Technical Report SERDP-98-3
March 1998

US Army Corps of Engineers
Waterways Experiment Station

Strategic Environmental Research and Development Program

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

by Darrell E. Evans, Wilma A. Mitchell, Richard A. Fischer

Prepared for Headquarters, U.S. Army Corps of Engineers

Strategic Environmental Research and Development Program

Technical Report SERDP-98-3
March 1998

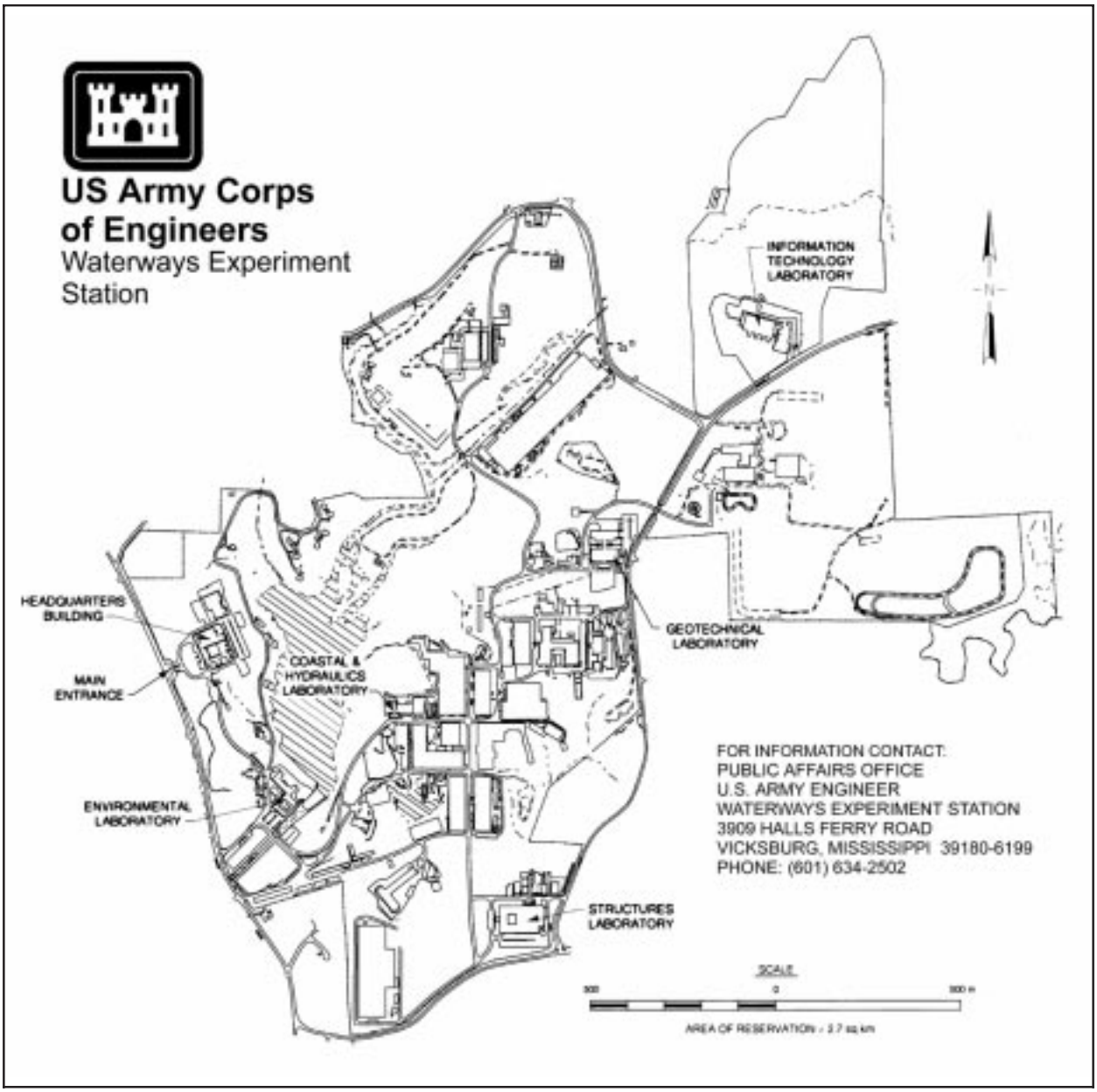
Species Profile: Indiana Bat (*Myotis sodalis*) on Military Installations in the Southeastern United States

by Darrell E. Evans, Wilma A. Mitchell, Richard A. Fischer

U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Final report

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000



Waterways Experiment Station Cataloging-in-Publication Data

Evans, Darrell E. (Darrell Edward), 1957-

Species profile : Indiana bat (*Myotis sodalis*) on military installations in the Southeastern United States / by Darrell E. Evans, Wilma A. Mitchell, Richard A. Fischer ; prepared for U.S. Army Corps of Engineers.

25 p. : ill. ; 28 cm. — (Technical report ; SERDP-98-3)

Includes bibliographic references.

1. Myotis sodalis — Speciation — United States. 2. Bats — Speciation — United States. 3. Endangered species. I. Mitchell, Wilma A. II. Fischer, Richard A. (Richard Alvin), 1964- III. United States. Army. Corps of Engineers. IV. U.S. Army Engineer Waterways Experiment Station. V. Strategic Environmental Research and Development Program (U.S.) VI. Title. VII. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; SERDP-98-3.

TA7 W34 no.SERDP-98-3

Preface

The work described in this report was authorized by the Strategic Environmental Research and Development Program (SERDP), Washington, DC. The work was performed under the SERDP study entitled "Regional Guidelines for Managing Threatened and Endangered Species Habitats." Mr. Brad Smith was Executive Director, SERDP.

This report was prepared by Mr. Darrell E. Evans and Drs. Wilma A. Mitchell and Richard A. Fischer, Natural Resources Division (NRD), Environmental Laboratory (EL), U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. Report review was provided by Dr. Virgil Brack, 3D/Environmental Services, Inc., Cincinnati, OH. Mr. Chester O. Martin, EL, WES, and Ms. Ann-Marie Trame, Land Management Laboratory, U.S. Army Construction Engineering Research Laboratories, were Principal Investigators for the regional guidelines work unit. WES technical review was provided by Messrs. Martin and John L. Tingle, EL. Ms. Tiffany Cook, EL, provided valuable assistance in assembling species information.

This report was prepared under the general supervision of Dr. Michael F. Passmore, Chief, Stewardship Branch, NRD; Dr. Dave Tazik, Chief, NRD; and Dr. John Harrison, Director, EL.

At the time of publication of this report, Dr. Robert W. Whalin was Director of WES. Commander was COL Robin R. Cababa, EN.

This report should be cited as follows:

Evans, D. E., Mitchell, W. A., and Fischer, R. A. (1998). "Species profile: Indiana bat (*Myotis sodalis*) on military installations in the southeastern United States," Technical Report SERDP-98-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Species Profile: Indiana Bat
(Myotis sodalis)

Photo by Merlin Tuttle, Bat Conservation International

Taxonomy

Class	Mammalia
Order	Chiroptera
Family	Vespertilionidae
Genus/species	*Myotis sodalis*
Other Common Names	Indiana myotis, social bat, Kentucky brown bat

Description

The Indiana bat is a medium-sized member of the genus *Myotis* first described by Miller and Allen (1928). Body length of adults is 7.5 to 10 cm (3.0 to 3.9 in.); wingspan is 24 to 27 cm (9.4 to 10.6 in.); hindfoot length is 8 to 10 mm (0.31 to 0.39 in.); and individuals typically weigh 7 to 9 g (0.25 to 0.32 oz) (Humphrey 1978, Hamilton and Whitaker 1979, U.S. Fish and Wildlife Service 1983, Clawson 1987).

Dorsal fur of the Indiana bat is finely textured and generally grayish-chestnut in color. Ventral fur is pinkish-white with slate-gray coloration at the base. A combination of several characteristics is used to distinguish the Indiana bat from similar species. These include the number and length of toe hairs, length and shape of the tragus (a fleshy appendage at the ear canal), and shape of the calcar (a small bone supporting the tail membrane) (Brack 1988). The species is often confused with the little brown bat (*Myotis lucifugus*), but the fur of the Indiana bat is not as glossy.

Status

Legal designation

Federal. The Indiana bat was listed as endangered in 1967 by the U.S. Fish and Wildlife Service (USFWS). The first formal recovery plan for the species was developed by Engel et al. (1976) and revised in 1983 as knowledge on the ecology of the Indiana bat increased (USFWS 1983).

State. The Indiana bat is listed as endangered in Georgia, Florida, Mississippi, Georgia, North Carolina, and South Carolina.

Military installations

Table 1 represents the known status of Indiana bats on military installations in the southeastern United States

Distribution and numbers

Indiana bats range from the western edge of the Ozark Plateau in Oklahoma, north to Iowa and southwestern Wisconsin, east to New Hampshire, and south to portions of Georgia and Alabama (Hall 1962; Hamilton and Whitaker 1979; Barbour and Davis 1969; Thomson 1982; Kurta et al. 1993; Mississippi Department of Wildlife, Fisheries, and Parks 1993). The main breeding and hibernating areas appear to be associated with the major cavernous limestone areas in the midwestern and eastern United States (Indiana, Kentucky, and Missouri) (Figure 1). In summer, Indiana bats are apparently absent south of Tennessee. The Indiana bat is nearly extinct over most of its former range in the northeastern States, and the major winter colonies in caves of West Virginia, Indiana, and Illinois have disappeared since 1950 (USFWS 1991).

Indiana bat populations have decreased dramatically over the past 40 years (Clawson 1987). The population declined from approximately 640,000 individuals during 1954 to 1966 (Humphrey 1978) to about 500,000 individuals in 1980 to 1981 (Richter et al. 1993, USFWS 1983). Recent population surveys (1983 to 1991) of seven of the largest hibernating populations indicated an overall decline of approximately 36 percent (Clawson 1991). Since 1960, Kentucky has had a greater population decline than any other State. Populations in the two largest hibernacula (caves and mines wherein bats hibernate)

Table 1
Known Status of Indiana Bats on Military Installations in the United States

State	Installation	Status on Installation
GA	Fort Gordon	Potential.
	Fort Benning	Potential.
AL	Redstone Arsenal	Indiana bats were listed as "potentially occurring" during the installation survey.
	Fort McClellan	Documented onsite (Virgil Brack, Personal Communication, 1996).
	Anniston Army Depot	Potential.
KY	Fort Knox	Documented onsite and adjacent to the installation (Schreiber et al. 1997).
	Fort Campbell	Potential; occurs in habitat adjacent to the installation (Schreiber et al. 1997).
IN	Indiana Army Ammunition Plant	Potential; occurs in habitat adjacent to the installation (Schreiber et al. 1997).
	Jefferson Proving Ground	Documented onsite (Schreiber et al. 1997).
NJ	Picatinny Arsenal TACOM-ARDEC	Documented onsite and adjacent to the installation (Schreiber et al. 1997).
OH	Ravenna Army Ammunition Plant	Potential; occurs in habitat adjacent to the installation (Schreiber et al. 1997).
IL	Savanna Army Depot Activity	Potential; occurs in habitat adjacent to the installation (Schreiber et al. 1997).
MO	Macon Training Site	Potential; occurs in habitat adjacent to the installation (Schreiber et al. 1997).
SC	Fort Jackson	Potential.

dropped approximately 75 percent because of microclimate changes in hibernacula subjected to poorly designed gates (USFWS 1983). During the winter, approximately 85 percent of the entire population hibernates in only seven caves (International Union for Conservation of Nature and Natural Resources (IUCN) 1978). The USFWS (1991) estimated that only 500,000 Indiana bats still exist, and about 20 percent of them are found in Kentucky. Despite attempts at protection, which include the curtailing of intentional killing and repeated disturbance, the species has continued to decline (Richter et al. 1993).

Animal Species Co-occurring with Indiana Bats

Indiana bats have been regularly captured with several other bat species, including the little brown bat, Keen's myotis (*M. keenii*), big brown bat (*Eptesicus fuscus*), red bat (*Lasiurus borealis*), hoary bat (*L. cinereus*), eastern pipistrelle (*Pipistrellus subflavus)*, and evening bat (*Nyctecius humeralis*) (King 1992). Indiana bats have been known to roost with several other bat species, including the little brown bat, gray bat (*M. septentrialis)*, southeastern myotis, big brown bat, and eastern pipistrelle (Griffin 1940, Sealander

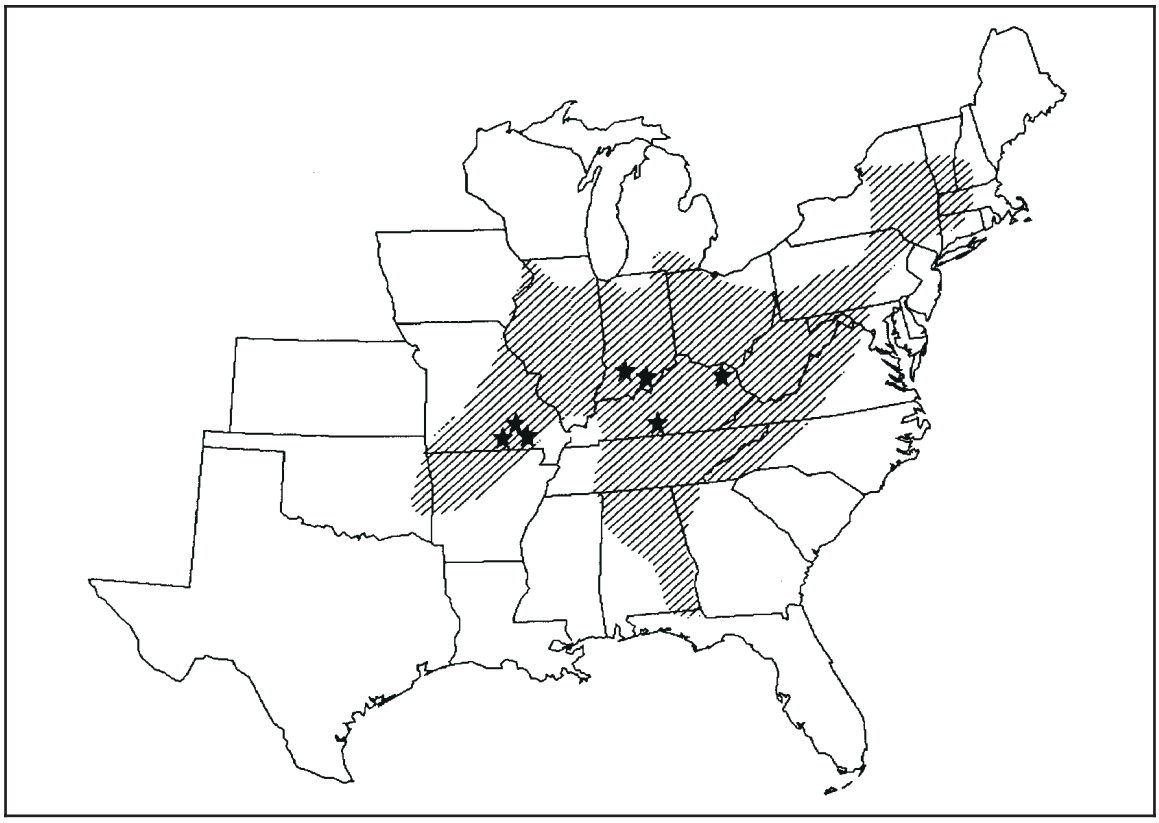


Figure 1. Distribution of Indiana bats in North America. Priority 1 hibernacula are noted with stars (after Brack 1988)

and Young 1955, Fenton 1966, LaVal 1967, Kunz and Schlitter 1968, van Zyll de Jong 1979).

Life History and Ecology

Indiana bats migrate between winter and summer habitats. During fall and winter months, they hibernate in caves and mines to avoid extreme temperatures (Brack 1988) and to ensure that their finite fat reserves outlast the winter food shortage (Brack 1988, Richter et al. 1993). During spring, bats migrate to more northern latitudes, where they forage throughout the summer; during this time, the young are born and develop into volant (flying) juveniles.

Migration

Migration from summer range to winter hibernacula for females and juveniles usually begins in August, and individuals tend to return to the same cave each year. Hall (1962) suggested that rivers served as navigation aides during migration. Distance from winter to summer areas varies, depending on region and availability of suitable hibernacula, but

summer roosting areas are often hundreds of kilometers north of winter hibernacula. Barbour and Davis (1969) reported Indiana bats migrating approximately 482 km (300 miles) between summer roosts and hibernacula. Several individuals have been documented to migrate over 449 km (279 miles) (Myers 1964). Hall (1962) reported that a juvenile Indiana bat moved approximately 274 km (170 miles) between seasonal ranges in its first year. The summer habits of males are not completely understood, but they are often observed or captured in or around hibernacula (Hall 1962, Myers 1964, King 1992). Bats migrate south to winter hibernacula in late summer.

Hibernation

Bats enter the warm parts of caves during early fall and forage each night to replenish the fat reserves depleted by migration (Hassell 1967). They move to cooler parts of the caves during winter and form large, dense aggregations on the flat surfaces of ceilings and walls (Guthrie 1933). When hibernating, Indiana bats form large, dense clusters of 500 to 1,000 individuals on the walls and ceilings (Hall 1962). Density of bats in these clusters is difficult to estimate, but LaVal and LaVal (1980) reported clusters of approximately 3,000 individuals per square meter (approximately 300 individuals per square foot). Every 8 to 15 days, hibernating individuals spontaneously awaken to spend an hour or more flying about or to join a small cluster of active bats elsewhere in the cave before returning to hibernation. Occasional foraging in winter has been reported. Fecal samples collected under hibernating Indiana bats in Kentucky contained recently ingested insect parts, thus supporting this hypothesis (Hall 1962). Disturbances in and near hibernacula can also result in disruption of hibernation. Energetic costs associated with repeated awakening due to disturbance during hibernation may cause death (Hall 1962). Movement between winter hibernacula has also been reported (Hall 1962, Fenton 1966, Hardin and Hassell 1970). Hibernating colonies disperse during late March and early April.

Richter et al. (1993) confirmed the importance of specific winter hibernacula that have suitable environmental conditions. They showed that bats roosting at winter temperatures higher than optimum lost body mass more rapidly, confirming the correlation between cave temperatures and fat metabolism. This has strong implications for overwinter survival (Richter et al. 1993).

Reproduction and development

The Indiana bat breeds during the first 10 days of October (USFWS 1991). Mating occurs at night on the ceilings of hibernacula, but ovulation, fertilization, and implantation probably do not occur until females leave hibernation in spring (Thomson 1982). Females typically segregate into small groups of 25 to 30 individuals after spring migration and form maternity colonies under the loose bark of dead and dying hardwoods (Cope et al. 1974, Humphrey et al. 1977). Most colonies are composed of less than 50 individuals, but some may be larger (100 reproductive females). Parturition occurs in June and July throughout most of the range with females giving birth to a single offspring (Easterla and Watkins 1969, Humphrey et al. 1977). Juveniles usually are weaned and volant (able to fly) within 37 days after birth (Humphrey et al. 1977).

Roosting

Indiana bats appear to exhibit some fidelity to roost sites; banded individuals (adult males and females) were observed using the same roost sites in successive years (Humphrey et al. 1977, Garner and Gardner 1992).

Food habits

Indiana bats are primarily insectivorous and feed on terrestrial insects in the forest canopy; they often consume up to one-third their weight in insects nightly (Brack 1988). They have been reported to feed on more than eight orders of insects, although moths (Lepidoptera), beetles (Coleoptera), and flies and midges (Diptera) are preferred (Clawson 1987). Summer food habit studies in Indiana indicated that hardbodied wasps (Hymenoptera) (50 percent), beetles (24 percent), and true bugs (Hemiptera) (19 percent) were also preferred (Whitaker 1972); caddisflies (Trichoptera) and stoneflies (Plecoptera) were also consumed (Belwood 1979, Brack 1983a, Brack and LaVal 1985, King 1992). In Indiana, reproductive condition of adult females directly influenced prey selection and preference (Thomson 1982). Females consumed soft-bodied insects almost exclusively during pregnancy but switched to moths during lactation. LaVal et al. (1977) and LaVal and LaVal (1980) reported similar findings in Missouri. Postlactation diets included moths (54 percent), beetles (13 percent), and harder bodied Dipterans (12 percent) (Belwood 1979). Females and volant juveniles fly in tandem and forage in the air space near the foliage of riparian and floodplain trees (Humphrey et al. 1977), while males forage in the canopy of densely wooded areas (LaVal et al. 1977).

Other

Known predators of Indiana bats include mink (*Mustella vison*), screech owls (*Otus asio*), and black rat snakes (*Elaphe obseleta obseleta*) (Goodpaster and Hoffmeister 1950, Barr and Norton 1965, Humphrey et al. 1977, Thomson 1982). The species is fairly long-lived, and studies have reported banded individuals that were between 13 and 20 years old (Humphrey and Cope 1977, LaVal and LaVal 1980). Rabies has not been reported in the Indiana bat (Constantine 1979).

Habitat Requirements

Habitat requirements for Indiana bats vary seasonally (Hall 1962; Humphrey 1978, 1982; The Nature Conservancy (TNC) 1992). Winter hibernacula typically are in caves and abandoned mineshafts associated with major river systems. Summer maternity colonies are most often located in floodplain deciduous forests or upland stands adjacent to riparian or floodplain forests.

Winter habitat

Winter hibernacula are located in cool limestone caves and abandoned mineshafts having stable temperatures and high humidity (Humphrey et al. 1977, USFWS 1983).

The start and duration of hibernation are influenced by local climate, but hibernation generally lasts from October to mid-April throughout much of the bats' range (USFWS 1983). Environmental conditions in hibernacula are extremely important to Indiana bats, and the species only selects stable undisturbed sites for hibernacula. In midwinter, bats selected caves and mineshafts with temperatures ranging from 4 to 8 °C (29.2 to 46.4 °F) and relative humidity levels between 66 and 95 percent (Hall 1962, Henshaw and Folk 1966, Barbour and Davis 1969, Clawson et al. 1981). Rock temperatures in hibernacula have also been reported to range from 4 to 8 °C (Hall 1962, Myers 1964, Humphrey 1978).

Summer habitat

During summer, Indiana bats require closed canopy, riparian forests for foraging and hardwood stands with open to partially closed canopies for roosting. Essential summer habitat described by Garner and Gardner (1992) included any site within the currently delineated summer range of the species that has foraging areas consisting of deciduous forest cover equal to or greater than 30 percent, suitable roost trees located within 0.4 km (0.25 miles) of the foraging area, and permanent water available within a 0.5-km (0.31-mile) radius of the roost. Suitable summer habitat is determined by the same criteria except that forest cover is equal to or greater than 5 percent.

King (1992, 1993) reported on habitat characteristics of summer habitat in Indiana. Overstory, understory, and herbaceous vegetation at capture sites (n = 26) were characterized as part of a 2-year study aimed at developing a summer habitat assessment model. Dominant overstory plant species on capture sites included American sycamore (*Platanus occidentalis)*, black walnut *(Carya nigra)*, sugar maple *(Acer saccharum)*, silver maple *(A. saccharinum)*, box elder *(A. negundo)*, cottonwood *(Populus deltoides)*, green ash *(Fraxinus pennsylvanica*), slippery elm *(Ulmus rubra)*, black cherry *(Prunus serotina)*, and American basswood *(Tilia americana)*. Diameter at breast height (dbh) of dominant overstory species ranged from 25 to 60 cm (9.8 to 23.6 in.) ($\bar{x}$ = 44 cm; 17.3 in.). Dominant plant species in the understory included sugar maple, silver maple, box elder, hackberry *(Celtis occidentalis)*, slippery elm, sycamore, American elm *(U. americana)*, black walnut, eastern redbud *(Cercis canadensis)*, American basswood, ash, and black cherry. The dbh of understory species ranged from 10 to 25 cm (3.9 to 9.8 in.) ($\bar{x}$ =14 cm; 5.5 in.) (King 1992, 1993). Herbaceous vegetation at capture sites was dominated by poison ivy (*Toxicodendron radicans)*, grasses, jewelweed *(Impatiens pallida)*, stinging nettle (*Solanum* spp.), Virginia creeper (*Parthenocissus quinquifolia*), and wild grape (*Vitis* spp.). Brady et al. (1983) reported that summer habitat in east-central Indiana was dominated by box elder, ash, sycamore, hackberry, American elm, willow (*Salix* spp.), cottonwood, black walnut, honey locust *(Gleditsia triacanthos)*, Ohio buckeye (*Aesculus glabra*), and red alder (*Alnus rubra*).

Foraging habitat

Indiana bats primarily forage in closed canopy riparian woodlands and uplands forests (Humphrey et al. 1977, LaVal et al. 1977, LaVal and LaVal 1980, Brack 1983b, Clark et al. 1987). Streams without riparian vegetation do not appear to be suitable foraging habitat for the Indiana bat (Cope et al. 1978). Bats have been observed foraging in

the canopy of riparian forests, around upland slopes and ridges, in early successional openings in the forest, over impounded water, and in the transition zone between forested and agricultural lands (Gardner et al. 1991). LaVal et al. (1977) reported that bats in eastern Missouri foraged under the forest canopy on hillsides and ridges. They were not observed foraging over open water. Cope et al. (1978) and Lowe (1990) reported that Indiana bats preferred to forage in riparian areas that were at least 60.5 m (200 ft) wide and composed of mature, riparian vegetation.

Streams in forest stands where Indiana bats were captured varied in width from 3 to 21 m (10 to 70 ft) ($\bar{x}$ = 10.2 m; 33.5 ft), and water depth ranged from 10 to 91 cm (3.9 to 35.8 in.) ($\bar{x}$ = 39 cm; 15.4 in.). Maximum bank height ranged from 0.6 to 3.3 m (2.0 to 10.8 ft) ($\bar{x}$ = 2.9 m; 9.5 ft) (King 1993).

Garner and Gardner (1992) radiomarked Indiana bats in Pike and Adams counties, Illinois, to monitor foraging activities. Foraging ranges appeared to be influenced by reproductive state and were largest (212.7 ha (526 acres)) in females (postlactation) and smallest in juvenile males (28.5 ha (70 acres)). Foraging range for five lactating adult females averaged 94.2 ha (233 acres). Mean distance moved by lactating females between roost sites and foraging areas was 1 km (0.6 mile). The greatest distance moved between foraging and roosting habitat by adult males was 1.5 km (0.9 mile). Garner and Gardner (1992) analyzed cover type data from 49 capture sites (344 plots) and developed minimum and maximum cover standards for assessment of potential foraging habitat.

A nursery/maternity population in Indiana was observed foraging in the foliage (2 to 30 m (6.5 to 98 ft) high) of floodplain hardwoods associated with riparian zones (Humphrey et al. 1977). Bats were not observed foraging in forests, agricultural fields, hedgerows (upland), open pasture, and creeks that were void of riparian vegetation. Dominant overstory species in foraging habitat included box elder, sycamore, black willow, and cottonwood; however, the bats foraged around sycamore, cottonwood, black walnut, black willow, and oaks.

Roosting habitat

Adult female bats establish maternity roosts in hollow trees and under the loose bark of a variety of tree species (Humphrey et al. 1977, Cope et al. 1978). These roost trees are located at various distances from foraging habitat. Optimal roost sites occur beneath the bark of dead hollow trees with adequate space to allow for air circulation and for bats to change position on the trunk (Garner and Gardner 1992). Tree species such as cottonwood, northern red oak (*Q. rubra*), post oak (*Q. stellata*), shagbark hickory *(C. ovata)*, bitternut hickory *(C. cordiformis)*, pignut hickory *(C. ovalis)*, and slippery elm are highly suitable for roosts. Green ash (*F. pennsylvanica*) was also used extensively by Indiana bats in Michigan, where it is an abundant tree (Kurta et al. 1993). Senescent, severely injured, or dead portions of these trees possess bark that is tenacious and springs away from the trunk upon drying. Living shagbark hickory also produces long strips of loose persistent bark that can provide adequate shelter.

Mean diameter (n = 87) of green ash and silver maples used as roost sites in Michigan was 80 ± 3 cm (31.5 ± 1.2 in.), and 103 ± 13 cm (40.5 ± 5.1 in.), respectively (Kurta et al. 1993). Average dbh and height of roost trees were 36.6 ± 2.3 cm (14.4 ± 0.9 in.) and 23.7 ± 0.2 m (77.8 ± 0.7 ft), respectively, with the bats exhibiting a preference for dead or dying trees. Forty-three trees were classified as being marginally alive, and 47 were dead. Roosts were 600 m (1,970 ft) from the nearest paved road, 500 m (1,640 ft) from the nearest unpaved road, 300 m (984 ft) from a large river, and 100 to 500 m (328 to 1,640 ft) from an intermittent creek. Average distance between roost trees was 34 m (112 ft) and ranged from 9 to 81 m (29.5 to 266 ft).

Shade is often considered essential to protect roost sites from the intense solar radiation of midsummer. Sixty-eight percent of the roost trees in Illinois forested habitats had >80 percent canopy cover (Garner and Gardner 1992). In Michigan, however, roost trees without any shade were used by bats throughout the summer even though other suitable trees were nearby (Kurta et al. 1993). The cooler climate in Michigan probably prevents roost temperatures from rising high enough to be lethal to the bats.

Optimal densities of potential roost trees (≥22.9 cm (9.0 in.)) in an area are believed to be approximately 67 trees/ha (27/acre) in upland habitats and 42 trees/ha (17/acre) in floodplain habitats (Garner and Gardner 1992). Densities of potential roost trees in suitable roosting habitat has been reported to be ≥1 tree/ha (0.4/acre). Stands with <1 tree/ha should be considered marginally suitable as roosting habitat. Inventories to determine the density of potential roost trees on a site should be conducted using one of the minimal area sampling methods (e.g., point-quarter, quadrat sampling described by Hays et al. (1981)).

Garner and Gardner (1992) showed that maternity populations used upland habitats extensively. Seventy-five percent of the roost trees were located near intermittent streams in upland habitats. Roost trees were found in other habitat types that were wooded or contained dead trees; however, they were not found in old fields, residential areas, or agricultural lands other than pastures with scattered trees.

Roost tree characteristics in maternity habitat. Tree species selected as maternity roost sites vary regionally, but most trees are either dead or nearly dead (Kurta et al. 1993). Garner and Gardner (1992) reported that Indiana bats in Pike and Adams counties, Illinois, did not use tree cavities as maternal roosts. Mean diameter of live and dead trees used as roost sites was 46.7 and 35.6 cm (18.4 and 14.0 in.), respectively. Humphrey et al. (1977) reported on a nursery population in Indiana that occasionally switched between a dead tree (species not mentioned) and a living shagbark hickory. Bats displaced by power-line maintenance moved to an alternate roost tree in the area and remained in their original foraging range. Bats may roost in dead trees for thermoregulation. The trunks of dead trees receive more direct solar radiation during the day and presumably create a more favorable, stable, microclimate in the roost (Humphrey et al. 1977).

King (1993) investigated the physical and structural characteristics of summer habitat in Indiana and indicated that the Indiana bat was most common in closed canopy

(63.5 ± 9.4 percent) stands having large diameter ($\bar{x}$ = 42.7 cm, n = 7) trees. Mean diameter of woody understory species was 19.6 cm (n = 7). Bryan (1993) reported that potential maternity sites in Kentucky were dominated by hardwood species in the 15- to 51-cm (5.9- to 20.1-in.) diameter class.

General maternity habitat. Studies in Illinois have indicated that 74 percent (n = 38) of roost trees used by maternity colonies were located in upland areas, and 25 percent (n = 13) were located in floodplains (Garner and Gardner 1992). Thirty-two roost trees were located in stands with closed canopies (80-100 percent), and 15 were found in stands with an intermediate-medium (30-80 percent) canopy closure. Indiana bats were not observed roosting in forested areas with open canopies (10-30 percent), agricultural fields, old fields (with plain ≤10 percent canopy cover), or residential areas (Garner and Gardner 1992). Upland roost sites were generally closer to intermittent streams than perennial streams. Colonial maternity roosts (containing pregnant or lactating females) were at least 450 m (1,476 ft) from paved roads. Reproductive females moved as far as 2.4 km (1.5 miles) between roosting and foraging habitat.

Roost sites were usually located in stands with open to partially closed canopies (Humphrey et al. 1977, Gardner et al. 1991). Open-canopied stands are believed to be preferred for roosting because (a) roost trees in such stands receive solar radiation throughout the day and generally have more favorable microclimates for roosting, and (b) open-canopied conditions allow better access (approach and exit) to the roost tree (Garner and Gardner 1992).

Significance of summer habitat

Recovery began in the early 1980s to protect the winter hibernacula of the Indiana bat. According to an information survey conducted by TNC (1992), the overall population of Indiana bats has continued to decline despite strict conservation efforts at winter caves. Expert respondents felt that the loss of summer habitat may be the primary factor in continuing population declines. Therefore, it appears that summer habitat is essential for recovery and should be maintained wherever it is found.

Critical habitat

The limiting factor facing the Indiana bat is the availability and protection of suitable hibernacula. During winter, 85 percent of the entire population can be found in seven caves in three States (Humphrey 1982, USFWS 1983): Twin Dome and Bat Wing caves in Indiana; Bat, Hundred Dome, and Dixon caves in Kentucky; and Bat Cave, Great Scott Cave, and the Pilot Knob Mine in Missouri. The USFWS has classified hibernacula based on the number of individuals overwintering in the cave. Hibernacula estimated to contain over 30,000 individuals since 1960 have been designated as Priority 1, and caves estimated to support from 1 to 30,000 individuals (since 1960) were designated as Priority 2. Each of the seven caves listed above was classified as a Priority 1 hibernacula. Other caves in the southeastern United States are probably used as hibernacula, but this has not been documented.

The USFWS (1991) has designated the following caves as Critical Habitat:

Tennessee:	White Oak Blowhole Cave, Blount County
Kentucky:	Bat Cave, Carter County Coach Cave, Edmonson County

Habitat Assessment Techniques (See Garner and Gardner (1992))

An in-depth evaluation of habitat should be conducted on installations potentially harboring Indiana bats using information obtained from literature detailing habitat characteristics of summer roost and foraging sites. Variables that should be used in the assessment of potential summer habitat include distance from nearest paved road, height and dbh of dominant overstory species, forest/habitat type, species composition of the understory, species composition of herbaceous vegetation, and the presence/absence of preferred tree species used as potential roost trees. Detailed justification for the selection of these variables is listed below.

Distance to nearest paved road

Information in the literature indicated that Indiana bats tend to avoid areas adjacent to paved or well-traveled roads (Garner and Gardner 1992, Kurta et al. 1993).

Forest/habitat type

Preference for hardwood stands (i.e., floodplain, bottomland, riparian, and mixed upland stand types) is well documented (Humphrey et al. 1977; LaVal et al. 1977; Brack 1983b; Clark et al. 1987; King 1992, 1993). A list of tree species found in Indiana bat summer habitat should be compiled from the literature and used to identify stands with potentially suitable habitat conditions (in terms of overstory species composition).

Height of dominant overstory species

Height of the overstory was reported as an important factor influencing the selection and utilization of summer roosting and foraging habitat. Information in the literature indicated that Indiana bats most often foraged in the upper canopy of riparian/bottomland stands. Humphrey et al. (1977) reported maternity colonies in Indiana foraging from 2 to 30 m (6.6 to 98.4 ft) high with most activity observed in the top portions of the canopy. Mean height of roost trees used by Indiana bats in Michigan was 23.5 m (77.1 ft) (Kurta et al. 1993). Overstory heights were divided into three distinct classes for scoring purposes. Stands with a mean height of ≥19.8 m (65.0 ft) were considered to represent preferred conditions.

Diameter at breast height of dominant overstory species

The dbh of dominant overstory species should be used to assess potential summer habitat. Several studies reported on the Indiana bat's preference for more mature, closed-canopy stands with large-diameter trees. King (1992, 1993) reported that average dbh

of trees on sites known to support Indiana bats in summer ranged from 24.9 to 59.9 cm (9.8 to 23.6 in.) and averaged 43.9 cm (17.3 in.). Bryan (1993) reported that summer Indiana bat habitat in Kentucky was dominated by trees over 25.4 cm (10.0 in.). Garner and Gardner (1992) studied characteristics of individual roost trees in Illinois and reported a mean dbh of 46.7 cm (18.4 in.) for living roost trees and 35.6 cm (14.0 in.) for dead roost trees.

Species composition of the understory

King (1992, 1993) reported on characteristics of the understory vegetation on Indiana bat capture sites in Indiana. Dominant tree species included sugar maple, silver maple, box elder, hackberry, slippery elm, sycamore, American elm, black walnut, eastern redbud, and American basswood.

Species composition of herbaceous vegetation

Herbaceous vegetation around Indiana bat capture sites was described by King (1992, 1993). Herbaceous vegetation on capture sites was dominated by poison ivy, various grasses (genera not specified), jewelweed, stinging nettle, Virginia creeper, and wild grape.

Presence/absence of suitable roost trees

Several tree species are used by Indiana bats for roosting (Cope et al. 1974, Humphrey et al. 1977, Clawson 1986, Gardner et al. 1991, King 1992, TNC 1992, King 1993, Kurta et al. 1993). Surveys to locate and identify potential roost trees on installations with Indiana bats should be conducted annually. Garner and Gardner (1992) developed a simple, qualitative method for assessing the suitability of potential roost trees. The assessment involves visually estimating the amount of loose or peeling bark visible on the main trunk and limbs and placing the tree into one of four suitability classes. Trees estimated to have ≥25-percent coverage of loose, sloughing bark were rated as having high potential for roosting Indiana bats, and trees with ≥10-percent but ≤25-percent coverage are considered to have moderate potential as roost sites. Trees with <10-percent but >1-percent coverage are rated as having low potential as roost sites. Trees that are devoid of loose or peeling bark are not considered as potential roost sites.

Impacts and Causes of Decline

The long-term decline of the Indiana bat population is a direct result of several natural and human-induced factors. Natural factors include flooding, cave-ins, and freezing (Hall 1962, Humphrey 1978, Brady 1982, and Clawson 1987), but these are rare. A high degree of aggregation during hibernation makes bats vulnerable to alterations in roosting caves (USFWS 1991). Human factors adding to the decline include intentional killing, cave commercialization, physical modifications to cave entrances, spelunking, deforestation-land clearing, stream channelization and bank modification, strip-mining (destruction of summer habitat), agricultural development, and human encroachment (Hall 1962, Mohr 1972, Clawson 1987, Lowe 1990, Garner 1991, TNC 1992, Garner and Gardner 1992,

Richter et al. 1993). Pesticide-related mortality has not been documented in Indiana bats but probably has contributed to decline of Indiana bats in certain regions (Garner and Gardner 1992).

Modification of cave entrances is one of the more serious human-induced problems (Tuttle 1977, Tuttle and Stevenson 1977, Humphrey 1978, Richter et al. 1993). Barriers constructed at the entrances of hibernacula to control public access and protect hibernating bats have resulted in drastic losses of local populations. Improperly designed and constructed barriers and gates alter airflow and result in changes to hibernacula microclimates (e.g., temperature and humidity). This often causes individuals to abandon caves (Richter et al. 1993). Several barriers at entrances to hibernacula have made Indiana bats more susceptible to predation as they leave the cave (Tuttle 1977, TNC 1992). Richter et al. (1993) showed how recovery of bat populations could be aided by removal of entrance-constricting structures.

Military training maneuvers that degrade riparian habitat could render summer roosting and foraging sites unsuitable for Indiana bats. Military exercises should be avoided in areas of riparian forests with known or potential roost trees (old-growth hardwoods), especially if potential nest trees (large hardwoods with exfoliating bark) are present. If planned military activities that could negatively impact Indiana bat habitat are unavoidable, the USFWS should be contacted for guidance on the correct legal procedure for endangered species. All Federal agencies must consult with the USFWS about any planned activities on their lands that could adversely affect Indiana bat populations (USFWS 1983).

Management and Protection

Management techniques

Because of fidelity to winter hibernacula, existing hibernacula must be protected. Gates or barriers should be constructed at the entrance to hibernacula to prevent human entry and disturbance of hibernating bats during winter. Barriers should be constructed that retain the physical or thermal environment of the caves, and paths leading to and from potential hibernacula should be closed, blocked, or camouflaged to deter use. Perimeter fences, gates, or barriers installed at cave entrances, and signs posted along the perimeter and at the entrance to hibernacula may be necessary to deter human disturbance at some sites (Brady 1982). Any gates or barriers used to control access to the cave should be designed in such a way that they will not modify the thermal environment of the hibernacula or create a hazard to bats exiting the cave.

Development in riparian areas should be closely regulated to minimize any adverse effects to summer habitat and water quality (USFWS 1983, Clawson 1986), and vegetation along streams and rivers should be protected. Any riparian vegetation removed from a site because of development (e.g., construction, stream diversion) should be replanted with the same/like species once the disturbance is completed. Bands of riparian vegetation at least 30 m (98.4 ft) wide should be planted on disturbed creek banks (USFWS

1983). Avoidance of detrimental activities in potential summer habitat is probably the best management alternative and should always be considered at the beginning of any project. Mitigation in riparian areas is costly and can take several decades to produce suitable habitat conditions for Indiana bats.

Garner and Gardner (1992) reported that selection cutting in summer habitat was not detrimental to roost sites if done properly. Cutting in areas thought to contain roost trees should be restricted to a time of the year when Indiana bats are least likely to be present (1 Sept - 1 May) (Clawson 1986). Roost trees should be visibly marked, and a protective no-cut barrier should be maintained around the roost trees to avoid damage from falling trees. Prior to any field work, loggers working on the site should be briefed on the location of roost trees and their significance.

Conner (1978) reported that noncommercial firewood cutting in and on Federal lands could present a potential threat to species requiring dead or dying trees (e.g., bats, woodpeckers, some songbirds, squirrels). Firewood cutting creates problems for Indiana bats because of the loss of potential roost trees. However, firewood cutting and Indiana bat management can coexist if resource managers are cautious in their location of firewood sites. Cutting should be limited to dead, nonpreferred tree species in areas not reported to support Indiana bats. Diameter restrictions (only remove trees ≤15.2 cm (6 in.) in diameter) to avoid destruction of potential roost trees should also be considered.

Garner and Gardner (1992) reported that loud noise (e.g., construction equipment, live-fire ranges, aircraft noise) can disturb maternity colonies and suggested that loud activities around or near maternity colonies should be regulated when the species is using the roost.

Recovery plan

The primary objective of the Indiana Bat Recovery Plan is to remove the bat from endangered status (USFWS 1983). The major emphasis is on protection of hibernacula from human disturbance. However, the maintenance, protection, and restoration of foraging and nursery habitat are also considerations. Methods suggested to help protect and maintain this summer habitat include the following:

a. Avoid forest destruction and stream alteration whenever possible.

b. Determine bat habitat requirements and conduct summer surveys to locate potential nursery habitat.

c. Maintain large, dead trees that are potential nursery sites.

d. Preserve or restore forest cover along rivers and streams.

e. Preserve water quality for the insect fauna that serve as food for the Indiana bat.

f. Monitor the habitat for foraging areas and nursery roosts.

Management and protection of Indiana bat populations can only be accomplished through a series of measures designed to (a) protect hibernacula and hibernating bats from disturbance, (b) develop measures to prevent adverse modifications to fall and winter roost sites, (c) protect, maintain, and restore damaged summer habitat (maternity and foraging), (d) protect riparian and stream habitats from degradation, (e) protect and retain snags (living and dead) for roosting habitat, (f) establish buffer/no-disturbance zones around roost sites to protect the animals when they are using the area, and (g) inform and educate the public on the importance and significance of the Indiana bat (Belwood 1979, Humphrey 1975, LaVal and LaVal 1980, USFWS 1983). Proposed land-use activities that have the potential to impact Indiana bat habitat should be coordinated with the regional USFWS office to determine if the proposed activities warrant a Section 7 consultation.

Inventory and Monitoring — Census methods

Surveys of potential habitat should be conducted periodically to document the presence/absence of Indiana bats on installations and to gain a better understanding of distribution, ecology, and habitat use by the bats on the installation. Surveys should be conducted from mid-May to mid-August by individuals familiar with both the species and the techniques used to capture them. Garner and Gardner (1992) presented background information and general guidelines for mist netting Indiana bats. Capture of reproductive females and juveniles would confirm the presence of a maternity colony on or near the installation.

Literature Cited

Barbour, R. W., and W. H. Davis. 1969. Bats of North America. University Press of Kentucky, Lexington.

Barr, T. C., Jr., and R. M. Norton. 1965. Predation on cave bats by the pilot black snake. Journal of Mammalogy 46:672.

Belwood, J. J. 1979. Feeding ecology of an Indiana bat community with emphasis on the endangered Indiana bat, *Myotis sodalis*. M.S. Thesis, University of Florida, Gainesville.

Brack, V., Jr. 1982. Status and management of the Indiana bat. Pages 127-132 *In* R. C. Wilson and J. J. Lewis, (eds.). Proc. Nat. Cave Manage. Symp., Pygmy Dwarf Press. Oregon City, OR.

Brack, V., Jr. 1983a. Feeding ecology of bats in Indiana with emphasis on the endangered Indiana bat, *Myotis sodalis*. Ph.D. Dissertation, Purdue Univ., West Lafayette, IN.

Brack, V., Jr. 1983b. Use of dead trees by the endangered Indiana bat. Pages 111-113 *In* Snag habitat management: Proceedings of the symposium. USDA, Forest Service Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-99. Fort Collins, CO.

Brack, V., Jr. 1988. The Indiana bat. Pages 602-624 *In* W. C. Chandler (ed.). Audubon wildlife report, 1988/1989. The National Audubon Society, NY.

Brack, V., Jr., and R. K. LaVal. 1985. Food habits of the Indiana bat in Missouri. Journal of Mammalogy 66:308-315.

Brady, J. T. 1982. Status and management of the Indiana bat. Pages 127-132 *In* R. C. Wilson and J. J. Lewis (eds.). The status of the Indiana bat (*Mytosis sodalis*). Proc. national cave management symposium. Pygmy Dwarf Press, Oregon City, OR.

Brady, J. T., R. K. LaVal, T. H. Kunz, M. D. Tuttle, D. E. Wilson, and R. L. Clawson. 1983. Recovery plan for the Indiana bat. U.S. Fish and Wildlife Service, Washington, DC.

Bryan, H. D. 1993. An assessment of potential summer habitat of the Federally endangered Indiana bat *Myotis sodalis*. Rep. prep. for the Paducah Gaseous Diffusion Plant, McCracken County, Kentucky. Eco-Tech, Inc. Frankfort, KY.

Clark, B. K., J. B. Bowels, and B. S. Clark. 1987. Summer habitat of the endangered Indiana bat in Iowa. American Midland Naturalist 118:32-39.

Clawson, R. L. 1986. Investigations of endangered Indiana bat and gray bat summer ecology, distribution and status. Missouri Department of Conservation. Federal Aid in Wildlife Report Number W-13-R-40.

Clawson, R. L.. 1987. Indiana bats: Down for the count. Endangered Species Technical Bulletin 7:9-11.

Clawson, R. L. 1991. Report on the status of Priority 1 Indiana bat hibernacula. U.S. Fish and Wildlife Service, Twin Cities, MN.

Clawson, R. L., R. K. LaVal, M. L. LaVal, and W. Caire. 1981. Clustering behavior of hibernating *Myotis sodalis* in Missouri. Journal of Mammalogy 61:245-253.

Conner, R. N. 1978. Snag management for cavity nesting birds. Proc. Work. for Manage. of Non-game Birds. USDA, For. Service General Technical Report SE-14. Southeastern Forest Experiment Station, Atlanta, GA.

Constantine, D. G. 1979. An updated list of rabies infected bats in North America. Journal of Wildlife Diseases 15:347-349.

Cope, J. B., A. R. Richter, and R. S. Mills. 1974. A summer concentration of the Indiana bat, *Myotis sodalis* in Wayne County, Indiana. Indiana Academy of Sciences 83:482-484.

Cope, J. B, A. R. Richter, and D. A. Searley. 1978. A survey of the bats in the Big Blue Lake project area in Indiana. Final Rep., U.S. Army Eng. District, Louisville.

Easterla, D. A., and L. C. Watkins. 1969. Pregnant *Myotis sodalis* in northwestern Missouri. Journal of Mammalogy 52:372-373.

Engel, J. M., F. R. Courtsal, R. L. Martin, J. R. Messerlis, T. H. Hooper, R. E. Mumford, and L. E. Terry. 1976. Recovery plan for the Indiana bat. USDI, Fish and Wildlife Service, Twin Cities, MN.

Fenton, M. B. 1966. *Myotis sodalis* in caves near Watertown, New York. Journal of Mammalogy 47:526.

Gardner, J. E., J. D. Garner, and J. E. Hoffman. 1991. Summer roost selection and roosting behavior of *Myotis sodalis* (Indiana bat) in Illinois. Unpublished Report, Illinois Natural History Survey, Champaign, IL.

Garner, J. D. 1991. Determination of summer distribution and habitat utilization of the Indiana bat *Myotis sodalis* in Illinois. Final Report, Illinois Natural History Survey.

Garner, J. D., and J. E. Gardner. 1992. Determination and summer distribution and habitat utilization of the Indiana Bat (*Myotis sodalis*) in Illinois. Illinois Department of Conservation. Final Project Report No. E-3. Springfield, IL.

Goodpaster, W., and D. F. Hoffmeister. 1950. Bats prey for mink in Kentucky cave. Journal of Mammalogy 31:457.

Griffin, D. R. 1940. Notes on the life histories of New England cave bats. Journal of Mammalogy 21:181-187.

Guthrie, M. J. 1933. The reproductive cycles of some cave bats. Journal of Mammalogy 14:199-216.

Hall, J. S. 1962. A life history and taxonomic study of the Indiana bat, *Myotis sodalis*. Sci. Publ., Reading Pub. Mus. and Art Gallery, 12:1-68. Reading, PA.

Hamilton, W. J., Jr., and J. O. Whitaker, Jr. 1979. Indiana bat. Pages 76-79 *In* Mammals of the eastern United States (2nd Edition). Cornell Univ. Press. Ithaca, NY.

Hardin, J. W., and M. D. Hassell. 1970. Observations on waking periods and movements of *M. sodalis* during hibernation. Journal of Mammalogy 51:829-831.

Hassell, M. D. 1967. Intra-cave activity of four species of bats hibernating in Kentucky. Ph.D. Dissertation, University of Kentucky, Lexington.

Hays, R. L., C. Summers, and W. Seitz. 1981. Estimating wildlife habitat variables. USDI, Fish and Wildlife Service, FWS/OBS-81/47. Washington, DC.

Henshaw, R. E., and G. E. Folk, Jr. 1966. Regulation of thermoregulation to seasonally changing microclimate in two species of bats (*Myotis lucifugus* and *M. sodalis*). Physiol. Zoology 39:223-236.

Humphrey, S. R. 1975. Nursery roosts and community diversity of Nearctic bats. Journal of Mammalogy 56:321-346.

Humphrey, S. R.. 1978. Status, winter habitat, and management of the endangered Indiana bat, *Myotis sodalis*. Florida Sci., 41:65-76.

Humphrey, S. R. 1982. Bats. Pages 52-70. *In* J. A. Chapman and G. A. Feldhamer (eds). Wild mammals of North America. Johns Hopkins University Press. Baltimore, MD.

Humphrey, S. R., and J. B. Cope. 1977. Survival rates of the Indiana bat, *Myotis sodalis.* Journal of Mammalogy 58:32-36.

Humphrey, S. R., A. R. Richter, and J. B. Cope. 1977. Summer habitat and ecology of the endangered Indiana bat, *Myotis sodalis*. Journal of Mammalogy 58:334-346.

International Union for Conservation of Nature and Natural Resources (IUCN). 1978. Red data book-mammalia. IUCN, Morges, Switzerland.

King, R. A. 1992. A model of summer habitat use by the Federally endangered Indiana bat (*Myotis sodalis*) in Indiana: 1991 field studies. Rep. Prep. for the Indiana Dep. Nat. Resour., 3D/Environmental Services, Inc., Pro. Rep. No. C7105.01. Cincinnati, OH.

King, R. A. 1993. A model of summer habitat use by the Federally endangered Indiana bat (*Myotis sodalis*) in Indiana: 1992 field studies. Report prepared for the Indiana Department of Natural Resources, 3D/Environmental Services, Incorporated, Project Report Number C7188.01. Cincinnati, OH.

Kunz, T. H., and D. A. Schlitter. 1968. An annotated checklist of bats from Iowa. Transactions of the Kansas Academy of Sciences 71:166-175.

Kurta, A., D. King, J. A. Teramino, J. M. Stribley, and K. J. Williams. 1993. Summer roosts of the endangered Indiana bat (*Myotis sodalis*) on the northern edge of its range. American Midland Naturalist 129:132-138.

LaVal, R. K. 1967. Records of bats from the southeastern United States. Journal of Mammalogy 48:645-648.

LaVal, R. K, R. C. Clawson, M. L. LaVal, and W. Claire. 1977. Foraging behavior and nocturnal activity patterns of Missouri bats, with emphasis on the endangered species *Myotis grisescens* and *M. sodalis*. Journal of Mammalogy 58:592-599.

LaVal, R. K, and M. L. LaVal. 1980. Ecological studies and management of Missouri bats with emphasis on cave-dwelling species. Terrestrial Series, Missouri Department of Conservation, Jefferson City, MO. 8:1-53.

Lowe, D. W. 1990. The Indiana bat, *Myotis sodalis*. Pages 506-508 *In* J. R. Matthews and C. J. Moseley (eds.). The official world wildlife guide to endangered species of North America. Beachum Publishing, Incorporated, Washington, DC.

Miller, G. S., Jr., and G. M. Allen. 1928. The American bats of the genera *Myotis* and *Pizonyx*. Bulletin American Museum of Natural History 144:130-135.

Mississippi Department of Wildlife, Fisheries, and Parks. 1993. Bats - gray bat and Indiana bat. Endangered Species of Mississippi. PL93-208. Jackson, MS.

Mohr, C. E. 1972. The status of threatened species of cave-dwelling bats. Bulletin National Speleological Society 34:33-47.

Myers, R. F. 1964. Ecology of three species of myotine bats in the Ozark Plateau. Ph.D. Dissertation, University of Missouri, Columbia.

Richter, A. R., S. R., Humphrey, J. B. Cope, and V. Brack, Jr. 1993. Modified cave entrances: Thermal effect on body mass and resulting decline of endangered Indiana bats (*Myotis sodalis*). Conservation Biology 7:407-415.

Schreiber, E. R., R. A. Shaw, A. Hill, and M. A. Reed. 1997. Installation summaries from the 1996 survey of threatened and endangered species on Army lands. U.S. Army Construction Engineering Research Laboratories, Technical Report 98/19.

Sealander, J. A., Jr., and H. Young. 1955. Preliminary observations on the cave bats of Arkansas. Proceedings Arkansas Academy of Sciences 7:21-31.

The Nature Conservancy. 1992. Elemental Stewardship Abstracts. The Indiana Bat. The Nature Conservancy. Arlington, VA.

Thomson, C. E. 1982. *Myotis sodalis*. American Society of Mammalogists 163:1-5.

Tuttle, M. D. 1977. Gating as a means of protecting cave-dwelling bats. Pages 77-82 *In* T. Aley and D. Rhoades (eds.). Proc. 1976 Nat. Cave Manage. Symp. Speleobooks, Albuquerque, NM.

Tuttle, M. D., and D. E. Stevenson. 1977. Variation in the cave environment and its biological implications. Pages 108-120 *In* Proc. 1976 national cave management symposium Speleobooks, Albuquerque, NM.

U.S. Fish and Wildlife Service. 1983. Recovery plan for the Indiana bat-Revision. USDI, Fish and Wildlife Service, Twin Cities, MN.

U.S. Fish and Wildlife Service. 1991. Indiana bat: *Myotis sodalis* (Miller and Allen). USFWS Red Data Book. U.S. Fish and Wildlife Service, Washington, DC.

van Zyll de Jong, C. G. 1979. Distribution and systematic relationships of long-eared *Myotis* in western Canada. Canadian Journal of Zoology 57:987-994.

Whitaker, J. O., Jr. 1972. Food habits of bats from Indiana. Canadian Journal of Zoology 58:1148-1150.

Personal Communications

Brack, Virgil. 1996. 3D/Environmental Services, Inc., 781 Neeb Rd., Suite 5, Cincinnati, OH 45233.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
March 1998

3. REPORT TYPE AND DATES COVERED
Final report

4. TITLE AND SUBTITLE
Species Profile: Indiana Bat (*Myotis sodalis*) on Military Installations in the Southeastern United States

5. FUNDING NUMBERS

6. AUTHOR(S)
Darrell E. Evans, Wilma A. Mitchell, Richard A. Fischer

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER
Technical Report SERDP-98-3

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers
Washington, DC 20314-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***

The Indiana bat (*Myotis sodalis*) is a medium-sized bat with grayish-chestnut fur on the dorsum. The species is found from the western edge of the Ozark Plateau in Oklahoma, north to Iowa and southwestern Wisconsin, east to New Hampshire, and south to portions of Georgia and Alabama. The Indiana bat was listed as Federally endangered in 1967 by the U.S. Fish and Wildlife Service, primarily due to disturbance and habitat destruction. Indiana bats migrate between wintering and summering areas. Winter hibernacula are located in cool limestone caves and abandoned mineshafts. During summer, Indiana bats require closed canopy, riparian forests for foraging and hardwood stands with open to partially closed canopies for roosting. The species has been documented on at least one military installation in the southeastern United States; installations with suitable habitat in other portions of the United States should also benefit from this document. This document is one of a series of Species Profiles being developed for threatened, endangered, and sensitive species inhabiting southeastern United States plant communities. The work is being conducted as part of the Department of Defense (DoD) Strategic Environmental Research and Development Program (SERDP). The report is designed to supplement information provided in plant community management reports for major United States plant communities found on military installations. Information provided on the Indiana bat includes status, life history and ecology, habitat requirements, impacts and causes of decline, habitat assessment techniques, inventory and monitoring, and management and protection.

14. SUBJECT TERMS
DoD installations
Indiana bat
Management techniques
Plant communities
SERDP
Species profile
Threatened and Endangered species

15. NUMBER OF PAGES
25

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		

Miscellaneous Paper ITL-95-
June 1995

US Army Corps of Engineers
Waterways Experiment Station

Prepared for Headquarters, U.S. Army Corps of Engineers