AGENCY DRAFT

INDIANA BAT (Myotis sodalis) REVISED RECOVERY PLAN

(Original Approved: October 14, 1983)
(Technical Draft of Revised Plan Completed: October 1996)

Prepared by the Indiana Bat Recovery Team
for

Region 3
U.S. Fish and Wildlife Service
Ft. Snelling, Minnesota

March 1999

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DISCLAIMER

Recovery Plans delineate reasonable actions that are believed to be required to recover and protect the species. Plans are prepared by the U.S. Fish and Wildlife Service with the assistance of recovery tearns, contractors, state agencies, and others. Objectives will be attained and necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not necessarily represent views, official positions, or approval of individuals or agencies involved in the plan formulation, other than the U.S. Fish and Wildlife Service. They represent the official position of the U. S. Fish and Wildlife Service only after they have been signed by the Regional Director or Director as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks. The Technical Draft of the Revised Indiana Bat Recovery Plan was completed in October 1996, and distributed to Indiana bat experts and state agencies within the range of the species. The Agency Draft incorporates most of the comments received on the Technical Draft.

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EXECUTIVE SUMMARY

Current Species Status: The Indiana bat is an endangered species that has been found in 27 states throughout much of the eastern United States. Based on censuses taken at hibernacula, the total, known Indiana bat population was estimated to number about 353,000 bats in 1995 1997; this represented a decline of about 60% since population surveys began in the 1960s. Although 1997 data were incomplete, the trend continued downward. The most severe declines have occurred in two states: Kentucky, where 180,000 bats were lost between 1960 and 1997, and Missouri, where 250,000 Indiana bats may have been lost between 1980 and 1997. In Indiana, on the other hand, populations dropped by 50,000 between the earliest censuses and 1980, but have rebounded to former levels in recent years. Currently, half of all the hibernating Indiana bats in existence winter in Indiana.

Habitat Requirements and Limiting Factors: Indiana bats winter in caves or mines that satisfy their highly specific needs for cold (but not freezing) temperatures during hibernation. The fact that Indiana bats congregate and form large aggregations in only a small percentage of known caves suggests that very few caves meet their requirements. Exclusion of Indiana bats from hibernacula by blockage of entrances, gates that do not allow for bat flight or proper air flow, and human disturbance of hibernating bats have been major documented causes of Indiana bat declines.

During the summer, Indiana bats roost in trees and forage for insects primarily in riparian and upland forest. The most important characteristics of roost trees probably are structural - exfoliating bark with space for bats to roost between the bark and the bole of the tree; to a limited extent, tree cavities and crevices also are used for roosting. Maternity colonies use multiple roosts. Each colony has at least one (but there may be more than one) "primary" roost that is used by a majority of the bats most of the summer, and a number of "secondary" roosts, that are used intermittently and by fewer bats, especially during periods of precipitation or extreme temperatures. Thus there may be more than a dozen roosts used by some Indiana bat maternity colonies. Indiana bats feed exclusively on flying insects.

Recovery Objective: The short term objective ofthe recovery plan is to halt and reverse the continued decline of the Indiana bat. The long term objective is the species' eventual delisting.

Recovery Criteria: Criteria for reclassification will be based upon the status of the Indiana bat throughout its range, as determined through a 12 year, two-stage process. The species may be reclassified from endangered to threatened following documentation of stable or increasing populations for three consecutive census periods (six years) and permanent protection [i.e., public ownership or long-term easement/lease, and gate/fence (where necessary and feasible)] at all Priority One hibernacula. To delist, the above criteria must be met, in addition to protection and documentation of stable or increasing populations for three consecutive census periods at 50% of the Priority Two hibernacula in each state, and the overall population level must be restored to that of 1980.

Actions Needed:
1. Conduct research necessary for the survival and recovery of the Indiana bat.
2. Obtain information on population distribution, status and trends.
3. Protect and maintain Indiana bat populations.
4. Provide information and technical assistance outreach.
5. Coordinate and implement the conservation and recovery of the Indiana bat.

Total Estimated Cost (in $1,000s) of Recovery:

FISCAL YEAR	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
COST	314.4	362.4	332.4	212.4	187.4	110.4	55.4	70.4	55.4	70.4	1771

Date of Recovery: If recovery criteria are adequately met, reclassification to threatened will be considered in 2005 and delisting will be considered in 2011.

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INTRODUCTION

The Indiana bat (Myotis sodalis) was officially listed as an endangered species on March 11, 1967 (32 FR 4001) under the Endangered Species Preservation Act of October 15, 1966 [80 Stat. 926; 16 U. S. C. 668aa(c)]. Critical Habitat was designated for the Indiana bat on September 24, 1976 (41 FR 41914); 11 caves and two mines in six states were listed as critical habitat: Illinois - Blackball Mine LaSalle Co.); Indiana - Big Wyandotte Cave (Crawford Co.), Ray's Cave (Greene Co.); Kentucky - Bat Cave (Carter Co.), Coach Cave (Edmonson Co.); Missouri - Cave 021 (Crawford Co.), Caves 009 and 017 (Franklin Co.), Pilot Knob Mine (Iron Co.), Bat Cave (Shannon Co.), Cave 029 (Washington Co.); Tennessee - White Oak Blowhole Cave (Blount Co.); and West Virginia - Hellhole Cave (Pendleton Co.).

The purpose of the *Revised Recovery Plan* is fourfold: (1) to update the recovery plan with information on the life history and ecology of the Indiana bat, especially information on summer ecology, that has been gathered since 1983; (2) to highlight the continued and accelerated decline of the species; (3) to continue site protection and monitoring efforts at hibernacula; and (4) to focus new recovery efforts towards research to determine the factor or factors causing population declines.

Description

The Indiana bat is a medium-sized, monotypic species (there are no subspecies) of the genus Myotis. Its forearm length is 1 3/8 - 1 5/8 inches (in) [35 to 41 millimeters (mm)]. The head and body length ranges from 1 5/8 - 1 7/8 in (41 to 49 mm). This species closely resembles the little brown bat (M. IuciJugus) and the northern long-eared bat (M. septentrionalis). The Indiana bat usually has a distinctly keeled calcar. The hind feet tend to be small and delicate with fewer, shorter hairs (do not extend beyond the toenails) than its congeners. The fur lacks luster (Hall 1981; Barbour and Davis 1969). The ears and wing membranes have a dull appearance and flat coloration that do not contrast with the fur. The fur of the chest and belly is lighter than the flat (not glossy), pinkish-brown fur on the back but does not contrast as strongly as does that of the little brown bat or northern long-eared bat, for example (Richard Clawson, Missouri Department of Conservation, pers. observ., October 1996). The skull has a small sagittal crest, and the braincase tends to be smaller, lower, and narrower than that ofthe little brown bat (Hall 1981; Barbour and Davis 1969).

Distribution

The Indiana bat is a migratory species found throughout much of the eastern half of the United States (Figures 1 and 2; Table 1; Appendix I). During winter, Indiana bats are restricted to suitable hibernacula (mostly caves, but also a few abandoned mines, and even a tunnel and a hydroelectric dam) that primarily are located in karst areas of the east-central U. S. (Figure 1).

Figure 1. Counties with current and historic records of Indiana bat hibernacula.

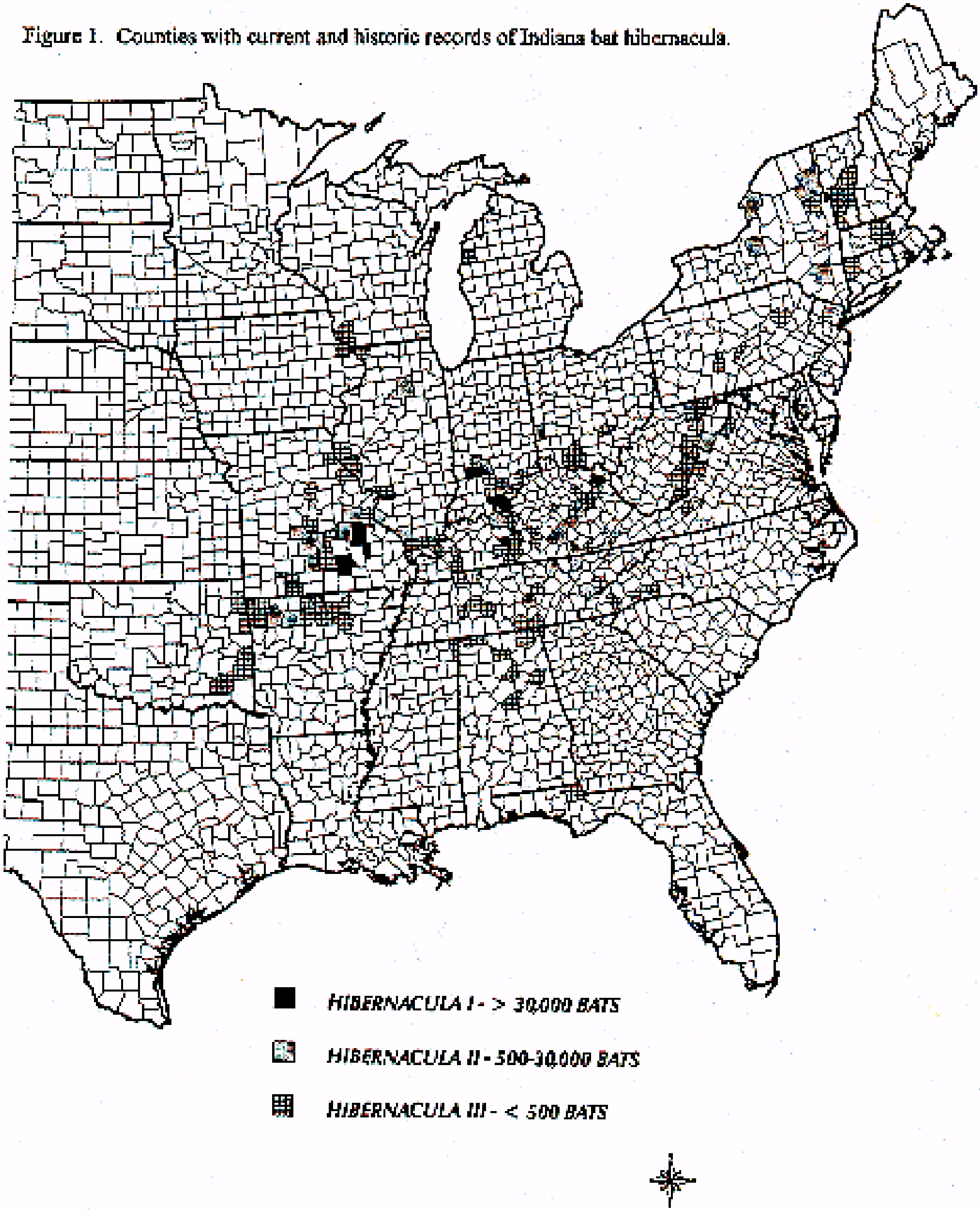

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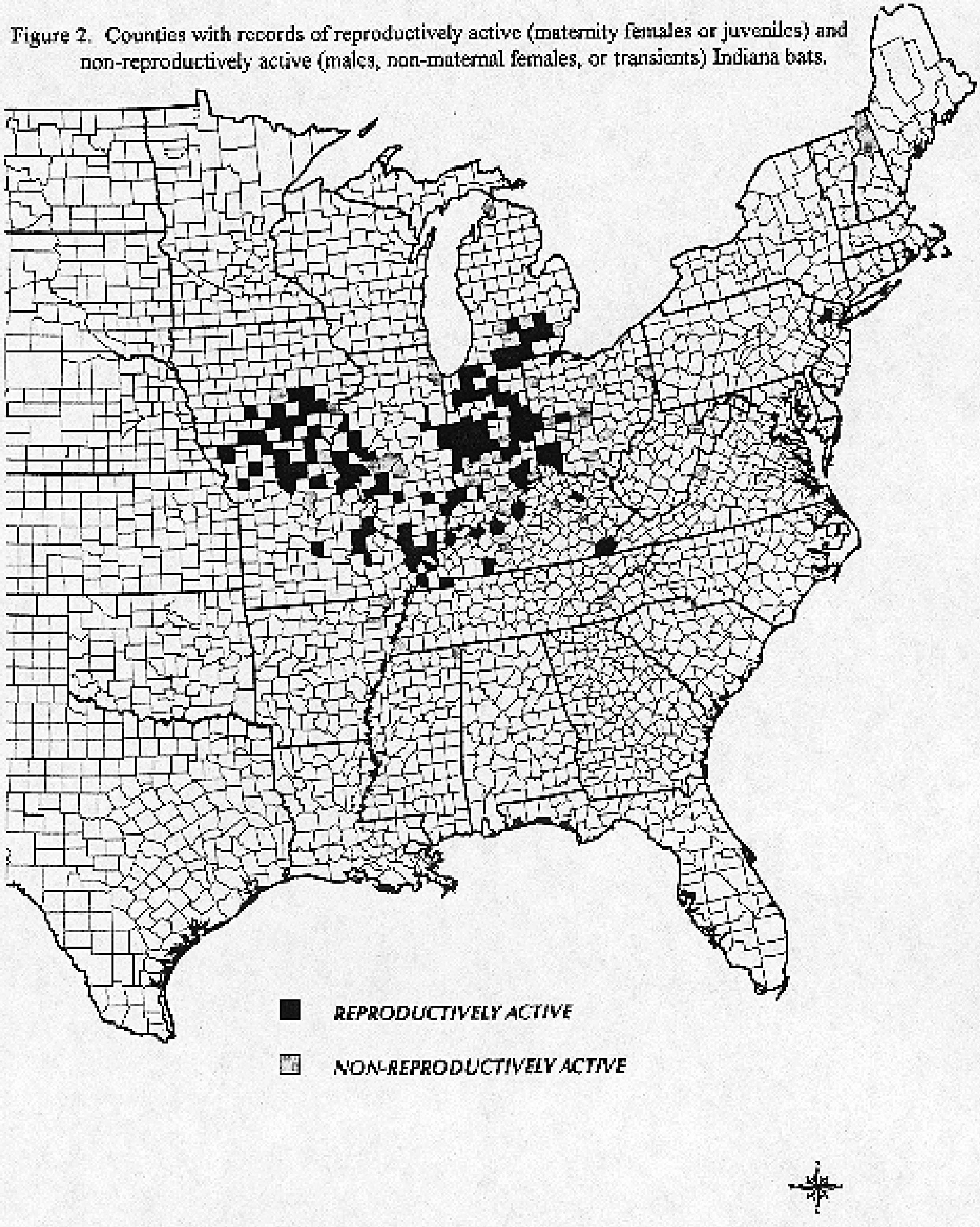
Figure 2. Counties with records of reproductively active (maternity females or juveniles) and non-reproductively active (males, non-maternal females, or transients) Indiana bats.



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More than 85 percent of the range wide population occupies nine Priority One' hibernacula (hibernation sites with a recorded population >30,000 bats since 1960 - although two of these currently have extremely low numbers of bats). Indiana, Kentucky, and Missouri each contain three Priority One hibernacula. Priority Two hibernacula (recorded population >500 but <30,000 bats since 1960) are known from the aforementioned states, in addition to Arkansas, Illinois, New York, Ohio, Tennessee, Virginia, and West Virginia. Priority Three hibernacula with recorded populations <500 bats or records of single hibernating individuals have been reported in 17 states, including all of the aforementioned states (see Appendix I).

Hibernacula with recorded populations of <500 bats (Priority Three hibernacula) or records of single hibernating individuals have been reported in the above states in addition to Alabama, Connecticut, Florida, Georgia, Iowa, Maryland, Massachusetts, Michigan, Mississippi, New Jersey, North Carolina, Ohio, Oklahoma, Pennsylvania, South Carolina, Vermont, and Wisconsin (see Appendix I).

Although certain migration patterns may be inferred from limited band returns, they should be interpreted with caution. The sparse band recovery records, all of which are from the Midwest (see Figure 3), indicate that females and some males migrate north in the spring upon emergence from hibernation (Hall 1962; Barbour and Davis 1969; Kurta 1980; LaVal and LaVal 1980; Bowles, 1982), although there also is evidence that movements may occur in other directions. However, summer habitats in the eastern and southern United States have not been well investigated; it is possible that both sexes of Indiana bats occur throughout these regions. Very little is known about Indiana bat summer habitat use in the southern and eastern United States, or how many Indiana bats may migrate to form maternity colonies there. Most summer captures of reproductively active Indiana bats (pregnant or lactating females or juveniles) have been made between April 15 and August 15 in areas generally north of the major cave areas (see Figures 1 and 2 and Appendix I). While these observations suggest that many or most female Indiana bats in the Midwest migrate north in the spring and south in the fall, potentially significant numbers also may migrate in other directions. Additional work is especially needed to better understand Indiana bat summer distribution.

Most of the maternity records of the Indiana bat originated in the Midwest (southern Iowa, northern Missouri, northern Illinois, northern Indiana, southern Michigan, and western Ohio). The first maternity colony was found and several studies of Indiana bat maternity habitat were conducted in the Midwest region. Although the woodland in this glaciated region is mostly fragmented, it has a relatively high density of maternity colonies. Today, small bottomland and upland forested tracts with predominantly oak-hickory forest types and riparian/bottomland forests of elm-ash-cottonwood associations exist in an otherwise agriculturally dominated (nonforested) landscape.

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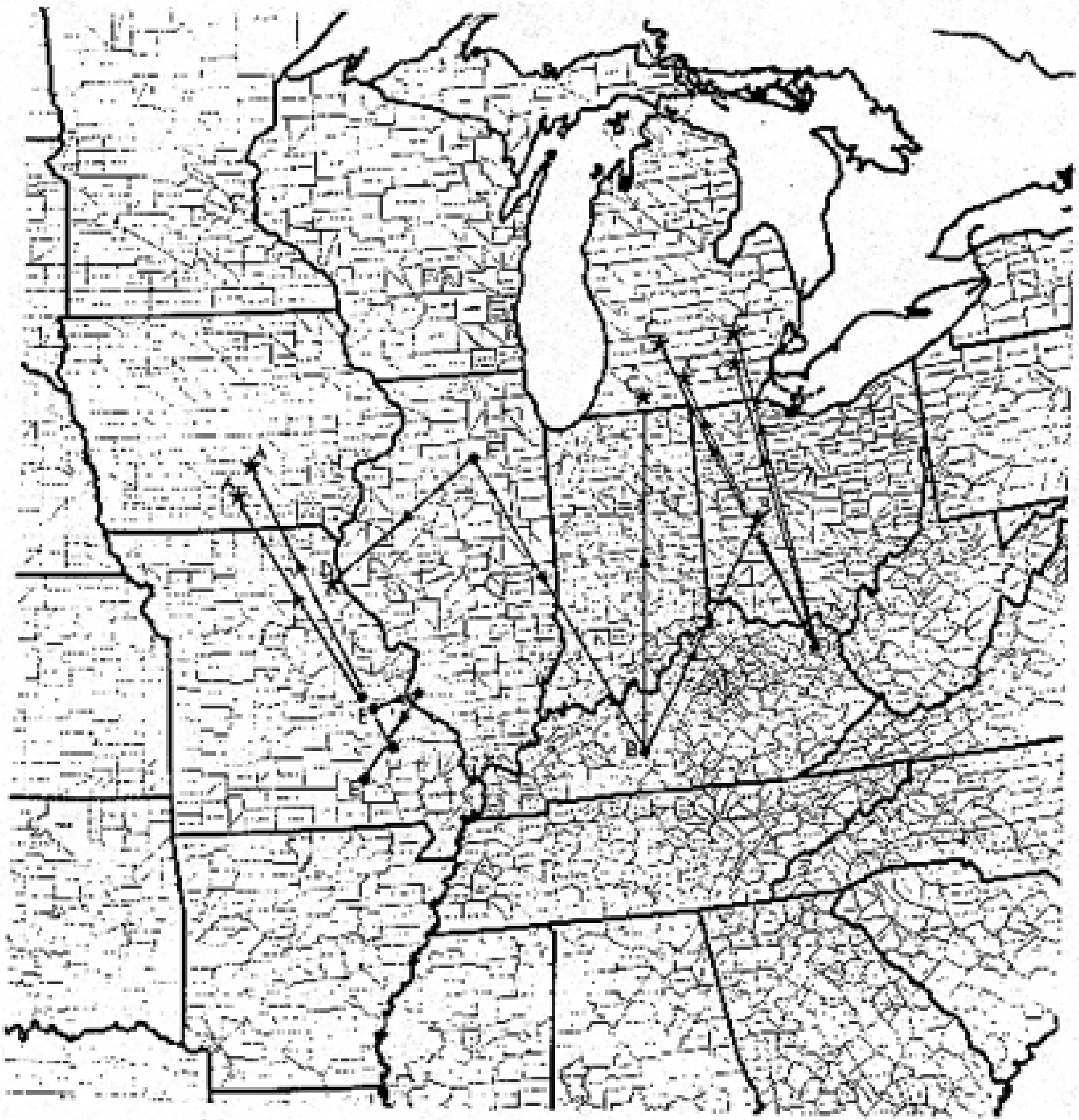
1 Hibernacula Priorities One through Three are based upon population sizes at the various sites; they do not correspond to Implementation Schedule task priorities.

Figure 3. Inferred migratory movements of Indiana bats banded at hibernacula (solid circles) and later recaptured in summer habitats (stars) or other hibernacula, based on reports from five different sources (letters A - E).



Unglaciated portions of the Midwest (southern Missouri, southern Illinois, southern Indiana), Kentucky, and most of the eastern and southern portions of the species' range appear to have fewer maternity colonies per unit area of forest. However, such conclusions may be premature, given the lack of search effort in these areas.

Male Indiana bats may be found throughout the entire range of the species. Mates appear to roost singly or in small groups, except during brief summer visits to hibernacula.

Current Status and Population Trends in Hibernacula

Based on censuses taken at hibernacula, the total, known Indiana bat population in 1997 was estimated at 353,000 bats (Table 1). Indiana bat populations first were first surveyed in the late 1950s (Hall 1962). In the decades since then, additional colonies of hibernating Indiana bats were discovered and our knowledge of the distribution and status of the species has expanded. Many hibernacula populations have decreased in number since monitoring began, especially in Kentucky and Missouri. The most recent population estimates and estimates of historical populations of the known hibernacula are on file and available from the U. S. Fish and Wildlife Service (USFWS).

Table 1 Summary of hibernating Indiana bat populations by State, based upon estimates nearest to year indicated 1, 2.

	Estimated Population		
State	Historic Level (1960 or Earliest #)	When Regular Surveys Began (~1980)	Most Recent Survey (1995-1997)
Alabama	300	300	300
Arkansas	14,930	14,830	2,700
Illinois	4,140	3,990	4,530
Indiana	177,885	124,080	182,510
Kentucky	241,335	96,235	61,370
Missouri	323,120	302,915	47,135
New York	7,805	7,805	14,990
Ohio	--	--	9,300
Pennsylvania	65	65	270
Tennessee	19,305	19,305	16,580
Virginia	5,620	5,620	1,840
West Virginia	4.700	4.675	11.660
Total	808,505	589,120	353,185

1 Due to inconsistent records, population estimates for a particular period were extrapolated from the nearest survey prior to or subsequent to the year displayed in the table; therefore, all caves are represented in each period.
2 States with records of fewer than 100 hibernating Indiana bats are not listed.

More than half of the current population of the Indiana bat hibernates in the nine Priority One hibernacula. Eight of the nine have been surveyed every two years from 1983 to 1998. Due to the unsafe conditions at Pilot Knob Mine in Iron County, Missouri, this site has not been able to be surveyed. The populations in these caves are represented in Figure 4. During the period 1983 through 1997, the populations in these caves have declined by 38%.

The status of the Indiana bat in the three states with the largest hibernating populations is reviewed below:

<u>Indiana:</u> The known population in Indiana appeared to drop from the earliest known surveys through 1980, but has been growing almost steadily in recent years (Table 1). Indiana now contains half (182,500) of all the Indiana bats in existence.

<u>Kentucky:</u> Between 1960 and 1975, Kentucky had the greatest Indiana bat population decline among the states, an estimated 145,000 bats (Table 1). Losses were attributable to exclusion and changes in microclimate at two of the three most important hibernation sites; most were caused by poorly designed cave gates (Humphrey 1978) and by construction of a building over the upper entrance to one of the hibernacula (John MacGregor, Daniel Boone National Forest, pers. observ., October 1996). Although not as dramatic as earlier losses, many of the most important remaining hibernating populations have declined steadily during the past 15 years. During this period, populations in west central, northeastern, and extreme southeastern Kentucky have declined, while the populations in east-central Kentucky and those in western Kentucky have increased.

<u>Missouri:</u> Despite efforts such as the construction of bat friendly gates at cave entrances, populations of hibernating Indiana bats in Missouri have declined steadily and drastically since 1980 (see Table 1). The colonies of Indiana bats in the two Priority One caves that can be surveyed and 12 of the 13 Priority Two hibernacula in the state have declined during this period. Since 1983, the overall Missouri population has shown a cumulative estimated decline of over 250,000 bats, a loss of more than 80% of the population.

<u>Other States:</u> Among the other states with regularly occurring hibernating populations of Indiana bats, recent trends are mixed (Table 1). Population trends in Alabama, Illinois, Ohio, Tennessee, and Virginia are either not known or are not well documented. Alabama, Illinois, Tennessee, and Virginia do not have enough recent survey information for a trend analysis, and the only known hibernaculum in Ohio was not discovered until the winter of 1995/1996. The population of Indiana bats is apparently declining in Arkansas. The species may be increasing in New York, Pennsylvania, and West Virginia, but complex cave systems such as those at Hellhole Cave in West Virginia and several caves in New York caves make surveying Indiana bats difficult and complicate population trend analysis.

A few Indiana bats have been documented in the winter in Connecticut, Florida, Georgia, Iowa,

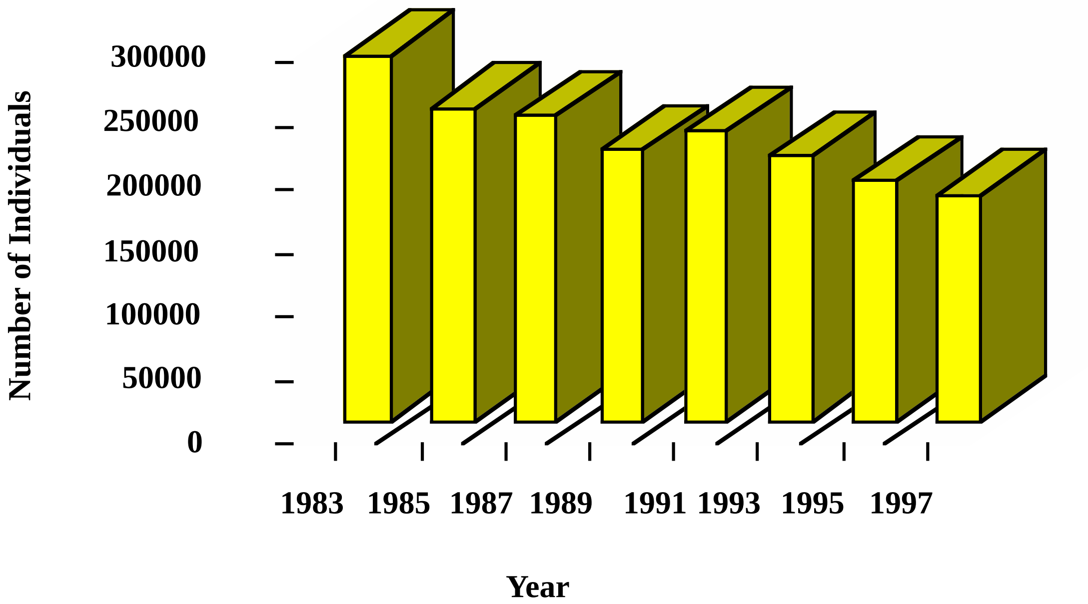


Figure 4. Indiana bat Priority One hibernacula populations, 1983-1997

Maryland, Massachusetts, Michigan, Mississippi, New Hampshire, New Jersey, North Carolina, Oklahoma, South Carolina, Vermont, and Wisconsin (Table 1). However, because most of these records usually involve less than 10 individuals, no regular hibernacula surveys are conducted in these states.

Habitat Requirements

1. Winter Habitat. Indiana bats requires require specific roost sites in caves or mines that attain appropriate temperatures to hibernate. In southern parts of the bat's range, hibernacula trap large volumes of cold air and the bats hibernate where resulting rock temperatures drop; in northern parts of the range, however, the bats avoid the coldest sites. In both cases, the bats choose roosts with a low risk of freezing. Ideal sites are 50°F (10°C) or below when the bats arrive in October and November. Early studies identified a preferred mid-winter temperature range of 39-46°F (48°C), but a recent examination of long-term data suggests that a slightly lower and narrower range of 37-43°F (3-6°C) may be ideal for the species. Only a small percentage of available caves provide for this specialized requirement. Stable low temperatures allow the bats to maintain a low rate of metabolism and conserve fat reserves through the winter, until spring (Humphrey 1978; Richter et al. 1993).

Relative humidity at roost sites during hibernation usually is above 74% but below saturation (Hall 1962; Humphrey 1978; LaVal et al. 1976), although relative humidity as low as 54% has been observed (Myers 1964). Humidity may be an important factor in successful hibernation (Thomas and Cloutier 1992).

Specific cave configurations determine temperature and humidity microclimates, and thus suitability for Indiana bats (Tuttle and Stevenson 1978; LaVal and LaVal 1980). Indiana bats select roosts within hibernacula that best meet their needs for cool temperatures; in many hibernacula, these roosting sites are near an entrance, but may be deeper in the cave or mine if that is where cold air flows and is trapped (Tuttle and Stevenson 1978; Clawson, pers. observ. October 1996).

2. Summer Habitat. A full, well-integrated understanding of the summer needs of this endangered species is yet to be attained. Early researchers considered flood plain and riparian forest to be the primary roosting and foraging habitats used in the summer by the Indiana bat (Humphrey et al. 1977), and these forest types unquestionably are important. More recently, upland forest has been shown to be used by Indiana bats for roosting (Clark et al. 1987; Gardner et al. l 991b; Callahan et al. 1997; MacGregor, pers. observ. October 1996); and upland forest, old fields, and pastures with scattered trees have been shown to provide foraging habitat (Gardner et al. l991b; MacGregor, pers. observ. October 1996).

Indiana bats live in highly altered landscapes and use an ephemeral resource (dead and dying trees) as roost sites. Anecdotal evidence suggests that the Indiana bat may, in fact, respond positively to habitat disturbance. Maternity roosts have been found where hog lots have killed overstory trees and removed understory trees in Illinois, Indiana, and Missouri (Gene Gardner, Missouri Department of Transportation; Jim Cope, Earlham College (retired); and Clawson, respectively, pers. observ. October 1996). Timber harvest activities neither directly damaged known roosts nor discouraged bats from continuing to forage in one harvested area that was studied in Illinois (Gardner et al. l 991a), and Indiana bats have been found roosting in shelterwood cuts in Kentucky (MacGregor, pers. observ. June 1997). A couple of maternity colonies, including the first discovered maternity roost in Indiana, were found when a tree was cut down and the bats moved to another tree. These observations suggest that the Indiana bat may be a more adaptable species than previously thought.

Conceptually, at least in the western part of the species' range, the Indiana bat may have been a savanna species. The following facts support this contention: Indiana bats prefer large trees in the open or at edges, they seem to prefer open canopies and fragmented forest landscapes, and they seem to prefer forest with an open understory.

Within the range of the species, the existence of Indiana bats in a particular area may be governed by the availability of natural roost structures, primarily standing dead trees with loose bark. The suitability of any tree as a roost site is determined by (1) its condition (dead or alive), (2) the quantity of loose bark, (3) the tree's solar exposure and location in relation to other trees, and (4) the tree's spatial relationship to water sources and foraging areas.

A number of tree species have been reported to be used as roosts by Indiana bats - too many to be listed herein (see Cope et al. 1974; Humphrey et al. 1977; Gardner et al. 1991a; Kurta et al. 1993a; Kiser and Elliott 1996; Kurta et al. 1996; Callahan et al. 1997). Morphological characteristics of the bark of a number of trees make them suitable as roosts for Indiana bats; that is, when dead, senescent, or severely injured (e.g., lightning-struck) these trees possess bark that springs away from the trunk upon drying. Additionally, the shaggy bark of some living hickories (Carya spp.) and large white oaks (Quercus alba) also provide roost sites. The most important characteristics of trees that provide roosts are not species but structure: exfoliating bark with space for bats to roost between the bark and the bole of the tree. The length of persistence of peeling bark varies with the species of tree and the severity of environmental factors to which it is subjected.

To a very limited extent, tree cavities or hollow portions of tree boles and limbs also provide roost sites for Indiana bats (Gardner et al. 1991a; Kurta et al. 1993b). A crevice in the top of a lightning-struck tree (Gardner et al. l991a), and splits below splintered, broken tree tops have also been used as roosts (MacGregor, pers. observ. June 1997).

Indiana bat maternity colonies use multiple roosts, in both dead and living trees. Exposure of roost trees to sunlight and location relative to other trees are important factors in suitability and use. Because cool temperatures can delay the development of fetal and juvenile young (Racey 1982), selection of maternity roost sites may be critical to reproductive success. Dead trees with east-southeast and south-southwest exposures may allow solar radiation to effectively warm nursery roosts. Roosts in some species of living trees (e.g., shagbark hickory [Carya ovata]), on the other hand, may provide better protection from rain water and other unfavorable environmental conditions. Their greater thermal mass holds more favorable temperatures for roosting bats during cool periods (Humphrey et al. 1977).

Most of the roost trees used by a maternity colony are close together. The spatial extent and configuration of a colony's regular use area is probably determined by the availability of suitable roosts. The distances between roosts occupied by bats within a single maternity colony have ranged from just a few meters for nearest distance to another roost to several kilometers (km) and, in one case, 5 km for furthest distance between roosts (Al Kurta, Eastern Michigan University, pers. observ., October 1996; Callahan et al. 1997). Miller (1996) compared habitat variables for sites in northern Missouri where surveys for Indiana bats had been conducted and noted that significantly larger trees [> 30 centimeters (cm) (12 in) diameter breast height (dbh)] were found where reproductively active Indiana bats had been netted, than at sites at where bats had not been captured.

Indiana bat maternity roosts can be described as "primary" or "alternate" based upon the proportion of bats in a colony occupying the roost site, and location in relation to forest canopy cover (Callahan et al. 1997; Kurta et al. 1996). Maternity colonies have at least one primary roost (up to three have been identified for a single colony) that is used by the majority of the bats throughout the summer. Colonies also use multiple alternate roosts that are used by small numbers of bats intermittently throughout the summer (up to 17 have been found for a single colony). Primary roosts are located in openings or at the edge of forest stands, while alternate roosts can be in either the open or the interior of forest stands. Thermoregulatory needs may be a factor in roost site selection. Primary roosts are not surrounded by closed canopy and can be warmed by solar radiation, thus providing a favorable microclimate for growth and development of young during normal weather. Alternate roosts tend to be more shaded, frequently are within forest stands, and are selected when temperatures are above normal or during periods of precipitation. Shagbark hickories seem to be particularly good alternate roosts because they provide cooler roost conditions during periods of high heat and their tight bark shields bats from the encroachment of water into the roost during rain events (Callahan et al. 1997).

Roost site selection and use may differ between northern and southern parts of the species' range. More data are needed before such differences can be specified.

Trees that provide Indiana bat roosts are ephemeral. It is not possible to generalize or estimate roost longevity due to the many factors that influence it. Bark may slough off completely or the tree may fall over. Although roosts may only be habitable for one to two years under "natural conditions" for some tree species (Humphrey et al. 1977), others with good bark retention such as slippery elm (Ulmus rubra) cottonwood (Populus deltoides), Green ash (Fraxinus pennsylvanica), and oaks (Quercus spp.), may provide roosting habitat four to eight years (Gardner et al. l 991a; Callahan et al. 1997; Kurta, pers. observ. June 1997). Hickories also retain bark well.

Indiana bats have strong site fidelity to summer colony areas, roosts, and foraging habitat. Females have been documented returning to the same roosts from one year to the next (Humphrey et al. 1977; Gardner et al. 1991a,b; Callahan et al. 1997). Male Indiana bats also have been recaptured when foraging in habitat occupied during prior summers (Gardner et al. 1991b).

The Indiana bat may be more adaptable with regard to roosts than previously believed. Humphrey et al. (1977) suggested that previously used summer roosts may be important to the reproductive success of local Indiana bat populations; that if these roosts are lost or unavailable, adult females may be faced with finding suitable maternity sites at a time when they are already stressed from post- hibernation migration and the increased metabolic energy costs of pregnancy. Recent studies have shown, however, that Indiana bats know of and occupy a number of roost sites within a maternity colony area. Bats move from one roost to another within a season, in addition to responding to changes in environmental conditions (temperature and precipitation), and when a particular roost becomes unavailable (Gardner et al. 1991a; Callahan et al. 1997). Therefore, while the Indiana bat appears to be an adaptable animal, it is essential that a variety of suitable roosts exist within a colony's occupied summer area to assure the continuance of the colony in that area (Kurta et al. 1993a; Callahan et al. 1997).

3. Fall and Spring Roosts. Indiana bats use roosts in the spring and fall similar to those selected during the summer. During the fall, when Indiana bats swarm and mate at their hibernacula, male bats roost in trees nearby during the day and fly to the cave during the night. In Kentucky, Kiser and Elliott (1996) found male Indiana bats roosting primarily in dead trees on upper slopes and ridgetops within 1.5 mi (2.4 km) of their hibernaculum. During September in West Virginia, male Indiana bats roosted within 3.5 miles (ml) (5.6 km) in trees near ridgetops, and often switched roost trees from day to day (Craig Stihler, West Virginia Division of Natural Resources, pers. observ. October 1996). Fall roost trees more often tend to be exposed to sunshine rather than being shaded (MacGregor, pers. observ. October 1996).

Upon emergence from hibernation in the spring, some males remain within the vicinity of their hibernacula, where they roost and forage in mature forest; movements of 2.5 - 10 mi (4 - 16 km) have been reported in Kentucky, Missouri, and Virginia respectively (MacGregor, pers. comm. December 1998; Hobson and Holland 1995; 3D/International 1996). However, other males leave the area entirely upon emergence in the spring. Females dispersing from a Kentucky hibernaculum in the spring moved 4- 10 mi (6.4- 16 km) within 10 days of emergence (MacGregor, pers. comm. December 1998).

4. Foraging Habitat and Behavior. Indiana bats forage in and around tree canopy of flood plain, riparian, and upland forest. In riparian areas, Indiana bats primarily forage around and near riparian and flood plain trees [e.g., sycamore (Platanus occidentalis), cottonwood, black walnut (Juglans nigra), black willow (Salix nigra), and oaks], and solitary trees and forest edge on the flood plain (Belwood 1979; Cope et al. 1974; Humphrey et al. 1977; Clark et al. 1987; Gardner et al. l991b). Within flood plain forests where Indiana bats forage, canopy closures range from 30 to 100% (Gardner et al. l991b). Cope et al. (1978) characterized woody vegetation with a width of at least 30 m on both sides of a stream as excellent foraging habitat. Streams, associated flood plain forests, and impounded bodies of water (e.g., ponds, wetlands, reservoirs) are preferred foraging habitats for pregnant and lactating Indiana bats, some of which may fly up to 1 1/2 mi (2.5 km) from upland roosts (Gardner et al. l991b). Indiana bats also forage within the canopy of upland forests, over clearings with early successional vegetation (e.g., old fields), along the borders of croplands, along wooded fencerows, and over farm ponds in pastures (Clark et al. 1987; Gardner et al. l991b).

The extent of foraging area used by an Indiana bat maternity colony has been reported to range from a linear strip of creek vegetation 0.5 mi (0.8 km) in length (Belwood, 1979; Cope et al. 1974; Humphrey et al. 1977), to a foraging area 0.75 mi (1.2 km) in length, within which bats flew over the wooded river or around the riverside trees (Cope et al. 1978). Indiana bats return nightly to their foraging areas (Gardner et al. l991b).

Indiana bats usually forage and fly within an air space from 6 - 100 ft (2 - 30 m) above ground level (Humphrey et al. 1977). Most Indiana bats caught in mist nets are captured over streams and other flyways at heights greater than 6 ft (2 m) (Gardner et al. 1989).

During summer, male Indiana bats that remained near their Missouri hibernacula flew crosscountry or upstream toward narrower, more densely wooded riparian areas during nightly foraging bouts, perhaps due to interspecific competition with gray bats (M. grisescens). Some male bats also foraged at the edges of small flood plain pastures, within dense forest, and on hillsides and ridgetops; maximum reported distance was 1.2 mi (2 km) (LaVal et al. 1976; LaVal et al. 1977; LaVal and LaVal 1980; MacGregor, m litt. April 1997). In Kentucky, MacGregor (pers. comm. December 1998) reported that the maximum distance males moved from their hibernaculum in the summer was about 2.6 mi (4.2 km). In the fall, male Indiana bats tend to roost and forage in upland and ridgetop forests, but also may forage in valley and riparian forest; movements of 1.8 - 4.2 mi (2.5 - 6.8 km) have been reported in Kentucky and Missouri (Kiser and Elliott 1996; 3D/lnternational 1996; MacGregor, m litt. June 1997).

Life History

1. Behavior. Generally, Indiana bats hibernate from October through April (Hall, 1962; LaVal and LaVal, 1980) [September - May in northern areas (Kurta, pers. observ. June 1997)], depending upon local weather conditions (see Figure 5 for a depiction of the annual cycle). They hibernate in large, dense clusters, ranging from 300 bats per square foot (3,230 bats/m2) (Clawson et al. 1980)

Upon arrival at hibernating caves in August-September, Indiana bats "swarm," a behavior in which "large numbers of bats fly in and out of cave entrances from dusk to dawn, while relatively few roost in the caves during the day" (Cope and Humphrey 1977). Swarming continues for several weeks and mating occurs during the latter part of the period. Fat supplies are replenished

Figure 5. Indiana bat annual chronology.

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Both sexes:
Hibernation (JAN–MAY) ... Hibernation (AUG–DEC)
Females: Emerge Pregnant Swarming
" Lactating
Young: Born Flying
Males: Emerge Swarming
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

as the bats forage prior to hibernation. Indiana bats tend to hibernate in the same cave in which they swarm (LaVal et al. 1976; Stihler, pers. observ. October 1996), although swarming has occurred in caves other than those in which the bats hibernated (Cope and Humphrey 1977; MacGregor, pers. observ. October 1996).

During swarming, males remain active over a longer period of time at cave entrances than do females (LaVal and LaVal 1980), probably to mate with the females as they arrive. After mating, females enter directly into hibernation. A majority of bats of both sexes hibernate by the end of November [by mid-October in northern areas (Kurta, pers. observ. June 1997)], but hibernacula populations may increase throughout the fall and even into early January (Clawson et al. 1980).

Adult females store sperm through the winter and become pregnant via delayed fertilization soon after emergence from hibernation. Young female bats can mate in their first autumn and have off-spring the following year, whereas males may not mature until the second year. Limited mating activity occurs throughout the winter and in late April as the bats leave hibernation (Hall 1962).

Females emerge from hibernation ahead of males; most winter populations leave by early May. Some males spend the summer near hibernacula in Missouri (LaVal and LaVal 1980) and West Virginia (Stihler, pers. observ. October 1996). In spring when fat reserves and food supplies are low, migration is probably hazardous (Tuttle and Stevenson 1977). Consequently, mortality may be higher in the early spring, immediately following emergence.

Females may arrive in their summer habitats as early as April 15 in Illinois (Gardner et al. 1991a; Brack 1979). During this early spring period, a number of roosts (e.g., small cavities) may be used temporarily, until a roost with larger numbers of bats is established. Humphrey et al. (1977) reported that Indiana bats first arrived at their maternity roost in early May in Indiana, with substantial numbers arriving in mid-May. Parturition occurs in late June and early July (Easterla and Watkins 1969; Humphrey et al. 1977) and the young are able to fly between mid-July and early August (Mumford and Cope 1958; Cope et al. 1974; Humphrey et al. 1977; Clark et al. 1987; Gardner et al 1991a; Kurta et al. 1996).

Most of the documented maternity colonies contained 100 or fewer adult bats. After grouping into nursery colonies, females give birth to a single young between late June and early July. Some males disperse throughout the range and roost individually or in small numbers in the same types of trees and in the same areas as females, while other males remain near their hibernacula. Maternity colonies occupy roost sites in forested riparian, flood plain, or upland habitats, and exhibit strong roost site fidelity (Cope et al. 1978; Clark et al 1987; Gardner et al. 1991a, b; Brack 1983; Callahan et al. 1977; MacGregor, pers. observ. October 1996; Stihler, pers. observ. October 1996).

Young Indiana bats are capable of flight within a month of birth. Young born in late June may be flying as early as the first week of July (Clark et al 1987), others from mid- to late July. Indiana bats spend the latter part of the summer accumulating fat reserves for fall migration and hibernation.

2. Food Habits. Indiana bats feed strictly on flying insects; their selection of prey items reflects the environment in which they forage. Both aquatic and terrestrial insects are consumed. Diet varies seasonally and variation is observed among different ages, sexes, and reproductive-status

groups (Belwood 1979; Lee 1993). Reproductively active females and juveniles exhibit greater dietary diversity than males and non-reproductively active adult females, perhaps due to higher energy demands. Reproductively active females eat more aquatic insects than do adult males or juveniles (Lee 1993).

Moths (Lepidoptera) are major prey items identified in several studies (Belwood 1979; Brack and LaVal 1985; Lee 1993; Gardner and Brack, unpubl. data), but caddisflies (Trichoptera) and flies (Diptera) are major prey items documented in another (Kurta and Whitaker 1998). Another major prey group includes mosquitoes and midges (Belwood 1979; Gardner and Brack, unpubl. data), especially species that form large mating aggregations above or near water (Belwood 1979). Other prey include bees, wasps, and flying ants (Hymenoptera), beetles (Coleoptera), leafhoppers (Homoptera), treehoppers (Homoptera), stoneflies (Plecoptera), and lacewings (Neuroptera) (Whitaker 1972; Belwood 1979; Gardner and Brack, unpubl. data).

Male Indiana bats summering in or near a hibernation cave feed preferentially on moths and beetles. Additionally, caddisflies, flies, mosquitoes, midges, stone flies, leafhoppers, treehoppers, and true bugs are consumed, but in low percentages. Bats predominately eat terrestrial insects, as would be expected from observations of their foraging habitat (Brack and LaVal 1985).

Associations with Other Listed Species

Bat hibernacula often contain temperature and humidity gradients suitable for several species of bats. Consequently, cave management targeted for one species usually benefits other associated species, such as when two listed species hibernate in the same cave [e. g., Indiana bats and gray bats or Indiana bats and Virginia big-eared bats (Plecotus townsendii virginianus)]. It is often difficult, however, to accommodate the desires of recreational cavers or other user groups when listed species of different needs occupy the same cave during opposite seasons (summer and winter), as happens when Indiana bats hibernate in a cave that also houses a gray bat maternity colony in the summer.

Reasons for Decline

Not all of the causes of Indiana bat population declines have been determined; the decline of the species at its current rate is unknown. Although several known human-related factors have caused declines in the past, they do not appear to account for the declines we are now witnessing.

1. Documented Causes.

a. Disturbance and Vandalism. A serious cause of Indiana bat decline has been human disturbance of hibernating bats during the decades of the 1960s through the 1980s. Bats enter hibernation with only enough fat reserves to last until spring. When a bat is aroused, as much as 68 days of fat supply is used in a single disturbance (Thomas et al. 1990). Humans, including recreational cavers and researchers, passing near hibernating Indiana bats can cause arousal (Humphrey 1978; Thomas 1995). If this happens too often, the bats' fat reserves may be exhausted before the species is able to forage in the spring.

Direct mortality due to human vandalism has been documented. The worst known case occurred in 1960 when an estimated 10,000 Indiana bats were killed in Carter Cave State Park, Kentucky by three youths who tore masses of bats from the ceiling and trampled and stoned them to death (Mohr 1972). Another documented incident was reported from Thomhill Cave, Kentucky, where at least 255 Indiana bats were found in January 1987, killed by shotgun blasts (Anon. 1987).

b. Improper Cave Gates and Structures. Some hibernacula have been rendered unavailable to Indiana bats by the erection of solid gates in the entrances (Humphrey 1978). Since the 1950's, the exclusion of Indiana bats from caves and changes in air flow are the major cause of loss in Kentucky (an estimated 200,000 bats at three caves) (MacGregor, pers. observ. October 1996). Other cave gates have so modified the climate of hibernacula that Indiana bats were unable to survive the winter because changes in air flow elevated temperatures which caused an increase in metabolic rate and a premature exhaustion of fat reserves (Richter et al. 1993; Merlin Tuttle, Bat Conservation International, m. Iitt. 1998).

Conversely, an Indiana bat population may be restored if an improper gate is replaced with one of appropriate design. In Wyandotte Cave, Indiana, dramatic population increases followed gate replacement and restoration of traditional air flow. Success, however, may not be immediate or automatic, as in Hundred Dome Cave, Kentucky. At Hundred Dome, air flow obstructions have been removed and bat-friendly gates installed. Indiana bats have resumed to their traditional hibernation site, but expected population gains have not yet materialized. Additional experimentation may be needed to ensure that this site is again suitable for a large population.

c. Natural Hazards. Indiana bats are subject to a number of natural hazards. River flooding in Bat Cave, Mammoth Cave National Park, drowned large numbers of Indiana bats (Hall 1962). Other cases of hibernacula being flooded have been recorded by Hall (1962), DeBlase et al. (1965), and MacGregor (pers. observ. October 1996). A case of internal cave flooding occurred when tree slash and debris (produced by forest clearing to convert the land to pasture) were bulldozed into a sinkhole, blocking the cave's rain water outlet and drowning an estimated 150 Indiana bats (MacGregor, pers. observ. October 1997). One case of flash flooding compounded by cave gates occurred in 1997: in early March, a severe flood occurred at Bat Cave (Carter Caves State Park, Kentucky- a Priority One hibernaculum). Debris that had accumulated on the gate at the upper Bat Cave entrance impounded rain water until pressure completely destroyed the gate, allowing a surge of water through the cave system where it was backed up again at the gate in the lower cave entrance. Water reached the ceiling in portions of the hibernation section of the cave and drowned an estimated 3,000 Indiana bats (Tracy Wethington, Kentucky Department of Natural Resources, pers. comm. March 1997).

Bats hibernating in mines are vulnerable to ceiling collapse (Hall 1962), and this is a serious concern at Pilot Knob Mine in Missouri, once the largest known Indiana bat hibernating population. To a lesser extent, ceiling collapse in caves is also possible.

Another hazard exists because Indiana bats hibernate in cool portions of caves that tend to be near entrances, or where cold air is trapped. Some bats may freeze to death during severe winters (Humphrey 1978; Richter et al. 1993). Indiana bats apparently froze to death in Bat Cave (Shannon County, Missouri) in the 1950s (Richard Myers, U. S. Weather Service (retired), pers. comm. October 1996). The population at the same site was 30,450 in 1985, when the bats were observed roosting on a high ceiling, presumably to escape severe cold at their traditional roosting ledges 7-9 ft above the cave floor. In the subsequent 1987 survey, the population plummeted to 4,150 bats and the floor of the cave was littered with bat bones, suggesting that the bats died during hibernation, and most likely from freezing (Clawson, pers. observ. October 1996).

At Missouri's Great Scott Cave, average mid-winter temperatures appear to have risen 8°F (4.4°C) from the mid 1980s through the present, compared to temperatures in the 1970s and early 1980s; a major population loss occurred between the mid 1980's and 1998. Preliminary analysis of fall and winter temperature data suggests that a similar trend has occurred in ambient temperature outside the cave, and thus appears to have played a role in these population losses (Clawson, pers. observ. July 1998). A much more detailed analysis is needed, along with detailed temperature profiles of this and other hibernacula, to better understand the relationships) between climate, air flow, and hibernation microclimates within important hibernacula.

Indiana bats are vulnerable to the effects of severe weather when roosting under exfoliating bark during summer. For example, a maternity colony was displaced when strong winds and hail produced by a thunderstorm stripped the bark from their cottonwood roost and the bats were forced to move to another roost (Gardner, pers. observ. October 1996.).

d. Other. Other documented sources of decline include indiscriminate collecting, handling and banding of hibernating bats by biologists, and flooding of caves by reservoirs (Humphrey 1978).

2. Suspected Causes.

a. Microclimate Effects. Caves and mines change far more than is generally recognized. Entrances and internal passages essential to air flow may become larger, smaller, or close altogether, with concomitant increases or decreases in air flow. Blockage of entry points, even those too small to be recognized, can be extremely important in hibernacula that require chimney effect air flow to function. As suggested by Richter et al. (1993) and Tuttle (in litt. 1998), changes in air flow can elevate temperatures which can cause an increase in metabolic rate and a premature exhaustion of fat reserves.

Hibernacula in the southern portions of the Indiana bat's range may be either near the warm edge of the bat's hibernating tolerance or have relatively less stable temperatures. Hibernacula in the North may have passages that become too cold. In the former case, bats may be forced to roost near entrances or floors to find low enough temperatures, thus increasing their vulnerability to freezing or predation. In the North, bats must be able to escape particularly cold temperatures.

In both cases, modifications that obstruct air flow or bat movement could have serious consequences.

Recent analysis of mid-winter temperature records obtained during hibernacula surveys, especially of Priority One caves, suggests that unacceptable deviations in roost temperatures may account for some of the overall population decline (Tuttle, pers. comm. July 1998). Although scanty, the data suggest that when populations roost mostly at temperatures below 35°F or above 47°F (2°C and 8°C), they usually decline and when roosting between 37°F and 45°F (3°C and 7.2°C) they tend to grow. This hypothesis needs immediate and careful testing.

b. Land Use Practices. The Indiana bats' maternity range has been changed dramatically from pre-settlement conditions: forest has been fragmented in the upper Midwest, fire has been suppressed, and prairie has been supplanted with agricultural systems (primarily row crop and pasture/hayland). Native plants, especially grasses, have been replaced with exotics in large portions of the maternity range, and diverse plant communities have been replaced with simple ones or monocultures. Simplification of the habitat can have profound effects through factors such as availability and abundance of insects on which the bats prey.

Conversely, regions surrounding hibernacula in the Missouri Ozarks and elsewhere may be more densely forested than they were historically. If the Indiana bat is a savanna species, maternity habitat in these regions may be more scarce than previously known.

In the eastern U. S., the area of land covered by forest has been increasing in recent years. Whether or not this is beneficial to the Indiana bat is an open question. The age, composition, and size class distribution of the woodlands will have a bearing on their suitability as habitat for the species.

A clearer picture of the relationship between the Indiana bat and its summer habitat is urgently needed. Until we better understand the factor or factors that have contributed to the decline of the species, we cannot accurately assess whether the loss of summer habitat (especially riparian, flood plain, or upland forest) is limiting to regional or range wide populations of the species.

c. Chemical Contamination. Pesticides have been implicated in the declines of a number of insectivorous bats in North America (Mohr 1972; Reidinger 1972, 1976; Clark and Prouty 1976; Clark et al. 1978; Geluso et al. 1976; Clark 1981). The effects of pesticides on Indiana bats have yet to be studied. McFarland (1998) studied two sympatric species, the little brown bat (M. Iucifugus) and the northern long-eared bat (Ad: septentrionalis keenii) as surrogates in northern Missouri and documented depressed levels of acetylcholinesterase, suggesting that bats there may be exposed to sublethal levels of organophosphate and/or carbamate insecticides applied to agricultural crops. McFarland (1998) also demonstrated that bats in northern Missouri are exposed to significant amounts of agricultural chemicals, especially those applied to corn. BHE Environmental, Inc. (1999) collected tissue and guano samples from five species of bats at Fort

Leonard Wood, Missouri and documented the exposure of bats to p,p'-DDE, heptachlor epoxide, and dieldrin. Similar, additional work is needed.

Conservation Measures

To date, conservation efforts have concentrated on protection of winter habitat, although there has been some research into the life history of the Indiana bat. Active programs by state and federal agencies have led to the acquisition and protection of a number of Indiana bat hibernation caves. Of 127 caves/mines with populations >100 bats, 54 (43%) are in public ownership or control. Most of the 46 (36%) that are gated or fenced are on public land. Given the divergent population trends throughout the range of the Indiana bat, however, it is evident that these measures have not produced the desired result of recovery of the species.

Strategy of Recovery

Recovery of the Indiana bat is subdivided into three basic components: (1) continued protection during the hibernation season, (2) long-term monitoring, and (3) research to determine the factor(s) causing the species decline. Hibernation and maternity requirements should be more clearly defined throughout the range of the species. Presently, limited knowledge of the species ecology during the summer and migration seasons significantly impairs agencies' ability to conserve and restore Indiana bat populations. From a regulatory perspective, protecting habitat for this wide-ranging species without certainty of the benefit may be counterproductive to the broad effort of endangered species protection. Therefore, it is imperative that priority for conservation of this species be placed on the identification of factors that affect its survival and recovery.

RECOVERY

Objective and Criteria

The primary objective of the Recovery Plan is to remove the Indiana bat from endangered status. The important features are: (1) to determine the cause(s) of observed declines during both nonhibernation and hibernation seasons, and (2) to control access to important Indiana bat hibernacula, thus protecting the bats from human disturbance.

Criteria for reclassification will be based upon the status of the Indiana bat throughout its range, as determined through a 12 year, two-stage process. The species will be evaluated for reclassification from endangered to threatened following documentation of stable or increasing populations for three consecutive census periods (six years) and permanent protection [i.e., public ownership or long- term easement/lease, and gate/fence (where necessary and feasible)] at all Priority One hibernacula. To delist, the above criteria must be met, in addition to protection and documentation of stable or increasing populations for three consecutive census periods at 50% of the Priority Two hibernacula in each state, and the overall population level must be restored to that of 1980. This level is believed to be sufficient to maintain enough genetic diversity to enable the species to persist over a large geographic area and avoid extinction.

Narrative Outline for Recovery Actions Addressing Threats

1. CONDUCT RESEARCH NECESSARY FOR THE SURVIVAL AND RECOVERY OF THE INDIANA BAT.

It is unlikely that the Indiana bat can be recovered until factors limiting populations throughout its range are determined. Therefore, research designed to identify the cause(s) of the current population decline must be the number one priority of the recovery plan. Further, definitive habitat management recommendations cannot be made until the importance of various habitat characteristics is known. Research and monitoring projects need to be initiated immediately and simultaneously to answer these important questions.

Understanding of the summer ecology and habitat requirements of the Indiana bat is limited because these bats are nocturnal, widely dispersed within their summer range, and difficult to observe. Although previous researchers have provided valuable preliminary information, additional insight into the habitat requirements of both maternity colonies and males during the summer is needed. Much of the research to date has been done in the western and northern portions of the Indiana bat's range; comparable studies are needed east of Kentucky, Indiana, and Michigan to understand summer habitat throughout the entire range of the species.

A number of research issues should incorporate banding into the study design. By focusing on banding newly flying young at summer colony sites, every bat later recaptured would provide valuable data on movements and survival. In contrast, banding unknown age bats at hibernacula typically results in limited value data from winter recaptures, while summer recaptures are almost non- existent. Therefore, selectively banding at maternity colonies will dramatically increase the amount of information gathered for the amount of effort expended. The use of color-coded reflective bands would greatly increase the identification of banded bats during hibernacula surveys.

The following are priority research needs:

1.1 Research the ecology and life history of the Indiana bat

Research designed to identify the cause(s) of the current population decline and improve understanding of the ecology of the Indiana bat must be high priority. Management and recovery of the species depends upon determining the factor(s) that limit populations throughout the bat's range.

1.1.1. Document potential impacts of changes in temperature and humidity profiles on hibernating bats.

A better understanding of the effects of temperature and humidity on hibernating

Indiana bat populations is needed, including a determination of whether or not microclimates at major hibernacula are changing over time.

1.1.2. Determine the demographic structure of the population (age and sex ratios).

Population demographics are needed in order to understand recruitment, survival, mortality, and other factors that affect population dynamics.

1.1.3. Determine and monitor reproductive success. including recruitment of young into the population.

Measures of reproductive success are needed to determine population growth rates.

l. 1.4. Determine and monitor survival of adults and young.

Measures of survival are needed to determine population dynamics.

1.1.5. Determine and monitor movements among caves.

Information is needed on migration and on movements among hibernacula in order to understand regional population relationships.

l. 1.6. Determine the significance of swarming sites to the survival of the species.

Swarming is not well defined nor understood. In order to understand how swarming sites and behavior relate to mating, selection of hibernacula, and other aspects of the ecology of the Indiana bat, more information is needed.

1.1.7. Determine the food habits and foraging behavior of the Indiana bat. including sex specific foraging behavior and prey selection.

Focused work on Indiana bat food habits and foraging habitat has been limited to three studies. This knowledge should be supplemented with additional studies throughout the range of the bat.

1.1.8. Conduct population viability analyses on populations and subpopulations of the Indiana bat.

Population viability analyses may shed light on regional differences in population trends.

1.1.9. Determine if Indiana bats use night roosts and. if so. determine whether night roosts differ in structure or habitat from day roosts.

If Indiana bats use night roosts in addition to, or that are different from those used during the day, describing them would add to the understanding of habitat use.

1.2. Research the genetics of the Indiana bat.

Information on the genetic makeup of regional populations of Indiana bats is needed.

1.2.1. Determine associations of summer range with hibernacula.

Knowledge of the associations among hibernacula and summering areas, especially if discrete regional differences are determined, may provide clues as to the causes of population decline.

1.2.2. Determine subpopulations via genetics.

The possibility that genetically distinct regional subpopulations of Indiana bats exist should be investigated, because this could lead to genetically meaningful management regions for the Indiana bat. It also is possible that relationships exist between subpopulations and regional population trends.

1.3. Research the summer habitat of the Indiana bat.

Quantifiable measures are needed to assist managers in the identification and maintenance of Indiana bat summer habitat. Information is especially critical from the eastern and southern portions of the Indiana bat's range.

1.3.1. Determine if there are regional differences in roosting or foraging habitat for maternity colonies and males.

Knowledge of regional differences in habitat use may help scientists clarify regional population trends.

1.3.2. Further delineate the range of the Indiana bat.

Promote standardization of field techniques and assemble information gathered by surveys to more clearly define the range of the Indiana bat. New locations of hibernacula or summer maternity sites should be mapped and made available to the USFWS. Both positive and negative survey results should be maintained in a database.

1.3.3. Use Forest Inventory Data. LANDSAT imagery. aerial photography. or other sources to assess extent and condition of Indiana bat summer habitat.

The summer range of the Indiana bat should be delineated and its full range of habitats characterized at the landscape level. Many Indiana bat maternity colonies have been associated with oak-hickory and elm-ash-cottonwood forest types. LANSAT imagery, GIS (Geographical information System) evaluations, aerial photograph, and forestry inventory data may be used to characterize landscapes and identify potential maternity habitat. Because the elm-ash-cottonwood forest type is associated with wetland habitats, NWI (National Wetland Inventory) maps can be employed to locate suitable roosting areas. Once oak-hickory and elm-ash-cottonwood forest types have been identified, other variables such as the percent of forest cover, canopy closure, and the number of standing dead trees by size class can be used to further delineate areas that have a high probability of being used by Indiana bats. These data should be segregated and compared for different areas (e.g., relatively higher density maternity habitat in north Indiana versus relatively lower density maternity habitat in Kentucky) so that the significance of current and projected forest condtions for the species may be assessed.

1.3.4. Determine summer habitat trends.

Landscape level parameters that characterize Indiana bat summer habitat should be used to determine trends in summer habitat throughout the range of the species. Forest inventory data may be examined for changes in forest cover or composition and are collected approximately every 10-15 years. Other data may provide trend information as well. Changes and trends in forest cover, age, species composition, and size class should be determined to adequately address questions concerning habitat trends. Detailed analyses of these sources may provide trend data in the future for forest types that are associated with Indiana bats.

1.3.5 Evaluate. refine. and validate HSI model.

A Habitat Suitability Index (HSI) model developed by Romme et al. (1995) should be evaluated, refined, and validated by field testing and expanded or improved as test results and new information become available (see 3.3.1).

1.3.6. Evaluate the use of bat detectors for determining the presence and habitat use of Indiana bats.

This technique is currently being developed and tested, but further research is necessary before its use is accepted as an assessment tool.

1.4. Determine if Indiana bats are being contaminated by chemicals.

The accumulation of pesticide residues in insectivorous bats is well documented (Clark 1981). Little is known, however, about the extent of this problem in Indiana bats. Indiana bat population losses in Missouri point to an unknown mortality factor or factors, despite extensive efforts to protect bats during hibernation. Toxic chemicals in the environment are potential causes. Further investigations, similar to those conducted by McFarland (1998) and BHE Environmental, Inc. (1999) in Missouri are needed throughout the range of the species.

1.4.1. Determine concentrations of organic and inorganic contaminants in Indiana bats, their food, and habitats.

Surrogates, such as the little brown, bat may be used to investigate the possibility of Indiana bat exposure to chemicals, but small numbers of Indiana bats may need to be sacrificed to determine exposure conclusively. If numbers of dead Indiana bats are found, they should be examined for cause of death using methods described by Clark (1981). In addition to sacrificing live bats for contaminant analyses, guano should be collected at summer colony site, and analyzed for chemical residues. Where bat mortality has been demonstrated, insect samples from known Indiana bat foraging areas should be collected and analyzed for chemical residues using techniques described by Clark (1981). The important questions of what chemicals are involved, where they are, and how they are acting must be addressed. If identified, patterns of use can indicate the most probable origin, and further investigations can be undertaken to alleviate the source of contamination.

1.4.2. Determine the effects of contaminants on survival and reproduction of Indiana bats

Research is needed throughout the range of the Indiana bat, especially where population declines have been observed, to determine exposure of Indiana bats to environmental contaminants and the effects of chemicals on the species. Because Indiana bats frequently are found in riparian areas and feed upon aquatic insects, water quality is probably important to their continued existence. Studies are needed to determine the effects of water pollution and siltation on insect availability and contamination of the bats themselves.

1.5. Determine effects of cave modifications. especially currently used gates. on air flow and temperature.

Studies should be conducted to evaluate and monitor the effectiveness of management methods such as gating, fencing, signing, and other attempts to preclude disturbance at hibernacula. Angle iron gates typically are used to protect bat caves because they are the strongest against vandalism; many clearly have benefitted populations of hibernating bats. Nonetheless, few gate designs have been thoroughly tested for impact on air flow and temperature under the range of conditions in which they are used. The only relevant study to date was conducted by White and Seginak (1987). It is urgent that the angle iron design receive additional testing in laboratory and field settings because even small upward shifts in temperature may be critical to bat survival (especially at southern hibernacula). Temperatures always should be carefully monitored and compared before and after gating.

2. OBTAIN INFORMATION ON POPULATION DISTRIBUTION, STATUS, AND TRENDS.

To measure the effectiveness of recovery actions, it is necessary to monitor the status of the various colonies by surveying the Priority One and Two hibernacula every two years. Monitoring will allow managers to evaluate protection efforts at each hibernaculum, and, in the aggregate, the status of the species throughout its range. Decreasing populations will signal the need for additional action, and stable or increasing populations should be used to measure progress toward the prime objective of removing the Indiana bat from the endangered species list. Census information should be provided to the USFWS. Appropriate funding will ensure that hibernacula censuses are conducted range wide on the schedule described in 2.1. In addition to monitoring populations in hibernacula, summer populations and habitat should be monitored, as well.

2.1. Monitor the status of populations in hibernacula.

The USFWS should continue to coordinate a monitoring system whereby all accessible Priority One and Priority Two hibernacula are surveyed every two years. Experienced bat biologists should conduct censuses to ensure reliable estimates. For consistency of data, one observer has surveyed seven of the Priority One hibernacula since 1983; this practice should continue with trained observers. Priority Two caves are surveyed by personnel in various state and Federal agencies. Data should be provided to the USFWS.

The following procedures should be followed for surveying Indiana bats: Censuses should be conducted during mid-winter (January 15 - February 15). Bats hanging singly and in small clusters (up to 25) should be counted individually. The numbers of bats in larger clusters may be estimated as a function of cluster surface area. The area of such clusters should be measured, if possible; otherwise they should be ocularly estimated. The number of bats then is calculated using observed density. In most cases, density ranges from 300 bats per ft2 (3,230/m2) to 484 bats/ft2 (5,215/m2).

2.2. Monitor the status of populations in summer.

Because it is difficult to locate Indiana bat colonies during the summer, known colonies should be revisited periodically for the purpose of monitoring their status.

2.2.1 Maintain and update distribution records of known maternity colonies.

States in the range of the Indiana bat should maintain files such as Heritage databases on summer occurrence records of the species and update them as new information is generated. Information on the summer occurrence of Indiana bats should be made available to appropriate Federal agencies, state agencies, and other organizations.

2.2.2 Identify and monitor maternity colonies.

Maternity colonies in the eastern and southern parts of the Indiana bat's range should be located so that the summer status of Indiana bats can be determined and monitored in these areas.

2.3. Reestablish a central banding authority.

Potentially important information on bat movements, geographic associations, and survival is being lost because there is no central authority for issuing bat bands and serving as a repository for banding data. The USFWS should assure a system is created to accomplish these purposes.

3. PROTECT AND MAINTAIN INDIANA BAT POPULATIONS.

Indiana bat populations need to be protected from disturbance during hibernation. Current hibernacula should be protected and abandoned hibernacula should be restored, if it is feasible to do so. Forest management activities should incorporate standards and guidelines outlined in the most current scientific information that protect and enhance Indiana bat roosting and foraging habitat.

3.1. Restore abandoned hibernation caves.

Previously occupied caves that have been abandoned or have severely reduced populations due to heavy disturbance or adverse modification will likely be recolonized if protected.

3.1.1. Eliminate disturbance at historic caves.

Where human disturbance of hibernating Indiana bats has caused population decline or elimination, protection of the site may allow bats to recolonize and populations to increase.

3.1.2. Restore hibernating microclimate.

A number of caves that were formerly important roost sites for Indiana bats have been modified adversely due to the installation of improper gates. Modifications that impede air flow should be removed or replaced with appropriate structures to restore the cave's microclimate. Existing roost sites that have been adversely modified should be given first priority for restoration. Many Indiana bat caves have more than one natural entrances, all of which are important in maintaining winter microclimate. Hibernation caves should be thoroughly explored and mapped during the non-closure season so that all entrances are identified, and each entrance protected.

3.2. Protect Indiana bats during hibernation.

Preservation and protection of Indiana bat hibernacula is necessary throughout the species range.

3.2.1. Prevent unauthorized entry by humans.

Preventing unwarranted entry by humans is the best way to curtail disturbance at these sites. Because Indiana bat use of caves is seasonal, protection efforts should be concentrated during the hibernation period. While it is advisable to avoid disturbance between mid-August and mid-May, entry to hibernacula should be prohibited during the period of September 1 - April 30 in most of the species' range, and September 1 - May 31 in the northern portion of the range (Connecticut, Massachusetts, Michigan, New York, and Vermont).

3.2.1.1. Erect warning signs.

Signs may be used at caves to discourage entry. Signs should be used in conjunction with gates to inform the public. Signs should be placed inside cave entrances so as not to attract potential violators to the cave, but not block bat movement or air flow. The placement of signs to assist in controlling access to privately-owned caves should be coordinated with private landowners. Informative signs may elicit cooperation from uninformed people, especially if a definite time period is identified when access to a cave may be allowed. The wording of the sign should be similar to the following: "ATTENTION! DO NOT ENTER THIS CAVE BETWEEN SEPTEMBER 1 AND APRIL 30. The endangered Indiana bat hibernates in this cave and must survive the winter on stored fat. Any disturbance that causes the bats to arouse will deplete this limited fat supply and they could die. To enter when Indiana bats are present is a violation of the Federal and state law(s), punishable by arrest, a fine of up to $50,000 for each violation, and possible imprisonment. "

3.2.1.2. Erect barriers - Gate or fence cave.

A structure placed at the roost cave entrance will prevent unauthorized human access (such as an angle-iron gate or fence). The structure must permit Indiana bats to pass without danger and must not alter air flow. Plans to gate or fence hibernacula must be reviewed by USFWS personnel and state agency endangered species personnel to ensure that gates are properly designed and constructed. Upon contemplating construction of a gate, refer to plans and descriptions of proper gate designs available from the American Cave Conservation Association, and a publication by Tuttle and Taylor (1994). Caves that are prone to flash flooding, however, should be carefully evaluated before barriers are constructed, especially if the bats roost where water may be impounded by a gate. Special care must be taken to prevent increased water levels with subsequent flooding events or blocking air flow, when debris can accumulate against gates.

3.2.1.3. Patrol caves.

Regular law enforcement patrols of the entrances to hibernacula by various Federal, state, and local authorities during the closed period would help in protecting hibernating bats. Local authorities can best decide the amount of effort needed to safeguard bat caves, depending upon site-specific factors such as accessibility, past history of disturbance, strength of the protective barrier, etc. "Speloggers" or other devices that assist in the monitoring or apprehension of violators may materially aid law enforcement personnel.

3.2.1.4. Deter human access in vicinity of hibernacula.

In addition to gating, fencing or posting signs at Indiana bat hibernacula, roads and trails leading to hibernacula may be blocked or obliterated to further discourage access. Closure decisions should be made locally in consultation with the USFWS, and reflect site-specific considerations such as the need to leave hibernacula open to public use during non-hibernation season, or where trail closure may create controversy between managers and resource users, the wishes of the landowner, etc.

3.2.2. Minimize disturbance due to monitoring and research activities.

Monitoring should be conducted with sufficient regularity to effectively determine population trends, but not so frequently that they put additional pressure on the species. In addition, only research that is essential to the survival or recovery of the species should be conducted during this critical period.

3.2.2.1. Survey populations every two years.

In order to minimize the amount of disturbance from monitoring activities, yet maintain data on population levels and trends, surveys should be conducted in alternate years.

3.2.3 Protect hibernacula.

Because Indiana bats hibernate exclusively in caves and mines, a substantial measure of protection will be afforded the species if important hibernacula are protected from human disturbance and adverse modification. To assure that these sites remain available to Indiana bats, all Priority One hibernacula should be protected and gated or fenced. Priority Two hibernacula should be protected if their populations have declined, if they are accessible to a management agency, and if the needed degree of protection is feasible. Local management authorities should evaluate the need and opportunity for protecting Priority Three Indiana bat hibernacula within their jurisdictions.

3.2.3.1. Work with private landowners.

Information and assistance to private landowners to help them protect important Indiana bat hibernacula, up to and including the erection of protective barriers, would help accomplish protection of these bats during hibernation. Posting privately-owned caves with signs that outline reasons for bat protection and specific times when entry is prohibited would also assist in safeguarding the bats.

3.2.3.2. Purchase or lease hibernacula to assure long-term protection.

Long-term protection may be accomplished if access to these hibernacula is controlled through fee acquisition, lease, easement, cooperative agreement, or other arrangement, provided that management and enforcement personnel may legally take steps to eliminate disturbance to the bats.

3.2.3.3. Protect the integrity of hibernacula systems.

Not only do Indiana bats need protection from disturbance while they occupy hibernacula, but the physical structures themselves and the conditions that provide favorable roosting microclimates for the bats need to be recognized and protected, as well.

3.2.3.3.1. Protect the surface surrounding hibernacula.

Hibernacula are vulnerable to changes made to the surface areas above them, including the immediate areas that drain into them. Some have other entrances, well away from the main entrance, that are crucial to chimney-effect air flow. Activities such as road construction, urban development, the conversion of forest to pasture or cropland, surface mining, or logging may cause increased storm water runoff or siltation into a cave and increase the likelihood of cave flooding, or adversely change temperature and humidity regimes. While a 1/4 mi (0.4 km) buffer zone is recommended, this is a general guideline. Forested buffer zones should be designed to conform to the surrounding topography on a case by case basis. The maintenance of forest cover in the vicinity of hibernacula also is important because male Indiana bats forage nearby and use snags and loose-barked trees as daytime roosts prior to entering hibernation (Kiser and Elliott 1996).

3.2.3.3.2. Protect the physical characteristics of hibernacula.

Success has recently been obtained in stabilizing collapsed entrances at a major little brown bat hibernation site in a Wisconsin mine (Tuttle 1996). The possibility of stabilizing Missouri's Pilot Knob Mine entrance to prevent collapsing should be investigated.

3.2.3.4. Make locations of hibernacula available to appropriate Federal offices. state wildlife agencies. and non-governmental organizations (NGOs)

Provide locations of hibernacula to appropriate USFWS offices, as well as Federal and state wildlife or land management agencies, so that potential conflicts may be identified during Section 7 consultations and other planning activities, and for law enforcement activities. The locations of hibernacula that are not protected by barriers should not be publicized to diminish the potential for destructive human disturbance.

3.2.3.5. Identify new Indiana bat winter roost sites.

Although the locations of many (perhaps most) Indiana bat hibernacula are known, cavers or other private individuals may know of or discover and reveal the locations of additional caves occupied by Indiana bats. Such caves should be evaluated and added to existing data bases when discovered. Involve the organized caving community (e. g., National Speleological Society affiliated grottoes) as a resource in locating, evaluating, and protecting important Indiana bat caves.

3.3. Provide maternity roosts.

The selective harvest of trees need not endanger maternity colonies or male Indiana bats. Forest management practices should incorporate standards that protect and enhance roost trees for Indiana bats. Silvicultural practices should favor the creation and retention of suitable roost trees, including the development of multiple age classes so that a sustainable supply of large diameter, mature and over-mature trees is assured through the foreseeable future. Uneven-aged management or even-aged management that includes provisions for snag retention may be used. Large diameter, standing dead trees, especially those at forest edges or in the open, should be retained. Snag retention guidelines developed by the USFS Daniel Boone National Forest are considered adequate. Managers are encouraged to use life history information from published sources, and from the Recovery Plan, as well as new information as it becomes available, in combination with their own experiences to tailor management strategies to their own particular circumstances and situations. Guidelines for (1) habitat assessment where specific projects are proposed and (2) habitat management should be developed at the local, state, and regional levels by land management agencies in consultation with the USFWS.

3.3.1. Assess habitat using a Habitat Suitability Index model developed for the species

A habitat suitability index (HSI) model (Romme et al. 1995) of the summer habitat of the Indiana bat was developed to 1) aid in environmental review of actions that may affect the species, 2) provide a tool to measure the effectiveness of habitat mitigation efforts, and 3) assist land managers in developing a "desired future condition" where Indiana bat summer habitat is to be managed or created. This HSI model is under review by the USGS, Midcontinent Ecological Science Center, and is slated to be tested and refined.

3.3.2. Determine Indiana bat presence/absence via mist netting or trapping.

If land managers need to determine whether or not Indiana bats are present at a particular site, until ultrasonic bat detection methodology is developed and proven, the only way to know if bats are present is by mist netting or trapping. Appendix II provides guidelines that will standardize mist netting procedures and maximize the potential for catching Indiana bats with a minimum acceptable level of effort.

4. <u>PROVIDE INFORMATION AND TECHNICAL ASSISTANCE OUTREACH</u>.

Information on Indiana bat ecology and management should be disseminated among public officials, the public, and private landowners.

4.1. <u>Promote awareness of the needs of Indiana bats.</u>

Land management agencies should be informed of methods for protecting Indiana bat roosts (winter and summer) from disturbance and of the habitat needs of Indiana bats during the summer. Awareness of the beneficial qualities of Indiana bats should be promoted. Landowners in the vicinity of known Indiana bat roosts should be urged to leave natural forest corridors, especially around cave entrances, between known cave roosts and foraging areas, and along streams. Guidelines for the management and creation of Indiana bat summer habitat should be developed and shared with land managers.

4.1.1. <u>Provide outreach to private landowners.</u>

Major efforts should be made to educate and gain the cooperation of landowners. Many will cooperate when contacted by wildlife officials or conservation groups. Cave owners should be provided with a written explanation of the problems faced by Indiana bats, the value of protecting bats, and information on Federal and state laws. It is important to inform landowners that they have a valuable and rare resource, and to generate a sense of pride and stewardship, thus making a protective posture a positive action. Formal cooperative agreements should be arranged with the private landowners of important roost sites, including identified summer habitat. Contact programs should be developed that emphasize positive interactions between biologists and landowners. Incentive programs that benefit private land owners for instituting Indiana bat habitat improvement measures may encourage others to manage for the species and foster good will.

4.1.2. <u>Prepare and distribute pamphlets.</u>

Carefully written brochures should be distributed throughout the range of the Indiana bat. Their purpose should be to educate the public regarding the ecological importance of bats and informing the public why their cooperation is essential if protection efforts are to be successful. Habitat management and the needs of Indiana bats during the different seasons of the year should be emphasized. "Bats of the

United States" by Harvey e' al. (1998) is an example of an informative pamphlet that is available to the public from the USFWS.

4.1.3. Prepare and present slide programs.

Slide presentations such as "Bats of America," available from Bat Conservation International (P.O. Box 162603, Austin, TX 78716), as well as materials from states and NGOs, should be used in parks, nature centers, schools, etc. throughout the range of the Indiana bat. Organizations whose members explore caves should receive special emphasis in these efforts. Using the expertise of the Indiana Bat Recovery Team, a slide program explaining Indiana bat habitat identification and management should be developed for the presentation to professionals and the public.

4.1.4. Assist rangers and naturalists in the development of presentations.

Presentations and programs should include more detailed information about the species. Agencies and organizations giving natural history programs within the range of the Indiana bat should include information on the needs and habitat requirements of Indiana bats.

4.1.5. Provide outreach to government officials.

Officials at all levels of government should be educated regarding the ecological role of bats. Exaggerated fear of bats as disease vectors may lead to unwarranted destruction of bat colonies. Disease problems should be put in perspective, and officials and the public informed of the beneficial qualities of bats, especially as predators of night-flying insects and as biological indicators of environmental pollutants. Specific habitat management guidelines should be developed and distributed to natural resource professionals such as foresters, wildlife biologists, soil and water conservation district biologists, and others.

5. COORDINATE AND IMPLEMENT THE CONSERVATION AND RECOVERY OF THE INDIANA BAT.

In order to use limited fiscal resources efficiently, managers and researchers should share information and coordinate their activities throughout the range of the Indiana bat.

5.1. Communicate with land managers and researchers.

In order to effectively advance recovery of the Indiana bat, land managers must be able to access information necessary to design management plans that incorporate the habitat needs of the species. Researchers should coordinate their efforts throughout the range of the Indiana bat so that a broad array of research needs are addressed and maximum efficiency of effort is achieved.

5.1.1. Communicate Indiana bat recovery efforts.

Improved communication among professional and managerial staffs in the dissemination of information will likely accelerate recovery efforts. Coordinating the exchange of information concerning research and management efforts would facilitate recovery efforts.

5.1.2. Encourage and support the publication of research. management. and other recovery related information.

Unpublished reports and summaries of Indiana bat population data have been compiled over the years and should be published. All researchers and managers are strongly encouraged to publish reports and research findings in peer reviewed technical publications intended for wide distribution.

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IMPLEMENTATION SCHEDULE

The following Implementation Schedule outlines actions and estimated costs for the recovery program. It is a guide for meeting the objective discussed in Part II of this Plan. This schedule indicates priorities, task numbers, task descriptions, duration of tasks, responsible agencies, and estimated costs. These actions, when accomplished, should lead to the recovery of the species and protect its essential habitat. The estimated funding needs for all parties anticipated to be involved in recovery are identified where possible. The estimated recovery costs for the 10-year program for this species is $1,771,000.

Priorities in the first column of the following implementation schedule are assigned as follows:

Priority 1: An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.
Priority 2: An action that must be taken to prevent a significant decline in species population/ habitat quality or some other significant negative impact short of extinction.
Priority 3: All other actions necessary to meet recovery objectives.

Abbreviations used in the Implementation Schedule are as follows:

AR	Arkansas Natural Heritage Commission
BRD	Biological Research Division of U. S. Geological Survey
DOD	Department of Defense
EA	External Affairs (U.S. Fish and Wildlife Service)
EMU	Eastern Michigan University
ES	Ecological Services (U.S. Fish and Wildlife Service)
LA	Iowa Department of Natural Resources
IL	Illinois Department of Conservation
IN	Indiana Department of Natural Resources
KY	Kentucky Department of Fish and Wildlife Resources; Kentucky State Nature Preserves Commission
LE	Law Enforcement (U.S. Fish and Wildlife Service)
MI	Michigan Department of Natural Resources
MO	Missouri Department of Conservation; Missouri Department of Natural Resources
NGOs	Non-Governmental Organizations
NPS	National Park Service
NY	New York Department of Environmental Conservation
OH	Ohio Department of Natural Resources
PA	Pennsylvania Game and Fish Commission
RW	Refuges and Wildlife (U.S. Fish and Wildlife Service)
States	State Agencies within the range of the Indiana bat
TNC	The Nature Conservancy
TTU	Tennessee Technological University
UK	University of Kentucky
USFS	U. S. Forest Service
USFWS	U. S. Fish and Wildlife Service
WV	West Virginia Division of Natural Resources

IMPLEMENTATION SCHEDULE FOR THE REVISED INDIANA BAT RECOVERY PLAN (AGENCY DRAFT)

PRIORITY NUMBER	TASK NUMBER	TASK DESCRIPTION	DURATION	RESPONSIBLE PARTY			COST ESTIMATES ($000)				NOTES
				USFWS			FY 1999	FY 2000	FY 2001	FY 2002-2008	
				REGION	PROGRAM	OTHER					
1	1.1.1	Document potential impacts of changes in temperature and humidity profiles on hibernating bats.	Ongoing	3, 4, 5	ES	States; Federal Agencies	5	5	5		
1	1.1.2	Determine the demographic structure of the population.	Ongoing	3, 4, 5	ES	States; Federal Agencies	5	5	5		
1	1.1.3	Determine and monitor reproductive success, including recruitment of young into the population.	Ongoing	3, 4, 5	ES	States; Federal Agencies	10	10	10		
1	1.1.4	Determine and monitor survival of adults and young.	Ongoing	3, 4, 5	ES	States; Federal Agencies	10	10	10		
1	1.1.5	Determine and monitor movement among caves.	Ongoing	3, 4, 5	ES	States; Federal Agencies	20	20	20		
1	1.1.6	Determine the significance of swarming sites.	Ongoing	3, 4, 5	ES	States; Federal Agencies				20	
1	1.1.7	Determine food habits and foraging behavior.	Ongoing	3, 4, 5	ES	States; Federal Agencies	20	20	20		
1	1.1.8	Conduct population viability analyses on populations and subpopulations.	Ongoing	3, 4, 5	ES	States; Federal Agencies				30	
1	1.1.9	Determine if Indiana bats use night roosts.	Ongoing	3, 4, 5	ES	States; Federal Agencies				20	

IMPLEMENTATION SCHEDULE FOR THE REVISED INDIANA BAT RECOVERY PLAN (AGENCY DRAFT)

PRIORITY NUMBER	TASK NUMBER	TASK DESCRIPTION	DURATION	RESPONSIBLE PARTY			COST ESTIMATES ($000)				NOTES
				USFWS			FY 1999	FY 2000	FY 2001	FY 2002-2008	
				REGION	PROGRAM	OTHER					
1	1.2.1	Determine associations of summer range with hibernacula.	8 Years	3, 4, 5	ES	USFS; States	10	10	10	30	
1	1.2.2	Determine subpopulations via genetics.	8 Years	3, 4, 5	ES	USFS; States	15	15	15		
1	1.3.1	Determine if there are regional differences in roosting or foraging habitat for 1) maternity colonies or 2) males.	Ongoing	3, 4, 5	ES	States; Federal Agencies	10	10	10	30	
1	1.3.2	Better delineate the range of the Indiana bat.	Ongoing	3, 4, 5	ES	States; Federal Agencies	No direct cost	No direct cost	No direct cost	No direct cost	
1	1.3.3 1.3.4	Use Forest Inventory Data, LANDSAT imagery, aerial photography, or other sources to assess extent and condition of Indiana bat summer habitat, and summer habitat trends.	Ongoing	3, 4, 5	ES	States; Federal Agencies	10	10	10	30	
1	1.3.6	Evaluate the use of bat detectors for determining the presence and habitat use of Indiana bats	3 years	3, 4, 5	ES	States; Federal Agencies	20	20	20		
1	1.4.1 1.4.2	Determine concentrations of contaminants in Indiana bats, their food, and habitats, and determine the effects of contaminants on survival and reproduction.	Ongoing	3, 4, 5	ES	States; Federal Agencies	50	50	50	100	

IMPLEMENTATION SCHEDULE FOR THE REVISED INDIANA BAT RECOVERY PLAN (AGENCY DRAFT)

PRIORITY NUMBER	TASK NUMBER	TASK DESCRIPTION	DURATION	RESPONSIBLE PARTY			COST ESTIMATES ($000)				NOTES
				USFWS			FY 1999	FY 2000	FY 2001	FY 2002-2008	
				REGION	PROGRAM	OTHER					
1	2.1 3.2.2.1	Monitor the status of populations in hibernacula.	Ongoing	3, 4, 5	ES	USFS; AR, IL, IN, KY, MO, NY, OH, WV		15		60	Conduct population surveys every two years.
1	2.2.1	Maintain and update distribution records of known maternity colonies.	Ongoing	3	ES		No direct cost	No direct cost	No direct cost	No direct cost	
1	2.2.2	Identify and monitor maternity colonies.	Ongoing	3, 4, 5	ES	USFS, DOD, IA, IL, IN, KY, MI, MO, OH, EMU, TTU, UK	15	15	15	105	
1	3.2.1.1	Erect warning signs.	Ongoing	3, 4, 5	ES, RW	USFS; DOD, NPS, States	.4	.4	.4	2.8	
1	3.2.1.2 3.2.1.4	Erect barriers (gate or fence) and deter human access at hibernacula.	Ongoing	3, 4, 5	ES, RW	USFS; DOD, NPS, States	5	5	5	35	
1	3.2.1.3	Patrol caves.	Ongoing	3, 4, 5	LE, RW	USFS; DOD, NPS, States	10	10	10	70	
1	3.2.3.2	Purchase of lease hibernacula.	Ongoing			States; TNC		10		10	Cost figured for 2 cave purchases and 3 cave leases during the planning period.
1	3.2.3.3.1 3.2.3.3.2	Protect the integrity of hibernacula cave systems: surface and subsurface.	Ongoing	3, 4, 5	LE, RW	States; Federal Agencies	5	5			Cost is for site appraisals; actual construction cost dependent on site.

IMPLEMENTATION SCHEDULE FOR THE REVISED INDIANA BAT RECOVERY PLAN (AGENCY DRAFT)

PRIORITY NUMBER	TASK NUMBER	TASK DESCRIPTION	DURATION	RESPONSIBLE PARTY			COST ESTIMATES ($000)				NOTES
				USFWS			FY 1999	FY 2000	FY 2001	FY 2002-2008	
				REGION	PROGRAM	OTHER					
2	1.3.5 3.3.1	Evaluate, refine, and validate HSI model; and assess habitat.	3 Years	3	ES	BRD	25	50	50		
2	1.5	Determine effects of cave modifications.	Ongoing	3, 4, 5	ES	States; Federal Agencies	20	20	20	40	
2	3.1.1	Eliminate disturbance at historic caves.	Ongoing		ES, LE	IL, IN, KY, MO, NY, PA, WV; others as appropriate	10	10	10		
2	3.1.2	Restore hibernating microclimate.	Ongoing	3, 4, 5	ES	States; Federal Agencies	10	10	10		
2	3.2.3.1	Work with private landowners.	Ongoing			States	5	5	5	35	
2	3.3.2	Determine Indiana bat presence/absence via mist netting.	Ongoing	3, 4, 5	ES	States; Federal Agencies	20	20	20	140	
3	2.3	Reestablish a central banding authority.				BRD	No direct cost	No direct cost	No direct cost	No direct cost	
3	3.2.3.4	Make locations of hibernacula available to appropriate federal offices, state wildlife agencies, and non-governmental organizations (NGOs).	Ongoing			States	See Note	See Note	See Note	See Note	Cost to be determined by state agencies with authority over Heritage databases.

IMPLEMENTATION SCHEDULE FOR THE REVISED INDIANA BAT RECOVERY PLAN (AGENCY DRAFT)

PRIORITY NUMBER	TASK NUMBER	TASK DESCRIPTION	DURATION	RESPONSIBLE PARTY			COST ESTIMATES ($000)				NOTES
				USFWS			FY 1999	FY 2000	FY 2001	FY 2002-2008	
				REGION	PROGRAM	OTHER					
3	3.2.3.5	Identify new Indiana bat winter roost sites.	Ongoing			States; NGOs	No direct cost	No direct cost	No direct cost	No direct cost	
3	4.1.1	Provide outreach to private landowners.	Ongoing	3, 4, 5	ES, RW	States; Federal Agencies; NGOs	No direct cost	No direct cost	No direct cost	No direct cost	
3	4.1.2	Prepare and distribute pamphlets.	Ongoing	3, 4, 5	ES, EA	States; Federal Agencies	2	2	2	4	
3	4.1.3	Prepare and present slide programs.	Ongoing	3, 4, 5	ES, EA	States; Federal Agencies	2				
3	4.1.4	Assist rangers and naturalists in the development of presentations.	Ongoing	3, 4, 5	ES	States; Federal Agencies	No direct cost	No direct cost	No direct cost	No direct cost	
3	4.1.5	Provide outreach to government officials.	Ongoing	3, 4, 5	ES	States; Federal Agencies	No direct cost	No direct cost	No direct cost	No direct cost	
3	5.1.1	Communicate Indiana bat recovery efforts.	Ongoing	3, 4, 5	ES	States; Federal Agencies	No direct cost	No direct cost	No direct cost	No direct cost	
3	5.1.2	Encourage and support publication of recovery-related information.	Ongoing	3, 4, 5	ES	States; Federal Agencies	No direct cost	No direct cost	No direct cost	No direct cost	

APPENDIX I
RANGE-WIDE DISTRIBUTION RECORDS FOR MYOTIS SODALIS

STATE COUNTY	HIBERNACULA PRIORITY LEVEL	MATERNITY SUMMER	OTHER SUMMER
ALABAMA			
Blount	III (2)		
Calhoun	III (1)		
Jackson	III (6)		
Lauderdale	III (1)		
Morgan	III (2)		
Shelby	III (1)		X (1)
ARKANSAS			
Baxter	III (1)		
Benton	III (1)		
Clay			X (1)
Craighead			X (1)
Independence	III (1)		
Izard	III (1)		
Madison	II (1)		
Marion	III (1)		
Newton	II (2), III (2)		
Searcy	III (1)		
Sharp	III (1)		
Stone	II (6)		
Washington	III (1)		
CONNECTICUT			
Litchfield	III (1)		
FLORIDA			
Jackson	III (1)		
GEORGIA			
Dade	III (2)		
ILLINOIS			
Adams	III (1)	X(3)	X(2)
Alexander	III (1)	X(2)	
Bond		X(1)	
Cass		X(1)	
Christian		X(1)	
Clay		X(1)	
Cook		X(1)	
Edwards		X(1)	
Ford		X(1)	
Hardin III (1)		X(1)	
Henderson		X(1)	

APPENDIX I (CONT.)

STATE COUNTY	HIBERNACULA PRIORITY LEVEL	MATERNITY SUMMER	OTHER SUMMER
ILLINOIS (cont.)			
Jackson	II (1)	X (4)	X (1)
Jersey		X (1)	
JoDaviess	III (1)		
Johnson	III (1)	X (1)	
LaSalle	II (1)		
Lawrence		X (1)	
Macoupin		X (1)	
Madison	III (1)		
McDonough		X (1)	
Monroe	II (1)		X (1)
Morgan			X (1)
Perry			X (3)
Pike	III (1)	X (5)	X (3)
Pope	III (2)	X (1)	X (1)
Pulaski		X (1)	
Saline		X (1)	
Sangamon			X (1)
Schuyler		X (1)	
Scott		X (1)	
Union	III (2)	X (3)	X (2)
Vermilion		X (1)	
Wabash		X (1)	
INDIANA			
Boone		X (1)	X (1)
Blackford		X (1)	
Clark	III (1)		X (1)
Clay			X (1)
Clinton		X (2)	
Crawford	I (1), II (2), III (2)		X (1)
Delaware		X(1)	X(1)
Fountain		X (1)	X (1)
Fulton		X (1)	X (1)
Greene	I (1), III (3)		X (1)
Hancock			X (1)
Harrison	I (1), II (2), III (3)		X (1)
Hendricks		X(2)	X(1)
Henry		X (2)	
Howard		X (1)	
Huntington		X (1)	
Jasper		X (1)	
Jay		X (1)	
Jefferson	III (1)	X (1)	
Jennings		X (2)	
Johnson			X (1)

STATE COUNTY	HIBERNACULA PRIORITY LEVEL	MATERNITY SUMMER	OTHER SUMMER
INDIANA (cont.)			
Knox		X (1)	
Kosciusko		X (1)	
LaGrang		X (1)	
Laporte		X (1)	
Lawrence	III (2)		X (1)
Marion		X (1)	X (1)
Martin		X (1)	X (1)
Monroe	II (3), III (4)		X (1)
Montgomery		X(3)	X(1)
Morgan			X(1)
Orange	III (1)		
Owen	III (1)		
Parke		X (2)	X (1)
Pulaski		X (1)	
Putnam		X (2)	X (2)
Randolph		X (3)	X (3)
Ripley		X (1)	
Rush		X (2)	
Shelby		X (2)	
Stark		X (1)	
Steuben		X (1)	
St. Joseph		X (1)	
Tippecanoe		X (2)	X (1)
Vermillion		X (1)	
Vigo		X (1)	X (1)
Wabash		X (2)	
Warren		X (1)	
Washington	II (1), III (3)		X (1)
Wayne		X (1)	
Wells		X (1)	
IOWA			
Appanoose		X (2)	
Decatur		X (1)	
DuBuque	III (2)		
Iowa		X (1)	
Jasper			X (1)
Keokuk		X (1)	X (1)
Louisa			X (1)
Lucas		X (2)	
Madison		X (1)	
Marion		X (5)	
Monroe		X (2)	
Poweshiek		X (1)	
Ringgold		X (1)	

APPENDIX I (CONT.)

STATE	COUNTY	HIBERNACULA PRIORITY LEVEL	MATERNITY SUMMER	OTHER SUMMER
IOWA (cont.)				
	Van Buren		X (2)	
	Wappelo		X (1)	
	Washington		X (1)	
KENTUCKY				
	Adair	III (1)		
	Allen	III (1)		
	Barren	III (1)		
	Bath	III (1)	X (2)	
	Bell	III (1)		
	Breckinridge	II (2), III (3)	X (3)	
	Bullitt		X (1)	
	Calloway			X (1)
	Carlisle		X (1)	
	Carter	I (1), III (2)		
	Daviess		X (1)	
	Edmonson	I(2), II (1), III (4)	X(2)	X (3)
	Elliott	III (1)		
	Estill	III (4)		X (1)
	Fayette			X (1)
	Franklin			X (1)
	Grayson			X (1)
	Hardin	III (2)		
	Harlan		X (3)	X (1)
	Hart	III (3)		X (1)
	Hickman		X (1)	
	Jackson	II (1), III (16)		X (5)
	Jefferson		X (2)	
	Jessamine			X (1)
	Lee	II (3), III (6)		X (4)
	Letcher	II (2)		X(1)
	Livingston	III (3)		
	Logan		X (1)	
	McCracken		X (2)	
	McCreary			X (1)
	Meade	III (1)		
	Menifee	II (3), III (5)		X(3)
	Morgan	III (1)		
	Powell	III (1)		X (2)
	Pulaski	III (7)	X(1)	X(3)
	Rockcastle	II (2), III (9)		X (1)
	Rowan			X (1)
	Taylor	III (1)		
	Trigg	III (2)		
	Trimble			X (1)

APPENDIX I (CONT.)

STATE	COUNTY	HIBERNACULA PRIORITY LEVEL	MATERNITY SUMMER	OTHER SUMMER
KENTUCKY (cont.)				
	Union		X (1)	
	Warren	III (1)		
	Whitley	II (1)		
	Wolfe	III (1)		
MARYLAND				
	Garrett	III (1)		
	Washington	III (1)		
MASSACHUSETTS				
	Worcester	III (1)		
MICHIGAN				
	Barry			X (1)
	Branch		X (1)	
	Calhoun			X (1)
	Eaton		X (1)	
	Emmet			X (1)
	Hillsdale		X (1)	X (1)
	Ingham			X (1)
	Jackson		X (1)	
	Livingston		X (1)	X (1)
	Manistee	III (1)		
	St. Joseph		X (2)	X (1)
	Washtenaw		X (3)	
	Wayne			X (1)
MISSISSIPPI				
	Tishomingo	III (1)		X (2)
MISSOURI				
	Barry	III (1)		
	Boone	III (1)		X (2)
	Camden	III (3)		X (1)
	Carter	III (1)		
	Chariton		X (1)	
	Christian	III (1)		X (1)
	Clinton		X (1)	
	Cole			X (1)
	Crawford	II (1), III (9)		X (1)
	Daviess		X (1)	
	Dent	III (3)		
	Franklin	II (2), III (5)		X (1)
	Hickory			X (1)
	Iron	I (1), III (1)	X (1)	X (1)

APPENDIX I (CONT.)

STATE	COUNTY	HIBERNACULA PRIORITY LEVEL	MATERNITY SUMMER	OTHER SUMMER
MISSOURI (cont.)				
	Jefferson	III (1)	X (1)	
	Knox		X (1)	X (1)
	Laclede	II (2), III (2)		X (1)
	Lewis			X (2)
	Linn		X (1)	
	Macon		X (1)	
	Marion	III (1)		X (1)
	McDonald			X (1)
	Mercer		X (1)	
	Miller	III (1)		X (1)
	Monroe		X (1)	
	Nodaway		X (2)	
	Oregon	III (1)		
	Phelps	III (1)		X (1)
	Pike	III (1)	X (1)	X (1)
	Pulaski	II (5), III (6)	X (1)	X (1)
	Scotland		X (1)	
	Shannon	I (1), II (2), III (2)		X (1)
	Sullivan		X (1)	
	Taney	III (1)		
	Texas	II (1), III (1)		
	Washington	I (1), II (1), III (4)	X (1)	X (1)
	Wright	II (1), III (2)		
NEW HAMPSHIRE				
	Coos			X (1)
NEW JERSEY				
	Morris	III (1)	X (1)	X (1)
NEW YORK				
	Albany	II (1)		
	Essex	II (1)		
	Jefferson	II (1)		
	Onondaga	II (1)		
	Ulster	II (1)		
	Warren	III (1)		
NORTH CAROLINA				
	Henderson	III (1)		
	Jackson	III (1)		
	Rutherford	III (1)		
	Mitchel			X (1)
	Swain			X (1)

APPENDIX I (CONT.)

STATE	COUNTY	HIBERNACULA PRIORITY LEVEL	MATERNITY SUMMER	OTHER SUMMER
OHIO				
	Adams	III (1)		
	Brown	III (1)		
	Butler		X (1)	
	Champaign		X (1)	
	Clermont		X (1)	
	Columbiana			X (1)
	Darke		X (1)	
	Delaware			X (1)
	Franklin			X (1)
	Greene			X (1)
	Hamilton		X (1)	
	Highland	III (1)		X (1)
	Hocking	III (1)		X (1)
	Lake			X (1)
	Lucas			X (1)
	Madison			X (1)
	Miami			X (1)
	Paulding			X (1)
	Pike			X (1)
	Preble	II (1)		
	Richland			X (1)
	Scioto			X (1)
	Warren		X (1)	
OKLAHOMA				
	Adair	III (1)		
	Delaware	III (1)		
	LeFlore	III (1)		
	Pushmataha	III (1)		
PENNSYLVANIA				
	Blair	III (1)		
	Luzerne	III (1)		X (1)
	Mifflin	III (1)		
SOUTH CAROLINA				
	unspecified	III (1)		
TENNESSEE				
	Blount	II (1)		
	Campbell	II (1)		
	Fentress	II (1)		
	Franklin	III (1)		
	Hawkins	II (1)		
	Hickman	III (1)		

APPENDIX I (CONT.)

STATE	COUNTY	HIBERNACULA PRIORITY LEVEL	MATERNITY SUMMER	OTHER SUMMER
TENNESSEE (cont.)				
	Marion	III (1)		
	Maury	III (1)		
	Montgomery	II (1)		
	Perry	III (1)		
	Sevier	III (1)		X (1)
	Shelby			X (1)
	Stewart	III (1)		
	Warren	II (1)		
	White	III (1)		
VERMONT				
	Bennington	III (2)		
	Orange	III (1)		
	Rutland	III (1)		
	Windsor	III (1)		
VIRGINIA				
	Bath	III (1)		X (1)
	Lee	II (1)	X (1)	
	Montgomery	III (1)		
	Shenandoah	III (1)		
	Wise	II (1)		
WEST VIRGINIA				
	Greenbrier	III (1)		
	Monroe	III (1)		
	Pendleton	II (1)		
	Pocohontas	III (1)		
	Preston	III (1)		
	Randolph	III (1)		
	Tucker	III (2)		X (1)
WISCONSIN				
	Grant	III (1)		

1( ) = Number of sites

APPENDIX II

MIST NETTING GUIDELINES

RATIONALE
A typical mist net survey is an attempt to determine presence or probable absence of the species; it does not provide sufficient data to determine population size or structure. Following these guidelines will standardize procedures for mist netting. It will help maximize the potential for capture of Indiana bats at a minimum acceptable level of effort. Although the capture of bats confirms their presence, failure to catch bats does not absolutely confirm their absence. Netting effort as extensive as outlined below usually is sufficient to capture Indiana bats. However, there have been instances in which additional effort was necessary to detect the presence of the species.

NETTING SEASON
May 15—August 15

These dates define acceptable limits for documenting the presence of summer populations of Indiana bats, especially maternity colonies. Several captures, including adult females and young of the year, indicate that a nursery colony is active in the area. Outside these dates, even when Indiana bats are caught, data should be carefully interpreted: If only a single bat is captured, it may be a transient or migratory individual.

EQUIPMENT
Mist nets - Use the finest, lowest visibility mesh commercially available:

1. In the past, this was 1 ply, 40 denier monofilament—denoted 40/1
2. Currently, monofilament is not available and the finest on the market is 2 ply, 50 denier nylon—denoted 50/2
3. Mesh of approximately 1 1/2 i/4 - 13/4) in (~38 mm)

Hardware - No specific hardware is required. There are many suitable systems of ropes and/or poles to hold the nets. See NET PLACEMENT below for minimum net heights, habitats, and other netting requirements that affect the choice of hardware. The system of Gardner, et al. (1989) has met the test of time.

NET PLACEMENT Potential travel corridors such as streams or logging trails typically are the most effective places to net. Place the nets approximately perpendicular across the corridor. Nets should fill the corridor from side to side and from stream (or ground) level up to the overhanging canopy. A typical set is seven meters high consisting of three or more nets "stacked" on top one another and up to 20 m wide. (Different width nets may be purchased and used as the situation dictates.)

APPENDIX II (CONT.)

Occasionally it may be desirable to net where there is no good corridor. Take caution to get the nets up into the canopy. The typical equipment described in the section above may be inadequate for these situations, requiring innovation on the part of the observers.

RECOMMENDED NET SITE SPACING:
Stream corridors—one net site per km of stream.
Non-corridor land tracts—two net sites per square km of forested habitat.

MINIMUM LEVEL OF EFFORT
Netting at each site should consist of:

At least three net nights (unless bats are caught sooner) (one net set up for one night = one net night)
A minimum of two net locations at each site (at least 30 m apart, especially in linear habitat such as a stream corridor)
A minimum of two nights of netting
Sample Period: begin at sunset; net for at least 5 hr
Each net should be checked approximately every 20 min
No disturbance near the nets, other than to check nets and remove bats

WEATHER CONDITIONS
Severe weather adversely affects capture of bats. If Indiana bats are caught during weather extremes, it is probably because they are at the site and active despite inclement weather. On the other hand, if bats are not caught, it may be that there are bats at the site but they may be inactive due to the weather. Negative results combined with any of the following weather conditions throughout all or most of a sampling period are likely to require additional netting:

Precipitation
Temperatures below 10°C
Strong winds (Use good judgment: moving nets are more likely to be detected by bats.)

MOONLIGHT
There is some evidence that small myotine bats avoid brightly lit areas, perhaps as predator avoidance. It is typically best to set nets under the canopy where they are out of the moon light, particularly when the moon is 1/2-full or greater.