidoptera on the Site.

Radio tracking on the Site indicated the home-range size of five Seminole bats to be between 189.2 and 704.4 ha, with an average of 423.8 ha (Carter 1998). Habitat types in the home-range areas included pine forests (55 percent), bottomland hardwoods (35 percent), and upland hardwoods (11 percent) (Carter 1998).

Effect of Habitat Type and Stand Age on Flight Activity

Because it is hard to differentiate calls of eastern red and Seminole bats, we included both calls in a single category. So far, using acoustical monitoring to determine the effect of habitat type and stand age on the flight activity of this species has not been possible. See the eastern red bat species account for a description of the effect of habitat type and stand age on the flight activity of the eastern red/Seminole bat group.

Reproduction

Pregnant Seminole bats have been collected between early May and mid-June (Barkalow 1948, Coleman 1950, Jennings 1958, Moore 1949). Parturition usually occurs in June and July, but the species' reproductive habits in South Carolina are not known. However, we captured juvenile Seminole bats on the Savannah River Site and tracked adult females to roosts occupied by their young. Seminole bats raise their progeny on the Site.

Hoary bat *(Lasiurus cinereus)*

Morphology and Distribution

The hoary bat is the largest bat species found in South Carolina. It has frosted pelage and cream-colored ears with a distinct back rim (fig. 28).

Of three subspecies of the hoary bat, one, *L. c. cinereus*, occurs in the State (Shump and Shump 1982b). Its mass ranges from 18 to 38 g, and its average total length is 134.8 mm (Whitaker and Hamilton 1998). See table 15 for average body measurements of individuals collected in the Southeast.

Table 15—Body measurements of the hoary bat in the Southeastern United States

Measurement	Number[a]	Mean	SD	CV	Range
		mm			
Total	7	132.5	12.72	9.60	106.0 – 146.0
Tail	7	58.0	4.73	8.15	51.0 – 63.0
Foot	6	11.5	1.52	13.19	10.0 – 14.0
Ear	7	14.9	2.79	18.81	10.0 – 18.0
Tragus	5	7.3	1.30	17.86	5.5 – 9.0
Forearm	6	55.2	1.94	3.52	53.0 – 58.0
		g			
Mass	6	21.2	2.40	11.32	19.0 – 24.9

[a] Number of individuals measured.

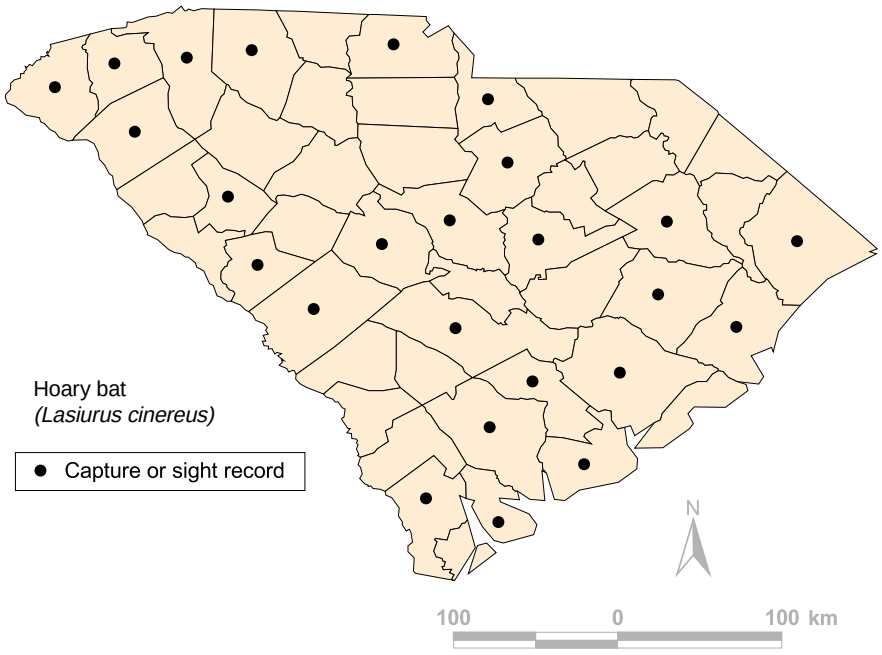


Figure 29—Distribution of the hoary bat in South Carolina (Menzel and others 2003). Symbols denote counties for which records exist.

The hoary bat has a more extensive distribution than any other bat species in South Carolina. Its range extends south from northern Canada near the tree line through Central America. The southern limit of its range extends into Argentina and Chile (Shump and Shump 1982b). Museum collections include two hoary bats from South Carolina; three have been live-captured in the State. The species' distribution in South Carolina (fig. 29) includes all four physiographic provinces, and its status is listed as undetermined (table 9) (South Carolina Department of Natural Resources 2001). Because of its migratory patterns, it probably is rare in the State during summer.

We captured three hoary bats (two females and one sex undetermined) on the Site from 1996 to 2001 (table 7). Whitaker and Hamilton's (1998) summer range map for hoary bats does not include South Carolina. Although our surveys indicate that they do occur on the Site in summer, they are not abundant.

Roosting

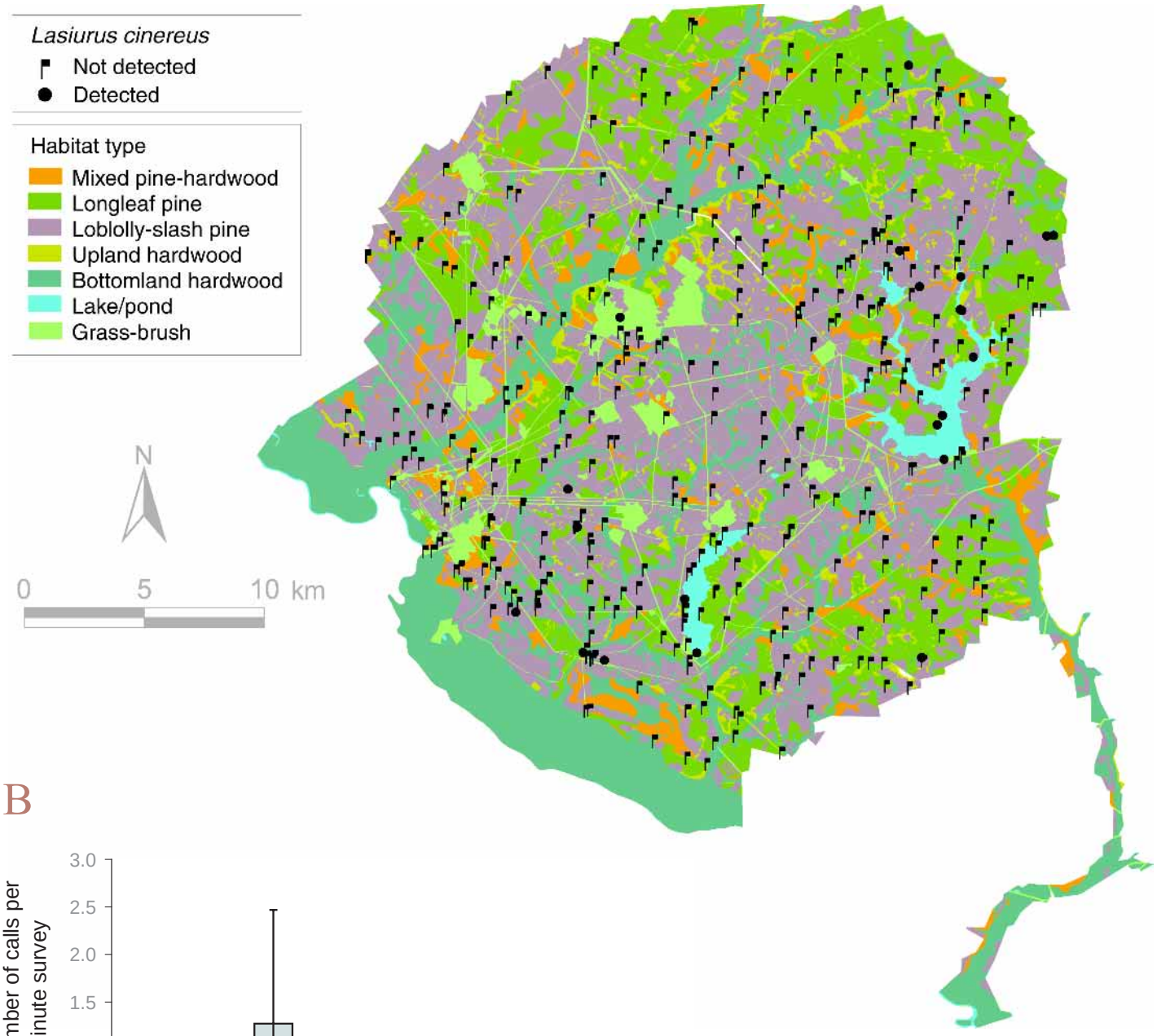
Although the hoary bat's winter roosts typically are found in tree foliage, they also have been found in tree cavities and squirrel nests (Constantine 1966, Cowan and Guiguet 1965, Neill 1952). The species typically does not roost in caves (Mumford 1953, Myers 1960).

Little is known about the hoary bat's summer or winter roosting habits in South Carolina, and nothing is known about its roosting requirements on the Site.

Foraging and Home Range

Hoary bats begin foraging in late evening (Barbour and Davis 1969), sometimes establishing foraging territories (Barclay 1984a). Prey items include Coleopterans, Dipterans, Orthopterans, Isopterans, Odonatans, Hymenopterans, and Lepidopterans (Black 1972, 1974; Ross 1967; Whitaker 1972; Whitaker and others 1977), but it seems to prefer Lepidopterans (Black 1972, Ross 1967). Its foraging habits in South

A



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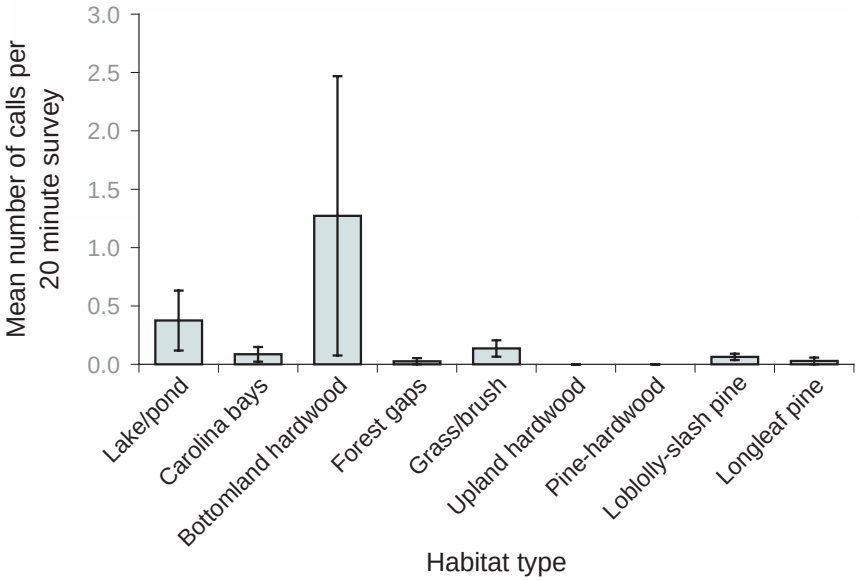

Figure 30—(A) AnaBat survey locations where hoary bats were detected in surveys conducted during summer 2001, and (B) a comparison of flight activity levels of hoary bats among vegetation community types on the Savannah River Site.

Carolina are poorly understood. However, its diet on the Savannah River Site probably is similar to its diet elsewhere in its range.

We have found no information about the size or spatial characteristics of the species' home range.

Effect of Habitat Type and Stand Age on Flight Activity

We recorded hoary bats on 18.8 percent of the lake and pond survey points, 5.7 percent of the Carolina bay survey points, 7.6 percent of the bottomland hardwood survey points, 2.6 percent of the forest gap survey locations, 6.8 percent of the grass-brush survey points, none of the upland hardwood points, none of the pine-hardwood points, 5.0 percent of the loblolly-slash survey points, and 1.4 percent of the longleaf survey locations. Overall, we recorded it on 5.2 percent of all survey locations (fig. 30). Its activity level was low throughout the Site, primarily concentrated in bottomland hardwood stands (table 4).

Stand age affected hoary bat activity differently than it affected that of other bat species on the Site (fig. 9). Based on the low call frequency, high wing loading, and moderately high wing-aspect ratio of the species, we expected activity would be highest in clearcuts; yet we recorded no hoary bat calls there and found most activity concentrated in stands aged > 60 years (table 5).

Reproduction

Hoary bats probably mate during autumn migration (Shump and Shump 1982b). Parturition occurs from May through July (Kurta 1982, McClure 1942, Mumford 1969, Provost and Kirkpatrick 1952, Whitaker and Mumford 1972). Because the species migrates north in spring, parturition may not occur in South Carolina.

Photo courtesy of John MacGregor

Figure 31—Big brown bat.

Big brown bat (*Eptesicus fuscus*)

Morphology and Distribution

The big brown bat is a medium sized, nondescript brown bat and is the third largest in South Carolina (fig. 31). One of the 11 subspecies of big brown bat, *E. f. fuscus*, occurs in the State (Kurta and Baker 1990). Its mass ranges from 13 to 25 g, and its average total length is 114.3 mm (Whitaker and Hamilton 1998). See table 16 for average body measurements of individuals collected in the Southeast.

The range of the big brown bat extends from the Atlantic to the Pacific Coasts, and south from Canada through Central America and into Brazil (Kurta and Baker 1990). It is found throughout the continental United States and is the most common bat species throughout much of its range. It is most abundant in the

Table 16—Body measurements of the big brown bat in the Southeastern United States

Measurement	Number[a]	Mean	SD	CV	Range
			mm		
Female					
Total	23	114.1	6.38	5.59	100.0 – 122.0
Tail	23	44.2	3.44	7.78	34.0 – 49.0
Foot	23	9.4	1.55	16.46	6.5 – 13.0
Ear	23	17.4	1.99	11.49	12.0 – 20.0
Tragus	20	5.7	1.43	25.21	3.0 – 9.0
Forearm	23	45.5	9.44	20.78	4.0 – 52.0
			g		
Mass	21	17.2	4.04	23.54	11.0 – 27.0
			mm		
Male					
Total	16	107.6	6.59	6.13	97.0 – 119.0
Tail	16	41.7	4.67	11.18	30.0 – 49.0
Foot	16	9.7	1.08	11.13	8.0 – 12.0
Ear	15	16.4	1.80	11.00	13.0 – 19.0
Tragus	14	6.4	1.11	17.40	5.0 – 8.0
Forearm	15	46.6	2.53	5.43	40.0 – 50.0
			g		
Mass	16	12.8	3.12	24.33	7.0 – 18.8

Measures that differed significantly between the sexes ($P \leq 0.05$).
[a] Number of individuals measured.

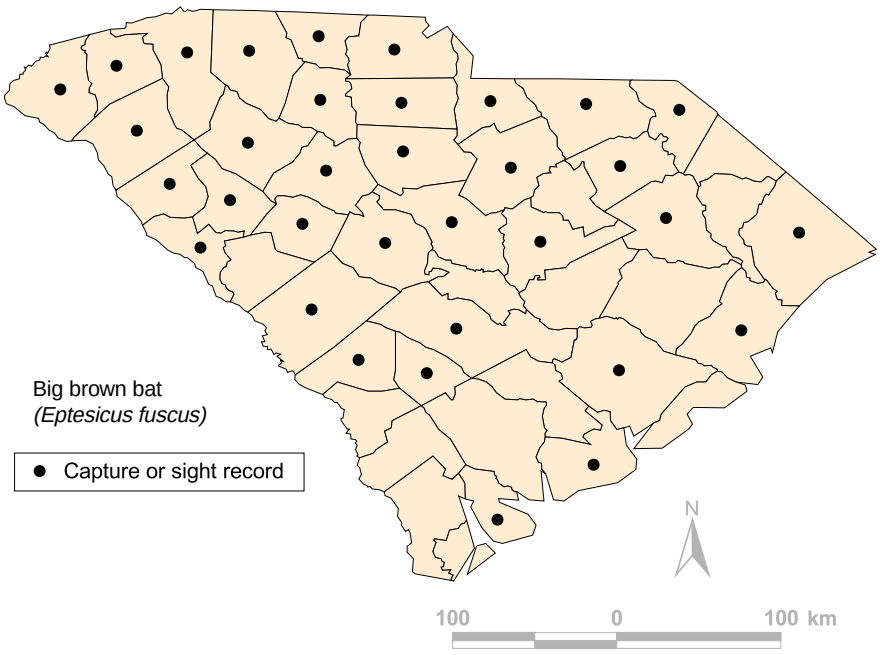

Figure 32—Distribution of the big brown bat in South Carolina (Menzel and others 2003). Symbols denote counties for which records exist.

deciduous forest biome (Kurta and others 1989). Museum collections include 15 big brown bats from South Carolina; 18 have been live-captured there. It is common throughout the State (fig. 32) and is found in all four physiographic provinces.

Despite its apparent abundance in South Carolina, this species was not documented in the 1979 survey, and between 1996 and 2001 we captured only six (two adult females, three adult males, and one juvenile female) (table 7). The relatively few captures on the Site probably was due to the scarcity of preferred roosts. Although it uses many different structures (see Roosting section), summer roosts are most often found in the attics of houses.

Roosting

Big brown bats are one of the most studied in North America. Their hibernacula have been found in mines, caves, rock crevices, storm sewers, and buildings (Barbour and Davis 1969, Beer 1955, Fenton 1972, Mills and others 1975, Mumford 1958, Nagorsen 1980, Phillips 1966, Quay 1949).

Summer roosts usually are found in hollow oak and American beech (*Fagus grandifolia* Ehrh.), but most commonly the species uses human-made structures such as barns or houses (Barbour and Davis 1969, Christian 1956, Kurta 1982). In early August 1996, Menzel (1998) and Carter (1998) radio tracked two big brown bats in a bottomland hardwood swamp to a maternity roost in a hollow bald cypress snag along the Savannah River. Other than this anecdotal account, no studies have investigated the species' summer or winter roosting habits in South Carolina.

Foraging and Home Range

Big brown bats typically begin foraging within the first hour after sunset (Kurta 1982, Phillips 1966). They feed on Isoptera, Hemiptera, Homoptera, Hymenoptera, Lepidoptera, and Diptera (Freeman 1981, Menzel and others 2000a, Ross 1967), although most of their diet is composed of beetles (Hamilton 1933; Menzel and others 2000a; Phillips 1966; Whitaker 1972, 1995). Menzel and others (2000a) reported that during the reproductive period, females selectively forage on Coleopterans and eat fewer Lepidopterans, Dipterans, and Hymenopterans, based on the availability of such insect orders in the foraging area. The species' foraging habits in South Carolina are not known.

To date, little quantitative information has been gathered about this species' foraging habitat selection. Furlonger and others (1987) found that they were generalists when selecting habitat. There are many reports of foraging around urban streetlights, e.g., Geggie and Fenton 1985. In the Georgia Piedmont, Menzel and others (2001c) found that big brown bats selectively foraged in rural rather than urban areas, and less often in agricultural fields and clearcuts than in hardwood and pine forests. Menzel and others (2001c) reported that the average home-range size was 2906 ha; Brigham (1991) reported their maximum foraging distance to be 4.4 km. Both these sets of data suggest large foraging ranges. Information about the foraging behavior of this species in other regions of its range suggests that foraging activity on the Site would not be concentrated in a single habitat type, but would be dispersed across a variety of types. The species probably forages in both upland and bottomland habitats on the Savannah River Site.

Effect of Habitat Type and Stand Age on Flight Activity

Big brown bats were recorded at 25.0 percent of the lake and pond survey points, 20.0 percent of the Carolina bay survey points, 15.2 percent of the bottomland hardwood survey points, 5.3 percent of the forest gap survey locations, 18.6 percent of the grass-brush survey points, none of the upland hardwood points, 7.1 percent of the pine-hardwood points, 7.9 percent of the loblolly-slash survey points, and 10.0 percent of the longleaf survey locations. We recorded them on 11.8 percent of all survey locations (fig. 33). Activity was concentrated over lakes and ponds, grass-brush, and in bottomland hardwoods (table 4). Foraging activity appeared to be unaffected by stand age (fig. 9).

Reproduction

Mating occurs in September and March (Mumford 1958, Phillips 1966), and fertilization in spring (Wimsatt 1944). The species' reproductive habits are unknown in South Carolina, but we captured a juvenile on the Site and tracked two females to a large (> 30 individuals) maternity colony located in a bald cypress snag where Pen Branch flows into a swamp forest adjacent to the Savannah River. The species probably raises its young on-site.

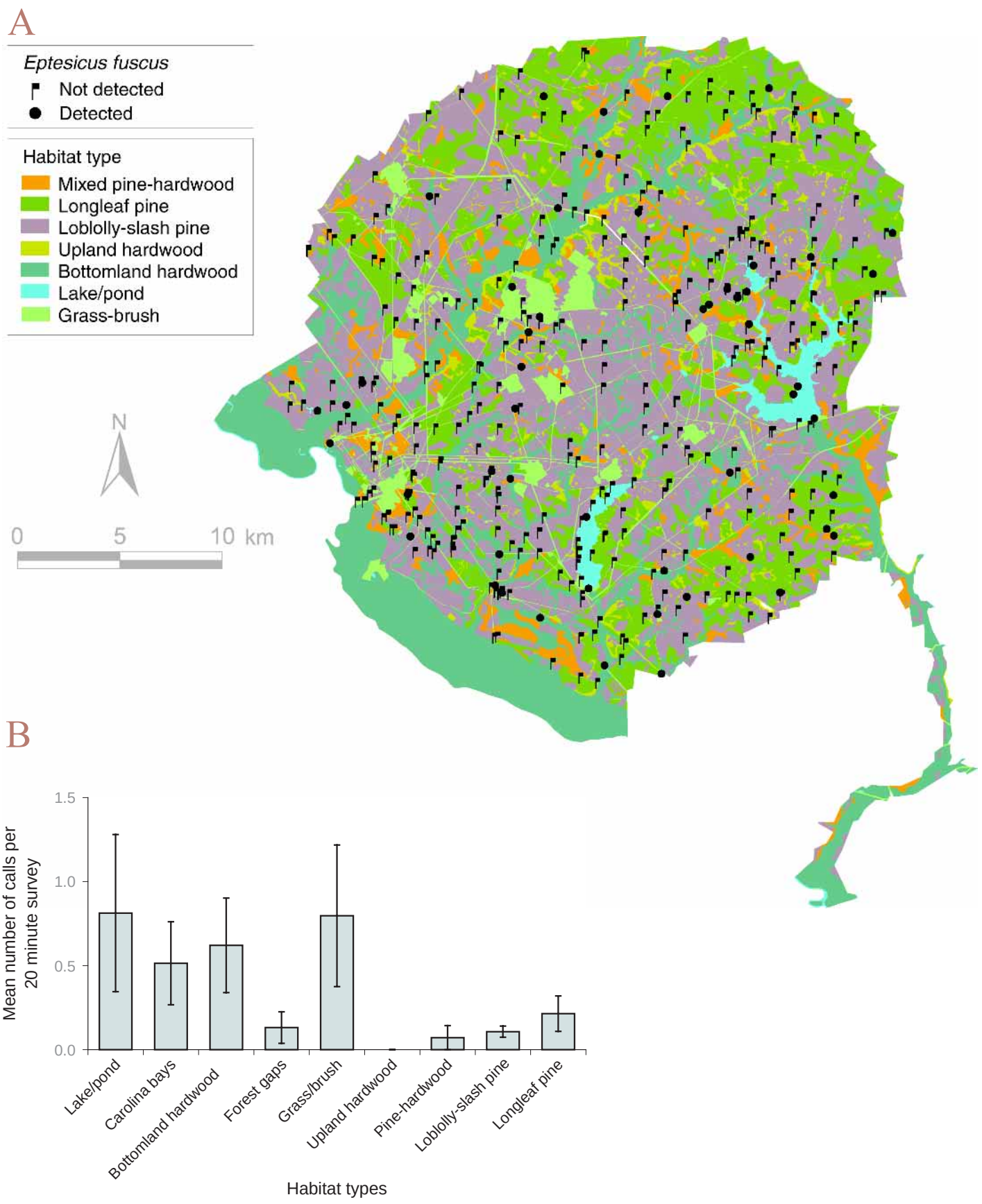

Figure 33—(A) AnaBat survey locations where big brown bats were detected in surveys conducted during summer 2001, and (B) a comparison of the flight-activity levels of big brown bats among vegetation community types on the Savannah River Site.

Photo courtesy of John MacGregor

Figure 34—Little brown bat.

Bats of South Carolina in Areas Neighboring the Savannah River Site

Family Vespertilionidae

Little brown bat *(Myotis lucifugus)*

Morphology and Distribution

The little brown bat is a small brown bat with glossy pelage that occurs in some areas of South Carolina (fig. 34). Of the six subspecies currently recognized, only *M. l. lucifugus* occurs in the State (Fenton and Barclay 1980). Its mass ranges from 4 to 8 g, and its average total length is 89.2 mm (Whitaker and Hamilton 1998). See table 17 for average body measurements of individuals collected in the Southeast.

The little brown bat is common throughout much of the United States. In the Eastern States, the southern limit of its range reaches into northern portions of South Carolina, Georgia, Alabama, and Mississippi (Fenton and Barclay 1980). Museum collections include three in South Carolina; three have been live-captured there. Although its typical distribution in the State is limited to the Blue Ridge (fig. 35), captures have been confirmed in Beaufort County on the lower Coastal Plain (Davis and Rippy 1968). South Carolina has listed it as uncommon or rare (South

Table 17—Body measurements of the little brown bat in the Southeastern United States

Measurement	Number[a]	Mean	SD	CV	Range
			mm		
Total	10	87.4	4.96	5.67	80.0 – 95.0
Tail	10	37.5	3.03	8.08	32.0 – 41.0
Foot	9	8.1	0.73	9.02	6.5 – 9.0
Ear	10	13.5	1.08	8.00	12.0 – 15.0
Tragus	9	5.7	1.30	22.92	4.5 – 8.0
Forearm	7	37.0	2.02	5.46	34.0 – 40.0
			g		
Mass	10	6.5	1.09	16.62	5.5 – 9.3

[a] Number of individuals measured.

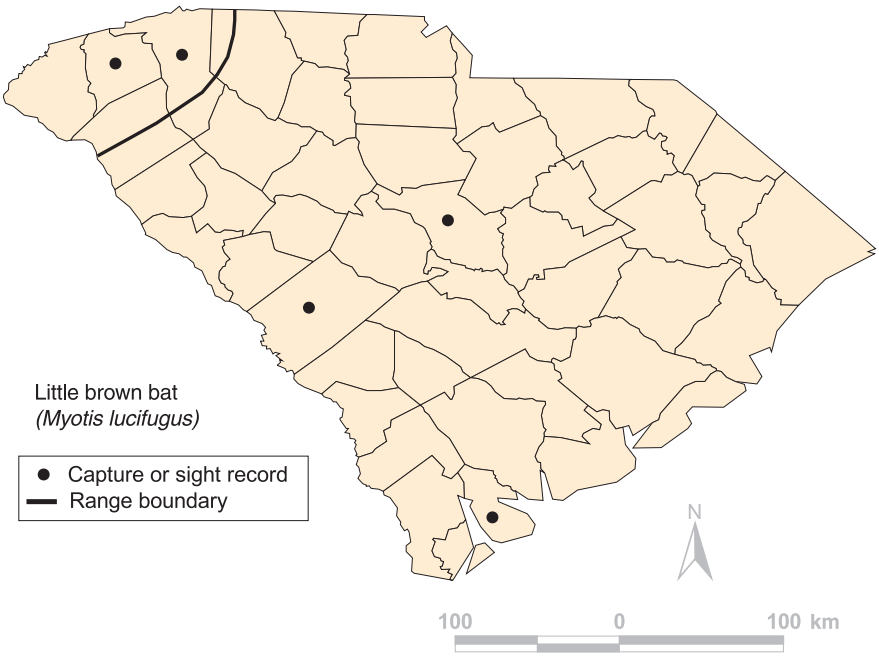

Figure 35—Distribution of the little brown bat in South Carolina (Menzel and others 2003). Symbols denote counties for which records exist. Records south of the range line likely are extralimital, because the primary distribution of this species is in the Blue Ridge and northward.

Carolina Department of Natural Resources 2001).

One female little brown bat was captured on the Site in 1996 (table 7). Because the Site is south of the species' typical range, that single record probably is extralimital. The species probably does not occur there regularly.

Roosting

Little is known about the roosting habits of little brown bats in South Carolina. Its hibernacula most commonly are found in caves and mines (Baker 1965, Humphrey and Cope 1976), but no hibernacula have been found in the State. In summer, little brown bats roost under rocks, in piles of wood, and in trees (Fenton and Barclay 1980). Maternity roosts commonly are found in buildings (Davis and Hitchcock 1965, Griffin 1940, Youngman 1975). The summer or winter roosting habits of this species in South Carolina have not been reported.

Foraging and Home Range

Little brown bats emerge shortly after dusk to feed (Nagorsen and Brigham 1990). Numerous foraging habit studies have been conducted (Anthony and Kunz 1977; Belwood and Fenton 1976; Buchler 1976; Ross 1961, 1967; Whitaker 1972), but the species' diet in South Carolina is not known. It typically forages along riparian areas (Fenton and Barclay 1980). Griffin and others (1960) found that when feeding in an insect swarm, little brown bats could capture up to 12 fruit flies per minute. Although the species' diet is variable, aquatic insects constitute most of its forage (Fenton and Barclay 1980). Little is known about the size of its home range, and nothing is known about its home range or habitat use in South Carolina. Because the species does not occur there regularly, its foraging behavior should be of little concern to land managers on the Site.

Effect of Habitat Type and Stand Age on Flight Activity

We did not record any calls of little brown bats during the 2001 AnaBat survey.

Reproduction

Little brown bats mate in autumn, and fertilization occurs in spring when females leave the hibernacula. Duration of hibernation typically decreases with decreasing latitude, resulting in earlier ovulation and parturition dates at more southerly latitudes (Fenton and Barclay 1980). Parturition occurs in late May and June (Barbour and Davis 1969, Hayward 1963, Hoffmeister 1989) on the Savannah River Site, and it is unlikely that little brown bats raise their young there.

Table 18—Body measurements of the eastern small-footed myotis in the Southeastern United States

Measurement	Number[a]	Mean	SD	CV	Range
			mm		
Total	2	78.0	2.83	3.63	76.0 – 80.0
Tail	2	33.0	1.41	4.28	32.0 – 34.0
Foot	2	6.0	1.41	23.57	5.0 – 7.0
Ear	2	14.0	0.	0.	14.0 – 14.0
Tragus	2	5.0	NA	NA	5.0 – 5.0
Forearm	1	31.0	1.41	4.56	30.0 – 32.0
			g		
Mass	2	4.2	0.07	1.66	4.2 – 4.3

[a] Number of individuals measured.

Photo courtesy of John MacGregor

Figure 36—Eastern small-footed myotis.

Eastern small-footed myotis *(Myotis leibii)*

Morphology and Distribution

The eastern small-footed myotis is a small brown bat with long, glossy pelage and a black mask (fig. 36). It is the smallest bat found in South Carolina. This species is monotypic (van Zyll de Jong 1985). Its mass ranges from 4 to 6 g, and its average total length is 77.5 mm (Whitaker and Hamilton 1998). See table 18 for average body measurements of individuals collected in the Southeast.

The species' range is restricted to northeastern North America, from extreme northwestern South Carolina west into Oklahoma and Missouri and north into the St. Lawrence forest region of Ontario and Quebec (van Zyll de Jong 1985). Museum collections include 42 eastern small-footed myotis from South Carolina. Within the State, its range is limited to the Blue Ridge in the extreme north (fig. 37). The species appears to be uncommon

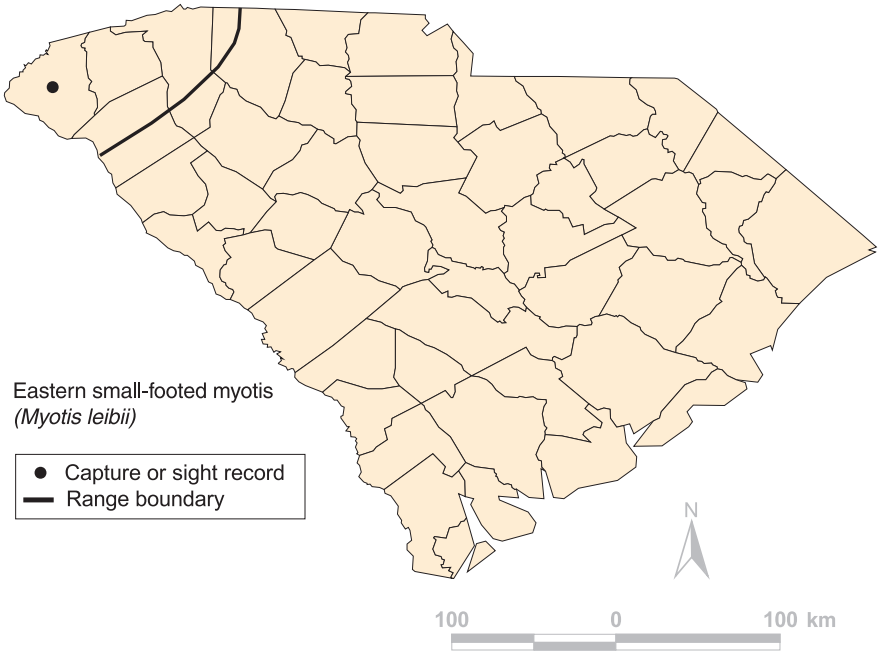

Figure 37—Distribution of the eastern small-footed myotis in South Carolina (Menzel and others 2003). Symbols denote counties for which records exist. Typical summer distribution is north of the range line.

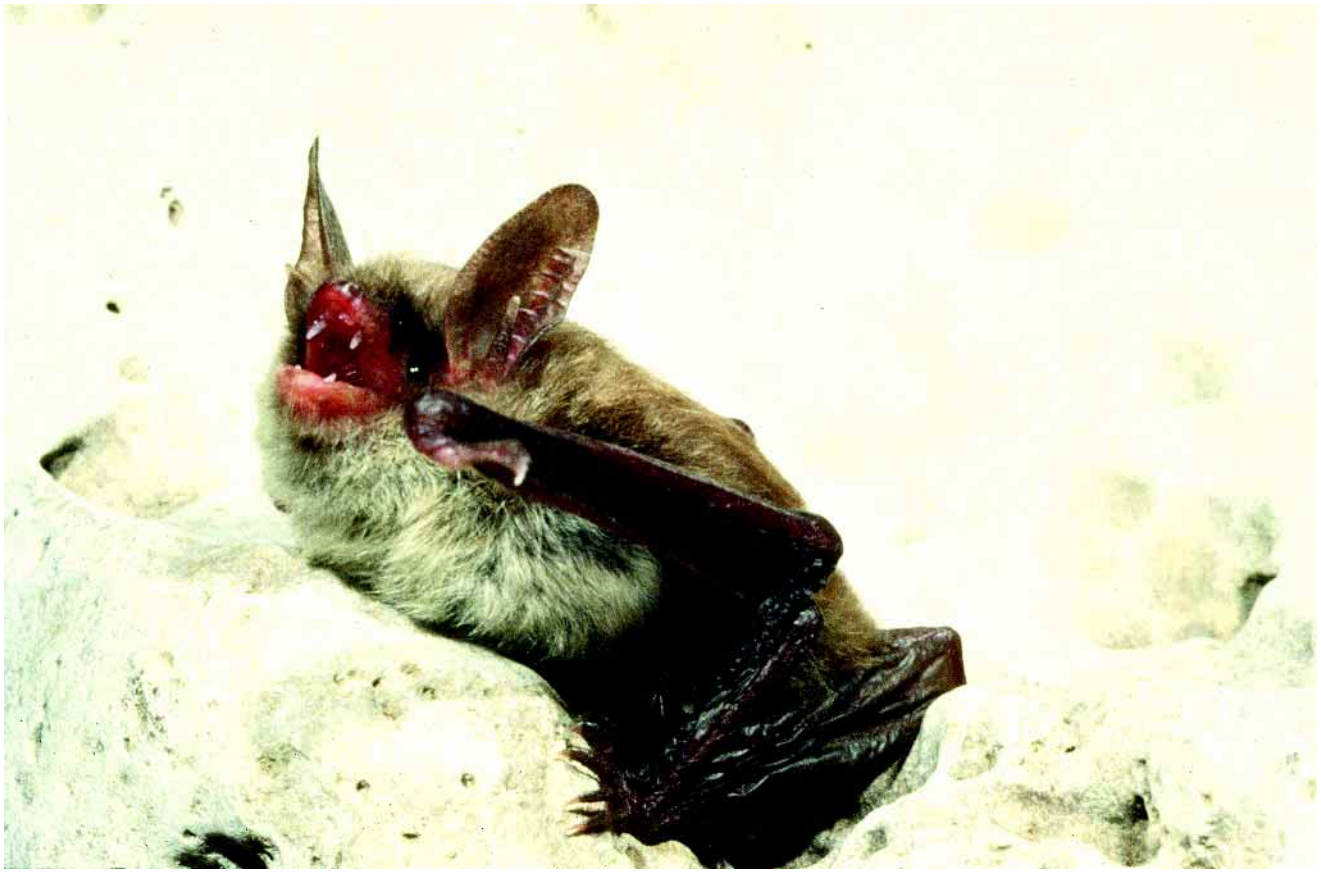

Photo courtesy of John MacGregor

Figure 38—Northern long-eared myotis.

throughout its range, and it is listed as threatened in South Carolina (table 9) (South Carolina Department of Natural Resources 2001).

No eastern small-footed myotis' have been captured on the Site. Based on its distribution and roosting-habitat preferences, i.e., rock outcrops, it is highly unlikely that this species would occur on the Site.

Roosting

Roosting habits of eastern small-footed myotis' in South Carolina are not well known. In other States, hibernacula have been found in caves and mines (Davis 1955; Fenton 1972; Hitchcock 1945, 1949; Mohr 1936). Summer roosts have been found under rocks and in buildings (Barbour and Davis 1969, Hitchcock 1955, Tuttle 1964).

Foraging and Home Range

Eastern small-footed myotis' begin foraging shortly after sunset. Average foraging height is 1 to 3 m above the ground (van Zyll de Jong 1985), but little is known about its prey.

Because it is so small, this species is difficult to track using radiotelemetry. To lessen the transmitter's effect on foraging behavior, transmitter mass was < 0.4 g. Because of this difficulty, and because of the species' rarity, characteristics of its home range have not been documented.

Effect of Habitat Type and Stand Age on Flight Activity

We did not record any eastern small-footed myotis calls during the 2001 AnaBat survey. This species has not been captured on the Site, and it is unlikely to occur there.

Reproduction

Information about eastern small-footed myotis reproduction is limited to one record of a maternity colony located behind the door of a barn in Ontario, Canada, in summer (Hitchcock 1955). No maternity colonies have been found in South Carolina.

Northern long-eared myotis *(Myotis septentrionalis)*

Morphology and Distribution

The northern long-eared myotis is a medium-sized bat with long, glossy brown pelage (fig. 38) (Fitch and Shump 1979). Its mass ranges from 5 to 10 g, and its average total length is 84.1 mm (Whitaker and Hamilton 1998). See table 19 for average body measurements of individuals collected in the Southeast.

The northern long-eared myotis occurs throughout much of the eastern half of the United States. Its range extends east from Saskatchewan to Quebec, Canada, and south to Florida (Fitch and Shump 1979). Although there are no museum specimens from South Carolina, 22 individuals have been live-captured in surveys. Its distribution in the State is

Table 19—Body measurements of the northern long-eared myotis in the Southeastern United States

Measurement	Number[a]	Mean	SD	CV	Range
			mm		
Total	15	85.3	5.09	5.97	75.0 – 92.0
Tail	15	37.6	3.42	9.09	30.0 – 42.0
Foot	15	7.2	0.86	11.97	6.0 – 9.0
Ear	14	15.3	1.88	12.25	11.0 – 17.0
Tragus	12	6.8	1.01	14.74	5.0 – 8.5
Forearm	15	35.1	0.89	2.54	33.5 – 36.0
			g		
Mass	12	8.0	11.65	144.92	3.6 – 45.0

[a] Number of individuals measured.

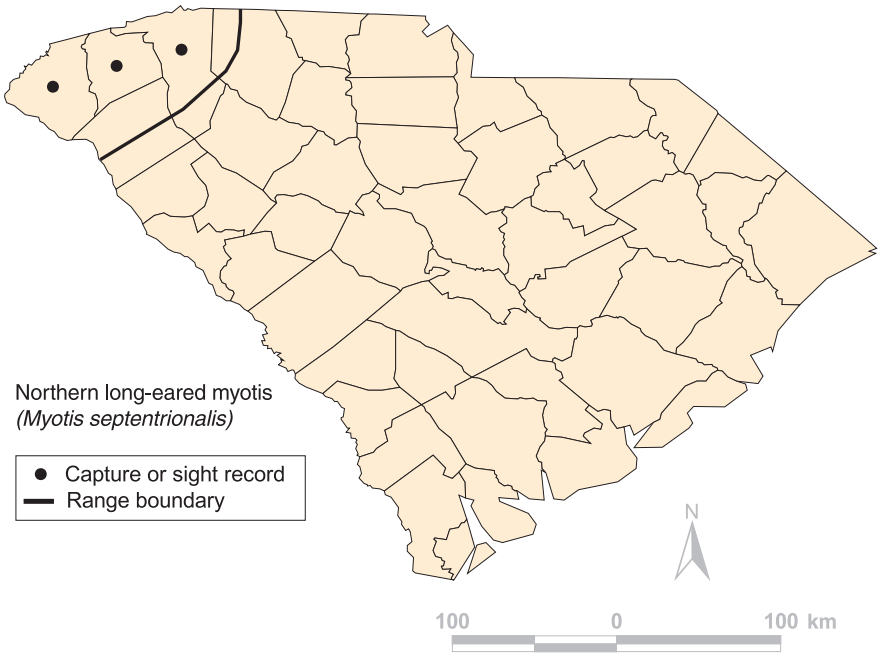

Figure 39—Distribution of the northern long-eared myotis in South Carolina (Menzel and others 2003). Symbols denote counties for which records exist. Typical summer distribution is north of the range line.

restricted to the Blue Ridge, where the species is common (fig. 39) (South Carolina Department of Natural Resources 2001).

No northern long-eared myotis have been captured on the Savannah River Site. Its typical range does not include the Site, and it is unlikely any occur there.

Roosting

Hibernacula used by northern long-eared myotis have been found in caves (Griffin 1940, Swanson and Evans 1936), mines (Stones and Fritz 1969), and a storm sewer (Goehring 1954). During summer, the species roosts in buildings (Doutt and others 1966, Turner 1974), behind shutters (Mumford 1969), and under the bark and in the cavities of trees (Menzel and others 2002d, Mumford and Cope 1964). Its summer or winter roosting habits in South Carolina are not known.

Foraging and Home Range

Northern long-eared myotis forage shortly after dusk and before dawn (Barbour and Davis 1969). They forage around ponds and along hillsides, both above (Cowan and Guiguet 1965) and beneath (LaVal and others 1977) the tree canopy. Little is known about their diet. Their foraging habits in South Carolina are not known.

Although this species' home-range characteristics in the Southeast have not been studied, data are available for the central Appalachians. In the Allegheny Mountains of West Virginia, its home ranges are unimodal, from 43 to 578 ha (mean 216 ha), and include clearcuts, deferment harvests, streams, road corridors, and mature second-growth eastern deciduous forests.[4]

Effect of Stand Age and Habitat Type on Flight Activity

We did not record any calls of northern long-eared myotis during the 2001 AnaBat survey. We have not captured any of this species on the Site, and it is unlikely to occur there.

Reproduction

Northern long-eared myotis copulate in autumn, and sperm is stored in the uterus throughout hibernation. Fertilization occurs in spring (Barbour and Davis 1969). Parturition occurs in June, and the young typically become volant in late July (Easterla 1968, Kunz 1971). Parturition times and maternity colony habits in South Carolina are not known.

[4] Menzel, M.A. Unpublished data. On file with: West Virginia University, Division of Forestry, Percival Hall, Morgantown, WV 26506.

Photo courtesy of J. Scott Altenbach

Figure 40—Northern yellow bat.

Northern yellow bat *(Lasiurus intermedius)*

Morphology and Distribution

The northern yellow bat is a large yellow bat and is the second largest bat in South Carolina (fig. 40). Although two subspecies of it are recognized, the validity of this designation is a matter of debate (Whitaker and Hamilton 1998). Of the two subspecies, *L. intermedius floridanus* occurs in South Carolina. Its mass ranges from 14 to 20 g, and average total length is 126.8 mm (Whitaker and Hamilton 1998). See table 20 for average body measurements of individuals collected in the Southeast.

Although one northern yellow bat was collected in New Jersey (Koopman 1965), typically the species is restricted to coastal areas of the Southeastern United States and Central America (Webster and others 1980). Museum collections include 11 northern yellow bats from South Carolina; one has been live-captured in the State. It occurs in the lower Coastal Plain, and its range extends into the upper Coastal Plain along the Savannah River (fig. 41). The State has listed the status of this species as undetermined (table 9) (South Carolina Department of Natural Resources 2001).

One northern yellow bat was collected along Upper Three Runs Creek in 1978. However, none was captured during the 1979 survey (Anon. 1980) or the 1996 to 2001 survey. Based on the species' distribution, it probably is not a common resident on the Savannah River Site. The individual collected along Upper Three Runs Creek probably represents an extralimital record.

Roosting

Little is known about the northern yellow bat's winter roosting habits in South Carolina or elsewhere.

Summer roosts have been located in palm groves (Davis 1960), on hardwood stems (Rageot 1955), in pine-oak woodlands (Carter and Jones 1978, Carter and others 1966, Jones 1964, Sherman 1944), and in Spanish moss (Jennings 1958).[5] Northern yellow bats usually roost alone; however, Baker and Dickerman (1956) reported seeing about 45 individuals fly from a communal roost under corn stalks hanging from the side of an old tobacco curing shed. The species is not a regular summer resident on the Site and should be of little management concern.

Foraging and Home Range

Northern yellow bats typically begin foraging well before dark (Lowery 1974). They forage 4 to 6 m above the ground (Barbour and Davis 1969) and prefer open foraging areas such as airports, golf courses, and fields (Jennings 1958). Lowery (1974) observed them foraging over the Mississippi River. After the young become volant, they form feeding

[5] Menzel, M.A.; Krishon, D.M.; Carter, T.C. 1995. Roosting, foraging, and habitat use by bats of Sapelo Island, Georgia. Unpublished Tech. Rep. 60 p. On file with: Georgia Department of Natural Resources, Attn: J. Ozier., Social Circle, GA.

Table 20—Body measurements of the northern yellow bat in the Southeastern United States

Measurement	Number[a]	Mean	SD	CV	Range
		----------mm----------			
Total	5	127.6	3.36	2.63	124.0 – 132.0
Tail	5	52.6	2.51	4.77	49.0 – 55.0
Foot	5	10.4	1.52	14.58	8.0 – 12.0
Ear	3	17.7	2.52	14.24	15.0 – 20.0
Tragus	3	7.7	3.05	39.85	5.0 – 11.0
Forearm	3	51.7	1.15	2.23	51.0 – 53.0
		----------g----------			
Mass	3	20.0	2.29	11.46	17.5 – 22.0

[a] Number of individuals measured.

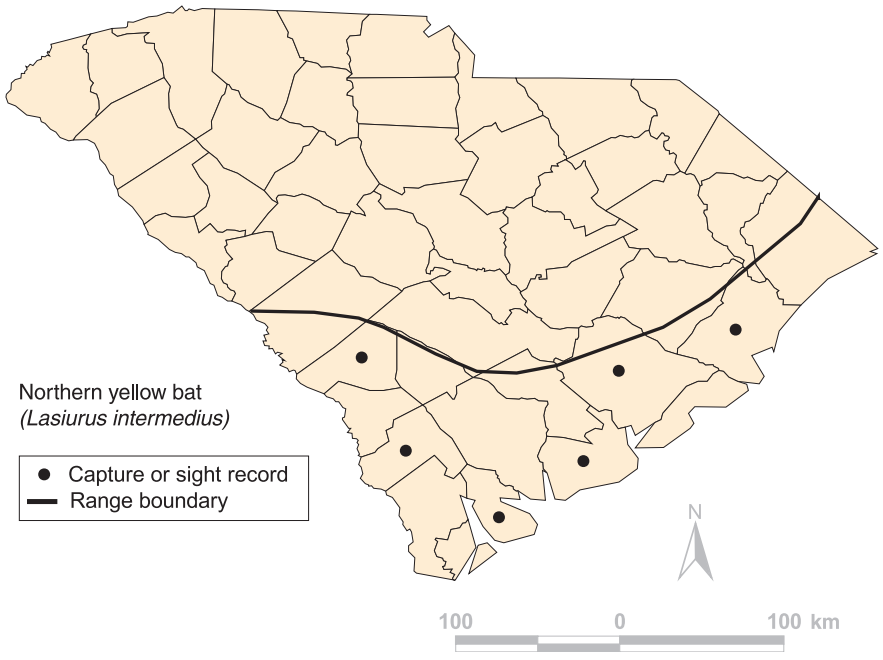

Figure 41—Distribution of the northern yellow bat in South Carolina (Menzel and others 2003). Symbols denote counties for which records exist. Typical summer distribution is north of the range line.

aggregations that may consist of > 100 individuals (Jennings 1958). Such aggregations primarily are composed of females. Northern yellow bats emerge and feed on warm nights throughout winter (Jennings 1958).

Northern yellow bats feed on Homoptera, Zygotera, Diptera, Coleoptera, and Hymenoptera (Sherman 1939), but their foraging habits in South Carolina are not known.

The home range of a northern yellow bat tracked on Sapelo Island, GA, was 10.5 ha (Krishon and others 1997). It was located in oak (73 percent) and slash-loblolly pine (25 percent) communities. The average distance from the roost area center to a foraging location was 109 m. This is a relatively small home range compared to the average home range of other, smaller lasiurines, e.g., eastern red bat = 453.2 ha, Seminole bat = 428.8 ha. This estimate is based on one individual and may not represent the species' average home-range size. No home range or habitat use studies of northern yellow bats have been conducted in South Carolina.

Effect of Habitat Type and Stand Age on Flight Activity

We did not record any calls of northern yellow bats during the 2001 AnaBat survey. Although we collected one on the Site, it is unlikely that this species regularly occurs there.

Reproduction

Parturition occurs in late May and June (Lowery 1974, Schmidly 1991). Litter size ranges from two to four individuals and averages 3.4 per litter (Jennings 1958). Mating probably occurs in autumn and fertilization in spring (Lowery 1974). The species' reproductive habits in South Carolina are not known.

Family Molossidae

There are 16 genera and 86 species in the family Molossidae (Nowak 1994). Members of this family are found in southern Europe, Asia, Africa, and from the northern half of South America north into the United States. Some are colonial and form the largest aggregations of mammals documented. Davis and others (1962) estimated that summer molossid populations in four caves (Bracken, Goodrich, Rucker, and Frio) in Texas exceeded 10 million individuals during peak periods. Molossids are medium to large bats. Because one of the most defining characteristics of this family is that the tail extends beyond the posterior border of the uropatagium, members of this family commonly are called the free-tailed bats.

Two genera and six species of molossids occur in the United States. One species occurs in South Carolina.

Brazilian free-tailed bat *(Tadarida brasiliensis)*

Morphology and Distribution

The Brazilian free-tailed bat is the only species of free-tailed bat that occurs in South Carolina (fig. 42). As its name suggests, the tail of this species extends beyond the posterior edge of the uropatagium. It is the smallest member of its genus in the United States. Of the nine subspecies now recognized, only *T. brasiliensis cynocephala* occurs in the State (Wilkins 1989). Its mass ranges from 8 to 14 g, and its average total length is 91.9 mm (Whitaker and Hamilton 1998). See table 21 for average body measurements of individuals collected in the Southeast.

The Brazilian free-tailed bat has one of the largest ranges of any mammal in the Western Hemisphere (Wilkins 1989). From South Carolina, the species' range extends west into southern Oregon and south through Central America. It reaches the southern limit of its range in the Patagonian region of southern Chile and Argentina (Wilkins 1989). A total of 338 Brazilian free-tailed bats from South Carolina are in museum collections. Its distribution in the State extends through the upper and lower Coastal Plain (fig. 43). There have been live captures in the Piedmont, but these isolated records may not reflect the species distribution in South Carolina.

Photo courtesy of John MacGregor

Figure 42—Brazilian free-tailed bat.

Free-tailed bats have been submitted for rabies testing from Aiken and Barnwell Counties, SC. Although none was captured during the 1979 or 1996 to 2001 surveys, it was recorded during a 1996 AnaBat study on Savannah River Site (Menzel and others 2002d). Additionally, its range in the Southeast, the individuals submitted for rabies testing from Aiken and Barnwell Counties, and recent reports that it is roosting in

Table 21—Body measurements of the Brazilian free-tailed bat in the Southeastern United States

Measurement	Number[a]	Mean	SD	CV	Range
		mm			
Total	14	93.1	6.65	7.14	75.0 – 101.0
Tail	14	33.0	1.66	5.04	30.0 – 36.0
Foot	14	9.2	0.85	9.18	8.0 – 11.0
Ear	11	16.9	3.51	20.73	7.0 – 20.0
Tragus	7	1.7	0.64	37.11	1.0 – 3.0
Forearm	13	43.4	0.77	1.77	42.0 – 45.0
		g			
Mass	12	11.5	2.03	17.27	9.3 – 16.0

[a] Number of individuals measured.

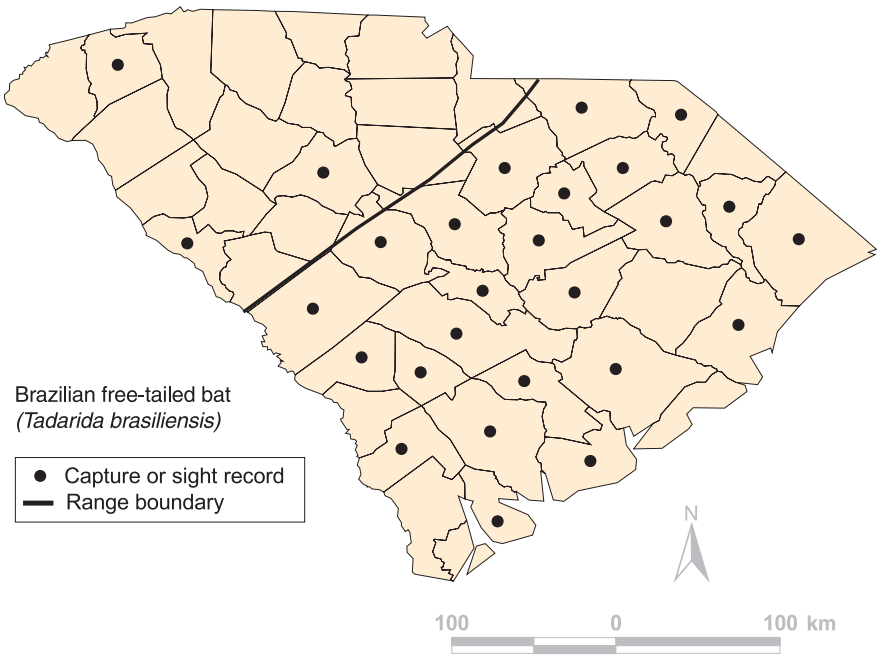

Figure 43—Distribution of the Brazilian free-tailed bat in South Carolina (Menzel and others 2003). Symbols denote counties for which records exist.

structures near Clemson, SC, suggest that it may be more common on the Site than survey results indicate.[6] Brazilian free-tailed bats typically roost in human-made structures. Their dependence on such structures for roosting habitat may limit their abundance on the Site.

Roosting

There is little difference between the summer and winter roosting habits of Brazilian free-tailed bats, although they do vary among different regions of the United States. Most roosts in the Southwest are found in caves, although the bat does use buildings sometimes during migration. In the Southeast, roosts typically are found in buildings (Barbour and Davis 1969), but they also have been found in hollow trees and in the expansion joints of bridges (Lowery 1974, Tuttle 1994). This species is very gregarious and almost always roosts in colonies (Barbour and Davis 1969). Although the size of cave colonies of the Southwest commonly exceeds 1 million individuals, colonies in the Southeast typically are composed of < 50,000. Roosting habits in South Carolina are not known. Although nothing is known about the species' on-site roosting requirements, there is no reason to suspect that they are different from other areas of the Southeast.

Foraging and Home Range

Although emergence time is variable, Brazilian free-tailed bats usually leave their roost shortly after sunset (Bailey 1951). As with most bat species inhabiting temperate regions, the length of the foraging bout varies with temperature. Bailey (1951) found that on warm nights, individuals in a colony of Brazilian free-tailed bats in Louisiana did not return to the roost until morning. Most studies of this bat's foraging habits have been conducted in the Southwest. In the Southeast, Brazilian free-tailed bats feed on Hymenoptera, Coleoptera, Diptera, and Lepidoptera (Sherman

[6] Personal communication. 1999. Mary Bunch, Wildlife Biologist, South Carolina Department of Natural Resources, Wildlife Diversity Section, P.O. Box 1806, Clemson, SC 29633.

1939). Their diet in South Carolina or on the Savannah River Site has not been studied. There is no reason to suspect that it would be any different than elsewhere in the Southeast, but because little is known about this species in the region, and because its diet may differ from the western subspecies, its diet in the eastern United States warrants future study.

Nothing is known about the size of the Brazilian free-tailed bat's home range in the Southeast; further study will be necessary to determine the spatial extent of its foraging areas in the region.

Effect of Habitat Type and Stand Age on Flight Activity

We did not record any calls of Brazilian free-tailed bats during the AnaBat survey. However, the species was detected during call surveys conducted in canopy gaps in a bottomland hardwood forest during summer 1997 (Menzel and others 2002a). Brazilian free-tailed bats have been collected from Aiken and Barnwell Counties, SC, and from areas south and north of the Site.

Reproduction

In Florida, spermatogenesis occurs throughout late autumn and winter (Sherman 1937). Unlike vespertilionid bats in South Carolina, which mate in autumn and ovulate in spring, Brazilian free-tailed bats both copulate and ovulate in spring (Cockrum 1955). Breeding occurs in February and March (Golley 1966). Parturition occurs from late May to early August (Barbour and Davis 1969, Sherman 1937), and the typical litter size is one (Wilkins 1989). Maternity colonies of this species have been located in the State, and the species occasionally may raise its young on the Savannah River Site.

Photo courtesy of John MacGregor

Figure 44—Rocket-box bat house, as described by Dourson and MacGregor 1997.

Conservation and Research Needs

Although no federally listed bat species occur on the Savannah River Site, the State of South Carolina lists the Rafinesque's big-eared bat as endangered and the southeastern myotis as threatened (table 9). Two of the nine species (22 percent) that occur on the Site regularly are protected. In the Southeast, 87 percent of all bat species carry special conservation designations somewhere within their regional distribution (Laerm and others 2000). Worldwide, a relatively high proportion of bat species are designated as threatened or endangered. All 15 bat species that occur in Great Britain are now considered threatened or endangered (Nagorsen and Brigham 1990, Stebbings 1988), and bat

populations seem to be declining globally (Nowak 1994).

Potential issues of conservation concern have been raised for the Site and surrounding areas. More than 75 percent of the Site is included in the timber management program and is therefore subject to some timber harvesting (Blake, in press). Although there has been a recent surge of information concerning the effects of forest management practices on forest bat communities, e.g., Barclay and Brigham 1996, Krusic and others 1996, little is known about the effects of most silvicultural practices in the Southeast. Studies investigating the effects that harvesting techniques, e.g., clearcutting, group-selection cuts, and various intermediate treatments, e.g., thinnings, herbicide application, and prescribed burning, may have on bat communities will be necessary to make more informed land management decisions. As more land area is devoted to short-rotation forestry practices, roosting habitat may become scarce for bat species that depend on older trees for cavity or bark roosts. Studies should investigate the potential use of bat houses to enhance roosting habitat where it has been compromised (fig. 44).

In addition to timber management, other large-scale agricultural practices are common throughout much of South Carolina. All nine species of bats that occur on the Site are insectivorous and therefore may be affected by pesticides that are applied to agricultural crops such as cotton, soybeans, and corn. We know little about how these pesticides will affect bat populations over the long term. The effects of pesticides on cavernicolous species such as the gray bat have been examined (Clawson and Clark 1989), but the effects of pesticides on tree-roosting bats are not known. All bat species that occur on the Savannah River Site roost in trees during at least part of the year.

Another conservation concern in the Coastal Plain of South Carolina focuses on the use of bridges as roosts by bats. In some areas of the United States, such as Texas, bridges are important roosting sites for many bat species (Keeley 1997). The endangered Rafinesque's big-eared bat and the threatened southeastern myotis roost under bridges (Lance and others 2001). Although many bridges on the Site may serve as roosts for these species, no surveys have been conducted to document the bats' use of them.

In the 1990s, great strides were made towards understanding the roosting and foraging ecology of bats, but much remains unknown. Few studies have been conducted in the Southeast, and results from studies conducted in other regions of the United States and Canada may not be applicable in South Carolina or on the Savannah River Site. To more effectively manage the Site's bat communities we need more information about their roosting and foraging ecology.

Bats and Rabies

No work on bats is complete without a discussion of rabies, a zoonotic disease that generates considerable concern among public health officials and an almost irrational fear among the general public. Found worldwide except in parts of Scandinavia, the Australian continent, and on island masses such as Hawaii, New Zealand, Papua New Guinea, Japan, and Taiwan, rabies is caused by exposure to and infection by single-strand RNA viruses in the genus *Lyssavirus*, family Rhabdoviridae (Krebs and others 1995, Wunner and others 1988). The British Isles had long been thought to be rabies-free until the discovery of a rabid Daubenton's bat (*Myotis daubentonii*) in 1996 (Whitby and others 1996). Transmission to humans or other mammals occurs primarily by introduction of the virus into wounds, cuts, scratches, and mucous membranes from an infected animal, usually by biting (Macinnes 1987). Other routes of viral transmission, such as inhalation of rabies-infected aerosol, are known, but they are extremely rare (Constantine 1962, 1967b; Winkler and others 1973), as is transmission through rabies-infected human tissue transplanted in uninfected organ recipients (Centers for Disease Control and Prevention 1980, 1981).

Rabies was first documented in bats in the United States in 1953 (Krebs and others 1994). Contrary to popular belief, bats are not nonsymptomatic carriers of rabies. However, the length of latency prior to onset of symptoms and eventual death in bats is highly variable (Bell and others 1969, Macinnes 1987, Moreno and Baer 1980). The rabies virus is reservoired in many wild mammal hosts, including bats (Davidson and Nettles 1997), although transmission cycles usually are separate between terrestrial mammals and bats (Constantine 1967a, 1979a; Smith 1989). In Latin America, vampire bats routinely spread rabies to domestic livestock and humans (Arellano-Sota 1988, Batista-da-Costa and others 1993, Martinez-Burnes and others 1997), and in North America, cases of rabies in terrestrial wild mammals and humans have resulted from contact with several of the insectivorous bat species commonly found in South Carolina (Constantine 1979b). Previous research linked the incidence of rabies in foxes to a number of bat caves in the Karst limestone regions of Tennessee (Fredrickson and Thomas 1965), but such relationships were poorly substantiated (Fischman 1976). Following the discovery of rabies virus strains and species-specific variants, most supposed links between bat rabies and the maintenance of rabies in terrestrial mammals have been discounted (Krebs and others 1995, Smith 1989, Smith and others 1986). However, in areas where the incidence of rabies in terrestrial mammals is low, bats are responsible for small rabies outbreaks or "clusters" (Daoust and others 1996).

Among terrestrial mammals in South Carolina and throughout the Southeast and mid-Atlantic regions, raccoons (*Procyon lotor*) are important

terrestrial reservoir species (Rosatte and others 1997). Skunks (*Memphitis memphitis*, *Spilogale putorius*) are rabies vectors in the Midwest and Mississippi Valley (Krebs and others 1994, 1995; Smith and others 1986), and foxes (*Urocyon cinereoargenteus*, *Vulpes vulpes*) are rabies reservoirs in Canada, New England, and parts of the Southwest (Davidson and Nettles 1997, Smith and others 1986). Coyotes (*Canis latrans*) also appear to be important vectors throughout much of the Southwest (Clark and others 1994, Davidson and Nettles 1997).

In developing countries, human cases of rabies are relatively common, accounting for approximately 50,000 deaths annually (Fishbein and Bernard 1995). Most routes of human exposure to rabies are from unvaccinated dogs and cats, particularly in developing countries, but wild animals, including bats, are responsible for many human cases (Krebs and others 1995). Advances in public health—such as animal control laws, mandatory vaccination measures for dogs in many jurisdictions, and aggressive and prompt medical attention following animal bites—have served to limit human exposure to and infection with rabies in North America (Rosatte and others 1997, Tierkel 1975). Today, human exposure to rabies in the United States is almost wholly limited to contact from wild animals, of which exposure to infected bats accounts for the majority of cases documented since the 1980s (Childs and others 1994, Hoff and others 1993, Krebs and others 1995). Nonetheless, the overall incidence of rabies contracted from bats in North America is low (Krebs and others 1995, Rotz and others 1998, Tuttle and Kern 1981). Efforts to develop effective oral rabies vaccines for wild, terrestrial mammals—and to distribute such vaccines by widespread baiting—are underway in the United States and Canada (Davidson and Nettles 1997), but such preventive measures for bats have not been contemplated.

In humans, rabies is almost always fatal. Following exposure, the incubation period may range from < 10 days to > 6 years (extreme latency). Commonly, incubation time from exposure to the first symptoms is 30 to 90 days. The rabies virus infects nervous tissue, eventually spreading to the spinal cord and brain, producing encephalitic lesions. It moves then throughout the central nervous system and to peripheral sites such as the salivary glands, where it is shed in saliva (thus facilitating transfer to another animal). Initial symptoms in humans can include pain and burning near the site of the wound where exposure occurred, headache, fever, flu-like malaise, and mental changes such as anxiety and apprehension. As the disease progresses, mental deterioration occurs in the form of disorientation and hallucinations. Aggressive behavior and hydrophobia, or "fear of water," does occur in human cases, although in less than one-half of documented rabies cases. Physically, difficulty in swallowing, muscle spasms, and paralysis occur as the disease advances; death usually results from respiratory failure. From the onset of initial symptoms, death may occur within 1 to a few weeks (Fishbein 1991, Jackson and others 2003, Krebs and others 1995).

In wild mammals, rabies takes two forms—a furious or aggressive form and a withdrawn or dumb form. Skunks, foxes, dogs, and raccoons often lose all fear of humans and other animals when exhibiting the furious form of the disease, and they may exhibit extremely aggressive behaviors. Activity patterns may change. For example, nocturnal animals may become active during the day (Davidson and Nettles 1997, Macinnes 1987). Rabid bats may be irritable and bite conspecifics, but furious behaviors, such as are seen in wild carnivores, are rare (Macinnes 1987, Sulkin and Allen 1974, Tuttle and Kern 1981). The extent to which bat-to-bat rabies transmission occurs through contact from grooming and nursing or from antagonistic interspecific encounters is unknown (Krebs and others 1995, Macinnes 1987). Actual unprovoked attacks by rabid, insectivorous bats on humans or other animals are extremely rare (Constantine 1979a, 1979b; Tuttle and Kern 1981). Animals infected with rabies from bats often exhibit a creeping paralysis (Baer 1975). In the dumb form of rabies, animals remain calm, yet are apparently disoriented and confused (Davidson and Nettles 1997, Macinnes 1987). In most wild mammals, symptoms similar to those affecting humans occur as the disease progresses, advancing to paralysis and eventual death.

Following a suspected or confirmed exposure to rabies—via the use of a fluorescent antibody test on brain tissue of the suspect animal (Kissling 1975, Wachendorfer and others 1985)—development of rabies can be prevented by prompt postexposure prophylaxis of human antirabies immunoglobulin injections. Such treatment is followed by a series of human diploid cell injections, rabies-adsorbed intramuscular vaccinations, or purified chick embryo cell culture vaccinations (Blythe and others 1998). For veterinarians, animal control officers, wildlife biologists, wildlife rehabilitators, and zoologists, who come into contact with wild and feral mammals on a regular basis, preexposure prophylaxis is recommended (Krebs and others 1995). Similarly, anyone handling bats or coming in close contact with bats should be preimmunized.

For many years, rabies was thought to be a single viral type. With the advent of monoclonal antibody surveys and advances in genetics research through polymerase chain reaction (PCR) techniques, epidemiologists have documented a number of antigenically and genetically distinct variants or strains of rabies virus (Koprowski and others 1985; Smith and others 1984, 1986). Strains unique to several species of bats throughout North America have been documented (Smith 1988), and within a species there may be more than one strain or variant across wide geographic regions or within a localized area (Smith and others 1984). Thus, rabies strains

found in bats are distinct from those in terrestrial mammals. As a result, public health officials and scientists can differentiate and document routes of human exposure by animal type and species. For example, of the 14 confirmed cases of human rabies in the United States contracted domestically from 1980 to 1994, 11 were linked to bats. Of those, eight were attributed to viral strains associated with silver-haired bats (Krebs and others 1995), although that species was not always the confirmed vector (Morimoto and others 1996), nor was evidence of a bat bite always present. Common carriers of the silver-haired bat rabies viral strain appear to be big brown bats, little brown bats, and eastern pipistrelles (Messenger and others 1997).

Rabies has been documented in most bat species that occur in South Carolina, including hoary bat, red bat, yellow bat, Seminole bat, big brown bat, little brown bat, small-footed bat, southeastern bat, gray bat, Townsend's big-eared bat, eastern pipistrelle, evening bat, silver-haired bat, and Brazilian free-tailed bat. Rabies has not been documented in Rafinesque's big-eared bat (Constantine 1979b). The common species most likely to occur in and near human dwellings and activity centers, such as the big brown bat, probably pose the greatest risk for transmitting rabies to humans (Childs and others 1994). Eastern red bats, perhaps the most widespread and numerous species in South Carolina, accounted for a large percentage of rabid bats collected in Illinois (Burnett 1989), while a high percentage of rabies-positive bats in Florida have been yellow bats (Bigler and others 1975). Nationwide, the Centers for Disease Control and Prevention statistics indicate that approximately 10 percent of all annually reported and confirmed rabid animals are bats (Krebs and others 1995). For example, in 1996, there were 7,124 documented cases of nonhuman rabies in the United States, of which 741 were bats (Krebs and others 1997). Still, the overall human health risks posed by rabid bats are extremely small in South Carolina. Simple preventive measures such as avoiding handling any bat and avoiding entry into caves, attics, and abandoned buildings that harbor roosting bats—or preventing roosting bats from using human-occupied dwellings—would eliminate most routes of contact and potential rabies transmission. Immediate postexposure rabies prophylaxis should proceed if one is bitten by or comes into close contact with a bat, such as waking to find a bat present in occupied sleeping quarters.

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Appendix

Keys to the Skins and Skulls of South Carolina Bats

Bat research as well as bat monitoring in the Southeast have been impeded by difficulty in training field personnel to reliably identify captured bats. Although many published keys contain information about particular species in the region (Barbour and Davis 1969, Golley 1962, Hoffmeister 1989, Jenkins 1949, Schmidly 1991, Whitaker and Hamilton 1998), many of them have been unreliable tools for teaching students and field personnel to identify bats by their skins and skulls. Most keys require the lower jaw, are poorly or inadequately illustrated, or contain unreliable univariate discriminatory measurements. To improve field identification capabilities we devised a tool combining traits that have been useful in the field and the lab with information from other published keys. Using the combined keys has facilitated relatively easy and accurate identification of the 14 bat species that occur in South Carolina. The keys are reprinted from Menzel and others (2002a).

We used measurements from museum specimens, information contained in recent publications about bat morphological characteristics, and information from published dichotomous keys (Barbour and Davis 1969, Golley 1962, Hoffmeister 1989, Jenkins 1949, Schmidly 1991). Because the bat's lower jaw often is damaged or missing from museum skeletal specimens or skulls found in the field, we devised a key that does not require the lower jaw for identification.

The eastern red (*Lasiurus borealis*) and Seminole (*L. seminolus*) bats are two of the most common species on the Site, but many keys to bats in the Southeast do not differentiate between their skulls. Because these two species are relatively abundant on the Site, we were able to incorporate information about the size of the protuberance of the lacrimal ridge, i.e., the lacrimal shelf, and accurately differentiate among about 75 percent of eastern red and Seminole bats skulls found there (Laerm and others 1999, Lowery 1974).

The key to the skulls allows a user to classify a specimen as belonging to the genus *Myotis*. Because simple univariate measures cannot be used to differentiate among southeastern myotid skulls, identification to species cannot be accomplished with this key. However, many nonmyotid bat skulls can be identified to species by counting the number of teeth in one upper quadrant (one-half of the upper jaw), measuring the skull's greatest length (from the posteriormost margin to the anteriormost portion, not including the incisors), and comparing these lengths using the dental formula for each species (table 22) and the skull key.

Table 22—Dental formulas for the bats of the Savannah River Site

Species	Upper teeth[a]				Lower teeth[a]				Total
	I	C	Pm	M	I	C	Pm	M	(x2)
Eastern pipistrelle	2	1	2	3	3	1	2	3	34
Southeastern myotis	2	1	3	3	3	1	3	3	38
Little brown bat	2	1	3	3	3	1	3	3	38
Evening bat	1	1	1	3	3	1	2	3	30
Rafinesque's big-eared bat	2	1	2	3	3	1	3	3	36
Silver-haired bat	2	1	2	3	3	1	3	3	36
Eastern red bat	1	1	2	3	3	1	2	3	32
Seminole bat	1	1	2	3	3	1	2	3	32
Northern yellow bat	1	1	1	3	3	1	2	3	30
Hoary bat	1	1	2	3	3	1	2	3	32
Big brown bat	2	1	1	3	3	1	2	3	32
Brazilian free-tailed bat[b]	1	1	2	3	2/3	1	2	3	30/32

I = incisors; C = canines; Pm = premolars; M = molars.

[a] Number of teeth in each side of jaw.

[b] Although the Brazilian free-tailed bat has not been captured on the Savannah River Site, it is likely this species occasionally occurs there.

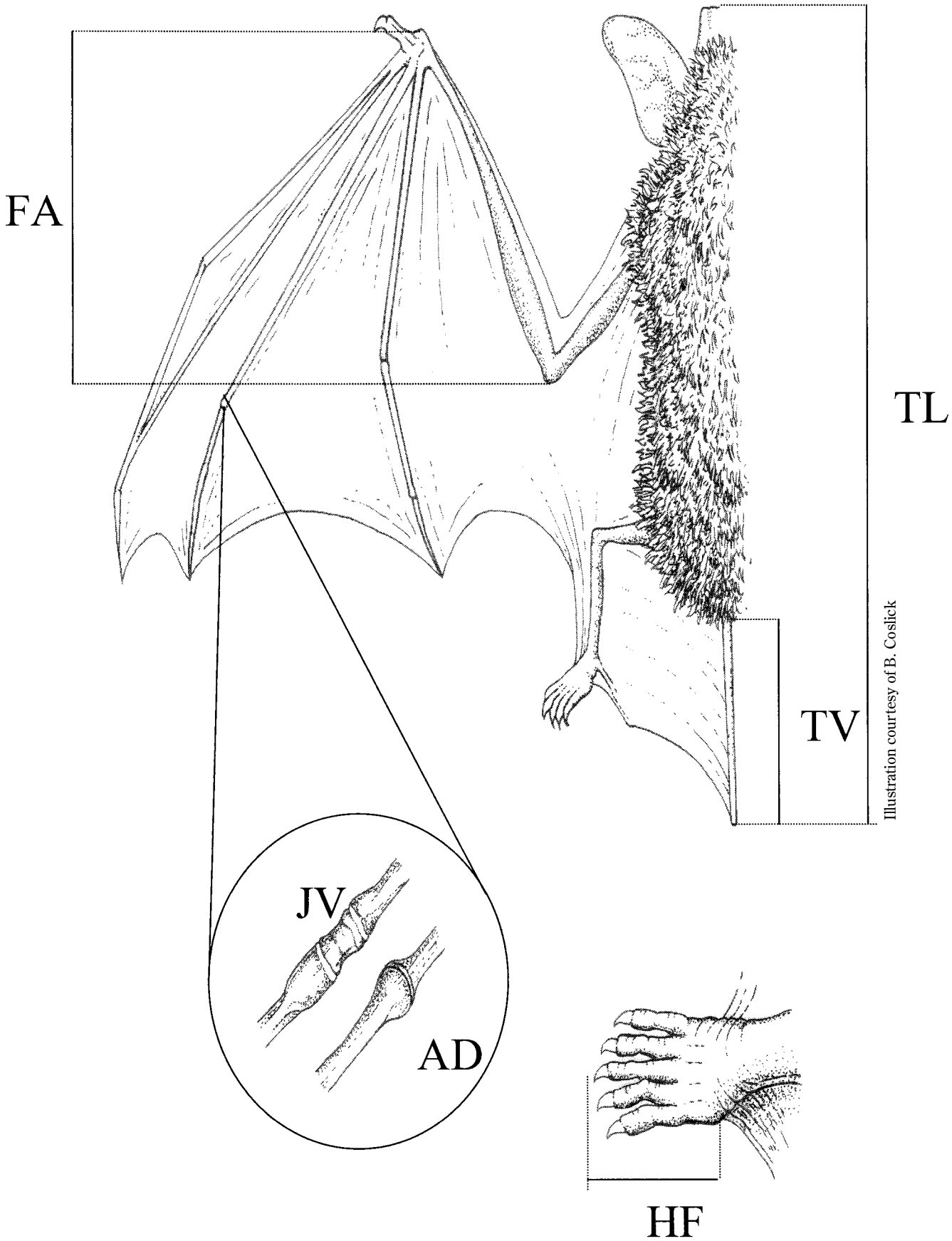

Figure 45—Location of the standard body measurements on a bat, including total length (TL), tail length (TV), forearm length (FA), and foot length (HF). Inset illustrates the extent of fusion in the epiphyseal gap of the finger joints of adults and juveniles. Adult joints (AD) appear fused and consist of a single protuberance; juvenile joints (JV) are not fused (cartilaginous plates remain in the joints) and consist of two protuberances or a single protuberance that is larger and more tapered than in adults.

Locations of the six standard body measurements—total length (TL), tail length (TV), foot length (HF), ear length (E), forearm length (FA), and tragus length (TR)—are illustrated in figures 45 and 46. These measurements can be taken from dead specimens prior to preparation or from live specimens prior to release. Because we designed the keys using characteristics and measurements taken from adult individuals, they may not be reliable when identifying juveniles. Juvenile and adult age classes can be determined by examining the extent of epiphyseal-diaphyseal fusion in the finger joints (Anthony 1988). Cartilaginous plates may not be apparent in the finger joints of adults; the joints may consist of a single, knobby protuberance (fig. 45). Cartilaginous plates are apparent in the finger joints of juveniles; the joints consist of two protuberances with a slight taper between or a single protuberance that is much longer and more tapered at both ends than the protuberance in adult joints (fig. 45). The most effective way to observe the cartilaginous plates is by back-lighting the wing and looking for semitransparent sections in joints of the phalanges. We also have included a summary table listing the characteristics of each species (table 23).

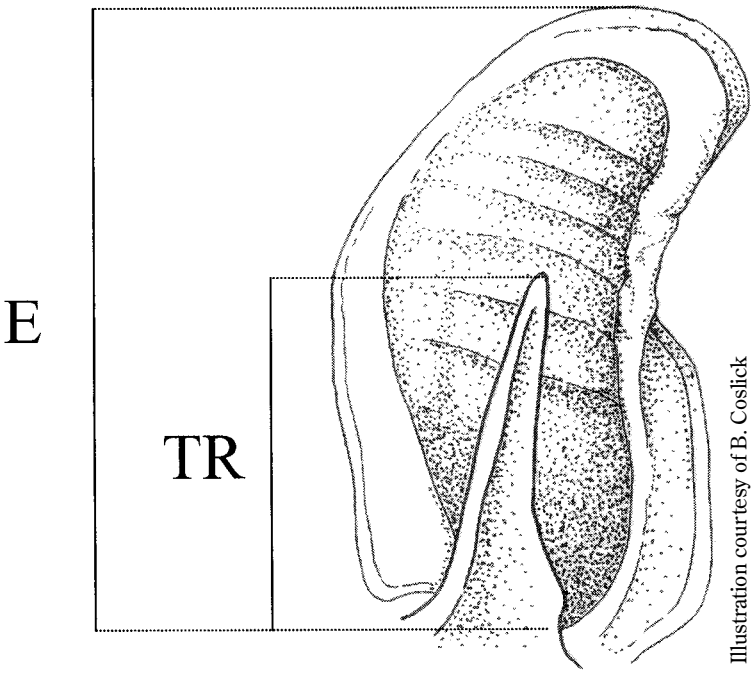

Figure 46—Location of ear (E) and tragus length (TR) measurements.

Table 23—A comparison of characteristics of bats of the Savannah River Site

Species	Pelage	Forearm	Weight	Foot	Ear	Tragus shape[a]	Calcar[a]	Other identifying traits
		mm	*g*	*mm*				
Brazilian free-tailed bat (*Tadarida brasiliensis*)	Short, brown to dark gray	43	11–14	8–11	19–20			Tail free from membrane
Rafinesque's big-eared bat (*Corynorhinus rafinesquii*)	Gray or brown above and whitish below	41	7–10	8–13	27–37	Broad and long		Large ears
Eastern red bat (*Lasiurus borealis*)	Bright red or rust color, females with frosting, males without	40	8–16	9–10	17–18	Short, blunt, and curved		Membrane between rear legs is completely furred
Hoary bat (*Lasiurus cinereus*)	Yellowish brown to dark brown with very heavy frosted tips	53	20–35	6–13	17	Short, blunt, and curved		Very large; membrane between rear legs is completely furred
Eastern pipistrelle (*Pipistrellus subflavus*)	Sandy brown to orange on back—tricolored	33	4–7	8–10	13–15	Blunt and straight	Not keeled	Pink forearms, black wings
Silver-haired bat (*Lasionycteris noctivagans*)	Dark blackish brown, with silver frosted tips	41	7–16	7–11	14	Blunt and rounded		Membrane between rear legs is furred on anterior half
Big brown bat (*Eptesicus fuscus*)	Long brown, with two-toned black base	47	13–25	10–12	17–18	Broad and rounded	Keeled	Large; prominent glands on mussel
Evening bat (*Nycteceius humeralis*)	Dull brown with paler belly, young much darker	36	5–14	7–8	14–15	Short and rounded	Not keeled	Strong odor, prominent glands on mussel, single upper incisor
Eastern small-footed myotis (*Myotis leibii*)	Blackish brown above, paler below	32	4–6	6–8	13–15	Sharp	Sharply keeled	Black mask, relatively long tail (33 mm)
Southeastern myotis (*Myotis austroriparius*)	Wooly, dull, little contrast between base and tips, yellowish to gray above, white below	40	5–12	10–13	13–16	Slender and pointed	Not keeled	Gray-black wings, long toe hairs
Northern long-eared myotis (*Myotis septentrionalis*)	Not glossy, brown above, grayish below	35	5–10	7–10	16–19	Very long and slender	Keeled	Large propatagium, ears extend beyond nose (3 mm)
Little brown bat (*Myotis lucifugus*)	Long glossy tan to dark brown above, gray to buff below	38	7–8	8–11	13–16	Slender and pointed	Not keeled	Long toe hairs (extending beyond claws), wings contrasting with body

[a] Blank cells indicate characteristics not important for species identification.

Key to the Skins

1. a. One-third or more of the tail extending beyond uropatagium (fig. 47a)—Brazilian free-tailed bat (*Tadarida brasiliensis*)
   b. Tail not extending beyond uropatagium, or only slightly (fig. 47b)—2
2. a. Dorsal surface of uropatagium at least partially furred—3
   b. Dorsal surface of uropatagium not furred or slightly furred at the junction with the body—7
3. a. Pelage black, tips of hairs frosted with white—4
   b. Pelage red, mahogany, or yellow—5
4. a. Total length > 120 mm, uropatagium heavily furred throughout, ear white or yellow with black rim—hoary bat (*Lasiurus cinereus*)
   b. Total length > 115 mm, posterior one-third of uropatagium bare, ear solid black—silver-haired bat (*Lasionycteris noctivagans*)
5. a. White shoulder patch absent, yellow coloration, frosting absent—northern yellow bat (*Lasiurus intermedius*)
   b. White shoulder patch present, red or mahogany coloration, frosting usually present (except male *Lasiurus borealis*)—6
6. a. Pelage bright-brick red, tips of hair frosted white (except males), face light red/yellow—eastern red bat (*Lasiurus borealis*)
   b. Pelage dark mahogany, tips of hair frosted white, face mahogany/red—Seminole bat (*Lasiurus seminolus*)

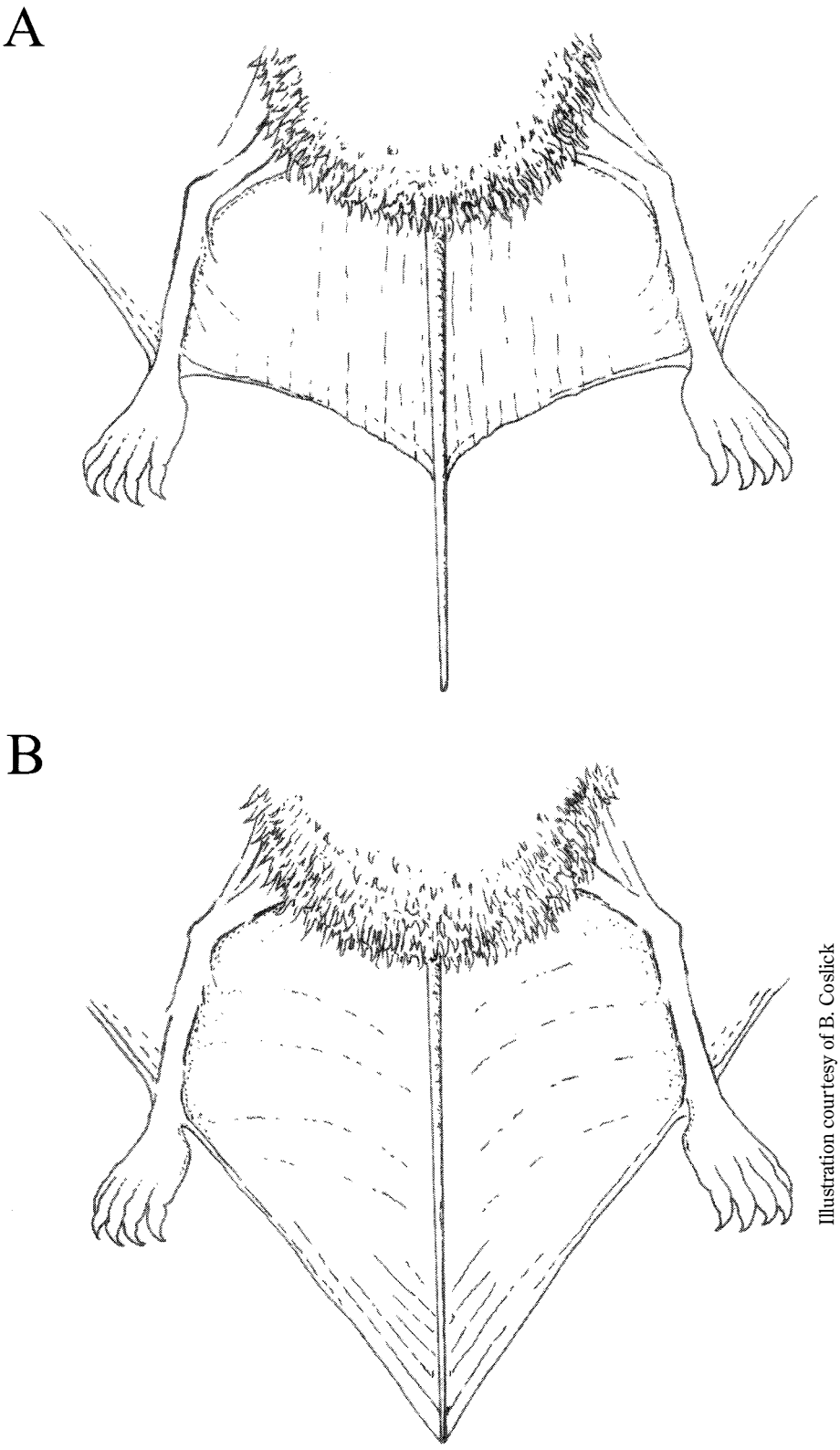

Illustration courtesy of B. Coslick

Figure 47—Contrast between the tail and uropatagium of the Brazilian free-tailed bat and the other 15 species of bats that occur in Georgia. The (A) tail of the Brazilian free-tailed bat extends beyond the posterior margin of the uropatagium; (B) tails of the other 15 bat species are completely enclosed in the uropatagium.

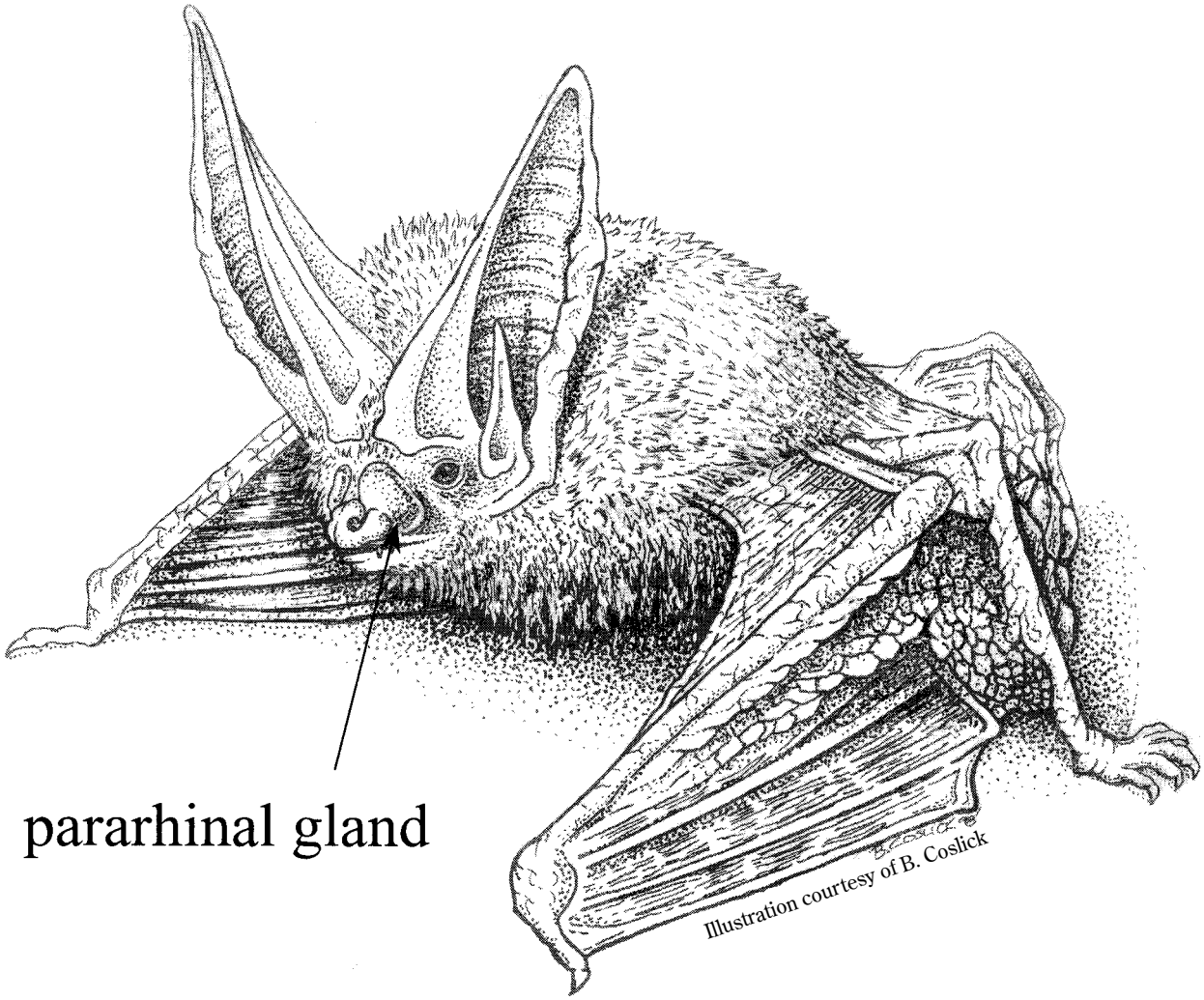

Figure 48—Large ears and location of the pararhinal glands on Rafinesque's big-eared bat.

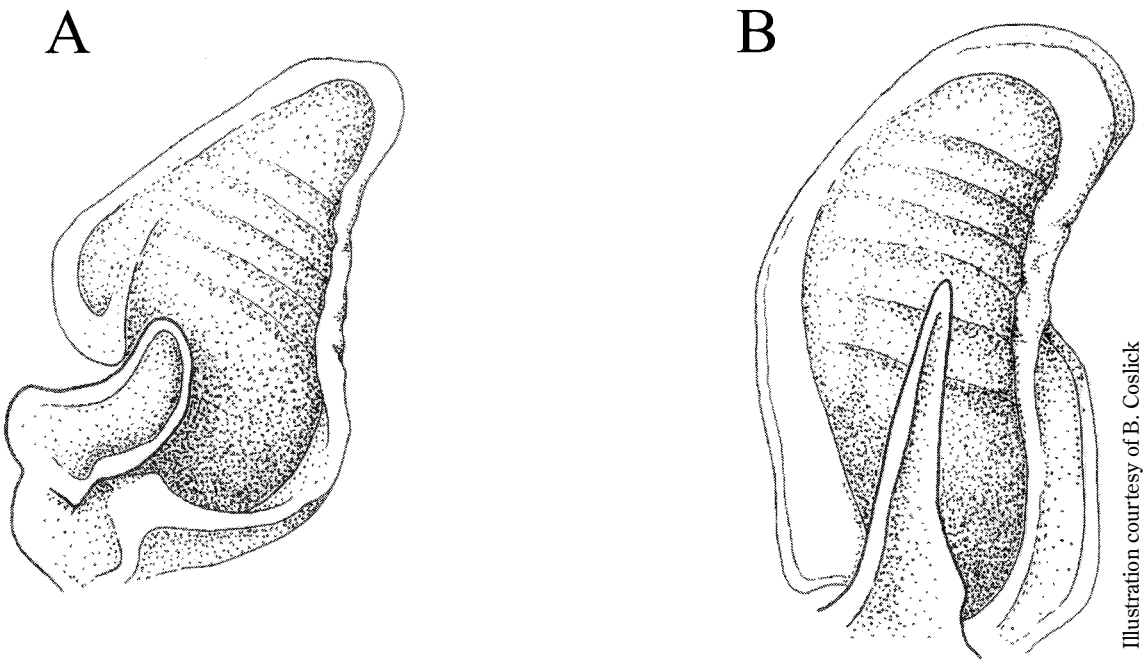

Figure 49—Comparison of (A) the short, blunt tragus characteristic of species such as the eastern pipistrelle and evening bat; and (B) the long, pointed, sharp tragus characteristic of *Myotis*.

7. a. Ears >25 mm long, distinctive pararhinal glands (large bumps, fig. 48) on either side of nose—Rafinesque's big-eared bat (*Corynorhinus rafinesquii*)
   b. Ears <25 mm long, pararhinal glands not distinct—8
8. a. Total length >100 mm, forearm >40 mm—big brown bat (*Eptesicus fuscus*)
   b. Total length <100 mm, forearm <40 mm—9
9. a. Tragus (projection within the ear) short, blunt, and curved (fig. 49a)—10
   b. Tragus long, pointed at tip, and straight (fig. 49b)—11
10. a. Dorsal fur tricolored when parted; coloration black at base, yellowish brown in the middle and dark brown at tips; forearm pink and <32 mm—eastern pipistrelle (*Pipistrellus subflavus*)
    b. Dorsal fur dark brown, forearm dark and >32 mm long—evening bat (*Nycticeius humeralis*)
11. a. Ear >16 mm long, extends >2 mm beyond the tip of nose when laid forward—northern long-eared myotis (*Myotis septentrionalis*)
    b. Ear does not extend beyond the tip of nose when laid forward—12
12. a. Calcar keeled (figs. 50a and 51a)—eastern small-footed myotis (*Myotis leibii*)
    b. Calcar not keeled (figs. 50b and 51b)—13
13. a. Tips of hairs reddish; hair long and glossy—little brown bat (*Myotis lucifugus*)
    b. Tips of hairs not reddish; hair short and wooly—southeastern myotis (*Myotis austroriparius*)

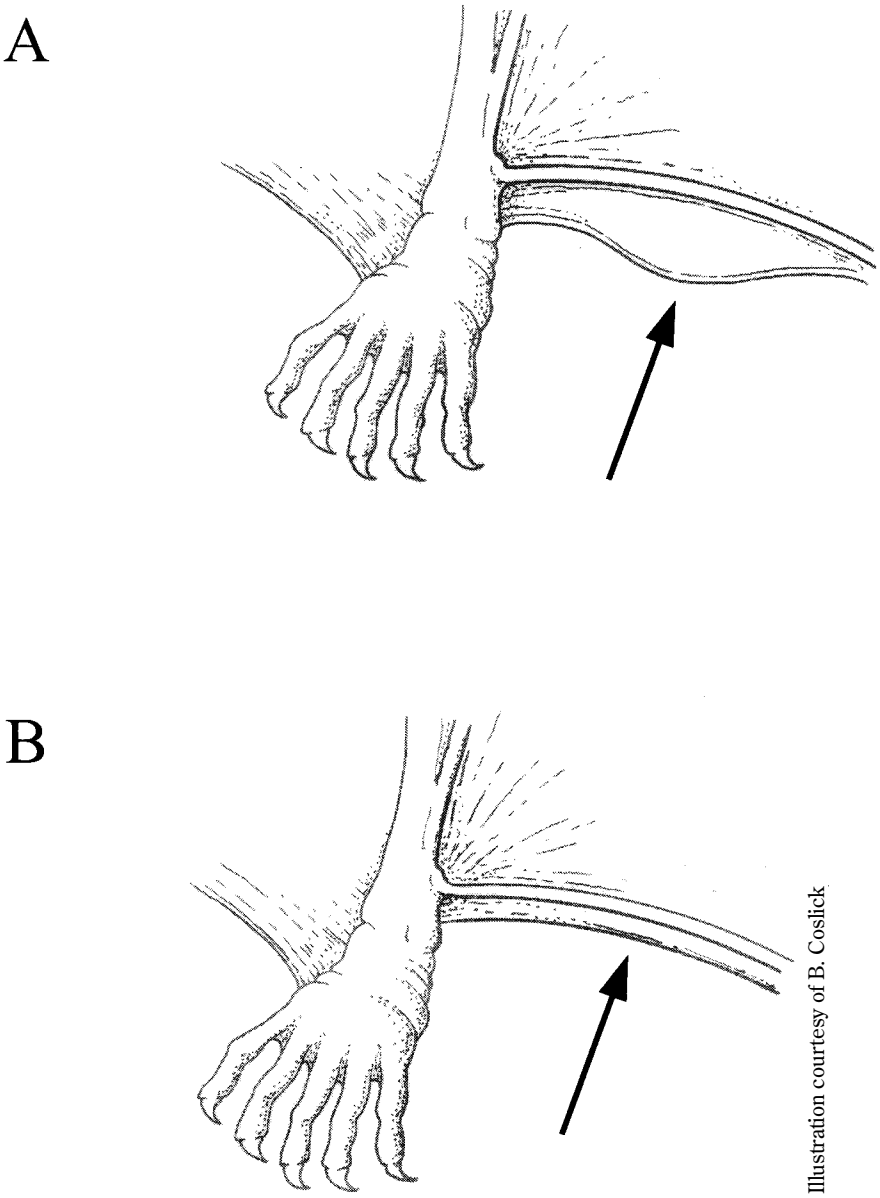

Illustration courtesy of B. Coslick

Figure 50—Comparison of a (A) keeled calcar characteristic of small-footed myotis and (B) an unkeeled calcar characteristic of little brown and southeastern myotis.

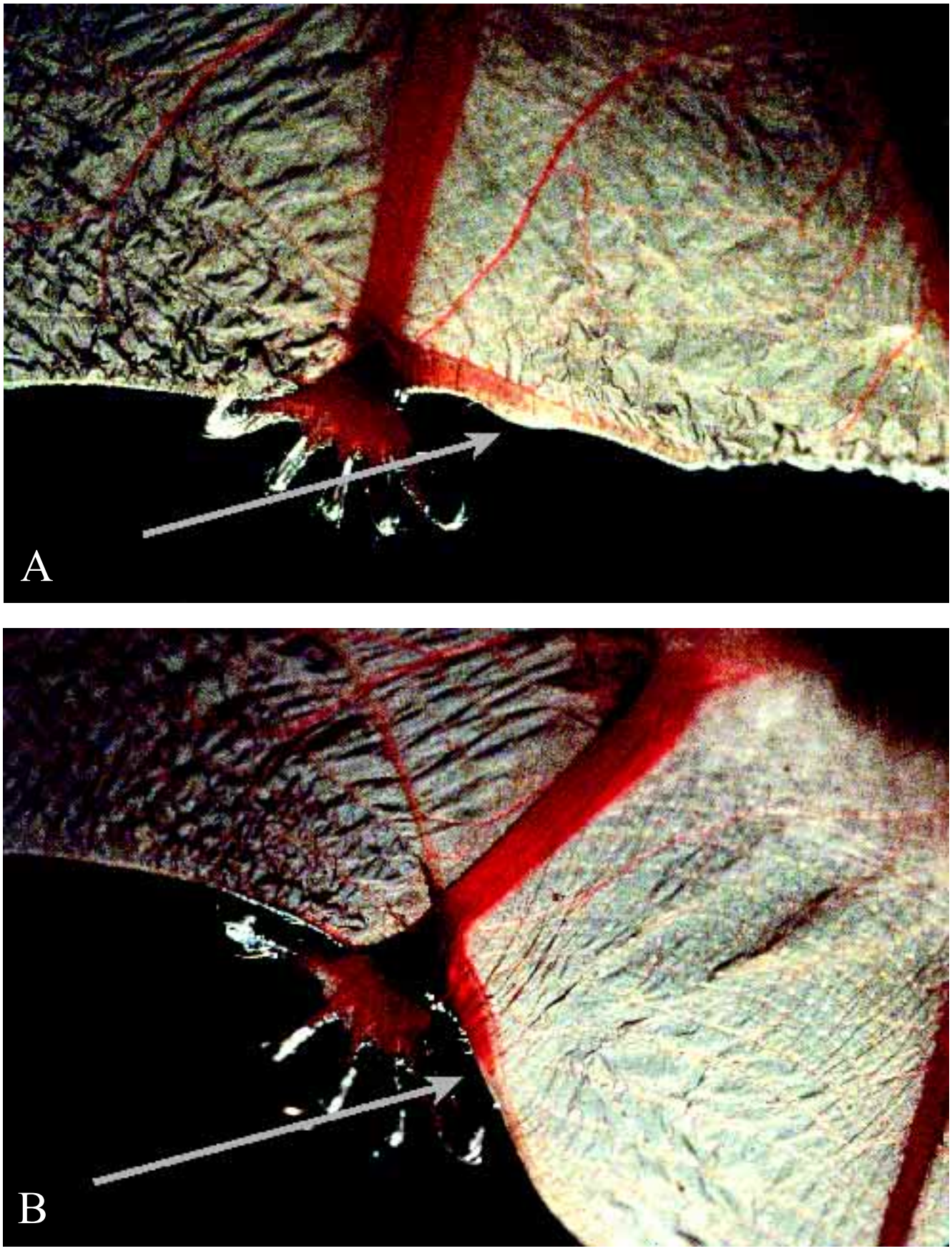

Figure 51—Photograph comparing (A) the keeled calcar characteristic of small-footed myotis to (B) an unkeeled calcar characteristic of little brown and southeastern myotis.

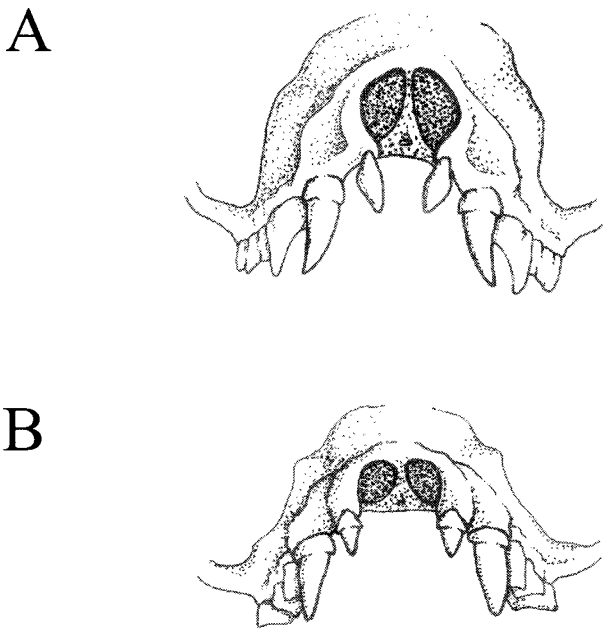

Illustration courtesy of B. Coslick

Figure 52—Comparison of (A) the upper incisors of Brazilian free-tailed bats, and (B) upper incisors of the other southeastern bats. Upper incisors of the Brazilian free-tailed bat converge at the tips; upper incisors of other southeastern bats do not.

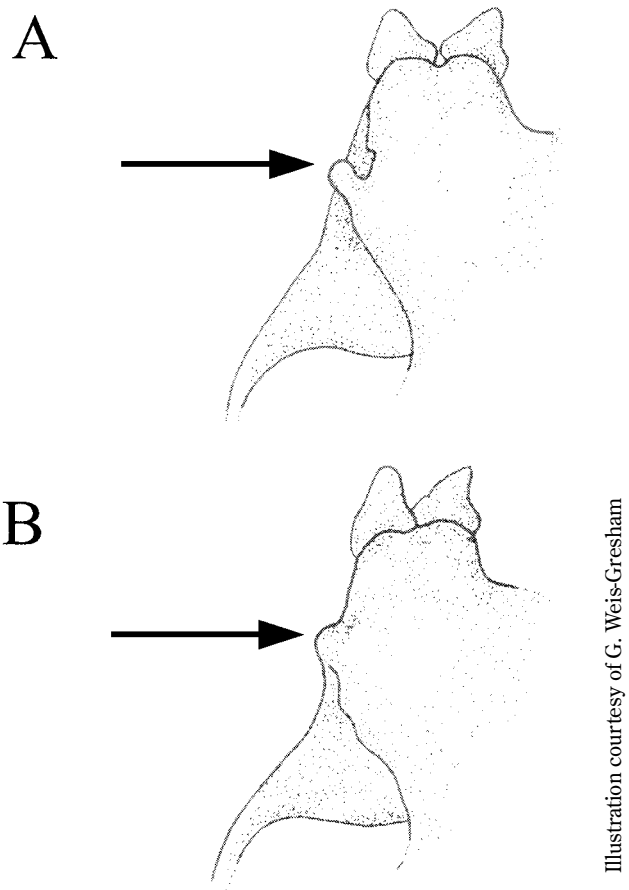

Illustration courtesy of G. Weis-Gresham

Figure 53—Comparison of the lacrimal ridge protuberance of (A) eastern red and (B) Seminole bats. Illustrations depict a dorsal surface view of the upper left skull quadrant. Note that the two triangular structures at the top are the upper incisor and the upper canine. The hooked structure at the lower left section is the anterior-most section of the zygomatic arch. The lacrimal ridge protuberance (lacrimal shelf) typically is larger in (A) eastern red bats than in (B) Seminole bats.

Key to Skulls

1. a. Upper incisors obviously converge at tips, i.e., much closer together at tips than at base (fig. 52a—Brazilian free-tailed bat (*Tadarida brasiliensis*)
   b. Upper incisors wider at tip than base, equidistant at tip and base, or tips slightly converging (fig. 52b); premaxillary gap square—2
2. a. Nine teeth present in upper quadrant—*Myotis* spp.
   b. Fewer than nine teeth in upper quadrant—3
3. a. Eight teeth in upper quadrant—4
   b. Fewer than eight teeth in upper quadrant—6
4. a. Upper incisor bifid (two-cusped)—Rafinesque's big-eared bat (*Corynorhinus rafinesquii*)
   b. Upper incisor unicuspid—5
5. a. Greatest length of skull >13.5 mm; rostrum flat with two concavities on dorsal surface—silver-haired bat (*Lasionycteris noctivagans*)
   b. Greatest length of skull <13.5 mm, rostrum sloped with no concavities on dorsal surface—eastern pipistrelle (*Pipistrellus subflavus*)
6. a. Seven teeth in upper quadrant—7
   b. Six teeth in upper quadrant—10
7. a. Two upper incisors (one large, one minute)—big brown bat (*Eptesicus fuscus*)
   b. One upper incisor—8
8. a. Greatest skull length >15.5 mm—hoary bat (*Lasiurus cinereus*)
   b. Greatest skull length <15.5 mm—9
9. a. Protuberance of the lacrimal ridge (shelf) well developed (fig. 53a)—eastern red bat (*Lasiurus borealis*)
   b. Protuberance of the lacrimal ridge poorly developed or absent (fig. 53b)—Seminole bat (*Lasiurus seminolus*)
10. a. Sagittal crest well developed, greatest length of skull >16 mm—northern yellow bat (*Lasiurus intermedius*)
    b. Sagittal crest absent or poorly developed, greatest length of skull <16 mm—evening bat (*Nycticeius humeralis*)

Menzel, Michael A.; Menzel, Jennifer M.; Kilgo, John C. [and others]. 2003. Bats of the Savannah River Site and vicinity. Gen. Tech. Rep. SRS-68. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 69 p.

The U.S. Department of Energy's Savannah River Site supports a diverse bat community. Nine species occur there regularly, including the eastern pipistrelle (*Pipistrellus subflavus*), southeastern myotis (*Myotis austroriparius*), evening bat (*Nycticeius humeralis*), Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), silver-haired bat (*Lasionycteris noctivagans*), eastern red bat (*Lasiurus borealis*), Seminole bat (*L. seminolus*), hoary bat (*L. cinereus*), and big brown bat (*Eptesicus fuscus*). There are extralimital capture records for two additional species: little brown bat (*M. lucifigus*) and northern yellow bat (*Lasiurus intermedius*). Acoustical sampling has documented the presence of Brazilian free-tailed bats (*Tadarida brasiliensis*), but none has been captured. Among those species common to the Site, the southeastern myotis and Rafinesque's big-eared bat are listed in South Carolina as threatened and endangered, respectively. The presence of those two species, and a growing concern for the conservation of forest-dwelling bats, led to extensive and focused research on the Savannah River Site between 1996 and 2002. Summarizing this and other bat research, we provide species accounts that discuss morphology and distribution, roosting and foraging behaviors, home range characteristics, habitat relations, and reproductive biology. We also present information on conservation needs and rabies issues; and, finally, identification keys that may be useful wherever the bat species we describe are found.

Keywords: Bats, foraging, habitat use, rabies, roosting, Savannah River Site.

The Forest Service, United States Department of Agriculture (USDA), is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

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