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Memorandum

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To: Field Supervisor, Frankfort, KY

From: Jennifer M. Garland, Fish and Wildlife Biologist
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Subject: Final Biological Opinion: Proposed Participation In and Approval of Conservation Memoranda of Agreement for the Indiana Bat (*Myotis sodalis*)

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This document transmits the Fish and Wildlife Service's (Service) final biological opinion based on our review of the Service's proposed participation in and approval of Conservation Memoranda of Agreement (Conservation Agreements) with Federal and non-Federal entities that would provide recovery-focused conservation benefits for the Indiana bat while allowing the removal of up to 40,000 acres of known and/or potential Indiana bat habitat throughout the Commonwealth of Kentucky. These actions will result in effects on the endangered Indiana bat (*Myotis sodalis*). This biological opinion completes the programmatic consultation on the Service's participation in and approval of these Conservation Agreements in accordance with section 7(a)(2) of the Act.

This biological opinion is based on information provided in the Indiana Bat Mitigation Guidance for the Commonwealth of Kentucky that was prepared by the Kentucky Field Office, the draft, revised Indiana Bat Recovery Plan (Service 2007), and various published and unpublished documents. A complete administrative record is on file at the Kentucky Field Office.

CONSULTATION HISTORY

Fall 2007, the Kentucky Field Office (KFO) began gathering information for the development of conservation memoranda of agreements, looking primarily at what the Jacksonville Field Office had developed for the Florida Scrub-jay.

January 2008, the KFO began drafting mitigation guidelines for the Indiana bat in Kentucky. The intent was to develop guidelines that could be used by project proponents to avoid, minimize, and/or mitigate impacts to the Indiana bat that occur as a result of the project implementation.

7 March 2008, the KFO met with the Wildlife Diversity staff from the Kentucky Department of Fish and Wildlife Resources (KDFWR) to discuss data regarding Indiana bat summer and winter distributions and habitat availability in maternity and swarming areas. The KDFWR agreed to assist the KFO in generating this data.

10 April 2008, KDFWR provided the KFO with information regarding habitat availability in Indiana bat maternity areas and within one mile, five mile and ten mile buffers of known priority one and two hibernacula.

April 2008, the KFO began drafting the programmatic biological opinion for the Service's participation in and approval of conservation memoranda of agreements. As the affects of the proposed action to Indiana bats were evaluated, the draft mitigation guidelines were adjusted to provide a sufficient level of protection and conservation for the Indiana bat.

5 June 2008, the KFO finalized the Indiana Bat Mitigation Guidance for the Commonwealth of Kentucky

5 June 2008, the KFO issued the final biological opinion on the proposed action.

BIOLOGICAL OPINION

DESCRIPTION OF PROPOSED ACTION

Proposed Action

As defined in the Service's section 7 regulations (50 CFR 402.02), "action" means "all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies in the United States or upon the high seas." The "action area" is defined as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action." The direct and indirect effects of the actions and activities must be considered in conjunction with the effects of other past and present Federal, State, or private activities, as well as the cumulative effects of reasonably certain future State or private activities within the action area.

The proposed action is the Service's participation in and approval of an unknown number of voluntary Conservation Memoranda of Agreements (Conservation Agreements) with Federal and non-Federal entities that would provide recovery-focused conservation benefits for the Indiana bat while allowing the removal of up to 40,000 acres of known and/or potential Indiana bat habitat throughout the Commonwealth of Kentucky. The Service views the development and implementation of the Conservation Agreements as a potential way to (a) engage the participation of a wider array of conservation partners in Indiana bat conservation and/or recovery in Kentucky and (b) provide authorization of Indiana bat incidental take associated with habitat-altering projects in a manner that would also yield tangible Indiana bat conservation and/or recovery benefits through implementation of various Indiana bat conservation measures. Currently, many such projects are reviewed under the normal consultation procedures of section 7(a)(2) of the Act/ESA, which promotes the avoidance and minimization of adverse effects and incidental take but does not require project proponents to provide any conservation and/or recovery benefit(s). Under the proposed approach, project proponents would have the option to enter into a Conservation Agreement with the Service that would include all three types of benefits to Indiana bats: avoidance, minimization, and added conservation and/or recovery benefits in the form of various types of mitigative conservation measures. The process established by the proposed action is supported by the April 2008 regional draft Guidance for Authorization of Incidental Take of Listed Species via Conservation Enhancement Memoranda of Agreement with Non-Federal Entities.

In order to implement this approach, the Service developed the "Indiana bat Mitigation Guidance for the Commonwealth of Kentucky" (Guidance); implementation of this Guidance in association with the Conservation Agreements is an integral part of the proposed action. This Guidance (Appendix A) was made available to the public on the effective date of this biological opinion for voluntary use by Federal agencies and non-Federal entities and identifies the conservation and/or recovery measures that could be undertaken by project proponents under an Conservation Agreement framework to assist in the conservation and/or recovery of the Indiana bat in Kentucky. These measures were identified as appropriate for use in Kentucky based on the priority recovery actions contained in the revised draft recovery plan, the Indiana bat location and demographic information for Kentucky available to the Service, and relevant Service regulations, policy, and guidance. The measures include: (1) protecting known and previously unprotected Indiana bat hibernacula, (2) protecting known and previously unprotected Indiana bat maternity and/or swarming habitat, and (3) contributing funding to the Indiana Bat Conservation Fund[1] sufficient to achieve identified mitigation needs if other measures are impractical or will be of limited value to Indiana bat conservation and/or recovery.

The Service expects the recovery-focused conservation benefits provided by the Conservation Agreements and Guidance to be greater than the minimization measures typically implemented during section 7 consultations in two ways. First, section 7 consultations only require minimization of adverse effects, which typically is for habitat loss that occurs during the period of occupation by Indiana bats. Most commonly, this involves the removal of suitable roosting and foraging habitat during the summer months. The Guidance supports this minimization approach but also includes provisions for mitigation of adverse effects; the minimization and mitigation measures are discussed later in this biological opinion. Second, impacts to Indiana bat summer roosting and foraging habitat were typically minimized through the use of "seasonal cutting restrictions". These seasonal cutting restrictions avoided direct impacts (e.g., mortality) to Indiana bats and these habitats by requiring project proponents to remove forested habitat during the Indiana bat's winter hibernation period (i.e., the habitat is removed while the species is not present). However, seasonal cutting restrictions do not address indirect and/or cumulative effects on the species and its summer habitat, as will be explained in greater detail later in the Effects of the Proposed Action section. The Guidance addresses these indirect and/or cumulative effects issues by ensuring that winter removal of habitat also requires mitigative conservation measures.

In executing a Conservation Agreement, the Service will ensure proper implementation of the Guidance. Conservation Agreements will outline each Cooperator's (i.e., the Service and project proponent(s)) commitments and responsibilities under the Conservation Agreement. In particular, the Conservation Agreements will outline: (a) the purpose and objectives of the Conservation Agreement, (b) the legal authority(ies) supporting the Conservation Agreement, (c) a statement of mutual interest in the conservation and recovery of the Indiana bat, (d) a description of qualifying projects, (e) the effective date and terms of the Conservation Agreement, (f) the specific obligations of the Cooperators, (g) a statement of cooperation, (h) the procedures for modification or termination of the Conservation Agreement, (i) a list of other provisions, as needed by the Cooperators, and (j) necessary information pertaining to notices and authorized representatives. However, the provisions of each Conservation Agreement will likely vary due to a variety of factors, including but not limited to, site-specific information, project schedule, the mitigation measures selected, etc. Within these provisions the Service may choose to establish a process for deviating (either up or down) from the mitigation ratios set forth in the Guidance. The Service will ensure that any deviation is appropriate for the impacts proposed and does not undermine the goals of the Guidance.

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[1] The Service developed the Indiana bat Conservation Fund in 2007 through a Memorandum of Agreement with the Kentucky Natural Lands Trust. A copy of this MOA is provided in Appendix B.

It is likely that Conservation Agreements will be both programmatic and project-specific in nature. Programmatic Conservation Agreements will describe routine or reoccurring project types that typically include the same or similar types of potential adverse effects to Indiana bats. For example, new highway, natural gas transmission, and electrical transmission lines are linear projects that typically involve the clearing and removal of trees and brush during construction and or right-of-way maintenance. As such, it is possible to accurately quantify potential adverse effects to Indiana bat summer habitat that can result from these project-specific impacts on an acreage basis. Therefore, the Service anticipates that programmatic Conservation Agreements can provide significant benefits to the Service and project proponents by streamlining routine or reoccurring projects and to Indiana bats by ensuring that potential impacts are quantified and conservation and/or recovery benefits are provided. Programmatic Conservation Agreements may also be developed for non-linear projects where there is sufficient basis to do so, such as phased development lot clearing, mining, or other projects where blocks of habitat are expected to be impacted according to a schedule and can be accurately quantified.

Project-specific Conservation Agreements will likely be used for projects that are not routine or reoccurring (i.e., one-time impacts) where the potential adverse effects to Indiana bats can be quantified. For example, the project proponent for a residential development could enter into an Conservation Agreement if the project involves adverse effects to Indiana bat foraging and roosting habitat. The Conservation Agreement would quantify the habitat that would be adversely affected and the type(s) of conservation and/or recovery benefits that would be attained through implementation of Indiana bat conservation measures.

Federal and non-federal entities that implement the Guidance in association with activities that are expected to result in adverse effects to Indiana bats will obtain authorization for any anticipated incidental take that occurs through the incidental take statement contained in this biological opinion. For federal action agencies, a Conservation Agreement, coupled with this biological opinion, will satisfy the consultation requirements under section 7(a)(2) of the Act. However, federal action agencies will not be precluded from implementing additional conservation measures or programs under section 7(a)(1) of the Act.

The Service proposes to enter into Conservation Agreements based on the Guidance until an accumulated total of not more than 40,000 acres of known and/or potential Indiana bat habitat is adversely affected by the projects implemented under Conservation Agreements with the Service or until September 30, 2012, whichever occurs first. At that time, the Service will re-initiate formal consultation on implementation of the Conservation Agreements and Guidance to ensure that their further use will not jeopardize the continued existence of the species or adversely modify its designated critical habitat. The Service will also re-evaluate the effectiveness of the proposed action, including the Guidance, to determine if the anticipated conservation and/or recovery benefits for Indiana bats were achieved. If these evaluations determine that (a) the continued use of Conservation Agreements and implementation of the Guidance will not jeopardize the species or result in the adverse modification of designated critical habitat and (b) the implementation of the Conservation Agreements and Guidance has achieved the expected conservation and/or recovery benefits, the Service may elect to continue use of Conservation Agreements and the Guidance. If the Service determines that the Guidance has not achieved the anticipated recovery-focused conservation benefits, the Service may terminate its use.

Action area

The Service has described the action area to include all lands within the geo-political boundaries of the Commonwealth of Kentucky. This action area allows the Service to take into consideration the fact that the impacts associated with the development and approval of Conservation Agreements and the associated implementation of the Guidance are likely to occur at scattered and undeterminable locations across the Commonwealth and will vary in size and distribution on the landscape. The action area is also sizeable enough to provide meaningful analysis of any other direct, indirect, and cumulative effects that could result from the proposed action.

The 40,395 square miles of Kentucky can be divided into five distinctive physiographic regions that include the Eastern Coal Fields, Bluegrass Region, Mississippian Plateau (Pennyrile), Western Kentucky Coalfields, and the Mississippi Embayment (Jackson Purchase). A wide range of habitat types are found in Kentucky, including numerous wetlands and streams, deciduous and evergreen forests, karst and cave features, and prairie habitat.

Land use in Kentucky varies across the state and includes: agricultural farmland, livestock farmland, forest, streams and wetlands, residential, industrial, mining for natural resources, infrastructure, urban development, and others. Today, much of Kentucky's natural habitat has been disturbed; however, about 1,950,541 acres land has been conserved to be publicly managed by state and federal agencies, many for fish and wildlife benefits (KDFWR 2005). There are also several non-governmental organizations (NGOs) actively preserving and conserving biologically important lands within the Commonwealth. The lands in conservation ownership by these NGOs are included in the 92.5 percent of Kentucky which remains privately owned and plays an important role in the overall landscape of Kentucky providing natural and semi-natural habitats to support wildlife diversity.

A 2004 Forest Inventory and Analysis published by the U.S. Forest Service and the Kentucky Division of Forestry (Turner, et al. 2004) reported that 12 million acres of Kentucky's land base (47 percent) is forest land. This was a six percent decrease since 1988 but still greater than those acreages reported in 1949 and 1963. Kentucky's forests are most heavily concentrated in the eastern third of the state with the remaining 50 percent distributed across central and western Kentucky. The predominant forest type is oak-hickory, which constitutes 72 percent of the total forestland acreage. The stand-size distribution has seen a steady increase in sawtimber-size stands since 1975 with a seven percent increase in acreage since 1988. In spite of the reduction in total forest land acreage between 1988 and 2004, Kentucky saw an increase in growing-stock volume and the percentage of hardwood board-foot volume for tree grades 1 and 2 for the same period (Turner, et al. 2004). These data appear to show that potentially available forest habitat for Indiana bats has slightly declined over the past 20 years in Kentucky, but the habitat has become larger and likely more suitable for use by Indiana bats.

STATUS OF THE SPECIES/CRITICAL HABITAT

Species/critical habitat description

Listing status

The Indiana bat (*Myotis sodalis*) is a temperate, insectivorous, migratory bat that hibernates in mines and caves in the winter and summers in wooded areas. The species was originally listed as being in danger of extinction under the Endangered Species Preservation Act of 1966 (32 FR 4001, March 11, 1967), and is currently listed as endangered under the Act of 1973, as amended. Critical habitat for the Indiana bat was designated on September 24, 1976; it consisted of 11 caves and two mines in six states (September 24, 1976). The original recovery plan for the species was published in 1983 (Service 1983). An agency draft of a revised plan was published in 1999 but was never finalized. A second draft revised recovery plan was noticed in 2007 and has not yet been finalized (Service 2007). The Recovery Priority of the Indiana Bat is 8, which means that the species has a moderate degree of threat and high recovery potential.

Critical Habitat

Critical habitat was designated for the species on 24 September 1976 (Service 1976). Eleven 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.).

Under section 7(a)(2) of the Act, Federal agencies must take such action as necessary to insure that actions authorized, funded, or carried out by them do not result in the destruction or modification of these critical habitat areas.

Species Description

The Indiana bat is a medium-sized bat in the genus *Myotis*. Its forearm length is 1 3/8 – 1 5/8 inches and the head and body length ranges from 1 5/8 – 1 7/8 inches. This species closely resembles the little brown bat (*M. lucifugus*) and the northern long-eared bat (*M. septentrionalis*) (Barbour and Davis 1969). The northern long-eared bat is separated easily from the other two species by its long, pointed, symmetrical tragus (see figs. 15 and 34 in Barbour and Davis 1969). The Indiana bat usually has a distinctly keeled calcar (spur-like projection on wing), whereas the little brown bat does not (see Figure 42 in Barbour and Davis 1969). The hind feet of an Indiana bat tend to be small and delicate, with fewer, shorter hairs (i.e., the hairs do not extend beyond the claws) than its congeners (see Figure 14 in Barbour and Davis 1969). The ears and wing membranes have a dull appearance and flat coloration that does not contrast with the fur and the fur lacks luster compared with that of little brown bats (Barbour and Davis 1969, Hall 1981). The nose of an Indiana bat is lighter in color than that of a little brown bat. The skull of an Indiana bat has a small sagittal crest (boney ridge on top of skull), and the braincase tends to be smaller, lower, and narrower than that of the little brown bat (Barbour and Davis 1969, Hall 1981).

Taxonomy

The Indiana bat was first described as a species by Miller and Allen (1928), based on museum specimens collected in 1904 from Wyandotte Cave in Crawford County, Indiana. Before that time, specimens of the Indiana bat often were confused with those of other *Myotis*, especially the little brown bat. "That *Myotis sodalis* has been so long overlooked is due no doubt to the general resemblance the animal bears to *Myotis lucifugus*, with which species the specimens of it in museums have generally been confused; when its characteristics are recognized, however, there is no doubt as to its identity" (Miller and Allen 1928). The Indiana bat is monotypic, indicating there are no recognized subspecies. Alternative common names for the species are Indiana myotis, social bat, pink bat, and little sooty bat (Bailey 1933, Osgood 1938, Nason 1948, Mumford and Whitaker 1982).

Life History

The Indiana bat is a migratory bat, hibernating in caves and mines in the winter and migrating to summer habitat. Although some Indiana bat bachelor colonies have been observed (Hall 1962, Carter et al. 2001), males and non-reproductive females typically do not roost in colonies and may stay close to their hibernaculum (Brack 1983, Whitaker and Brack 2002) or migrate long distances to their summer habitat (e.g., Kurta and Rice 2002). Reproductive females may migrate up to 357 mi (Winhold and Kurta 2006), to form maternity colonies to bear and raise their young. Both males and females return to hibernacula in late summer or early fall to mate and enter hibernation.

Demographics

Births, immigration, deaths, and emigration reflect the primary population processes responsible for changes in population size (Williams et al. 2002). Demographics include those biologically relevant parameters, such as total population size, age distribution, age-specific survival, sex ratio, sex-specific survival, and fecundity or reproductive rate, which influence population change by acting on one or more of these processes. These parameters are key components in understanding the extinction risk faced by the Indiana bat. Current demographic information for this species is mostly unknown.

In temperate-zone insectivorous bats, many young females mate their first autumn and have offspring the following year, whereas males usually do not sexually mature until the summer after their birth (Gustafson 1975, Schowalter et al. 1979, Racey and Entwistle 2000). The age of reproductive maturity or first breeding is important in determining reproductive potential (Racey and Entwistle 2003) and is highly variable in vespertilionids, ranging from 3 to 16 months in both sexes (Tuttle and Stevenson 1982). Guthrie (1933) reported that female Indiana bats are sexually mature by the end of their first summer, although there may be considerable intraspecific variation in the age of sexual maturity (Racey 1982). Butchkoski and Turner (2006) reported that one female Indiana bat in a Pennsylvania maternity colony, initially captured as a juvenile in July 2001 and recaptured each of the next four summers, did not reproduce until she was three years old. Age of reproductive maturity likely varies with latitude (Racey and

Entwistle 2003). In a review of pertinent literature, Tuttle and Stevenson (1982) concluded that male vespertilionids rarely attain sexual maturity ahead of females.

Female Indiana bats, like most temperate vespertilionids, give birth to one young each year (Mumford and Calvert 1960, Humphrey et al. 1977, Thomson 1982). Seven pregnant Indiana bats examined by Easterla and Watkins (1969) had single embryos, supporting conclusions that most species of bats have low reproductive rates (Herreid 1964, Racey and Entwistle 2003, Barclay et al. 2004). The proportion of female Indiana bats that produce young is not well documented. At a colony in Indiana, 23 of 25 female Indiana bats produced volant young during one year, and 28 females produced at least 23 young the following year (Humphrey et al. 1977). Based on cumulative mist-netting captures over multiple years, Kurta and Rice (2002) estimated that 89 percent of adult females in Michigan maternity colonies were in reproductive condition (pregnant, lactating, or post-lactating). Reproductive rates of the closely related little brown bat often exceed 95 percent (i.e., 95 percent of females give birth), but location and environmental factors (e.g., amount of rainfall and temperature) can lead to lower rates (Kurta and Rice 2002, Barclay et al. 2004). Many studies of vespertilionid bats showed that within a species, the proportion of breeding females may vary dramatically among populations and between years, and this variation is typically due to climate (Racey and Entwistle 2000, Barclay et al. 2004).

The sex ratio of the Indiana bat is generally reported as equal or nearly equal, based on early work by Hall (1962), Myers (1964), and LaVal and LaVal (1980). Humphrey et al. (1977) observed a nearly even sex ratio (nine females, eight males) in a sample of weaned young Indiana bats. However, differential survival in adults has been suggested (Humphrey and Cope 1977, LaVal and LaVal 1980).

No estimates of age structure have been made for winter populations, or for the population as a whole, due in part to the lack of an accurate technique for aging individuals once they are adults (Anthony 1988, Batulevicius et al. 2001). To date, published estimates of the lifespan of the Indiana bat are based on survival after banding, from bats captured in winter. Using winter sampling of unknown-age bats over a 23-year period, Humphrey and Cope (1977) estimated annual survival. Survival rates following weaning are unknown, although Humphrey and Cope (1977) surmised that the lowest survival occurred in the first year after marking. Those authors suspected their samples contained many young-of-the-year, but banding was conducted during the hibernation period when young were indistinguishable from adults.

Based on banding data, Humphrey and Cope (1977) proposed that the adult period of life is characterized by two distinct survival phases. The first is a high and apparently constant rate from 1 to 6 years after marking with 76 and 70 percent annual rates for females and males, respectively. The second phase is a lower constant rate after 6 years with annual survival of 66 percent for females up to 10 years and 36 percent for males. Following 10 years, the survival rate for females dropped to only 4 percent. Humphrey and Cope (1977) surmised that this lower rate may reflect an increased cost of migration and reproduction during old age, or may be attributable to sampling error, as a very small number of females remained alive after 10 years. However, individuals have been noted to live much longer, with the oldest known Indiana bat captured 20 years after it was first banded (LaVal and LaVal 1980). Humphrey et al. (1977) provided the only neonatal mortality estimate, 8 percent, based on one of two seasons of observation of one maternity colony. More research on differences in survival rate among life stages is needed.

In summary, the information necessary to model extinction risk and guide recovery of the Indiana bat is incomplete at this time. As referenced above, sex-specific survival, age structure, and age-specific survival data would vastly improve understanding of this species' demographics. The primary approach to gathering such information for other taxa requires capture-recapture methodologies that have not yet been applied to this species. Recent advances in marking and molecular genetic techniques, in combination with more powerful capture-recapture models, may offer the opportunity to close critical information gaps.

Chronology

Depending on local weather conditions, hibernation for Indiana bats typically lasts from October through April (Hall 1962, LaVal and LaVal 1980), although it may be extended from September to May in northern areas including New York, Vermont, and Michigan (Kurta et al. 1997, Hicks 2004). The nonhibernation season, which includes spring emergence, migration, reproductive activities, and fall swarming, varies depending upon the sex (males may enter hibernation later than females) and the location (northern latitudes may have shortened nonhibernation seasons) (Figure 1). The following sections describe the annual life cycle for the Indiana bat, beginning with the fall mating season.

Fall Swarming and Mating

Indiana bats arrive at their hibernacula in preparation for mating and hibernation as early as late July; usually adult males or nonreproductive females make up most of the early arrivals (Brack 1983). The number of Indiana bats active at hibernacula increases through August and peaks in September and early October (Cope and Humphrey 1977, Hawkins and Brack 2004, Rodrigue 2004, Hawkins et al. 2005). Males may remain active through mid-October or later, especially at southern sites. Upon arrival at a hibernaculum, 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 during this time mating occurs, generally in the latter part of the period. Adult females store sperm from autumn copulations throughout winter, and fertilization is delayed until soon after spring emergence from hibernation (Guthrie 1933). Limited mating activity occurs throughout winter and in spring as bats leave hibernation (Hall 1962).

Prior to hibernating, Indiana bats must store sufficient fat to support metabolic processes until spring. During fall swarming, fat supplies for Indiana bats are replenished as they forage in the vicinity of the hibernaculum. Hall (1962) studied fall weight gain in Indiana bats returning to Coach Cave in Edmonson County, Kentucky (which at the time harbored a hibernating

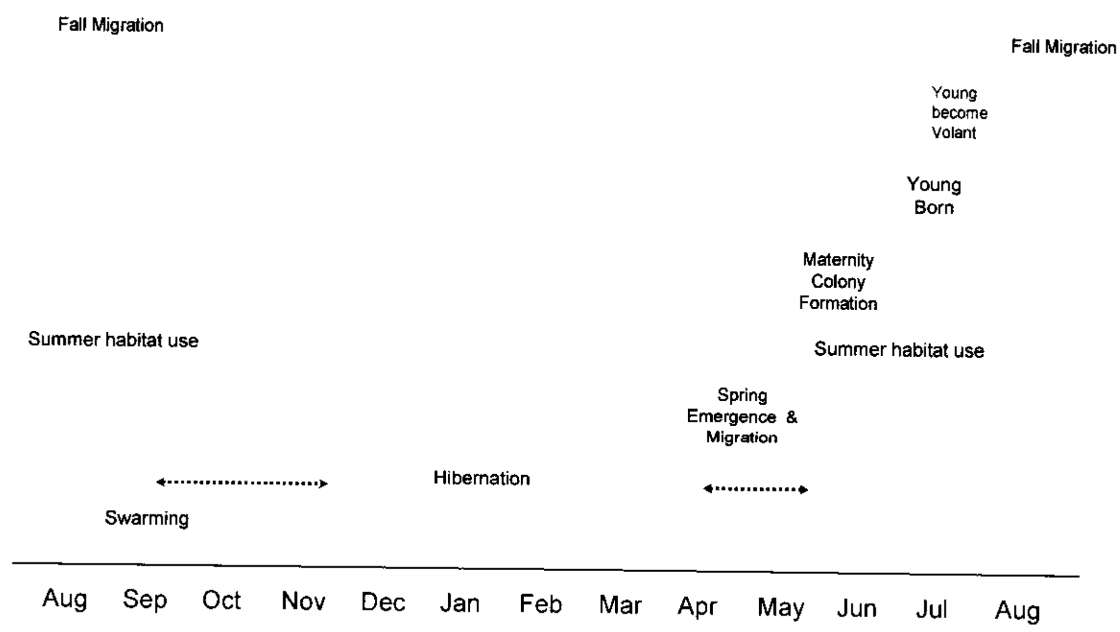


Figure 1. Indiana bat annual chronology.

population of approximately 100,000 Indiana bats). He documented that bat weights were at the lowest point in the annual cycle when they returned to the vicinity of the hibernaculum in late August and September. Dissection revealed no stored fat in the bats at that time. Weight, in the form of fat, was gained rapidly in September and bats entering hibernation were at maximum weight. LaVal and LaVal (1980) also evaluated seasonal changes in weight, based on weights of 3,290 male and 2,180 female Indiana bats in Missouri. At Pilot Knob Mine, the largest of the Indiana bat hibernacula studied, the number of females active at the cave peaked in late August. Females (on average) achieved maximum weight in early October. Compared to females, peak activity of males was later, and maximum weight gain was achieved in late October. A similar pattern of pre-hibernation weight gain was observed in little brown bats in the vicinity of a hibernaculum in Vermont (Kunz et al. 1998).

Male Indiana bats may make several stops at multiple hibernacula during the fall swarming period and remain active over a longer period of time at cave/mine entrances than do females (Cope and Humphrey 1977, LaVal and LaVal 1980), most likely to mate with females as they arrive (Brack et al. 2005b). Bats traveling between hibernacula during fall swarming may also be assessing the relative suitability of potential hibernation sites (Parsons et al. 2003). Nightly activity is correlated with temperature; bats and their prey become constrained by falling temperatures as autumn progresses. During swarming, most male bats roost in trees during the day and fly to the cave or mine at night. At Priority 3 hibernacula in eastern Kentucky, Kiser and Elliott (1996) found male Indiana bats roosting primarily in dead trees on upper slopes and ridgetops within 1.5 mi of the hibernaculum, and Gumbert (2001) found an average of 1.2 mi between roost trees and the hibernaculum for radio-tagged Indiana bats (mostly males). Two male Indiana bats in Michigan roosted in trees 1.4 mi and 2.1 mi from their hibernaculum (Priority 4) during fall swarming (Kurta 2000). Brack (2006) found a range of 0.2 to 0.9 mi between roost trees, used by male and female Indiana bats during fall swarming, and a Priority 3 hibernaculum in Virginia, although he could not follow bats if they left the "project area," so the range may have been greater.

Bat movement patterns in autumn often do not follow a simple linear pattern of migration from summer habitat to the hibernacula. Parsons et al. (2003) discussed the transitory nature of bats at this time of year, noting that bats may travel relatively long distances from a swarming site during the swarming season; they observed bats roosting up to 17 mi from swarming sites and completing the round trip between the swarming and roosting sites in one or two nights. Humphrey and Cope (1976) documented several little brown bats making movements up to 37 mi (away from the hibernaculum where they were captured during swarming). Indiana bats have also been found making relatively long trips from hibernacula during fall swarming.

Butchkoski (pers. comm., 2006) documented a radio-tagged male Indiana bat in Pennsylvania making two trips between the hibernaculum where it was captured to a site 9 mi away over a period of two weeks. Hawkins et al. (2005) documented several Indiana bats radio-tagged at Wyandotte Cave in Indiana traveling long distances from the cave during fall swarming, including two females that were relocated over 19 mi from the cave. Brack (2006) suggested that competition for foraging resources may force bats to leave the immediate vicinity of the hibernacula to find prime foraging habitat to replenish their energy reserves, particularly at hibernacula that support large populations of Indiana bats and/or multiple species.

Most swarming studies have been conducted at relatively small hibernacula (see discussion of Priority 3 and 4 hibernacula above). During the fall of 2003 and 2004, a radiotelemetry study of Indiana bats during fall swarming was conducted at Wyandotte Cave, a P1 hibernaculum in Indiana. Most radio-tagged bats were never relocated; four of 18 were relocated in 2003 (Hawkins and Brack 2004) and 10 of 32 were relocated in 2004 (Hawkins et al. 2005). All of the relocations occurred late in the fall swarming season. Some Indiana bats were found to leave the hibernaculum, traveling as far as 19 mi from the cave in a single night. Most radio-tracking was done using ground tracking techniques, but these long distance movements were documented using aerial tracking. Researchers concluded that many of the radio-tagged bats that were not relocated likely moved too far from the hibernaculum to be relocated using the ground tracking techniques that were employed during most tracking sessions. The long distances traveled by bats radio-tagged near Wyandotte Cave, compared to smaller hibernacula, suggest that use of habitat near hibernacula during swarming may differ between caves that support large versus small populations of bats (Hawkins et al. 2005). Wyandotte Cave, which currently supports a hibernating population of over 50,000 Indiana bats, is part of a complex of hibernacula; within an approximately 10 mi radius there are four Priority 1 hibernacula that collectively support 128,000 Indiana bats. If all species of bats hibernating in these caves are considered, the population may be near one million bats (Hawkins and Brack 2004). Additional study is needed to determine if fall swarming behaviors are affected by the size of a hibernating population.

<u>Hibernation</u>

Indiana bats tend to hibernate in the same cave or mine at which they swarm (LaVal et al. 1976), although swarming has been observed at hibernacula other than those in which the bats hibernated (Cope and Humphrey 1977) and at caves that do not serve as hibernacula for the species (V. Brack, Indiana State University, pers. comm., 2006). It is generally accepted that

Indiana bats, especially females, are philopatric; that is, they return annually to the same hibernacula (LaVal and LaVal 1980). However, exceptions have been noted (Hall 1962, Myers 1964). Some Indiana bats apparently also move from traditional hibernacula to occupy man-made hibernacula, primarily mines, as these become available (see discussion in the Population Distribution and Abundance section).

Most Indiana bats enter hibernation by the end of November (mid-October in northern areas) (Kurta et al. 1997), although populations of hibernating bats may increase throughout fall and into early January at some hibernacula (Clawson et al. 1980). Indiana bats usually hibernate in large, dense clusters ranging from 300 bats per square foot (LaVal and LaVal 1980) to 484 bats per square foot (Clawson et al. 1980, Hicks and Novak 2002), although cluster densities as high as 500 bats per square foot have been recorded (Stihler 2005). While the Indiana bat characteristically forms large clusters, small clusters and single bats also occur (Hall 1962, Hicks and Novak 2002).

Indiana bats often winter in the same hibernaculum with other species of bats and are occasionally observed clustered with or adjacent to other species, including gray bats, Virginia big-eared bats, little brown bats, and northern long-eared bats (Myers 1964, LaVal and LaVal 1980, Kurta and Teramino 1994). Additional habitat-specific information on Indiana bat hibernacula is found in the Hibernation Habitat section.

During hibernation, Indiana bats arouse naturally, as do all hibernating mammals (Thomas et al. 1990). Several researchers have observed that Indiana bats arouse during hibernation (Hall 1962, Myers 1964, Hardin and Hassell 1970, Henshaw 1970). Hicks and Novak (2002) noted that, in an Indiana bat hibernaculum in New York, there were long periods of little or no bat movement, with occasional bouts of activity. Generally, a rhythm of approximately one arousal every 12 to 15 days for hibernating bats is considered typical, but considerable variation has been observed (Speakman and Thomas 2003). Hardin and Hassell (1970) observed that the average time between movements of tagged Indiana bats during hibernation was 13.1 days, but noted that some movements may not have been detected. Further, some bats may arouse and not move; therefore, movement may not be a reliable indicator of arousal (Dunbar and Tomasi, 2006).

The frequency of arousal varies during the hibernation period. During the later stage of hibernation (i.e., spring), bats arouse more often and may move towards the entrance of the cave. In Barton Hill mine (New York) in early April, Indiana bat clusters shifted roost sites as the bats moved toward a "staging area" near the entrance; numbers within clusters also became more variable (A. Hicks, New York State Department of Environmental Conservation, pers. comm., 2002). Clawson et al. (1980) observed Indiana bats responding to cave wall temperatures in a study of five hibernacula in Missouri. Indiana bats roosted in deeper cave passages in the fall, moved to colder roosts (primary roosting areas) in mid-winter as the rock temperatures declined, and returned to warmer roost sites in the spring before emerging. Human disturbance can increase the frequency of arousal in hibernating bats. Microclimate factors in hibernacula can also influence the frequency of arousal (see discussion in the Hibernacula Microclimate section).

Spring Emergence

The timing of annual spring emergence of Indiana bats from their hibernacula may vary across the range, depending on latitude and weather (Hall 1962). Based on trapping conducted at the entrances of caves in Indiana and Kentucky, Cope and Humphrey (1977) observed that peak spring emergence of female Indiana bats was in mid-April, while most males were still hibernating. The proportion of females active at the entrance of hibernacula decreased through April, and by early May none remained. Peak emergence of males occurred in early May, and few were left hibernating by mid-May. LaVal and LaVal (1980) made similar observations at Missouri hibernacula; females started emerging in late March to early April, and outnumbered males active at hibernacula entrance during that period. By the end of April, few females remained, and males dominated the sample of bats captured at hibernacula entrances. At the Mt. Hope mine complex in New Jersey, peak spring emergence of females was in early April, and emergence of males peaked at the end of April (Scherer 2000). Exit counts from several hibernacula in southern Pennsylvania and Big Springs Cave in Tucker County, West Virginia, suggest that peak emergence is mid-April for these two areas (Butchkoski and Hassinger 2002, Rodrigue 2004). Spring surveys of the interior of Barton Hill mine in New York documented substantial numbers of Indiana bats through April and into mid-May; however, by the end of May, only one-tenth of the population remained (A. Hicks, pers. comm., 2005).

In spring when fat reserves and food supplies are low, migration provides an additional stress and, consequently, mortality may be higher immediately following emergence (Tuttle and Stevenson 1977). This increased risk of mortality may be one reason why many males do not migrate far from the hibernacula (Brack 1983, Gardner and Cook 2002, Whitaker and Brack 2002). Movements of 2.5-10 miles by radio-tagged male Indiana bats were reported in Kentucky, Missouri, and Virginia (Hobson and Holland 1995, Rommé et al. 2002). However, other males leave the area entirely upon emergence and have been captured throughout various summer habitats (Kurta and Rice 2002, Whitaker and Brack 2002).

Female Indiana bats may leave immediately for summer habitat or linger for a few days near the hibernaculum. Once en route to their summer destination, females move quickly across the landscape. One female released in southeastern New York moved 35 miles in about 85 minutes (Sanders et al. 2001). Radiotelemetry studies in New York documented females flying between 10 and 30 miles in one night after release from their hibernaculum, arriving at their maternity sites within one night (Sanders et al. 2001; Hicks 2004) One radiotagged female bat released from Canoe Creek Mine in Pennsylvania traveled approximately 60 miles in one evening (Butchkoski, pers. comm., 2005). A female Indiana bat from a hibernaculum in Luzerne County, Pennsylvania, traveled 56 miles to her summer habitat in Berks County, Pennsylvania, in two nights (Butchkoski and Turner 2006).

Indiana bats can migrate hundreds of miles from their hibernacula. Twelve female Indiana bats from maternity colonies in Michigan migrated an average of 296 miles to their hibernacula in Indiana and Kentucky, with a maximum migration of 357 miles (Winhold and Kurta 2006). Gardner and Cook (2002) also reported on long-distance migrations for Indiana bats traveling between their summer ranges and hibernacula. Shorter migration distances are also known to occur. Indiana bats banded (during summer) at multiple locations in Indiana have been found in hibernacula only 34 to 50 miles from their summer range (L. Pruitt, Service, pers. comm., 2006). Some banded female Indiana bats from maternity colonies in Mammoth Cave National Park have been found hibernating in nearby caves (J. MacGregor, pers. comm., 2006). Recent radiotelemetry studies of 70 spring emerging Indiana bats (primarily females) from three New York hibernacula found that most of these bats migrated less than 40 miles to their summer habitat (A. Hicks, pers. comm., 2005; S. von Oettingen, Service, unpublished data, 2005).

Little information is available to determine habitat use and needs for Indiana bats during migration. Recent spring emergence telemetry studies in New York and Pennsylvania are beginning to document migratory routes in the northeast (A. Hicks, pers. comm., 2005; C. Butchkoski, pers. comm., 2005; J. Chenger, pers. comm., 2005).

Summer Life History and Behavior

Reproductive females arrive at their summer habitats as early as mid-April in Illinois, New York, and Vermont (Gardner et al. 1991a, Britzke 2003, Hicks 2004). Humphrey et al. (1977) reported that Indiana bats first appeared at their maternity roost sites in early May in Indiana, with substantial numbers arriving in mid-May. However, Whitaker et al. (2005b) counted 25 bats emerging from a primary Indiana bat maternity roost tree (used in previous years) in central Indiana on April 9, and smaller numbers of bats have been observed emerging from known Indiana bat roosts on this study area as early as late March (Whitaker et al. 2005a). Indiana bats from hibernacula in southern Indiana and Kentucky enter southern Michigan as early as late April, although most do not arrive until the middle or end of May (Kurta and Rice 2002). Most Indiana bats from hibernacula in New York fly directly to their summer range in Vermont and southeastern New York beginning in mid-April (Britzke 2003, Hicks 2003).

Less is known about male migration patterns. Some males summer near their hibernacula (Whitaker and Brack 2002). Some males disperse throughout the range and roost individually or in small numbers in the same types of trees (although males often use smaller trees and are more likely to roost in live trees; see discussion in the Summer Habitat section) and in the same areas as females (Kurta and Rice 2002).

Non-reproductive females may also roost individually or in small numbers, including in the same trees as reproductive females (A. Kurta, Eastern Michigan University, pers. comm., 2005). Relatively little is known about the summer habits of males and non-reproductive females; therefore, the following section is primarily focused on summer life history of reproductive females.

Maternity Colony Formation

After arriving at their summer range, female Indiana bats form maternity colonies. Indiana bat maternity colonies can vary greatly in size. It is difficult to enumerate colony size because colony members are dispersed among various roosts at any given time (Kurta 2005). Most estimates of colony size are based on counts of bats emerging from known Indiana bat maternity roosts. Estimating colony size based on emergence counts requires the researcher to make assumptions. First, based on the date of the counts, researchers generally assume that emerging bats are adult female Indiana bats (if counts occur prior to dates when young typically become volant), or that young-of-the-year bats are included in the count. There are documented cases of adult male bats in maternity roosts, but it is considered unlikely that large numbers of male bats occupy maternity roosts. Second, the assumption is made that all bats emerging from the roost are Indiana bats, although this assumption is generally not tested. There are documented cases of more than one species of bats using the same maternity roost, either simultaneously, or within the same season. Third, assumptions must be made regarding what proportion of the colony may have been counted during emergence counts. Counts based on multiple nights at multiple known roost sites over the course of the maternity season provide better estimates than a single count at a single tree. However, even a single count at a primary maternity roost tree provides an estimate of minimum colony size.

Although most documented maternity colonies contained 100 or fewer adult females (Harvey 2002), as many as 384 bats have been reported emerging from one maternity roost tree in Indiana (Whitaker and Brack 2002). Whitaker and Brack (2002) indicated that average maternity colony size in Indiana was approximately 80 adult female bats. The mean maximum emergence count after young began to fly (measured in 12 studies) was approximately 119 bats (Kurta 2005), suggesting that 60 to 70 adult females were present (assuming that most adult females successfully raise one pup to volancy).

Barclay and Kurta (2007) suggested five potential explanations for the establishment of maternity colonies in cavity- and bark-roosting bats:

1) High-quality roosts may be limiting in some areas,
2) Foraging efficiency - members of a colony communicate regarding good foraging areas,
3) Reduced predation risk,
4) Thermoregulatory advantages - roosting in a large group may be a mechanism for reproductive females to reduce thermoregulatory costs by clustering, and
5) Water conservation by reducing evaporative water loss (However, see Kerth et al. 2001 for a discussion of why foraging efficiency is unlikely to explain coloniality in species of bats in which members of the colony do not forage together).

The relative importance of these benefits of coloniality is not known, but the thermoregulatory advantages of colonial roosting have been clearly demonstrated. Female bats in late pregnancy and their pups are poor thermo regulators (Speakman and Thomas 2003), and prenatal and postnatal growth are controlled by the rate of metabolism and body temperature (Racey 1982). Humphrey et al. (1977) demonstrated the importance of roost temperature in the growth and development of young Indiana bats. Barclay and Kurta (2007) concluded that "the weight of evidence suggests that roost microclimate and its impact on thermoregulation are the primary factors involved in roost selection by forest-dwelling bats," although experimental tests of this hypothesis are lacking. In addition to selecting favorable roost sites, clustering (in maternity roosts) is another mechanism used by bats to maintain roost temperatures favorable for prenatal and postnatal development. Thus, colonial roosting is likely a life history strategy adopted by Indiana bats (like many other temperate-zone bats) to improve reproductive success (Barclay and Harder 2003).

<u>Maternity Roosts</u>

Indiana bat maternity roosts can be described as primary or alternate based upon the proportion of bats in a colony consistently occupying the roost site (Kurta et al. 1996, Callahan et al. 1997, Kurta et al. 2002). In Missouri, Callahan (1993) defined primary roost trees as those with exit counts of more than 30 bats on more than one occasion; however, this number may not be applicable to small-to-moderate sized maternity colonies (Kurta et al. 1996). For smaller maternity colonies, determining the number of "bat days" over one maternity season (one bat day being one bat using a tree for one day) may be a better technique for distinguishing primary from alternate roosts (Kurta et al. 1996).

Maternity colonies typically use 10 to 20 trees each year, but only one to three of these are primary roosts used by the majority of bats for some or all of the summer (Callahan 1993, Callahan et al. 1997). After the young are capable of flight (volant), the composition of a colony at a primary roost is fluid, as individual bats leave and return (Barclay and Kurta, 2007). Kurta et al. (2002) observed that certain roost trees were occupied by a "quasi-stable number of Indiana bats for days or weeks" at a time. However, during this time, individuals (based on radiotelemetry observations) consistently moved into and out of the trees.

Alternate roosts are used by individuals or a small number of bats and may be used intermittently throughout the summer or used on only one or a few days. All roost trees eventually become unusable - by losing bark, falling over, or through competition with other animals - and these events can often occur suddenly and without warning (Gardner et al. 1991a, Kurta and Foster 1995, Belwood 2002). The use of alternate roosts may be a way of discovering new primary roosts since Indiana bats must maintain an awareness of suitable replacements in case of an emergency (Kurta et al. 1996, 2002). Thus, "primary" roosts are a function of bat behavior (aggregation) and roost physical characteristics (e.g., large size). Studies documenting roost trees used by individuals in a colony identified a range in the number of alternate roosts. For example, based on Callahan's (1993) definition, Watrous (unpublished data, 2005) documented 12, 9 and 14 alternate roost trees for three colonies in the Lake Champlain Valley of Vermont and New York.

Indiana bats appear to have a fission-fusion society as demonstrated by frequent roost changing (Kurta et al. 2002, Kurta 2005). Barclay and Kurta (2007) explain "that in this type of a society, members frequently coalesce to form a group (fusion), but composition of that group is in perpetual flux, with individuals frequently departing to be solitary or to form smaller groups (fission) for a variable time before returning to the main unit." It may be possible that some bats select individuals with whom to roost and avoid roosting with others (Barclay and Kurta, 2007). Although many members of a colony may reside in one tree at any one time, other members roost elsewhere as solitary individuals or in small subgroups of fluctuating composition. Such a fission-fusion society has been suggested for other species of forest bats, as well (Kerth and König 1999, O'Donnell 2000, Kurta et al. 2002, Willis and Brigham 2004).

On average, Indiana bats switch roosts every two to three days, although reproductive condition of the female, roost type, and time of year affect switching (Kurta et al. 2002, Kurta 2005). Lactating females may change roosts less often than pregnant or post-lactating females. Bats roosting under exfoliating bark may change more often than bats roosting in crevices (Kurta et al. 1996, 2002; Gumbert et al. 2002; Carter 2003; Kurta 2005). Roost switching occurs less often in the spring, most likely due to colder night temperatures that may induce extended torpor (Gumbert et al. 2002, Britzke et al. 2006).

Night Roosts

Indiana bats use night roosts (Butchkoski and Hassinger 2002, Kiser et al. 2002, Ormsbee et al., 2007), although there is limited research on where and why they night roost. Adults of both sexes as well as juveniles use night roosts (Kiser et al. 2002). Indiana bats may night roost for a variety of reasons, including (but not limited to) resting, aiding in digestion, protection from inclement weather, and conservation of energy (Ormsbee et al., 2007). Night roosting may occur at the bat's day roost in conjunction with nocturnal tending of its young or during inclement weather, or, more often, at sites not generally used as day roosts (Ormsbee et al., 2007). Indiana bats night roost in trees (Butchkoski and Hassinger 2002, Murray and Kurta 2004), bridges (Mumford and Whitaker 1982, Kiser et al. 2002), caves (Gumbert et al. 2002), and bat houses (Butchkoski and Hassinger 2002). We also have documentation that Indiana bats may night roost in abandoned underground mine portals from captures of bats entering portals during the night (P. Measel, pers. comm., 2005).

Reproduction

Females give birth to a single young in June or early July (Easterla and Watkins 1969, Humphrey et al. 1977, Kurta and Rice 2002) while in their maternity roosts. As previously discussed, maternity colonies reduce thermoregulatory costs, which, in turn, increases the energy available for birthing and raising young (Barclay and Harder 2003). There are no documented occurrences in which a female Indiana bat has successfully given birth and raised a pup alone without communal benefits of a maternity colony. A study by Belwood (2002) shows asynchronous births extending over two weeks within one colony. This asynchrony results in great variation in size of juveniles (newborn to almost adult size young) in the same colony.

In Indiana, lactating females have been recorded from June 10 to July 29 (Whitaker and Brack 2002). Lactation begins at birth and continues through early volancy of young. Young Indiana bats are volant within 3-5 weeks of birth (Mumford and Cope 1958, Easterla and Watkins 1969, Cope et al. 1974, Humphrey et al. 1977, Clark et al. 1987, Gardner et al. 1991a, Kurta and Rice 2002, Whitaker and Brack 2002). Young born in early June may fly as early as the first week of July (Clark et al. 1987), with others flying from mid-to-late July. Once young Indiana bats are volant, the maternity colony begins to disperse. The use of primary maternity roosts also diminishes, although the bats may stay in the maternity roost area until migrating to their respective hibernacula. The bats become less gregarious and the colony uses more alternate roosts (Kurta et al. 1996), possibly because there is no longer the need for the adult females to cluster for thermoregulation and to nurture their young. However, at least 69 bats were observed exiting a primary roost tree in central Indiana in late September (D. Sparks, pers. comm., 2006).

Although the preceding discussion provides a seasonal framework for Indiana bat reproduction, the timing of reproductive events is somewhat weather-dependent (Grindal et al. 1992, Lewis 1993, Racey and Entwistle 2003). Adverse weather, such as cold spells, increases energetic costs for thermoregulation and decreases availability of insect prey (i.e., the available energy supply). Bats may respond to a negative energy balance by using daily torpor, and some females may not bear a pup in years with adverse weather conditions (Barclay et al. 2004). In females that maintain pregnancy, low body temperatures associated with daily torpor slow chemical reactions associated with fetal and juvenile growth and milk production and may cause annual and individual variation in the time when young are born and how quickly young develop.

Site Fidelity

Research indicates that Indiana bats exhibit site fidelity to their traditional summer maternity areas. Numerous studies have documented female Indiana bats annually returning to the same home range to establish maternity colonies (Humphrey et al. 1977; Gardner et al. 1991a, 1991b; Gardner et al. 1996; Callahan et al. 1997; Whitaker and Sparks 2003; Whitaker et al. 2004). While use of new roosts that become available within established home ranges has been documented, pioneering of new maternity colonies has not been documented. We presume that the species is capable of forming new maternity colonies, but neither the mechanism nor circumstances under which the Indiana bat pioneers maternity colonies has been documented. Roost trees, although ephemeral in nature, may be occupied by a colony for a number of years until they are no longer available or suitable. Roost tree reoccupation of 2 to 6 years has been documented in a number of studies (Gardner et al. 1991b; Whitaker et al. 2004; Barclay and Kurta, 2007).

Maternity colonies of Indiana bats also appear to be faithful to their foraging areas within and between years (Cope et al. 1974; Humphrey et al. 1977; Gardner et al. 1991a, 1991b; Murray and Kurta 2004; Sparks et al. 2005b). Available data also suggest that individual Indiana bats are faithful to their foraging areas between years. Gardner et al. (1991a, 1991b) observed that individual females returned to the same foraging areas year after year, irrespective of whether they were captured as juveniles and recaptured and tracked as adults or captured as adults and then followed. In Indiana, one female Indiana bat was radio tracked in two different years and both roosting and foraging habits were found to be remarkably consistent between years (Sparks et al. 2005b). In Michigan, Murray and Kurta (2002, 2004) recaptured 41 percent (12 of 29) of banded females when mist netting at the same area in subsequent years. Further studies of this colony reported use of a wooded fenceline as a commuting corridor for at least nine years (Kurta 2005, Winhold et al. 2005).

Fall Migration

Maternity colonies begin disbanding during the first two weeks in August, although some large colonies may maintain a steadily declining number of bats into mid-September (Humphrey et al. 1977, Kurta et al. 1993b). It should be noted that, in some cases, bats emerging from documented Indiana bat roosts later in the season were determined to be another species (A. Hicks, pers. comm., 2005). Even in northern areas, such as Michigan, a few Indiana bats may remain into late September and early October; these late migrants may be young-of-the-year (Kurta and Rice 2002). Members of a maternity colony do not necessarily hibernate in the same hibernacula, and may migrate to hibernacula that are over 300 km (190 mi) apart (Kurta and Murray 2002, Winhold and Kurta 2006).

Food Habits

Indiana bats feed on flying insects, with only a very small amount of spiders (presumably ballooning individuals) included in the diet. Four orders of insects contribute most to the diet: Coleoptera, Diptera, Lepidoptera, and Trichoptera (Belwood 1979, Brack 1983, Brack and LaVal 1985, Lee 1993, Kiser and Elliot 1996, Kurta and Whitaker 1998, Murray and Kurta 2002, Whitaker 2004). Various reports differ considerably in which of these insect orders is most important. Terrestrial-based prey (moths and beetles) were more common in southern studies, whereas aquatic-based insects (flies and caddisflies) dominated in the north. Presumably, this difference indicates that southern bats foraged more in upland habitats, and northern bats hunted more in wetlands or above streams and ponds. These differences in diet are consistent with observations of foraging animals in various studies. However, apparent geographic differences are confounded by differences in survey techniques, in sex or age of animals studied, in availability and use of habitats, and in composition of the local bat community (i.e., presence of potential competitors) (Murray and Kurta 2002, Brack, in press).

Hymenopterans (winged ants) also are abundant in the diet of Indiana bats for brief, unpredictable periods corresponding with the sudden occurrence of mating swarms. Although not as dramatic, seasonal occurrence of Asiatic oak weevils in the diet indicates use of an abundant resource available only for a limited part of the season (Brack 1983, Brack and Whitaker 2004). Consistent use of moths, flies, beetles, and caddisflies throughout the year at various colonies suggests that Indiana bats are selective predators to a certain degree, but incorporation of ants into the diet also indicates that these bats can be opportunistic (Murray and Kurta 2002). Hence, Brack and LaVal (1985) and Murray and Kurta (2002) suggested that the Indiana bat may best be described as a "selective opportunist," as are a number of other *Myotis* species (Fenton and Morris 1976).

At individual colonies, dietary differences exist between years, within years by week, between pregnancy and lactation, and within nights (Murray and Kurta 2002). Although some authors ascribe various adaptationist reasons for these differences, it is difficult to explain why different studies are not consistent in their results. For example, Belwood (1979) reported an increase in moth consumption during lactation, but Kurta and Whitaker (1998) reported a decrease. Kurta and Whitaker (1998) stated that caddisfly consumption remained constant throughout the season, whereas Brack (1983) reported a decrease. Murray and Kurta (2002) found a significant increase in moth consumption by one colony during lactation in one year but not in the following year. These inconsistencies within and among studies suggest that Indiana bat diets, to a large degree, may reflect availability of preferred types of insects within the foraging areas that bats happen to be using, again suggesting that they are selective opportunists (Murray and Kurta 2002).

<u>Foraging Behavior</u>

The Indiana bat is a nocturnal insectivore. It emerges shortly after sunset and begins feeding on a variety of insects that are captured and consumed while flying (Sparks et al. 2005b). At two maternity colonies - one in Michigan and one in Illinois - Indiana bats began emerging from the roost to forage around 19 minutes after sunset, with peak emergence around 21 to 26 minutes after sunset (Viele et al. 2002). In western Illinois, emergence averaged 21 minutes after sunset and peaked 30 to 45 minutes after sunset (Gardner et al.1991b). There may be considerable variation in emergence times within a colony that is not related to light level, ambient temperature, or number of bats residing in the colony (Gardner et al. 1991a, Viele et al. 2002). Emergence occurs later in relation to sunset near the summer solstice and closer to sunset in spring and late summer (Viele et al. 2002). In Indiana, bats emerged 38-71 minutes after sunset throughout the season, but emergence was earlier when young became volant (i.e., the time of exit was inversely related to the number of bats exiting the roost) (Brack 1983). After juveniles become volant, they typically leave the roost for foraging after adults have departed (Kurta et al. 1993b). In Virginia, nightly activity started earlier in the evening in relation to sunset as autumn progressed (Brack 2006).

Thirteen foraging areas were identified that were used by pregnant and lactating Indiana bats in southern Michigan: five were used only by pregnant bats, four were used only by lactating bats, and four were used by both pregnant and lactating bats (Murray 1999, Murray and Kurta 2004). Individual females visited one to four foraging areas each night. When two or three bats were radio tracked simultaneously, they seldom used the same foraging area and were found in different areas over 5 km (3 mi) apart.

Indiana bats usually forage and fly within an air space from 6 to 100 ft 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 (Brack 1983, Gardner et al. 1989). In autumn, observations of light-tagged bats suggest that Indiana bats do not typically fly close to the ground or water (Brack 1983).

Linear distances between roosts and foraging areas for females range from 0.3 to 5.2 miles, although most distances were less than half the maximum distance (Murray and Kurta 2004, Sparks et al. 2005b). For example, one individual at a colony in Indiana moved 5.2 miles between roosts and foraging area; however, the mean distance of 41 bats from the same colony was 1.9 miles. In Canoe Creek, Pennsylvania, an area with significant changes in elevation, reported distances between roost and foraging areas ranged from 1.5 to 2.8 miles with an average distance of 2.1 miles (Butchkoski and Hassinger 2002). Murray and Kurta (2004) and Sparks et al. (2005b) speculate that the variations in distances to foraging areas were due to differences in habitat type, inter-specific competition, and landscape terrain.

<u>Home Range</u>

Indiana bats occupy distinct home ranges, particularly in the summer (Garner and Gardner 1992). However, relatively few studies have determined the home ranges of Indiana bats, and these studies based their calculations on a small number of individuals. Further, direct comparison of the home range estimates between studies is difficult due to different methodologies used in collecting the data, inconsistency in terminology, and different methods of calculating home range size (Lacki et al. 2006). Home range size varies between seasons, sexes, and reproductive status of the females (Lacki et al. 2006). Standardized methodology and terminology and additional research will be necessary to further refine home range estimates.

Kiser and Elliot (1996) identified minimum foraging areas for 15 Indiana bats (14 males, 1 female) at a hibernaculum in Kentucky. Their estimates ranged from about 69 to 734 acres (excluding the cave in the estimate), with a mean of 385 ± 249 acres. Rommé et al. (2002) calculated a mean home range near a hibernaculum in Missouri of 1,648 ± 2456 acres for spring and fall (based on pooled data for nine bats–male and female) and 3,825 ± 3,518 acres for fall home range (based on three males). In Virginia, Brack (2006) calculated average active areas for three females and eight males near a hibernaculum as 618 ± 247 acres (n=11) using mean convex polygons and 892 ± 640 acres (n=10) using adaptive kerneling (core areas). Menzel et al. (2005) tracked seven female and four male Indiana bats from May to August in Illinois. No significant differences in home ranges between males and females were observed and home range estimates were subsequently grouped. Menzel et al. (2005) determined the mean summer home range size of the 11 Indiana bats to be 357 acres. Watrous (2006) calculated a mean home range of 205 acres for 14 female Indiana bats in Vermont.

Hibernation Habitat

During winter, Indiana bats are restricted to suitable underground hibernacula. The majority of these sites are caves located in karst areas of the east-central United States; however, Indiana bats also hibernate in other cave-like locations, including abandoned mines in several states, a railroad tunnel in Pennsylvania, and even a hydroelectric dam in Michigan. Hall (1962) observed that Indiana bats find and occupy newly available hibernating sites very quickly. In some areas, such as Illinois and New York, the largest and most rapidly growing populations occur in abandoned mines (Hicks and Novak 2002, Kath 2002). Indiana bats occupied Pilot Knob Mine in Missouri after mining ceased in the 1890s; by the 1950s, Pilot Knob Mine held the largest population of Indiana bats in Missouri (>100,000 bats) and still has the largest population in the state (Hall 1962, Myers 1964, Clawson 2002). Rapid population growth has also occurred at caves where measures have been implemented to restore hibernacula in cases where previous alterations and/or disturbance made the cave unsuitable or marginally suitable for hibernation. For example, the population at Wyandotte Cave in Indiana grew from a low of 500 bats in 1955 to a current population of over 50,000 bats in response to restoration efforts and measures to eliminate disturbance of hibernating bats. At Saltpetre Cave in Kentucky, the population grew from 475 in 1999 to over 6,000 in 2005 in response to measures that were implemented to restore the microclimate and protect hibernating bats from disturbance. Only a small percentage of caves (and mines) within the range of the Indiana bat provide the conditions required for successful hibernation (Service 1983); for recovery, it is essential to conserve and manage those sites with suitable microclimate, and to restore suitable microclimate to sites that have been altered.

Hibernacula Microclimate

Ambient Temperature during Torpor

Most Indiana bats hibernate in caves or mines where the ambient temperature remains below 10°C (50.0°F) but infrequently drops below freezing (Hall 1962, Myers 1964, Henshaw 1965, Humphrey 1978), and the temperature is relatively stable (Tuttle and Kennedy 2002). Tuttle and Kennedy (2002) compared mid-winter temperatures at major hibernacula and reported that populations hibernating where temperatures were between 3° and 7.2°C (37.4° and 45°F) remained stable or increased, while populations hibernating at temperatures above or below this range were unstable or had declined. However, Brack et al. (2005a) reported that hibernacula temperatures below 5°C (41.0°F) are too cold because they observed that in hibernacula in Indiana the highest concentrations of Indiana bats were found at sites with mid-winter temperatures of 6° to 7°C (42.8° to 44.6°F).

Researchers studying hibernacula temperature have used different temperature monitoring instruments and techniques, making it difficult to compare results of studies. For example, among long-term (>2 years) datasets, Henshaw (1965) left thermometers inside hibernacula and measured maximum and minimum temperatures once every two weeks; Brack and his colleagues usually measured temperatures near hibernating clusters of Indiana bats during occasional cave visits (e.g., Brack et al. 1984, Brack et al. 2003, Whitaker et al. 2003); and Tuttle and Kennedy (2002) took near-continuous temperature readings using data loggers left inside hibernacula.

Standard (and thus comparable) protocols for quantifying the thermal profiles of hibernacula used by Indiana bats over ecologically meaningful periods (e.g., >5 years) have not been established, but continuous monitoring using data loggers is currently the most useful approach. Any protocol for monitoring with data loggers should be designed to maximize the likelihood that temperature measurements are taken in all areas of a hibernaculum used by bats during winter. Ideally, temperature measurements from data loggers would be temporally correlated to remotely-sensed information (e.g., images from infrared cameras) on the actual whereabouts of individuals or colonies within the hibernaculum. The second factor complicating the analysis of temperature data gathered by different researchers that work in different geographic areas is the relationship between temperature and the degree of gregariousness exhibited by Indiana bats.

Several researchers have noted an inverse relationship between ambient roost temperature and the size of hibernating clusters formed by Indiana bats (i.e., larger clusters are typically found at colder sites, whereas smaller clusters are found in warmer sites) (Clawson et al. 1980, Brack et al. 1984). Thus, studies that focus on characterizing temperatures of hibernacula with large, dense colonies of hibernating bats (e.g., P1 caves; Tuttle and Kennedy 2002) may be biased toward colder temperatures and studies of sites with relatively smaller numbers and dispersed clusters of Indiana bats may be biased toward warmer temperatures. Behavioral thermoregulation, in the form of clustering, likely allows Indiana bats to hibernate at a wider range of ambient temperatures than would be possible for non-colonial species, but the effect of clustering density is difficult to measure.

Discussion about the "optimum" range of temperatures for hibernation by Indiana bats relies heavily on temperature data collected inside hibernacula where large numbers are known (or in some cases were known) to hibernate. Such data are correlative and should be treated cautiously. For example, certain hibernating populations may be using available, rather than optimal, habitat. The assumption that the largest colonies aggregate in the most optimal conditions is likely an oversimplification (Henshaw 1970). Furthermore, intra-specific differences in thermal physiology between geographic regions have been observed in vespertilionid bats during warmer months (Willis et al. 2005) and such differences may persist into the winter. Without a clearer picture of the factors influencing the energy and water balance of Indiana bats under different microclimate conditions, the precise range of optimal hibernacula conditions will remain equivocal.

There are few quantitative data pertaining to energy use by Indiana bats during hibernation. In laboratory experiments, Henshaw (1965) measured energy expenditure by Indiana bats as a function of ambient temperature. During torpor, Indiana bats consumed the least amount of energy at 5°C, with energy use increasing at temperatures of both -5°C and 10°C (23.0°F and 50.0°F). However, Henshaw (1965) did not quantify energy expenditure by Indiana bats at intermediate temperatures (i.e., 1° to 4°C and 6° to 9°C (33.8° to 39.2°F and 42.8° to 48.2°F)). T. Tomasi (unpublished data, 2006) collected metabolic data for Indiana bats hibernating in a laboratory at 1°, 3°, 5°, 7°, and 9°C (33.8°, 37.4°, 41.0°, 44.6°, 48.2°F) and his preliminary analysis showed a significant effect of temperature on the metabolic rate of individual bats (n=13). Lowest metabolic rates were measured for bats in the 5°C (41.0°F) treatment. V. Brack (2005) raised concerns regarding laboratory experiments that measure the efficiency of hibernation at various temperatures without considering the energetic costs and frequency of arousals. He suggested that the energy savings of torpor at a low versus high ambient temperature (e.g., 3°C versus 8°C (37.4°F versus 46.4°F)) may be outweighed by the increased cost of arousal, the increased cost of maintenance of normothermic body temperatures during arousal, and the secondary effects of metabolic inhibition (e.g., oxidative stress, reduced immunocompetence; Geiser 2004). Patterns of energy use by hibernating Indiana bats over a range of ambient temperatures could be quantified in the laboratory (including the cost of arousal and maintenance of normothermic body temperatures during arousal). Tomasi (pers. comm., 2006) proposes to collect additional data to evaluate the energetic cost of arousal at various temperatures (to be analyzed in conjunction with data on the metabolic rates of Indiana bats hibernating at those temperatures). Further study is also needed to better understand how clustering affects heat loss and re-warming of hibernating Indiana bats. Decreased thermal conductance (Kurta 1985) and increased radiant heat gain experienced by bats in a cluster (Geiser and Drury 2003) may significantly decrease their energy expenditure during arousal from low ambient temperatures.

Water Balance and Winter Activity of Hibernating Bats

Little is known about the water balance of hibernating Indiana bats. Henshaw (1965, 1970) measured evaporative water loss by Indiana bats and noted that, as with other species, water loss was a function of the vapor pressure deficit of ambient air; bats lost more water as the humidity of air decreased. Although Indiana bats apparently experience less evaporative water loss during hibernation than little brown bats (Henshaw 1970, Brenner 1973), extensive laboratory research on the latter species offers insight into the importance of air moisture on hibernation by species of *Myotis*. Thomas and Cloutier (1992) observed that at relative humidity levels below 99.3 percent (air temperature 2° to 4°C), evaporative water loss rates of little brown bats exceeded metabolic water production under laboratory conditions. The implication of this research is that the lower the humidity in a hibernaculum, the more frequently a bat hibernating at that site will need to arouse and replenish water supplies.

Researchers have suggested that the need for water is a major factor influencing the arousal frequency of hibernating bats (Speakman and Racey 1989, Thomas and Geiser 1997, Speakman and Thomas 2003), and Indiana bats have been observed drinking during arousals (Hall 1962, Myers 1964). Considering that arousals account for approximately 75 to 85 percent of winter fat depletion (Thomas 1995, Speakman and Thomas 2003), humidity of the hibernacula could play a major role in both the water and energy balance of hibernating bats. Although quantitative field studies are limited, several early researchers noted that Indiana bats arouse frequently during hibernation (Hall 1962, Myers 1964, Hardin and Hassell 1970, Henshaw 1970). It is possible that arousal frequency in Indiana bats, and thus energy use and probability of survival, is partially a function of the humidity of the hibernacula. Laboratory measurements of arousal frequency as a function of water vapor pressure deficit in Indiana bats have not been made. Temperature may also play a role in the arousal frequency of hibernating Indiana bats, but targeted studies are lacking. Hicks and Novak (2002) observed infrequent arousals between late January and mid-May at a cold (-1.1°C to 3.3°C) (30.0° to 37.9°F) hibernaculum occupied by 700 to 1000 Indiana bats, but similar data from warmer sites or larger colonies are not available.

Henshaw (1965) reported air movement in most of the Indiana bat and little brown bat hibernacula that he studied. Although air circulation can have a dramatic influence on energy expenditure (through convective heat loss) and water balance (through transdermal water loss;

Bakken and Kunz 1988), few quantitative data on air movement in hibernacula used by Indiana bats are available.

Structure of the Hibernaculum

Myers (1964) observed that some caves are more attractive to bats and that larger caves invariably offer a greater variety of habitats. Caves that historically sheltered the largest populations of Indiana bats were those with the largest volumes and structural diversity, thus ensuring stable internal temperatures over wide ranges of external temperatures, with a low likelihood of freezing (Tuttle and Kennedy 2002). Caves that meet temperature requirements for Indiana bats are rare. The specific configurations of hibernacula determine levels of temperature and humidity and, thus, their habitat suitability (Humphrey 1978, Tuttle and Stevenson 1978, LaVal and LaVal 1980, Tuttle and Kennedy 2002).

In many hibernacula in the central and southern United States, roosting sites are near an entrance but may be deeper in a cave or mine if the deeper location is where cold air flows and is trapped (Tuttle and Stevenson 1978). The best hibernation sites in the central or southern United States provide a wide range of vertical structure and a cave configuration that provides temperatures ranging from below freezing to 13°C (55.4°F) or above. These hibernacula tend to have large volume and often have large rooms or vertical passages below the lowest entrance. Large volume helps buffer the cave environment against extreme changes in outside temperature, and complex vertical structure offers a wide range of temperatures and, therefore, diversity of roosting sites. Low chambers allow entrapment of cold air that is stored throughout summer, providing arriving bats with relatively low temperatures in early fall (Tuttle and Kennedy 2002).

In central and southern portions of the winter range, the best caves for hibernation consistently have multiple entrances that permit "chimney-effect" airflow. In winter, due to barometric pressure, cold outside air enters one or more lower entrances while warmer air rises and exits the cave through entrances that are at least a few feet higher in elevation. The chimney effect cools the cave more than a single entrance allows (Humphrey 1978, Tuttle and Kennedy 2002). In contrast, aboveground temperatures are lower in the north, and successful hibernation sites in northern hibernacula typically are further back from entrances and not in areas with strong chimney effect airflow, which may lead to subfreezing temperatures in areas between the entrances in small caves (M. Tuttle, pers. comm., 1999).

Fall and Spring Roosts near Hibernacula

Limited work has been done on roosting habitats of Indiana bats in spring and fall, and most data are associated with areas near hibernacula on the Daniel Boone National Forest in Kentucky (Kiser and Elliot 1996, Gumbert et al. 2002). These studies show that Indiana bats use roosting sites in the spring and fall that are similar to sites selected during summer (i.e., bats typically roost under exfoliating bark, with occasional use of vertical crevices in trees). Species of trees used for these roosts also are similar to summer sites, although various pines (*Pinus* spp.) commonly are occupied in spring and fall. During this time, Indiana bats tend to roost more often as individuals than in summer. Roost switching occurs every two to three days and Indiana bats show fidelity to individual trees and roosting areas, within and among years. Various trees used by the same individual tend to be clustered in the environment, and roost trees most often are in sunny openings in the forest created by human or natural disturbance.

During autumn, when Indiana bats swarm and mate at hibernacula, male bats roost in nearby trees during the day and fly to the cave at night. In Kentucky, Kiser and Elliott (1996) found male Indiana bats roosting primarily in dead trees on upper slopes and ridge tops within 2.4 km (1.5 mi) of their hibernaculum. During September, male Indiana bats in West Virginia roosted within 5.6 km (3.5 mi) of their cave in trees near ridge tops and often switched roost trees from day to day (C. Stihler, pers. comm., 1996). One Indiana bat in Michigan roosted 2.2 km (1.4 mi) away from the hibernaculum during fall swarming, and another chose trees at a distance of 3.4 km (2.1 mi) (Kurta 2000).

Summer Microhabitat

Bark or Crevice

In summer, female Indiana bats usually roost under slabs of exfoliating bark, and they occasionally use narrow cracks within trees (Callahan 1993; Kurta et al. 1993a, 1993b, 2002; Carter 2003; Britzke et al. 2006). For example, longitudinal crevices that formed when trees were snapped by a tornado were used as primary roosts in Michigan (Kurta et al. 2002). Although other species of bats frequently occupy tree hollows that were created by rot or woodpeckers (Barclay and Kurta, 2007), such cavities are rarely used by maternity colonies of Indiana bats. Even a "hollow" sycamore (*Platanus occidentalis*) that was used by Indiana bats in Illinois (Kurta et al. 1993b) was a crevice in the bole and not a rot-related or woodpecker-induced cavity (A. Kurta, pers. comm., 2006).

Species of Tree

At least 33 species of trees have supplied roosts for female Indiana bats and their young (Table 1), and 87 percent of the species used are various ash (*Fraxinus*; 13 percent), elm (*Ulmus*; 13 percent), hickory (*Carya*; 22 percent), maple (*Acer*; 15 percent), poplar (*Populus*; 9 percent), and oak (*Quercus*; 15 percent). At one time, it appeared that oak and hickory were used more commonly at southern sites (Callahan et al. 1997, Gardner et al. 1991b), whereas elm, ash, maple, and cottonwood were occupied more often in northern areas (Kurta et al. 1996, 2002; Whitaker and Brack 2002). Recent work, however, shows Indiana bats occupying ash and elm in southern Illinois (Carter 2003) and hickories in Vermont (Palm 2003), so type of tree seems related more to local availability of trees with suitable structure than to broad regional preferences for particular species of trees. Nonetheless, some common trees, such as American beech (*Fagus grandifolia*), basswood (*Tilia americana*), black cherry (*Prunus serotinus*), box elder (*A. negundo*), and willows (*Salix* spp.) have rarely or never been used, suggesting that they typically are not suitable, especially as primary roosts.

Most (97 percent) roost trees of female Indiana bats at maternity sites are deciduous species, except for a few coniferous trees recently discovered in the Great Smoky Mountains (Harvey 2002, Britzke et al. 2003) and in New England (Palm 2003). Although this may indicate a preference for deciduous trees, it more likely reflects availability. Many other species of bats roost in conifers (Barclay and Kurta, 2007), and Indiana bats consistently use coniferous trees at some sites during autumn swarming (Gumbert et al. 2002).

Many species of tree apparently make suitable roosts (Table 1), but some species are preferred under certain circumstances. Kurta et al. (1996), for example, demonstrated a preference by

Indiana bats for green ash (*F. pennsylvanica*) over silver maple (*A. saccharinum*) in Michigan, and Carter (2003) showed that Indiana bats chose green ash and pin oak (*Q. palustris*) more often than expected based on availability in Illinois. Both studies occurred at sites with very high snag densities. However, if suitable trees are less abundant, other factors that influence roost selection (e.g., canopy cover, exposure to wind, distance to foraging sites) may mask preferences displayed by bats in areas of superabundant roosts.

Living or Dead Trees

Most trees occupied by female Indiana bats in summer are dead or nearly so. Indiana bats sometimes are found under bark on large dead branches within a living tree or on a dead trunk of a living tree with multiple trunks. Indiana bats also occasionally roost under the naturally peeling bark of living trees, most often shagbark (*C. ovata*) and shellbark hickories (*C. lacinosa*) and occasionally white oak (*Q. alba*) (Callahan et al. 1997, Sparks 2003, Brack et al. 2004). These trees may be used especially as alternate roosts during exceptionally warm or wet weather (Humphrey et al. 1977, Callahan et al. 1997). Carter (2003), however, suggests that living trees are used as alternates only when suitable dead trees are not available.

Table 1. Species of tree and type of roosting site used by Indiana bats, based on studies conducted through 2004 (from Kurta 2005).

Scientific Name	*Common Name*	*Type of Roost*[a]	*Number of trees used by adult females and young*	*Percent of trees used by adult females and young*	*Number of trees used by adult males*	*Percent of trees used by adult males*	*References*[b]
Acer rubrum	Red maple	B, C	7	1.8	13	5.4	2, 4, 9, 12, 13, 16, 17
Acer saccharinum	Silver maple	B	25	6.4	1	0.4	5, 6, 8, 13, 18, 19
Acer saccharum	Sugar maple	B, C	18	4.6	2	0.8	1, 2, 8, 16-20
Acer sp.	Unidentified maple	B	9	2.3	0	0.0	13
Betula alleghaniensis	Yellow birch	?	2	0.5	0	0.0	2, 16
Betula lenta	Sweet birch	B	1	0.3	0	0.0	3
Carya cordiformis	Bitternut hickory	B	3	0.8	1	0.4	8, 11, 18, 19
Carya glabra	Pignut hickory	B	0	0.0	3	1.3	12, 17
Carya lacinosa	Shellbark hickory	B	4	1.0	0	0.0	18, 19
Carya ovata	Shagbark hickory	B	78	19.8	22	9.2	2, 5, 6, 8-13, 16-21
Carya tomentosa	Mockernut hickory	?	0	0.0	7	2.9	9
Celtis occidentalis	Northern hackberry	B	1	0.3	0	0.0	18, 19
Cornus florida	Flowering dogwood	?	0	0.0	4	1.7	9
Fagus grandifolia	American beech	?	1	0.3	0	0.0	2
Fraxinus americana	White ash	C	1	0.3	0	0.0	5
Fraxinus nigra	Black ash	B	4	1.0	3	1.3	13
Fraxinus pennsylvanica	Green ash	B, C	46	11.7	4	1.7	2, 6, 13, 18, 19
Gleditsia triacanthos	Honeylocust	B	2	0.5	0	0.0	7
Juglans cinerea	Butternut	B	1	0.3	0	0.0	20
Juglans nigra	Black walnut	B	1	0.3	0	0.0	18, 19
Liriodendron tulipifera	Tulip tree	B	1	0.3	6	2.5	9, 15
Ostrya virgiana	Hophornbeam	B	1	0.3	0	0.0	20
Oxydendrum arboreum	Sourwood	?	0	0.0	9	3.8	9, 12
Pinus echinata	Shortleaf pine	B	2	0.5	70	29.3	3, 9
Pinus rigida	Pitch pine	B	1	0.3	6	2.5	3, 9
Pinus sp.	Unidentified pine	B	1	0.3	4	1.7	3, 10, 21
Pinus strobus	White pine	B, C	8	2.0	0	0.0	16, 20
Pinus virginiana	Virginia pine	?	0	0.0	15	6.3	9, 12
Platanus occidentalis	Sycamore	C	2	0.5	0	0.0	14, 18, 19

Scientific Name	*Common Name*	*Type of Roost*[a]	*Number of trees used by adult females and young*	*Percent of trees used by adult females and young*	*Number of trees used by adult males*	*Percent of trees used by adult males*	*References*[b]
Populus deltoides	Cottonwood	B, C	25	6.4	0	0.0	5, 6, 8, 13, 18, 19, 21
Populus sp.	Unidentified poplar	B	5	1.3	0	0.0	20
Populus tremuloides	Trembling aspen	B	5	1.3	0	0.0	2, 16
Quercus alba	White oak	B	15	3.8	18	7.5	5, 8, 9, 17, 21
Quercus coccinea	Scarlet oak	?	0	0.0	5	2.1	9, 12
Quercus falcata	Spanish oak	?	0	0.0	1	0.4	9
Quercus imbricaria	Shingle oak	B	0	0.0	1	0.4	8
Quercus palustris	Pin oak	B	8	2.0	0	0.0	6
Quercus prinus	Chestnut oak	?	0	0.0	6	2.5	9
Quercus rubra	Red oak	B	30	7.6	9	3.8	3, 4, 5, 8-10, 12, 13, 21
Quercus sp.	Unidentified oak	B	3	0.8	0	0.0	20
Quercus stellata	Post oak	B	3	0.8	2	0.8	8
Quercus velutina	Black oak	B	0	0.0	2	0.8	9, 17
Robinia pseudoacacia	Black locust	B, C	12	3.1	0	0.0	2, 20
Sassafras albidium	Sassafras	B, Ca	0	0.0	2	0.8	8
Tilia americana	Basswood	B	1	0.3	0	0.0	20
Tsuga canadensis	Eastern hemlock	B	3	0.8	0	0.0	2, 3, 20
Ulmus americana	American elm	B	35	8.9	14	5.9	2, 4, 8, 9, 13, 16-22
Ulmus rubra	Slippery elm	B, C	9	2.3	9	3.8	4, 7, 8, 9, 13, 21
Ulmus sp.	Unidentified elm	B	8	2.0	0	0.0	6
Unidentified		B	11	2.8	0	0.0	2, 6, 13
Total			393	100.0	239	100.0	

[a] Type of roost: B = under bark; C = in crevice; and Ca = in cavity. Not all references indicated specifically which species of tree provided a bark vs. a crevice roost.

[b] References are: 1, Belwood 2002; 2, Britzke 2003; 3, Britzke et al. 2003; 4, Butchkoski and Hassinger 2002; 5, Callahan 1993; 6, Carter 2003; 7, Chenger 2003; 8, Gardner et al. 1991b; 9, Gumbert 2001; 10, Harvey 2002; 11, Humphrey and Cope 1977; 12, Kiser and Elliott 1996; 13, Kurta and Rice 2002; 14, Kurta et al. 1993b; 15, A. Kurta, pers. comm., 2004; 16, Palm 2003; 17, Schultes 2002; 18, Sparks 2003; 19, D. Sparks Indiana State University, pers. comm., 2004.; 20, K. Watrous, pers. comm., 2004; 21, Whitaker and Brack 2002; and 22, L. Winhold, Eastern Michigan University, pers. comm., 2004.

Size of Tree

Roost trees vary in size (Tables 2 and 3). Although minimum diameter reported so far is 6.4 cm (2.5 in) for a tree used by males (Gumbert 2001) and 11 cm (4.3 in) for one occupied by females (Britzke 2003), such small trees have not been documented as primary roosts. Average diameter of roost trees (primary and alternate) is 62, 55, and 41 cm (24, 22, and 16 in) for Indiana, Missouri, and Michigan, respectively (Callahan et al. 1997, Kurta and Rice 2002, Whitaker and Brack 2002). Differences in average diameter among states likely reflect differences in species of tree contained in each sample - the Indiana sample is dominated by cottonwood; Missouri, by oak and hickory; and Michigan, by ash. The smallest mean diameter in Table 2 (28 cm or 11 in) is for five trees in Pennsylvania; however, the primary roost for this colony was a building, and no tree sheltered more than four bats (Butchkoski and Hassinger 2002).

Larger-diameter trees presumably provide thermal advantages and more spaces for more bats to roost. As with most tree-roosting bats (Hayes 2003, Barclay and Kurta, 2007), female Indiana bats probably select trees, especially primary roosts, that are larger in diameter than nearby, apparently suitable, but unoccupied trees (Kurta et al. 1996, 2002; Britzke et al. 2003; Palm 2003; Sparks 2003). Nevertheless, whether a statistical difference in diameter is detected between roost and randomly selected trees is partly dependent on the definition of a "suitable" or "available" tree. Differences between roosts and random trees have been found when the minimum diameter of available trees is set at 4.5, 10, or 15 cm (2, 4, or 6 in) (Kurta et al. 1996, 2002; Palm 2003; Sparks 2003) but not at 18.5 or 25 cm (7 or 10 in) (Callahan et al. 1997, Carter 2003). Inclusion of small trees in the pool of randomly selected trees seems justified, because there are numerous instances of one or more Indiana bats using them; hence, they are "available" to the bats.

Average heights of roost trees range from 16 to 26 m (52 to 85 ft) (Tables 2 and 3). Variation in height among studies likely reflects species differences in the sample of roost trees but also in the manner in which the trees died. For example, roost trees at one site in Michigan were killed slowly by inundation and had an average height of 25 m (82 ft), whereas roosts at a second site were broken in a windstorm and averaged only 18 m (59 ft) (Kurta et al. 1996, 2002). Minimum tree heights are 3 m (10 ft) for an alternate roost (Carter 2003) and 3.7 m (12 ft) for a primary roost (Callahan 1993). Absolute height of the roost tree probably is less important than height relative to surrounding trees, because relative height can affect the amount of solar radiation impinging on the tree (e.g., Kurta and Rice 2002), ease of finding the tree, and ease of safely approaching the roost in flight (Barclay and Kurta, 2007, Hayes 2003).

Among 16 studies, mean height of the exit, which also is assumed to be the height of the roosting area, was 5 to 16 m (16 to 52 ft), although the mean more commonly ranged from7 to 10 m (23 to 33 ft) (Table 2). Nevertheless, minimum exit height for a primary roost is 1.8 m (6 ft); for an alternate roost it is only 0.6 m (2 ft) (Callahan 1993). Height of the exit is correlated with height of the tree (Kurta et al. 2002).

Table 2. Means or ranges (n) for roost parameters of adult female and/or young Indiana bats in various studies conducted through 2004 (from Kurta 2005). All means were rounded to the nearest whole number to facilitate comparison. Means were taken from the indicated references or calculated based on tabulated data contained in each reference.

Location/parameter	*Diameter of tree (cm)*	*Height of tree (m)*	*Height of exit or roosting area (m)*	*Bark remaining (%)*[a]	*Canopy cover (%)*	*Reference*
Illinois	39 (47)	18 (47)	10 (47)	47 (47)	36 (47)	Carter, 2003
Illinois	37 (48)					Gardner et al., 1991b
Illinois	56 (1)	16 (1)	5 (1)			Kurta et al., 1993b
Indiana						Humphrey et al., 1977
Indiana	47 (27)	23 (27)	9 (25)			Sparks, 2003
Indiana	62 (17)					Whitaker and Brack, 2002
Michigan	41 (23)	25 (23)	10 (23)		0-20 (23)[b]	Foster and Kurta, 1999; Kurta et al. 1996
Michigan	42 (38)	18 (38)	10 (34)		31 (35)	Kurta et al. 2002; A. Kurta, pers. comm., 2004
Michigan	43 (3)	26 (3)	16 (3)	60 (3)	54 (3)	L. Winhold, pers. comm., 2004
Missouri	54 (38)			73 (21)	67 (38)	Callahan, 1993; Callahan et al., 1997
New York, Vermont[c]	46 (31)	19 (34)				Britzke, 2003
New York, Vermont	48 (50)	21 (50)	7 (18)			K. Watrous, pers. comm. 2004
Pennsylvania	28 (5)	20 (5)	8 (5)	51 (5)		Butchkoski and Hassinger, 2002
North Carolina, Tennessee	46 (8)	18 (8)		46 (18)		Britzke et al., 2003
Ohio	38 (2)	21 (1)				Belwood, 2002
Vermont	50 (20)			77 (13)	88 (20)	Palm, 2003
Average ± SE[d]	45 ± 2	20 ± 1	9 ± 1	59 ± 5	50 ± 10	
Number of studies	15	11	8	6	6	
Number of trees	359	231	141	88	128	

[a] Total bark on tree, not just loose and peeling.
[b] A liberal value of 20 percent was used when calculating the overall mean.
[c] Trees were located primarily in April and early May; all other studies were mid-May to mid-August.
[d] Calculations of overall average and SE used the unweighted means from the various studies. Weighting each study, based on the number of trees, gave very similar results.

Table 3. Means (n) for roost parameters and roosting behavior of adult male Indiana bats in various studies conducted through 2004 (from Kurta 2005). All means were rounded to the nearest whole number to facilitate comparison. Means were taken from the indicated references or calculated based on tabulated data in each reference.

Location/ parameter	*Diameter of tree (cm)*	*Height of tree (m)*	*Height of exit or roosting area (m)*	*Bark remaining (%)*[a]	*Canopy cover (%)*	*Reference*
Illinois	32 (18)					Gardner et al., 1991b
Indiana	38 (12)	25 (1)		25 (12)[b]	49 (12)	Brack et al., 2004; Whitaker and Brack, 2002
Iowa	43 (1)	20 (1)	13 (1)			Chenger, 2003
Kentucky[c]	31 (169)	15 (169)			58 (169)	Gumbert, 2001; Gumbert et al., 2002
Kentucky	31 (8)			61 (8)		Kiser and Elliot, 1996
Michigan	37 (9)	21 (9)	9 (9)			Kurta and Rice, 2002
Ohio	32 (14)	16 (14)		56 (14)	81 (14)	Schultes, 2002
Pennsylvania	20 (2)	18 (2)	9 (2)	53 (2)		Butchkoski and Hassinger, 2002
Average ± SE[d]	33 ± 2	18 ± 1	10 ± 1	57 ± 1	63 ± 10	
Number of studies	8	5	3	3	3	
Number of trees	219	189	12	25	128	

[a] Total bark on tree, not just exfoliating, unless otherwise noted.
[b] Amount of exfoliating bark; not used in calculation of mean.
[c] Data collected from April through October; all others apparently were mid-May to mid-August. Data from Gumbert (2001) are confounded slightly with trees used by adult females (7.6 percent of bats located were female) and by multiple counting of trees (9.2%) used in more than one season (spring, summer, autumn).
[d] Calculations of overall average and SE used the unweighted means from the various studies. Weighting each study, based on the number of trees, gave very similar results.

Other Factors Affecting Access and Sunlight
In addition to height, other factors influence the amount of sunlight striking a roost tree and simultaneously impact the ease and safety of access for a flying bat (Barclay and Kurta, 2007). For example, roosts of the Indiana bat, especially primary roosts, typically are found in open situations, although definitions of "open" vary (Gardner et al. 1991b; Kurta et al. 1993b, 1996, 2002; Callahan et al. 1997; Carter 2003; Palm 2003; Sparks 2003). The immediate vicinity of a roost, especially a primary roost, often is open forest, or roosts may occur along the edge of a woodlot, in gaps within a forest, in a copse of dead trees, as part of a wooded fenceline, in grazed woodlands, or in pastures with scattered trees. When present in denser forests, primary roost trees often extend above the surrounding canopy (e.g., Callahan et al. 1997). Roosts occasionally occur in low-density residential areas with mature trees (e.g., Belwood 2002).

Mean values of canopy cover are highly variable among studies, ranging from <20 to 88 percent (Tables 6 and 7). Reports of roost trees in closed-canopy forests (e.g., Gardner et al. 1991b reported that 32 of 48 roost trees examined in Illinois occurred within forests with 80 percent to 100 percent canopy closure) may appear to conflict with statements that primary roosts are generally located in areas with high solar exposure. There are several points to consider in evaluating this apparent discrepancy. First, some variation undoubtedly is related to differences in methodology, because virtually every study measures canopy cover in a different way. Second, roosts found in closed-canopy forests, particularly primary roosts, are often associated with natural or man-made gaps (e.g., openings created when nearby trees fall, riparian edges, trail or forest road edges). Although the forest may be accurately described as closed canopy, the canopy in the immediate vicinity of the roost tree may have an opening that allows for solar radiation to reach the roost. Indiana bat roosts have been created by the death of a single large-canopy tree (A. King, pers. comm., 2005).

Regional differences in roost characteristics also account for some of the variability in canopy cover in the vicinity of Indiana bat roost sites. For example, average values for canopy cover may be higher in areas where many living shagbark hickories are used as alternate roosts (e.g., Palm 2003), compared with sites where most roost trees are dead and leafless (e.g., Kurta et al. 1996, 2002). In addition, Indiana bats may use sites that are more shaded during warm weather (e.g., Callahan et al. 1997). Sites in northern areas (e.g., Kurta et al. 1996) or at high altitudes (e.g., Britzke et al. 2003) are exposed to cooler temperatures, so use of highly shaded roosts probably is less common in these areas and may be restricted to periods of unusually warm weather, which may not occur every year. For example, a colony of 30 Indiana bats in Michigan used a tree with 58 percent canopy cover and an open southern exposure, but all bats shifted to a nearby tree with 90 percent canopy cover after a prolonged period of abnormally high ambient temperature (>32°C or 89.6°F) (L. Winhold, pers. comm., 2005). In a typical year, however, Indiana bats generally do not use such highly shaded sites in Michigan (Kurta et al. 1996, 2002).

Access by a flying bat and amount of sunlight striking the roost could be affected negatively by presence on the trunk of living or dead vines, such as wild grape (*Vitis* spp.) or Virginia creeper (*Parthenocissus quinquefolia*). In Michigan, all roost trees (n = 76) lacked vines at or above the roosting area, although no comparison was made with randomly selected trees (Kurta and Rice 2002; A. Kurta, pers. comm., 2005). A roost shaded by poison ivy (*Rhus radicans*) was observed in New York (V. Brack, pers. comm., 2006).

Amount of Bark Remaining

Amount of bark remaining on a tree is another parameter that often is measured, although not always in the same way. Some biologists record the total amount of bark remaining on a tree, whether the bark is suitable for roosting or not (e.g., Callahan et al. 1997), whereas other researchers record only the amount of exfoliating bark under which a bat might roost (e.g., Gardner et al. 1991b; Kurta et al. 1996, 2002). The two techniques must be distinguished because they mean different things; total bark indicates stage of decay, whereas exfoliating bark indexes roosting opportunities. Consequently, the two methods can yield different results. For example, a randomly selected tree that recently died may be covered totally by bark and yield a value of 100 percent; however, the same tree would be totally unsuitable for roosting, because all bark is still tight to the trunk. Although there is potential for confusion, neither the amount of total bark nor the amount of exfoliating bark is useful as a predictor of current occupancy by Indiana bats (Kurta et al. 1996, 2002; Callahan et al. 1997; Gumbert 2001; Britzke et al. 2003; Carter 2003; Palm 2003).

Primary vs. Alternate Roosts

Despite the number of studies of Indiana bats, few reports have statistically compared the attributes of primary roosts and alternate trees. In Missouri, primary trees were more likely to be in open situations, as opposed to the interior of the woods, and more likely to be dead trees, rather than living shagbark hickories; alternate roosts, in contrast, were more variable and could be either interior or open trees (Callahan et al. 1997). No other statistical differences were found between primary and alternate trees (Callahan et al. 1997). In Michigan, both primary and alternate roosts typically were in open sites, and there was no statistical difference between primary and alternate roosts in tree height, exit height, canopy cover, solar exposure, or amount of bark (Kurta et al. 1996, 2002). In addition, mean diameter did not differ, although diameter of primary trees was less variable than that of alternate roosts in Michigan (Kurta et al. 2002).

One proposed function of frequent roost switching by tree-living bats is that individuals are evaluating new trees for future use (Barclay and Kurta, 2007). Hence, primary roosts likely were alternate roosts initially, although most alternate roosts never become primary roosts. If so, an inability to detect statistical differences between primary and alternate roosts is understandable, because primary roosts represent a small subset of all sites that were evaluated by the bats. Alternate roosts probably are more variable in most parameters than are primary roosts (Callahan et al. 1997; Kurta et al. 2002), although most reports do not address the degree of variation.

A Summary of Characteristics of a Typical Primary Roost

Individual Indiana bats have been found roosting in a large number of types of trees and situations, but it is possible to summarize the essential characteristics of a typical primary roost.

A typical primary roost is located under exfoliating bark of a dead ash, elm, hickory, maple, oak, or poplar, although any tree that retains large, thick slabs of peeling bark probably is suitable. Average diameter of maternity roost trees is 45 cm (18 in) (Table 2) and average diameter of roosts used by adult males is 33 cm (13 in) (Table 3). Height of the tree (snag) is greater than 3 m (10 ft), but height of the roosting tree is not as important as height relative to surrounding trees and the position of the snag relative to other trees, because relative height and position affect the amount of solar exposure. Primary roosts usually receive direct sunlight for more than half the day. Access to the roost site is unimpeded by vines or small branches. The tree is typically within canopy gaps in a forest, in a fenceline, or along a wooded edge. Primary roosts usually are not found in the middle of extensive open fields but often are within 15 m (50 ft) of a forest edge. Primary roosts usually are in trees that are in early-to-mid stages of decay.

Roosts during Spring
Most studies of roosting preferences by adult females have occurred during the summer maternity season, which is typically defined as 15 May to 15 August. However, Indiana bats first arrive at their summer locations as early as April or early May (Humphrey et al. 1977, Kurta and Rice 2002). During this mid-spring period, adult females occupy trees that are similar to those used in summer in terms of species, size, and structure (Britzke 2003, Butchkoski and Turner 2005, Britzke et al. 2006).

Sexual Differences in Habitat Use
Adult males of most species of bats probably enter torpor in summer more frequently than reproductive females, and hence, males probably can use a wider range of roosting situations than females (Barclay and Kurta, 2007). Some adult male Indiana bats form colonies in caves in summer (Hall 1962), but most are solitary and roost in trees. Adult males have been radiotracked to at least 239 trees of 26 species in eight states (Table 1). Males occasionally roost with reproductive females in the same tree, and males have been tracked to trees up to 95 cm (37 in) in diameter (Kurta and Rice 2002). However, males accept small trees more often than do females, and, consequently, mean diameter of trees used by females and young (18 in or 45 cm; n=359) is 36 percent greater than the average for males (13 in or 33 cm; n = 219) (Tables 2 and 3). Males also may be more tolerant of shaded sites.

Like female Indiana bats, adult males roost primarily under bark and less often in narrow crevices, but two males have been tracked to small cavities in trees (Gardner et al. 1991b, Gumbert 2001). Tree species used by males generally are similar to those chosen by females, although males have been found more frequently in pines (Table 1). The large number of conifers used by males, however, likely reflects the abundance of these trees in the forest surrounding certain caves in Kentucky, where the most intensive studies of male roosting have occurred (Kiser and Elliott 1996, Gumbert 2001).

Artificial Roosts
During summer, female and juvenile Indiana bats roost almost always in trees, as do adult males. Adult females, however, apparently used a crevice in a utility pole in Indiana (Ritzi et al. 2005), and adult males were found under metal brackets on utility poles in Arkansas (Harvey 2002). There also are a few instances of adult male and juvenile Indiana bats day-roosting under concrete bridges in Indiana (reviewed in Kiser et al. 2002). Although a few Indiana bats have been captured in buildings during migration before 15 May or after 15 August (Belwood 2002), only four maternity colonies have been located in buildings. These include an abandoned church in Pennsylvania (Butchkoski and Hassinger, 2002), two houses in New York (A. Hicks, pers. comm., 2004; V. Brack, pers comm., 2005), and a barn in Iowa (Chenger 2003). Nevertheless, there are almost 400 roost trees for female Indiana bats indicated in Table 1, suggesting that use of buildings by maternity colonies is uncommon.

Similarly, bat houses are rarely occupied by Indiana bats. Reproductive females from the church in Pennsylvania also used a large free-standing bat house as an alternate roost, as well as a smaller bat house wrapped in aluminum sheeting (Butchkoski and Hassinger 2002, Butchkoski and Turner 2005). Before 2003, the only other published records of Indiana bats using bat houses were two solitary juvenile males using different bird-house-style bat boxes and a group of females in a rocket box after the reproductive period (Carter et al. 2001, Ritzi et al. 2005). However, Ritzi et al. (2005) recently found groups of reproductive females using two birdhouse-style bat boxes for prolonged periods in Indiana. Use of these artificial structures coincided with destruction of two primary roost trees, and the authors speculated that portions of the colony were using the boxes as temporary replacements. The boxes had been in place for 11 years before being occupied and were two of 3,204 artificial structures of various styles constructed.

Landscape Structure and Macrohabitat

Distance to Environmental Features

Distances from roosts to nearby environmental features have rarely been measured. Trees used by a colony in Illinois were closer to unpaved than paved roads and closer to intermittent streams than to perennial streams, although no comparison was made with randomly selected points (Gardner et al. 1991b). In Michigan, roost trees were closer to perennial streams than random locations, but there was no difference between roosts and random points in distance to roads of any type or to lakes/ponds (Kurta et al. 2002).

Insectivorous bats typically obtain 20 to 26 percent of their daily water from drinking (Kurta et al. 1989, 1990), and one might think that roost trees should be closer to water sources than random points. In upland areas lacking streams or lakes, Indiana bats, especially adult males, have been captured while flying over wildlife ponds and at water-filled road ruts (e.g., Wilhide et al. 1998), suggesting that the bats might be attracted to these artificial sources of water. However, water sources are ubiquitous in most areas where Indiana bat maternity roosts have been found. At one maternity site in Michigan, for example, average distance from a random point to a perennial stream is only 910 m (2,986 ft) and to a lake or pond, 541 m (1,775 ft) (Kurta et al. 2002). Such distances are energetically insignificant to a flying mammal (Barclay and Kurta, 2007), and distance to water likely does not impact selection of individual trees, at least in those areas of the continent where most maternity colonies of Indiana bats have been located. Although distance to water probably is not a factor in day-to-day roost selection, accessible sources of water might affect location of the home range of a colony on a broader landscape, i.e., colonies may locate in areas of more abundant, accessible sources of water (Carter et al. 2002).

Commuting Corridors

Many species of bats, including the Indiana bat, consistently follow tree-lined paths rather than crossing large open areas (Gardner et al. 1991b, Verboom and Huitema 1997, Carter 2003, Chenger 2003, Murray and Kurta 2004, Winhold et al. 2005). Therefore, suitable patches of forest may not be available to Indiana bats unless a wooded corridor connects the patches (i.e., a component of suitable habitat may be the connectedness of different forest patches). Unfortunately, biologists do not know how large an open area must be before Indiana bats hesitate or refuse to cross. There are observations of Indiana bats crossing interstate highways

(Brack and Whitaker 2004) and open fields (Brack 1983). V. Brack (pers. comm., 2006) noted that he has observed Indiana bats following linear features not associated with tree cover, such as a treeless channelized ditch. Murray and Kurta (2004), however, showed that Indiana bats increased commuting distance by 55 percent to follow tree-lined paths, rather than flying over large agricultural fields, some of which were at least 1-km (0.6 mi) wide (Winhold et al. 2005).

Surrounding Habitats
At one time, the Indiana bat was considered a riparian specialist (Humphrey et al. 1977), but further study demonstrated that this categorization is not valid. Maternity roosts of some colonies have been found primarily in riparian zones (Humphrey et al. 1977), bottomland and floodplain habitats (Carter 2003), upland communities (Gardner et al. 1991b, Palm 2003), or in a mix of riparian and upland habitat (Callahan 1993). Indiana bats in Michigan (Kurta et al. 2002), in contrast, preferred roosting in wooded wetlands; although some roosts were in the floodplain of a major river, most were in low areas not associated with the river. Differences among studies probably reflect, at least partly, the varying location of intact woods in different agricultural landscapes (Murray and Kurta 2002, 2004).

Although the presence of female Indiana bats (i.e., maternity colonies) generally is not correlated with high forest cover, several studies suggest a correlation with the density of suitable roost trees. Miller et al. (2002) compared landscape and macrohabitat features surrounding sites where female Indiana bats were caught (i.e., maternity colonies) to sites where they were not caught in Missouri. While the study found that landscape features (e.g., forest cover) were too variable to accurately show differences between occupied and unoccupied sites, the occupied sites contained a higher density of large-diameter trees. Similarly, after analyzing a model for predicting habitat suitability, Farmer et al. (2002) concluded that the amount of land in forest, number of different habitats available, and area of water were not useful for predicting presence of Indiana bats. However, they reported that the utility of the model was based on a single component - density of suitable roost trees - and Indiana bats were more likely to occur in areas with a high density of potential roost trees (see also Clark et al. 1987).

Composition of the landscape surrounding a colony's home range was determined for a few maternity colonies. In Illinois, 67 percent of the land near one colony was agricultural, 33 percent was forested, and 0.1 percent consisted of farm ponds (Gardner et al. 1991b). In Michigan, land cover consisted of 55 percent agricultural land, 19 percent wetlands (including lowland hardwood forest), 17 percent other forests, 6 percent urban development, and 3 percent lakes/ponds/rivers (Kurta et al. 2002). Land within 4 km (2.5 mi) of primary roosts in Indiana contained an average of 37 percent deciduous forest cover, although forest cover varied from 10 to 80 percent (L. Pruitt, pers. comm., 2005).

Using GIS, Carter et al. (2002) compared habitats in circles that were 2 km (1.2 mi) in diameter surrounding all roost trees known in Illinois with habitat surrounding randomly selected locations. Areas around roosts had fewer and smaller urban patches and more and larger patches of closed-canopy deciduous forest compared with random sites. Area and number of patches of coniferous forest did not differ between roosting and random locations, but roosting areas had more patches of water (e.g., ponds, lakes) than random sites. Finally, while roosts typically occurred in highly fragmented forests, roosting areas contained more patches of bottomland forest and agriculture than randomly chosen circles. Even though roosting areas contained more agriculture patches than randomly chosen circles, the overall area of agriculture was less for roosting areas. With regard to bottomland forests, the mean patch size of bottomland forest around known roost trees was 35.9 ha (88.7 ac) and the total area was 82.7 ha (204.4 ac), as compared to a mean patch size of bottomland forest around the randomly chosen circles of 1.5 ha (3.7 ac) and 2.7 ha (6.7 ac) for total area.

A Missouri study found that Indiana bats selected maternity roost sites based upon tree size, tree species, and surrounding canopy cover (Callahan 1993). In his study, the amount of forest within a 3-km (1.9 mi) radius of four maternity sites varied from 19 to 30 percent, while the amount of forest within a "minimum roost tree range" (i.e., the minimum-sized circle that would encompass all roost trees used by a colony) around the same four colonies ranged from 23 to 53 percent; the amount of agricultural land within the larger radius ranged from 58 to 81 percent, while the amount of agricultural land within the smaller radius ranged from 47 to 77 percent (Callahan 1993). Callahan suggested that the potential preference of Indiana bat maternity colonies for larger forested tracts would increase the chances that a suitable range of roost trees would be available for the colonies.

On a much larger scale, Gardner and Cook (2002) examined land cover in 132 counties in the United States for which there was evidence of reproduction by Indiana bats. Non-forested habitats, consisting primarily agricultural land, made up 75.7 percent of the total land area in those counties. Deciduous forest covered 20.5 percent of the land, whereas coniferous forests and mixed coniferous/deciduous woodland occupied 3.4 percent.

Most Indiana bat maternity colonies have been found in agricultural areas with fragmented forests. Most females from the major hibernacula in Indiana, Kentucky, and Missouri migrate north for summer, into agricultural landscapes of the Midwest (Gardner and Cook 2002, Whitaker and Brack 2002). Similarly, recently discovered colonies in Vermont and New York also occur in agricultural regions and other areas with fragmented forests. Bats from hibernacula in New York were followed with aircraft as they left hibernation and migrated to agricultural areas of the Lake Champlain Valley and southern New York (Britzke 2003; A. Hicks, pers. comm., 2004, 2005). However, maternity colonies of Indiana bats have also been found in large forested blocks, even in predominantly agricultural states such as Indiana. For example, at least five maternity colonies are known on the Big Oaks National Wildlife Refuge, where 88 percent of the land is classified as forest or forested grassland (L. Pruitt, pers. comm., 2006).

Although most focus to date has been on the extent of wooded areas that Indiana bats require, there are additional and possibly interrelated factors that may contribute to where Indiana bats typically reproduce on the continent. Climate likely plays an important role (Clark et al. 1987, Brack et al. 2002). As noted by Brack et al. (2002): "Areas of higher latitudes and elevations typically are cooler and wetter, and higher elevations experience greater seasonal variability, all of which can reduce the food supply, increase thermoregulatory demands, and reduce reproductive success of bats." Brack et al. (2002) suggested climate as a potential explanation for why forest cover is generally not predictive of the presence of Indiana bats, and why the species is more abundant in portions of its range where forest cover is lower, at a landscape scale. They noted: "The geographic association of good (i.e., warm) summer and good (i.e., cold) winter habitat is limiting for the Indiana bat (*Myotis sodalis*)." They further explained that during summer, the Indiana bat is most common in an area of the Midwest, comprised of most of Indiana and Illinois, southern Iowa, southern Michigan, the northern half of Missouri, and western Ohio. This area accounts for more than 80 percent of known maternity colonies (Service 2004). This portion of the species range is warmer in summer than more heavily forested parts of the species range to the east and northeast, where relatively higher latitudes and elevations typically are cooler and wetter, and temperatures at higher elevations are more variable, adding significantly to the cost of reproduction. Maternity colonies in this portion of the range are more likely to be found at lower elevations, where temperatures are more conducive to reproduction. For example, the recently discovered colonies in the Lake Champlain Valley occur in an area of fragmented forests relative to extensively forested and higher elevation areas nearby in the Adirondack Mountains. Harvey (2002) and Britzke et al. (2003) reported on the first documented maternity colony in western North Carolina on the Nantahala National Forest at an elevation of 1,158 m, the highest elevation reported for a maternity colony of Indiana bats (Britzke et al. 2003). The colony was originally located in 1999, and surveys at the site in 2000 failed to document the presence of the bats. Maternity colonies were located the same year in adjoining counties in eastern Tennessee in the Great Smoky Mountains National Park (Harvey 2002, Britzke et al. 2003). These colonies were found at elevations of 610 m and 670 m, and were subsequently relocated in both 2000 and 2001.

Other potential factors that likely affect where Indiana bats reproduce include distance from suitable hibernacula, competition for food with other species of bats, and competition with other bats or birds for roosting sites (Clark et al. 1987, Kurta and Foster 1995, Foster and Kurta 1999, Murray and Kurta 2002, Sparks 2003).

In summary, most maternity colonies of Indiana bats that are known exist in fragmented landscapes with low-to-moderate forest cover. However, it is not clear whether the distribution of known colonies reflects a preference for fragmented forests, a need for specific climates that happen to occur where forests have been fragmented by humans, degree of survey effort by biologists in different areas of the range, or some other factor. Maternity colonies of Indiana bats have been found in environments that vary considerably in amount of forest cover, and further study is needed to determine whether survival or productivity varies, positively or negatively, with the amount and type of forest available and the degree of fragmentation that is present.

Foraging Habitat

Observations of light-tagged animals and bats marked with reflective bands indicate that Indiana bats typically forage in closed to semi-open forested habitats and forest edges (Humphrey et al. 1977, LaVal et al. 1977, Brack 1983). Radiotracking studies of adult males, adult females, and juveniles consistently indicate that foraging occurs preferentially in wooded areas, although type of forest varies with individual studies; Indiana bats have been detected through telemetry using floodplain, riparian, lowland, and upland forest (Garner and Gardner 1992; Hobson and Holland 1995; Menzel et al. 2001; Butchkoski and Hassinger 2002; Chenger 2003; Sparks 2003; Murray and Kurta 2004; Sparks et al. 2005a, 2005b). Indiana bats hunt primarily around, not within, the canopy of trees, but they occasionally descend to subcanopy and shrub layers. In riparian areas, Indiana bats primarily forage around and near riparian and floodplain trees, as well as solitary trees and forest edges on the floodplain (Cope et al. 1974, Humphrey et al. 1977, Belwood 1979, Clark et al. 1987). Within floodplain forests where Indiana bats forage, canopy closures range from 30 to 100 percent (Gardner et al. 1991a).

Nevertheless, Indiana bats have been caught, observed, and radiotracked foraging in open habitats (Humphrey et al. 1977; Brack 1983; Clark et al. 1987; Hobson and Holland 1995; Gumbert 2001; Sparks et al. 2005a, 2005b). In Indiana, individuals foraged most in habitats with large foliage surfaces, including woodland edges and crowns of individual trees (Brack 1983). Many woodland bat species forage most along edges, an intermediate amount in openings, and least within forest interiors (Grindal 1996).

Analyses of habitats used by radiotracked adult females while foraging versus those habitats available for foraging have been performed in two states. In Illinois, floodplain forest was the most preferred habitat, followed by ponds, old fields, row crops, upland woods, and pastures (Gardner et al. 1991b, Garner and Gardner 1992). In Indiana, woodlands were used more often than areas of agriculture, low-density residential housing, and open water, and this latter group of habitats was used more than pastures, parkland, and heavily urbanized sites (Sparks 2003; Sparks et al. 2005a, 2005b). Old fields and agricultural areas seemed important in both studies, but bats likely were foraging most often along forest-field edges, rather than in the interior of fields, although errors inherent in determining the position of a rapidly moving animal through telemetry made it impossible to verify this (Sparks et al. 2005b). Nevertheless, visual observations suggest that foraging over open fields or bodies of water, more than 50 m (150 ft) from a forest edge, does occur, although less commonly than in forested sites or along edges (Brack 1983, Menzel et al. 2001).

In autumn, Brack (2006) found that Indiana bats in Virginia were active in nine habitats, and used open deciduous forests more than available, and developed lands, closed deciduous habitats, and mixed deciduous-evergreen habitats less than available. Agricultural lands, intermediate deciduous forests, old fields, and water were used in proportion to availability. Wooded pastures (agricultural) and recently logged areas (open woodland) also provided foraging habitat. As the autumn progressed, these bats included less agricultural habitat and more deciduous forests (combined open, intermediate, and closed canopy) in their activity areas. Relative abundance of insect prey in open, exposed agricultural lands decreases with cooling temperatures and crop harvest.

Habitat Suitability Index Models

Two habitat suitability index (HSI) models are available for maternity sites of the Indiana bat in the Midwest, but neither has been sufficiently validated. The model of Rommé et al. (1995) uses nine variables, including two with sub-variables. The model provides output to independently evaluate the quality of roosting and foraging habitat, and provides an evaluation of overall summer habitat quality as affected by two landscape-scale attributes.

The model of Farmer et al. (2002) distilled the model of Rommé et al. (1995) down to only three variables, including number of habitat types that contributed more than 10 percent of the surrounding area, density of suitable roost trees, and percent of land in forest. Based on mist-netting data previously gathered in Missouri by Miller (1996), Farmer et al. (2002) concluded that only the density of suitable roost trees was potentially useful in predicting whether Indiana bats were present in a particular area. Farmer et al. (2002) were careful to point out that sound empirical support was lacking for various components of their model.

Carter (2005) recently used data collected in Illinois in a post-hoc test of both models. Although he believed his study area should be considered well above average (HSI of 0.8 to 0.9) in terms of quality of habitat, the model of Rommé et al. (1995) resulted in a value of only 0.42. The model of Farmer et al. (2002), in contrast, indicated an HSI of up to 0.8, suggesting that it might be more useful. Although such a post-hoc test is suggestive, the value of these HSI models will remain in doubt until they are validated through field studies that are designed and implemented specifically to test the predictions of the models at multiple sites. Carter (2005) noted that the HSI models assume a circular home range, although bats frequently use linear landscape elements (e.g., streams).

Population Distribution and Abundance

Prehistoric Distribution and Abundance

Our understanding of the Indiana bat's prehistoric distribution and abundance is primarily limited to extrapolations from early historical accounts and the study of paleontological remains in caverns in the eastern United States because there does not appear to be a fossil record for *Myotis sodalis* (Thomson 1982). Researchers have identified several important prehistoric (and historic) Indiana bat hibernacula by analyzing bat bones, mummified bodies, guano deposits, stains and claw marks on cave ceilings and walls, and raccoon (*Procyon lotor*) scat containing *Myotis* bones and hair. For example, Tuttle (1997), using historical accounts and an analysis of staining (i.e., discolored areas of the wall or ceiling due to consistent and prolonged roosting by bats), concluded that Mammoth Cave, Kentucky, once housed one of the largest hibernating colonies of bats yet identified, with an estimated 9-13 million bats (primarily *M. sodalis* and *M. grisescens*). Even though Toomey et al. (2002) readily acknowledged difficulties in analyzing and limitations in interpreting cave roost stains, when taken together their historic and paleontological analysis in Mammoth Cave's Historic Entrance area supported the idea that Mammoth Cave once held a large number of Indiana bats.

Similarly, Munson and Keith's (1984) previous historic research and paleontological analysis of prehistoric raccoon scat in Wyandotte Cave, Indiana, suggested that a large hibernating population of *Myotis* roosted near the entrance of this extensive cave system throughout the last 1,500 years. Assuming their results were from a representative sample of the raccoon activity areas in Wyandotte Cave, they conservatively estimated that the cave contained 676,900 fecal segments, which collectively would contain remains of an estimated 1,713,000 individual bats (presumably *M. sodalis* was the predominant species present and preyed upon).

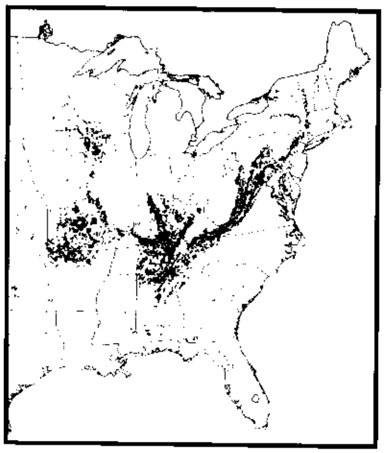
Other paleontological evidence indicating that prehistoric (or historic) Indiana bat numbers were once much higher has been documented in Bat Cave, Kentucky, where an analysis of bone deposits revealed an estimated 300,000 Indiana bats had died during a single flood event at some previous point in time (Hall 1962). It is uncertain whether this catastrophic population loss occurred during prehistoric times or perhaps as recently as "The Great Flood of 1937," which devastated much of the Ohio River valley (Hall 1962).

As a whole, existing paleontological evidence suggests that prehistoric abundance of Indiana bats may have exceeded most historic accounts and our current total population estimate by an order of magnitude. However, our degree of confidence in the accuracy of most prehistoric and historic population estimates remains relatively low because these estimates often depend on assumptions that cannot be readily tested, and confounding issues are common. For example, even conservative population estimates of Indiana bats based on stained areas on cave ceilings should be viewed with caution. Unfortunately, researchers currently have no means of empirically determining what percentage of the stained roosting areas found in caves today are attributable to the different *Myotis* species or over what period of time the stains were actually deposited (e.g., decades, centuries). Logically, in prehistoric or pre-settlement times, other *Myotis* species, such as the little brown bat and gray bat, may have been more abundant as well. However, because they typically do not aggregate on cave ceilings as tightly packed as do Indiana bats, population estimates made from their stains may not only be falsely attributed to *M. sodalis*, but would be overestimated as well.

Historic Winter Distribution

Historically, the Indiana bat had a winter range restricted to areas of cavernous limestone in the karst regions of the east-central United States (Miller and Allen 1928, Hall 1962, Thomson 1982, Figure 2). Prior to and during much of the European settlement of the eastern United States, winter populations of Indiana bats likely occurred in karst regions of what would eventually become Alabama, Arkansas, Georgia, Illinois, Indiana, Iowa, Kentucky, Maryland, Massachusetts, Missouri, New Jersey, New York, North Carolina, Oklahoma, Pennsylvania, Tennessee, Vermont, Virginia, and West Virginia. Based on early accounts and other indirect evidence (Silliman et al. 1851, Blatchley 1897, Tuttle 1997, Tuttle 1999), some researchers have suggested that vast numbers, presumably the majority, of Indiana bats historically converged at a relatively small number of large complex cave systems to hibernate (e.g., Wyandotte Cave in Indiana; Bat, Coach, and Mammoth caves in Kentucky; Great Scott Cave in Missouri; and Rocky Hollow Cave in Virginia) and used other caves to a lesser extent (Olson 1996, Tuttle 1997, Tuttle 1999, Toomey et al. 2002, Whitaker et al. 2003).

When Miller and Allen first described *Myotis sodalis* in 1928, they had examined museum specimens originating from ten states including Alabama, Arkansas, Illinois, Indiana, Kentucky, Michigan, North Carolina, Pennsylvania, Tennessee, and Vermont (Miller and Allen 1928). Based on these records, they described the species' distribution as the "eastern United States from the central Mississippi Valley and northern Alabama to the western part of New England" (Figure 3). Because the majority of the specimens they had studied were collected from wintering localities, Miller and Allen (1928) noted that the species' summer distribution likely covered a more considerable area, which decades later proved to be true. By 1960, winter populations of Indiana bats had been reported from about 74 different hibernacula in 18 states (Service, unpublished data, 2006).



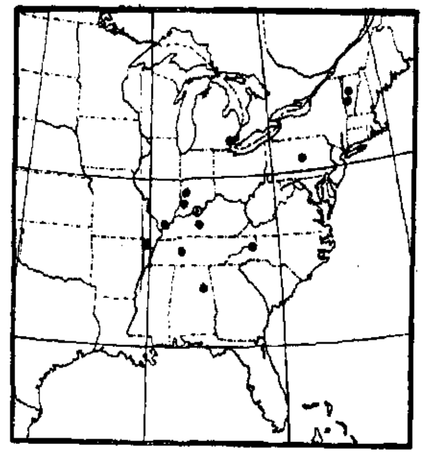


Figure 2. Cavern areas of the eastern United States (from Davies 1970) (on left).

Figure 3. Known distribution of *Myotis sodalis* in 1928 (from Miller and Allen 1928) (on right).

Historic Summer Distribution

The historic summer distribution and range for this species is poorly documented. The first maternity colony was not discovered until the summer of 1971 in east-central Indiana (Cope et al. 1974). Nonetheless, based on our knowledge of Indiana bat seasonal migration patterns and limits, and locations of historic and potential hibernacula, it is reasonable to assume that the species' historic summer distribution was more or less similar to its summer distribution (Figure 4).

The historic summer range included areas where the bats have now been locally extirpated due to extensive loss and fragmentation of summer habitat (e.g., forests, woodlands, wetlands). This loss of habitat resulted from land-use changes that began with pioneer settlements, and continue to the present in some areas from ongoing development, agriculture, and coal and mineral extraction. Habitat within the historic summer range sustained millions of Indiana bats during the pre-settlement and early settlement period, which may no longer be feasible today. Gardner and Cook (2002) provided a historical summary of the literature on the Indiana bat, especially that pertaining to summer distribution of reproductive individuals.

Historic Abundance

With the arrival of European settlers in the central portion of the Indiana bat's range in the late 1700s and early 1800s, land conditions and natural resource usage began to change dramatically (Parker and Ruffner 2004) and undoubtedly affected the species local and presumably regional abundance. For example, abundance of hibernating bat populations almost certainly declined after settlers discovered large deposits of nitrates or saltpeter, essential for making gunpowder, and began year-round mining operations within some of the major hibernacula. Saltpeter mining operations at Mammoth Cave, Kentucky, Wyandotte Cave, Indiana, and other Indiana bat hibernacula peaked during the War of 1812 and generally ended shortly after the war. Most historic accounts about winter bat populations in caves during this period are anecdotal and only offer an idea of the species' relative abundance. By the 1820s, tourism had become lucrative at several major hibernacula and increased rapidly over the next 100 years. In October 1850, biologist Benjamin Silliman, Jr. of Yale University visited Mammoth Cave, made detailed observations, and reported that "bats are numerous in the avenues within a mile or two of the mouth of the cave. We found countless groups of them on the ceilings" (Silliman et al. 1851, Tuttle 1997). Mammoth Cave, alone, still held "millions" of bats in 1850 (it has been assumed many were Indiana bats) after being subjected to severe winter disturbance from saltpeter mining, tourism, and adverse impacts associated with cave entrance alterations and restricted airflow (Tuttle 1997).

Categorization of Hibernacula[2]

In the Indiana Bat Draft Recovery Plan – First Revision (Service 2007), Indiana bat hibernacula are assigned priority numbers based on the number of Indiana bats they contain. Originally a Priority 1 (P1) hibernaculum w a site that has contained 30,000 or more Indiana bats since 1960. During a meeting between the Service and the members of the Indiana bat Recovery Team in November 2005, a decision was made to revise the existing hibernacula priority definitions in the revised Indiana Bat Recovery Plan. These hibernacula priority definitions (as described below) have the goal of achieving a wider and more even distribution of essential hibernation sites across the species' range.

Priority 1 (P1): P1 hibernacula are essential to recovery and long-term conservation of *M. sodalis*. P1 hibernacula typically have (1) a current and/or historically observed winter population greater than or equal to 10,000 Indiana bats and (2) currently have suitable and stable microclimates (e.g., they are not considered "ecological traps" as defined below). Priority 1 hibernacula are further divided into one of two subcategories, "A" or "B," depending on their recent population sizes. Priority 1A (P1A) hibernacula are those that have held 5,000 or more Indiana bats during one or more winter surveys conducted during the past 10 years. In contrast, Priority 1B (P1B) hibernacula are those that have sheltered ≥ 10,000 Indiana bats at some point in their past, but have consistently contained fewer than 5,000 bats over the past 10 years.

Priority 2 (P2): P2 hibernacula contribute to recovery and long-term conservation of *M. sodalis*. Priority 2 hibernacula have a current or observed historic population of 1,000 or greater but fewer than 10,000 and an appropriate microclimate.

Priority 3 (P3): P3 hibernacula contribute less to recovery and long-term conservation of *M. sodalis*. Priority 3 hibernacula have current or observed historic populations of 50-1,000 bats.

Priority 4 (P4): P4 hibernacula are least important to recovery and long-term conservation of *M. sodalis*. Priority 4 hibernacula typically have current or observed historic populations of fewer than 50 bats.

High Potential (HP): HP is a special designation given to P2, P3, or P4 hibernacula that are deemed capable of supporting 10,000 or more Indiana bats in the future if (1) an appropriate microclimate is restored (or created, as in the case of some mines) and/or (2) the site is protected from disturbance. These sites typically have no recorded direct observations of significant numbers of *M. sodalis* (i.e., at least none that can be readily confirmed, so they differ from a P1B

[2] Hibernacula priorities are primarily assigned based on winter population sizes.

site in this respect). Instead most "high-potential" hibernacula have one or more forms of indirect evidence indicating previous use by large numbers of *Myotis* and/or *M. sodalis* (e.g., anecdotal historic accounts and/or paleontological evidence such as bones, mummified remains, ceiling staining, etc.). As of October 2006, two caves had been designated as HP: Mammoth Cave in Kentucky and Rocky Hollow Cave in Virginia.

Ecological Trap (ET): An ET is a hibernaculum having a history of repeated flooding or severe freezing events that have resulted in the mortality of most hibernating *M. sodalis*. Hibernacula with other environmental conditions that pose a severe and/or imminent threat to the majority of hibernating bats may also be designated as "ecological traps" (e.g., threat of catastrophic collapse). As of October 2006, three caves had been preliminarily designated as ETs: Bat Cave (Shannon Co.) in Missouri (freezing), Haile's Cave in New York (flooding), and Clyfty Cave in Indiana (flooding). These preliminary designations were made based on the recommendations of Indiana bat experts familiar with these caves, and on the history of known Indiana bat mortality in these caves. The designations will be reevaluated when procedures for evaluation and designation of hibernacula as ETs are developed.

Current Winter Distribution

As of November 2006, the Service has winter records of extant (existing) winter populations (i.e., positive winter occurrence since 1995) of the Indiana bat at about 281 different hibernacula located in 19 states (Service, unpublished data, 2006) (Table 4, Figures 3 and 4). Likewise, based on the 2005 winter surveys, there were 23 Priority 1 hibernacula in seven states: Illinois (n=1), Indiana (n=7), Kentucky (n=5), Missouri (n=6), New York (n=2), Tennessee (n =1), and West Virginia (n=1) (Table 4, Table 5, Figure 4). Although winter 2007 survey data has been collected, it is currently being revised by the lead field office. As such, population estimates from 2005-2006 provide the most recent data available for use in this biological opinion. Fifty-three Priority 2 hibernacula are known from the aforementioned states, as well as Arkansas, Ohio, Pennsylvania, and Virginia (Table 4, Figure 4). One hundred fifty (150) Priority 3 hibernacula have been reported in 16 states (Table 4, Figure 4). Two hundred thirteen (213) Priority 4 hibernacula have been reported in 23 states (Table 4, Figure 4). Some records from the periphery of the range likely represent occasional occupations rather than viable winter populations (Service 1983). For example, only a single winter record of a single Indiana bat has been recorded in Florida and Wisconsin despite multiple winter surveys conducted over several decades (Service, unpublished data, 2006).

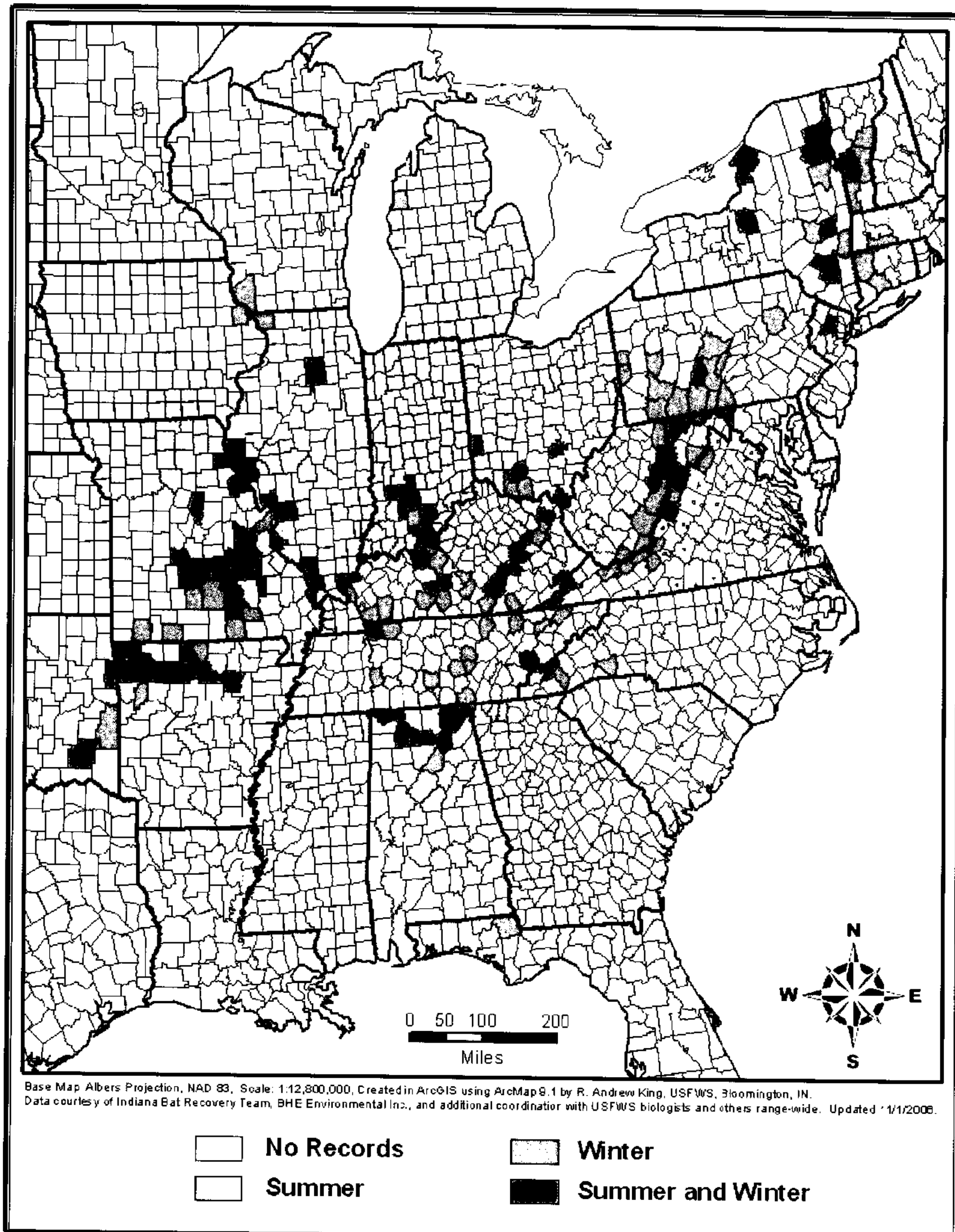


Figure 4. Distribution of counties with known summer and winter records of the Indiana bat.

Table 4. Distribution and priority numbers of Indiana bat hibernacula by state.

State	Number of Hibernacula by Priority Number[1] (Number with positive occurrence since 1995)					Total Number of Hibernacula with Any Previous Winter Record	Total Number of Hibernacula with "Extant" Winter Populations (≥1 bat since 1995)
	P1	P2	P3	P4	ET		
Alabama	-	-	2 (1)	8 (4)	-	10	5
Arkansas	-	4 (3)	12 (9)	18 (2)	-	34	14
Connecticut	-	-	1 (0)	1 (1)	-	2	1
Florida	-	-	-	1 (0)	-	1	0
Georgia	-	-	-	2 (0)	-	2	0
Illinois	1 (1)	6 (6)	7 (6)	8 (3)	-	22	16
Indiana	7 (7)	1 (1)	16 (16)	12 (9)	1 (1)	37	34
Iowa	-	-	-	2 (0)	-	2	0
Kentucky	5 (5)	15 (15)	39 (34)	50 (20)	-	109	74
Maryland	-	-	-	4 (3)	-	4	3
Massachusetts	-	-	1 (0)	-	-	1	0
Michigan	-	-	-	1 (1)	-	1	1
Missouri	6 (6)	10 (7)	24 (18)	26 (8)	1 (1)	67	40
New Jersey	-	-	2 (2)	1 (0)	-	3	2
New York	2 (2)	4 (4)	3 (3)	5 (2)	1 (1)	15	12
North Carolina	-	-	-	3 (1)	-	3	1
Ohio	-	1 (1)	1 (1)	5 (0)	-	7	2
Oklahoma	-	-	-	3 (2)	-	3	2
Pennsylvania	-	2 (1)	5 (3)	18 (7)	-	25	11
Tennessee	1 (1)	6 (3)	16 (13)	11 (4)	-	34	21
Vermont	-	-	5 (3)	1 (0)	-	6	3
Virginia	-	3 (3)	5 (5)	8 (4)	-	16	12
West Virginia	1 (1)	1 (1)	11 (11)	24 (14)	-	37	27
Wisconsin	-	-	-	1 (0)	-	1	0
Total	**23**	**53**	**150**	**213**	**3**	**442**	**281**

[1] P1: ≥10,000 bats. P2: 1,000-9,999 bats. P3: 50-999 bats. P4: 1-49 bats. ET: Ecological Trap.

Even though hibernating Indiana bats were dispersed across 16 states in 2005, over 90 percent of the estimated range-wide population hibernated in five states: Indiana (45.2%), Missouri (14.2%), Kentucky (13.6%), Illinois (9.7%), and New York (9.1%) (Service, unpublished data, 2006). In 2005, 81.9 percent (374,653 bats) of the range-wide winter population hibernated in P1 hibernacula (n=23), while P2 (n=53), P3 (n=150), and P4 (n=213) sheltered 14.4%, 3.3% and 0.4% of the total population, respectively (Service, unpublished data, 2006). The ten most populous hibernacula in 2005 collectively held 71.6 percent of the range-wide total with Wyandotte Cave in southern Indiana leading the list with 54,913 bats (12.0% of total) (Service, unpublished data, 2006) (Table 5).

Table 5. Winter population estimates through time for P1A (n=16) and P1B (n=7) Indiana bat hibernacula. All P1 hibernacula (n=23) have at some point in the recorded past had ≥10,000 hibernating Indiana bats and currently provide suitable winter habitat. P1A hibernacula have maintained a minimum of 5,000 Indiana bats during the last 10 years, whereas P1B hibernacula have not met this criterion in the last 10+ years.

State	County	Hibernaculum Name	Priority	Max. Pop. Estimate Since 1960	Max. Pop. Estimate Since 1980	Max. Pop. Estimate Since 1995	Current/ 2005 Pop. Estimate
IL	Alexander	Magazine Mine	P1A	33,500	33,500	33,500	33,500
IN	Crawford	Batwing Cave	P1A	50,000	29,960	10,125	6,850
IN	Crawford	Wyandotte Cave	P1A	54,913	54,913	54,913	54,913
IN	Greene	Ray's Cave	P1A	62,464	62,464	62,464	54,325
IN	Harrison	Jug Hole Cave	P1A	29,430	29,430	29,430	29,430
IN	Harrison	Twin Domes Cave	P1A	100,000	98,250	78,875	36,800
IN	Monroe	Coon Cave	P1A	10,675	10,675	10,675	9,270
IN	Monroe	Grotto Cave	P1A	10,338	10,338	10,338	9,875
KY	Carter	Bat Cave	P1A	100,000	51,500	31,400	29,500
KY	Edmonson	Dixon Cave	P1A	16,550	16,550	7,200	3,100
MO	Iron	Pilot Knob Mine	P1A	139,000	94,775	50,550	50,550
MO	Washington	Great Scott Cave	P1A	85,700	85,700	14,850	6,450
NY	Ulster	Walter Wm. Pres. Mine	P1A	11,394	11,394	11,394	11,394
NY	Ulster	Williams Hotel Mine	P1A	15,438	15,438	15,438	15,438
TN	Blount	White Oak Blowhole Cave	P1A	12,500	12,500	7,861	7,861
WV	Pendleton	Hellhole Cave	P1A	11,890	11,890	11,890	11,890
KY	Edmonson	Coach Cave	P1B	100,000	600	101	0
KY	Edmonson	Long Cave	P1B	7,600	7,527	1,153	1,153
KY	Letcher	Line Fork Cave	P1B	10,000	8,379	1,863	1,844
MO	Crawford	Onyx Cave	P1B	12,850	8,994	380	180
MO	Franklin	Copper Hollow Sink Cave	P1B	21,000	9,295	250	250
MO	Pulaski	Brooks Cave	P1B	19,461	11,850	750	70
MO	Pulaski	Ryden Cave	P1B	10,539	5,800	40	10

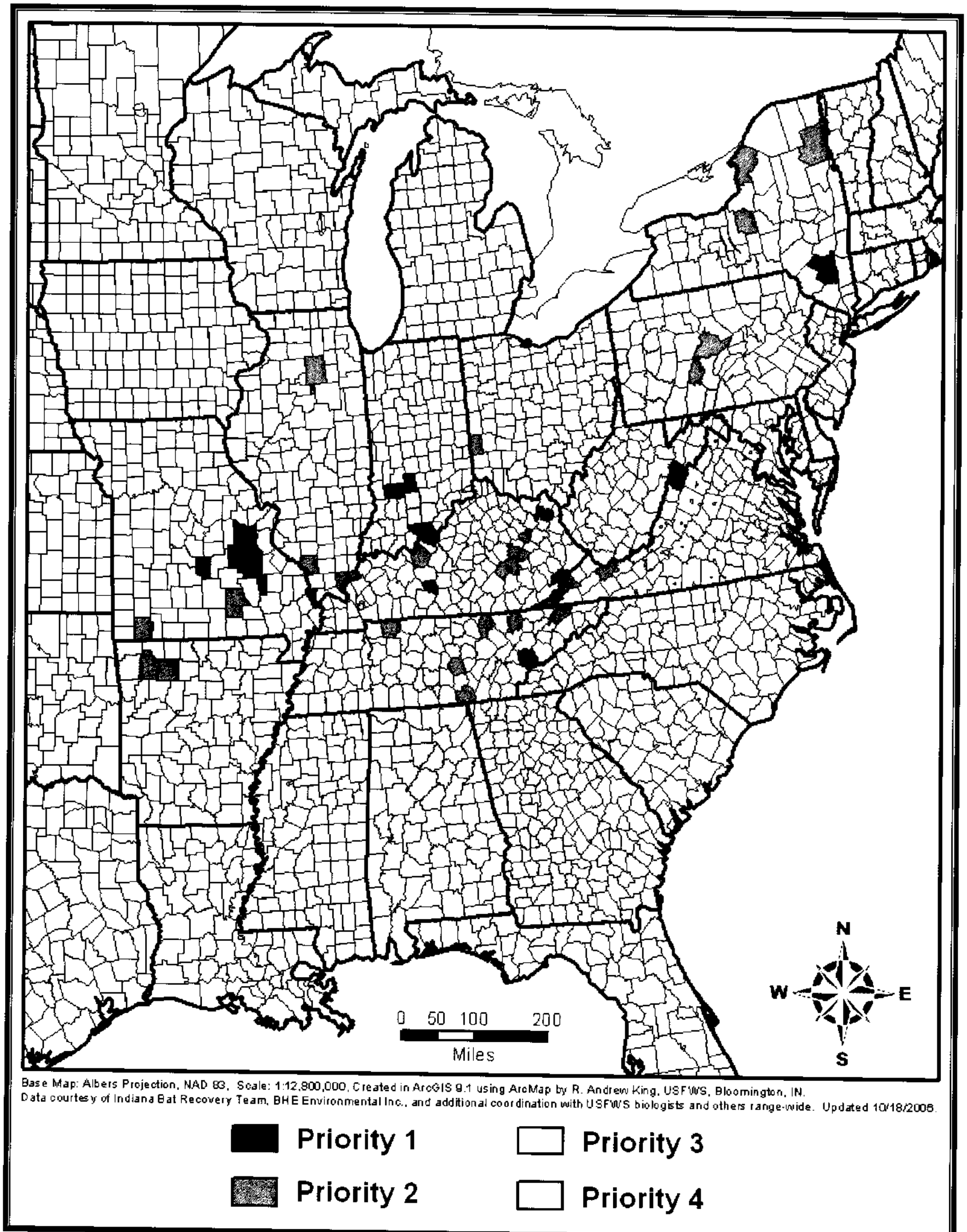


Figure 5. Distribution of counties with known Indiana bat hibernacula records and their current priority numbers. Note: For counties with multiple hibernacula with different priority numbers, only the color of the highest priority hibernacula is shown.

In the 1960s and 1970s, 75 percent of the known range-wide population hibernated in the southern portion of the species' winter range (i.e., Kentucky and Missouri) (Clawson 2002). However, by 2001 and through 2005, 60 percent of remaining Indiana bats occupied hibernacula in the (more or less) northern portion of the winter range (Table 6). Few specific drivers of this apparent population shift have been rigorously explored or identified, but inappropriate hibernacula temperatures (see Tuttle and Kennedy 2002) and regional climate change are either known or generally suspected in having had a role. We have an incomplete understanding of the links among *M. sodalis*' hibernation energetics, its biogeographical distribution, and climate change. However, the predictive modeling approach recently used by Humphries et al. (2002) for *M. lucifugus* could provide some insight into *M. sodalis*' potential winter distribution as global climate change occurs.

In at least three known cases, the species has expanded its winter range beyond its historic winter limits because of occupying man-made hibernacula (e.g., mines, tunnels, a dam) in relatively recent times. Some occupied man-made structures are relatively far removed from natural cave areas (e.g., Black Ball Mine in northern Illinois, Lewisburg Limestone Mine in west central Ohio, Tippy Dam near the eastern border of Lake Michigan in Michigan). Of the 33 mines with extant winter populations (i.e., one or more positive records since 1995), some have served as hibernacula for Indiana bats for nearly a century or more (e.g., Pilot Knob Mine in Missouri) (Clawson 2002). Others, where mining activities have been abandoned more recently, have only supported significant winter populations within the past decade, such as the Magazine Mine in southern Illinois (Kath 2002). These findings suggest that Indiana bats are capable of expanding their winter distribution by colonizing suitable hibernacula as they become available within and near their traditional winter range. In 2005, about 30 percent (136,410 bats) of the range-wide population of Indiana bats hibernated in man-made hibernacula (24 mines, one dam, and one tunnel) and the other 70 percent (320,964 bats) hibernated in natural caves (Service, unpublished data, 2006). In addition, it appears in some instances that Indiana bats may redistribute themselves over several years as evidenced by population declines in some hibernacula that coincided with population increases at others nearby (e.g., Twin Domes and Wyandotte caves in Indiana) (Service, unpublished data, 2006). Such rapid increases cannot be attributed to reproduction alone and are due, at least in part, to immigration.

Emigration and immigration of bats between regional hibernacula occurs, but a detailed characterization or quantification of these movements has not been made. Initial observations of local and regional winter population dynamics suggest Indiana bat winter populations likely follow some form of a metapopulation model (Hanski 1998, Cronin 2003). While records of short and long-distance movements of banded bats between caves have been known (Hall 1962), only recently has genetic analysis been used to determine the relative degree of gene flow occurring among and between winter populations.

Table 6. Size and distribution of hibernating populations of the Indiana bat by region and state, based upon estimates nearest to the year indicated.[1]

Region	State	1965	1980	1990	2001	2003	2005
Southern Region	Alabama	350	350	350	250	317	296
	Arkansas	15,000	15,000	4,500	2,476	2,124	2,067
	Illinois (southern)	14,700	14,700	14,500	19,491	32,330	42,539
	Kentucky	248,100	102,200	78,700	50,047	47,876	62,380
	Missouri	399,000	342,000	150,100	72,983	66,805	65,104
	Oklahoma	0	0	0	0	5	5
	Tennessee	20,100	20,100	16,400	10,172	8,900	9,971
	Virginia	3,100	2,500	1,900	833	1,090	735
	Subtotal	700,350	496,850	266,450	156,252	159,447	183,097
	% of Rangewide Total	79.3%	73.2%	56.3%	41.0%	40.0%	40.0%
Northern Region	Illinois (Blackball Mine)	100	100	400	1562	1648	1804
	Indiana	160,300	155,200	163,500	173,076	183,332	206,610
	Michigan	0	0	0	20	20	20
	New Jersey	0	0	0	107	644	652
	New York	20,200	21,100	26,800	29,746	32,924	41,702
	Ohio	150	3,600	9,500	9,788	9,436	9,769
	Pennsylvania	700	700	400	702	853	746
	Vermont	0	0	0	159	175	297
	West Virginia	1,500	1,200	6,500	9,744	9,741	12,677
	Subtotal	182,950	181,900	207,100	224,904	238,773	274,277
	% of Rangewide Total	20.7%	26.8%	43.7%	59.0%	60.0%	60.0%
	Grand Total	883,300	678,750	473,550	381,156	398,220	457,374

[1]Not all surveys occurred exactly as portrayed in the table. Population estimates for a particular period were based on the survey nearest to the year indicated, either prior to or subsequent to that year, so that all caves are represented in each period.

Current Winter Population Groups

Vonhof and McCracken's statistical analysis of genetic samples (mtDNA extracted from wing membrane punches) (Vonhof, pers. comm., 2006) collected from hibernating Indiana bats from widely dispersed hibernacula suggested that genetic variance among samples was best explained by dividing sampled hibernacula (n=13) into four separately defined population groups, as follows:

- Midwest, included sampled populations in AR, MO, IN, KY, OH, Cumberland Gap Saltpeter Cave in southwestern VA, and Jamesville Quarry Cave in Onondaga Co., NY,
- Appalachia, included White Oak Blowhole Cave in east TN, and Hellhole Cave in WV,
- Northeast 1 (NE1), included Barton Hill Mine and Glen Park Caves in northern NY (Essex and Jefferson counties, respectively), and
- Northeast 2 (NE2), included Walter Williams Preserve Mine in Ulster Co., NY.

Vonhof and McCracken's other findings and conclusions included:

- Most winter populations had a high haplotype and nucleotide diversity,
- Low genetic diversity in 3 of the 4 winter populations sampled in NY,

- Some level of male- and/or female-mediated gene flow was occurring among 3 of the 4 defined groups (Midwest, Appalachia, and NE2), but apparently there was no gene flow for either sex between the NE1 group and the other groups.
- The low levels of genetic diversity in NE1 and NE2 (i.e., a severe genetic "bottleneck"), are indicative of relatively recent colonization of the Northeast within historical times (e.g., estimated at 153 years before present for NE1) by a small number of individuals.

Interestingly, these recent findings also agree with Hall's (1962) taxonomic studies of over 1,000 museum specimens collected from throughout the Indiana bat's range. Hall noticed that Vermont specimens tended to have more distinct banding of the fur, longer hairs on the feet, and that their skulls had significantly narrower nasal breadth than those in other parts of the range. He stated "if the establishment of populational ranges has acted as an isolating mechanism, it has not produced any noticeable variation, except in the case of the northeast population." Hall concluded that "the establishment of populational ranges restricts gene flow within the species" and that "this apparently has not been in effect long enough to allow race differentiation to occur."

Within the Northeast Recover Unit of Indiana bat populations (USFWS 2007), specifically within New York, Vermont, Connecticut and Massachusetts, biologists and/or cavers have documented a mysterious illness that is causing widespread mortality of the wintering bat populations in the affected hibernacula. This illness has been dubbed "white-nose syndrome" due to the white fungus found on the noses of many of the affected bats. At this time, researchers do not know what is causing the illness or how it is spread. Species affected include *Myotis lucifugus* (little brown bat), *Myotis sodalis* (Indiana bat), *Myotis leibi* (eastern small-footed bat, *Myotis septentrionalis* (northern long-eared bat), and *Pipistrellus subflavus* (eastern pipestrelle bat) ("Bats and White-nose Syndrome" 2008).

<u>Current Summer Distribution</u>

Maternity Colonies

The first Indiana bat maternity colony was not discovered until 1971 (in east-central Indiana, Cope et al. 1974). As of October 2006, we have records of 272 maternity colonies in 16 states that are considered locally extant (Table 7). Of the 272 colonies, 55 percent (n=149) have been found (mostly during mist-netting surveys) within the past 10 years (i.e., since 1997) (Table 7, Figure 6). Because maternity colonies are widely dispersed during the summer and difficult to locate, it is presumed that all the combined summer survey efforts have found only a fraction of the maternity colonies based on the range-wide population estimates derived from winter hibernacula surveys. For example, based on the 2005 range-wide population estimate of 457,374 bats, and assuming a 50:50 sex ratio and an average maternity colony size of 50 to 80 adult females (Whitaker and Brack 2002), then the 272 maternity colonies in Table 7 may only represent 6 to 9 percent of the 2,859 to 4,574 maternity colonies we would assume exist. Regardless of reasonable disagreements on the average colony size, the geographic locations of the majority of Indiana bat maternity colonies remain unknown.

Table 7. States and counties with recorded Indiana bat maternity colonies.[1,2,3] These colonies are considered likely to be locally extant (within limits of data noted in footnote 3).

State	No. of Recorded Maternity Colonies	Counties with Recorded Maternity Colonies (if multiple colonies, then # is shown)
Arkansas	1	Clay
Illinois	28	Adams (2), Alexander, Bond, Cass, Ford, Henderson, Jackson (3), Jersey, Macoupin, Monroe (4), Pike (2), Pulaski, Randolf, Saline, Schuyler, Scott, St. Clair, Union, Vermilion, and Washington (2)
Indiana	83	Bartholomew (3), Clinton (2), Crawford, Davies (2), Dearborn, Gibson (2), Greene (3), Hendricks (2), Henry, Howard, Huntington, Jackson (3), Jasper, Jay, Jefferson (2), Jennings (2), Johnson (3), Knox, Koskiusko, LaPorte (2), Marion, Martin, Monroe (2), Montgomery (3), Morgan (4), Newton, Parke (2), Perry (2), Pike (2), Posey, Pulaski (2), Putnam (2), Randolph (3), Ripley (2), Rush, Shelby (2), Spencer, St. Joseph, Steuben, Tippecanoe (4), Vermillion, Vigo, Wabash (2), Warren (2), Warrick (2), Wayne, and Wells
Iowa	27	Appanoose (2), Davis, Decatur (2), Des Moines (2), Iowa, Jasper, Keokuk, Lucas (2), Madison (2), Marion (7), Monroe, Ringgold, Van Buren, Wapello, and Washington (2)
Kentucky	35	Ballard (2), Ballard/Carlisle, Bath (3), Breckinridge, Bullitt (4), Clay, Daviess, Edmonson (3), Floyd, Harlan (4), Henderson, Hickman (2), Jefferson (2), Letcher, Magoffin, McCracken (2), Meade, Pulaski, Rowan, Spencer, and Union
Maryland	2	Carroll (2)
Michigan	11	Calhoun, Cass, Eaton, Hillsdale, Jackson, Lenawee (2), Livingston, St. Joseph (2), and Van Buren
Missouri	20	Chariton, Gasconade, Iron, Jefferson, Knox (2), Lewis, Linn, Macon, Madison, Marion, Mercer, Monroe, Nodaway, Pulaski, Scotland, St. Francois, St. Genevieve, Sullivan, and Wayne
New Jersey	7	Morris (5), Somerset, and Sussex
New York	31	Cayuga, Dutchess (5), Essex, Jefferson (9), Onondaga (4), Orange (8), and Oswego (3)
Ohio	11	Ashtabula, Butler, Clermont, Cuyahoga, Greene, Hocking, Lawrence, Paulding, Pickaway, Summit, and Wayne
Pennsylvania	2	Berks and Blair
Tennessee	3	Blount (2) and Monroe
Vermont	7	Addison (6) and Chittenden
Virginia	1	Lee
West Virginia	3	Boone (2) and Tucker
Total	**272**	

[1] Unpublished data obtained in response to a data request sent to Service Field Offices in February 2006. The data for Kentucky were updated in this table from the draft revised recovery plan based on the data available to the Kentucky Field Office as of the date of this biological opinion.

[2] Most maternity colony records were based upon the capture of reproductively active females and/or juveniles between 15 May and 15 August.

[3] This table includes records of maternity colonies considered to be locally extant (even though records may not have been verified in recent years). Although some additional records exist, we did not include them if subsequent surveys failed to detect their presence (i.e., the colony may have disbanded, relocated, was extirpated, or was present but not found). Records were also not included if suitable habitat no longer exists at a previously occupied site.

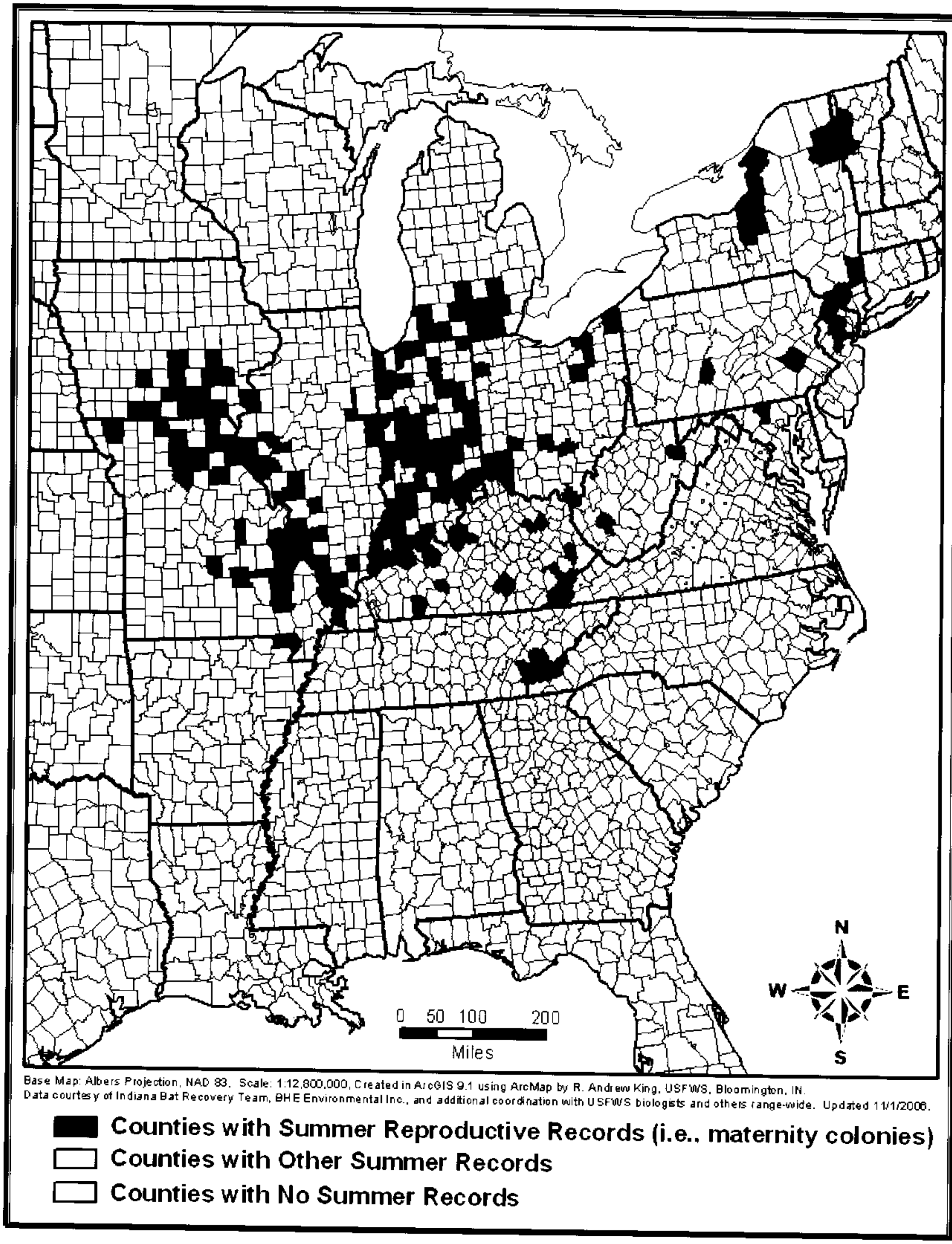


Figure 6. Distribution of counties with known summer reproductive records of Indiana bats (i.e., presence of reproductively active females and/or juveniles between 15 May and 15 August). Lack of records does not necessarily mean the species is not present.

Most capture records of reproductively active female and juvenile Indiana bats (i.e., evidence of a nearby maternity colony) have occurred in glaciated portions of the upper Midwest including southern Iowa, northern Missouri, much of Illinois, most of Indiana, southern Michigan, and western Ohio, and in Kentucky. However, a growing number of maternity records have been documented in New York, New Jersey, and Vermont recently due to spring emergence studies and mist netting efforts (Gardner and Cook 2002; Service, unpublished data, 2006) (Table 7; Figure 6). The more rugged, unglaciated portions of the Midwest (Ozarks/southern Missouri, parts of southern Illinois, and south-central 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 than does the upper Midwest. Additional summer survey efforts and spring emergence studies will be needed in some areas, particularly along the periphery of the range, before conclusions may be reached on the extent of the species' summer range. Likewise, a comprehensive analysis of existing positive and negative summer survey data is warranted.

Although Indiana bat maternity colonies occur throughout much of the mid-eastern United States (e.g., West Virginia, Virginia, Pennsylvania, New York), they appear to be relatively less abundant than in the Midwest or more central portion of the range. This apparent regional difference in summer distribution and relative abundance, especially of maternity colonies, may be influenced in large part by geographic distribution of important hibernacula and by regional differences in climate and elevation. During the summer, higher latitudes and elevations typically are cooler and wetter, and temperatures at higher elevations are more variable, adding significantly to the cost of reproduction (Brack et al. 2002). In short, our understanding of how and to what extent distribution of hibernacula and local and regional climate and elevation differences influence the distribution and abundance of maternity colonies is still evolving.

Adult Males

Male Indiana bats are found throughout the range of the species, but in summer are most common in areas near hibernacula (Hall 1962, Gardner and Cook 2002, Figure 5). Please refer to the Life History and Summer Habitat sections for additional information.

Current Abundance

By compiling individual population estimates from bat surveys conducted within 214 hibernacula during the winters of 2003-2004 and 2004-2005, the Service has estimated that the Indiana bat's 2005 range-wide population was approximately 457,000 bats (Service, unpublished data, 2006) (Table 6).

In 2005, 82 percent of the range-wide population hibernated within 22 of the 23 Priority 1 hibernacula (Table 5). Thirteen of the 23 Priority 1 hibernacula have been surveyed every 2 years from 1983 to 2005. Due to hazardous conditions within Pilot Knob Mine in Missouri, this P1 hibernaculum cannot be safely entered to conduct a standard winter survey. Fall trapping rates at the entrance to this mine, however, have shown that large numbers of bats continue to use it (Clawson 2002). Although it is not feasible to confirm, bat surveyors are aware of some hibernacula that have physically inaccessible areas. These hibernacula range in size from small cracks and crevices to large rooms where Indiana bats are known or believed to roost. In these situations, our population estimates may be viewed as conservative (i.e., under estimations).

In most winters, a few new hibernacula are discovered, but most of these contain less than 1,000 Indiana bats (i.e., P3) and many contain less than 50 bats (i.e., P4) (Service, unpublished data, 2006). Discovery of new hibernacula with >1,000 Indiana bats is uncommon, but occasionally does occur. Of hibernacula first documented during the past 10 years, only three have held more than 5,000 Indiana bats when initially discovered: Magazine Mine in Illinois, Lewisburg Limestone Mine in Ohio, and Williams Hotel Mine in New York. Over the past 25 years, no hibernaculum has contained more than 10,000 Indiana bats when initially discovered (Service, unpublished data, 2006).

Population Trends in Hibernacula

Background

During the 1950s, biologists began conducting winter bat surveys at irregular intervals and recording population estimates for about a dozen Indiana bat hibernacula (Hall 1962; Service, unpublished data, 2006). Since that time, hundreds of additional populations of hibernating Indiana bats have been discovered, and our knowledge of the winter distribution and status of the species has expanded. Many hibernating populations have decreased in size since range-wide monitoring began (Figure 7), especially in Kentucky and Missouri (Table 6). By the time the status of the Indiana bat was officially recognized in 1967, it is assumed, the remaining populations represented a portion of historical numbers. These hibernating populations were often confined to smaller caves, which likely had less thermal stability, fewer and less optimal roosting options, and had a higher risk of predation than traditional hibernacula. By 1985, more than 85 percent of the known, range-wide population hibernated in just eight caves and one mine.

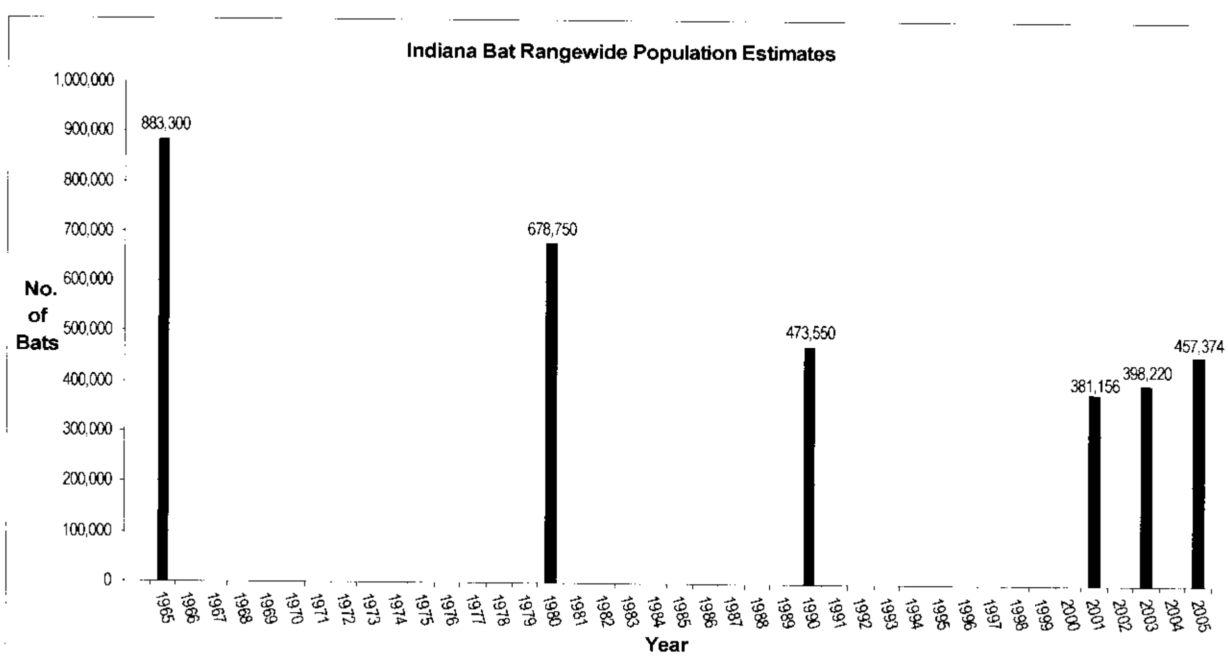


Figure 7. Indiana bat rangewide population estimates (Data sources: 1965-1990, Clawson 2002; 2001-2005, Service, unpublished data, 2006). Rangewide estimates calculated from all known hibernacula were not attempted or data was not available for most years prior to 2001.

During the 1960s and most of the 1970s, winter surveys of the largest Indiana bat populations known at that time were inconsistent, and many medium-sized and large winter populations had not yet been discovered. Since the release of the original Recovery Plan in 1983, with few exceptions, a standardized survey approach has been used to make biennial estimates of all known winter bat populations within the most populous hibernacula (i.e., P1s and P2s).

Range-wide Population Estimates

Nearly all of the existing range-wide population estimates for the Indiana bat were generated by simply adding together all available estimates from traditional winter surveys of all known hibernacula during a specified period in time. However, if one looks at the actual proportion of the known hibernacula that were known and/or actually surveyed during previous decades, it is apparent that range-wide estimates calculated for any given year prior to about 1980 should be regarded as approximate. The uncertainty associated with these early range-wide estimates is relatively high (compared to recent estimates) due to large, irregular gaps of time between winter surveys, small number of surveys conducted in any given year, and asynchrony and non-standardization among the surveys that were conducted (Figure 7).

After standardized surveys of all known P1 hibernacula were initiated in the 1983, the quality of the range-wide estimates improved. Clawson (2002) made a reasonable and conservative effort to reduce the amount of error associated with calculating range-wide estimates (especially for decades with limited data) by forward- and/or backfilling in the missing data cells with the same estimates for each individual hibernaculum that had been recorded during its most recent survey. In a similar manner, when a "new" P1 or P2 hibernaculum was discovered, Clawson used its first post-discovery population estimate to backfill the blanks in the data set for each of the previous time periods being calculated (see Clawson 2002 for rationale for backward projection of estimates for newly discovered populations). Again, while such data manipulations were necessary and undoubtedly improved the accuracy of range-wide population estimates, the current estimates calculated for years prior to 1980 should be considered as approximate. As an example, more than half of the bats that were included in the calculation of the range-wide estimate for the year "1965" in Figure 7 were attributed to hibernacula that had not yet been discovered, but those bats were assumed to have been present in those hibernacula prior to discovery of the hibernacula.

Apparent Long-term Trend

Over the long term, from 1965 to 2001, there has been an overall decline in Indiana bat numbers, (Figure 7, Service 1983, Kurta and Kennedy 2002). Estimated numbers consistently declined through this period. Even with the discovery of many new, large hibernacula, the range-wide population estimate dropped about 57 percent from 1965 to 2001. Since the advent of systematic attempts to estimate population numbers, some specific drivers (e.g., changes in cave air flow/temperatures, human disturbance levels) have been linked to positive and negative trends in some of the most important hibernacula (see Tuttle and Kennedy 2002), but the underlying causes of population changes at other hibernacula remain unknown or incompletely known. The Service's confidence in apparent positive and negative population trends within individual hibernacula and collectively in the long-term, range-wide decline remains relatively high for the following reasons:

1) Continuity and consistency – with very few exceptions, the same small group of highly qualified biologists have been surveying the same caves/mines using consistent survey techniques since standardized surveys began in the 1983
2) Surveyors have demonstrated high levels of attentiveness, thoroughness, and scientific integrity while completing the winter surveys through the years; and
3) Other lines of evidence clearly point to large population changes in numerous hibernacula.

For example, consistently observed gradual population declines in numerous regional hibernacula and obvious population crashes (e.g., >50 percent declines and complete absence of Indiana bats in some cases) in other traditionally important hibernacula in the same region of the bat's range (e.g., Missouri, Kentucky) are compelling evidence of a true decline, regardless of whether statistical significance can be applied to the numbers.

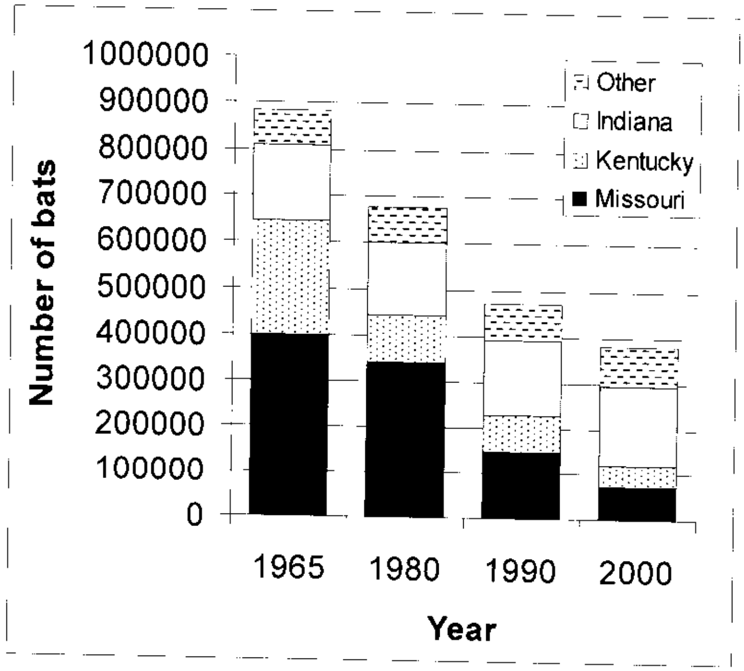
Apparent Short-term Trend

Range-wide estimates of species numbers over the three most recent biennial survey periods do not show the same declining trend seen in estimates spanning 1965-2000 (Figure 7). There was about a 16 percent increase from the 2003 estimate of 393,000 bats to the rounded estimate of 457,000 bats Service in 2005 (USFWS, unpublished data, 2006) (Table 6; Figure 7). In spite of some changes in methodology over time and a general lack of data on the statistical accuracy and variability of hibernacula estimates, the Service believes that the apparent upward trend in recent years is real because the same biologists have been consistently conducting the winter surveys at all of the largest hibernacula over the past 20 years. This level of surveyor consistency, coupled with obvious, increases at some high-priority hibernacula in Indiana, Illinois, Kentucky and New York in recent years (see Table 6), provides us with some confidence that the long-term decline may have halted. We anticipate that planned improvements in hibernacula survey methodology will soon provide for a greater level of confidence in the overall population trend.

Apparent Trends by Cave 1965-2005: Missouri, Indiana, and Kentucky

Missouri, Indiana, and Kentucky have historically had the highest estimated numbers of hibernating bats (Figure 8); all had estimated populations of >100,000 bats in 1965. Over the period 1965-2005, estimated numbers of hibernating bats in Missouri and Kentucky clearly declined. Of Missouri hibernacula that were estimated to contain at least 10,000 bats at least once, all had estimates that declined since 1985, although two hibernacula showed strong increases before that time (Figure 9). Kentucky hibernacula that sheltered at least 10,000 (estimated) bats at least once had less consistent patterns (Figure 10). The total number of Indiana bats appears to have declined but trends at individual hibernacula is generally upward. Indiana bat hibernacula that had at least one estimate of >10,000 hibernating bats also showed little consistency (Figure 11). Four of seven hibernacula seem to show periods of increase and periods of decrease, including the three hibernacula with the highest one-time counts. The other three hibernacula show consistent increases, two of them reaching 10,000 in the 2003 survey.

Figure 8. States with the largest numbers of Indiana bats in hibernacula. For years in which a hibernaculum was not yet known, the first post-discovery survey results were used (V. Meretsky, pers. comm., 2006).



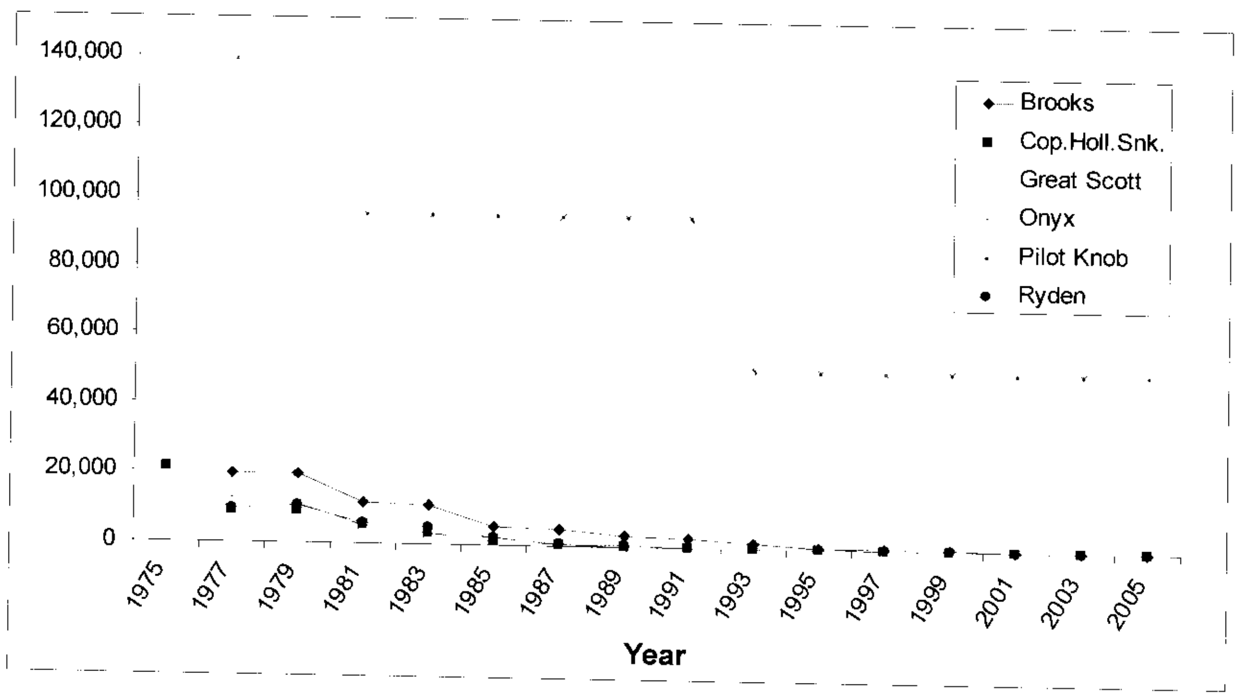


Figure 9. Estimated numbers of Indiana bats in P1A and P1B hibernacula in Missouri (Service, unpublished data, 2006).

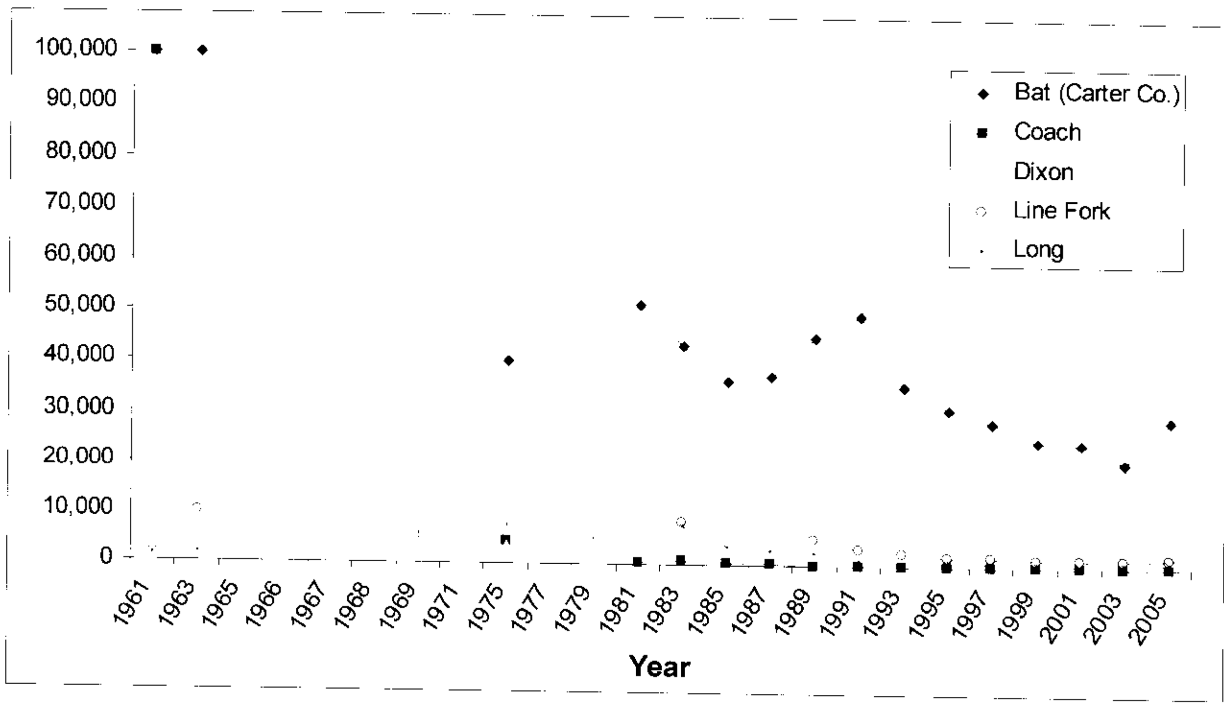


Figure 10. Estimated numbers of Indiana bats in P1A and P1B hibernacula in Kentucky (Service, unpublished data, 2006).

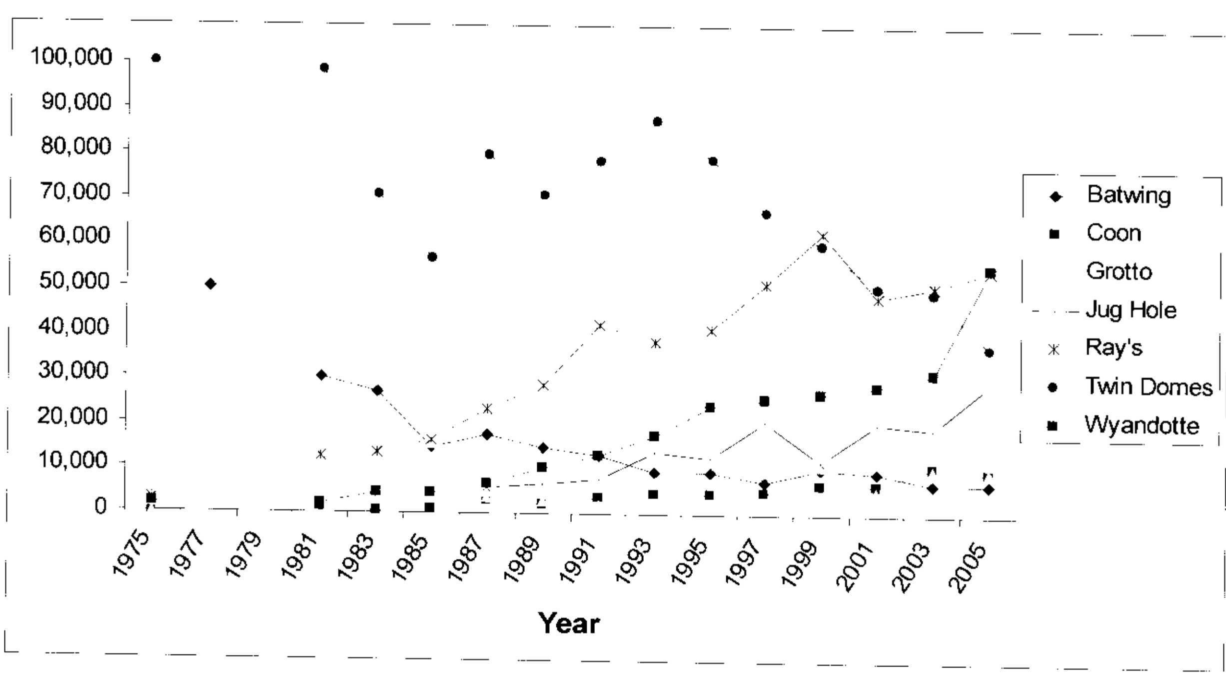


Figure 11. Estimated numbers of Indiana bats in P1A hibernacula in Indiana (Service, unpublished data, 2006).

Population Patterns in States with <100,000 Bats

Among the group of states in which aggregate hibernaculum surveys have never reached 100,000 bats, hibernaculum surveys in Arkansas, Tennessee, and Virginia have consistently declined from 1965 to 2000 (Figure 12). Hibernacula surveys in Illinois, New York, Ohio, and West Virginia are greater in 2000 than in 1965, but trends are not consistent through the period. Thus, the southern tier of states in the species' range shows declines in counts at hibernacula, whereas some states in the northern tier show increasing counts (Table 6). Connecticut and other states with very small populations were too small or too recently discovered to show graphically, and we do not discuss them here.

Apparent Regional Population Trends and Climate Change

It is nearly impossible to consider the geographic positions of states where Indiana bat populations are declining and states where they are stable or increasing without considering the possibility that climate change or other environmental issue is driving some changes in Indiana bat populations. Table 6 reveals a clear division in apparent population trends between states in the northern portion of the Indiana bat's range versus states in the southern portion of the range (Clawson 2002). Steep declines in Kentucky and Missouri hibernacula have largely contributed to the apparent decline in the southern population during the 45-year period from 1960 through the present. In contrast, there apparently has been an overall increase in population in northern states over the same time period. The role of climate change and its effect on temperatures in hibernacula need investigation. Although current data are not sufficient to definitively determine the cause of apparent regional disparities, it appears that both protection of hibernacula and suitable temperature regimes may be key to understanding trends in the overall population and recovery of the species.

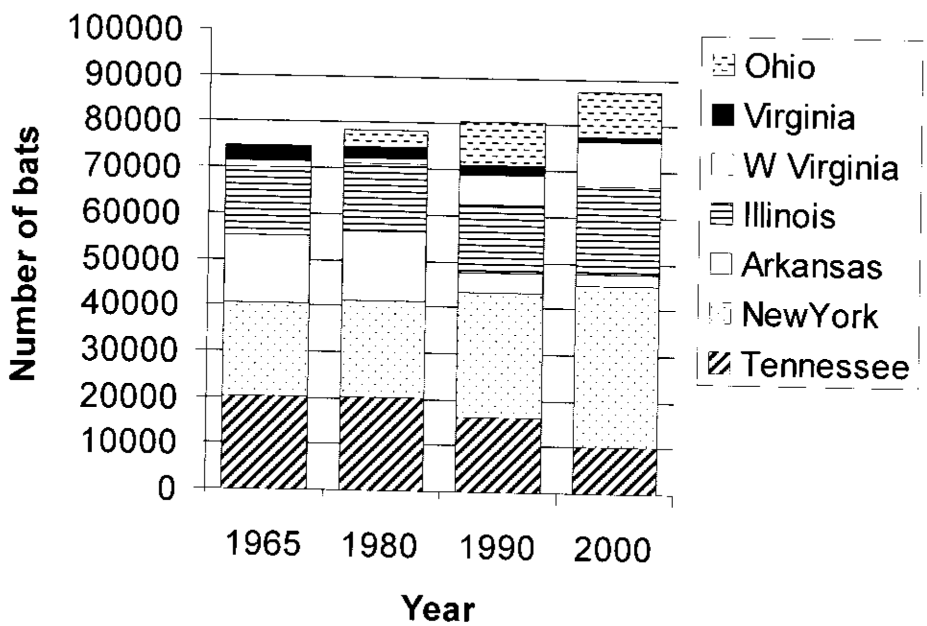


Figure 12. Estimated numbers of Indiana bats in states with counts always below 100,000 bats. For years in which a cave was not yet known, the first survey results for the cave are used. Counts for Alabama, Massachusetts, Pennsylvania, and Vermont were too small to show at this scale (Meretsky, pers. comm., 2006).

Species Recovery

The existing recovery program for the Indiana bat focuses on protection of hibernacula (Service 1983). However, the Service is currently revising the recovery plan for the species, and, based on the species' population trends, threats, biological constraints, ongoing conservation measures, and information needs, the future recovery program for this species is anticipated to include four broad components: 1) rangewide population monitoring at the hibernacula with improvements in census techniques, 2) conservation and management of habitat (hibernacula, swarming, and, to a degree, summer), 3) further research into the requirements of and threats to the species, and 4) public education and outreach. This anticipated approach may increase the focus on summer (i.e., non-hibernation) habitat and proposes the use of Recovery Units. This potential increased focus on summer habitat will likely be based on the principles of conservation biology and research on the importance of addressing both core and peripheral populations in conservation strategies for rare species.

Previous Incidental Take Authorizations

Prior formal consultations involving the Indiana bat have involved a variety of action agencies and project types. These have included:

(a) The Forest Service for activities implemented under various Land and Resource Management Plans on National Forests in the eastern United States;
(b) The Federal Highway Administration for various transportation projects;
(c) The U.S. Army Corps of Engineers (Corps), Federal Energy Regulatory Commission (FERC), Tennessee Valley Authority (TVA) and West Virginia Department of Environmental Protection for various water-related and coal mining projects;
(d) The Department of Defense for operations at several different military installations;
(e) The National Park Service for vegetation management and prescribed burn activities; and
(f) The Fish and Wildlife Service for the management of national wildlife refuges.

Additionally, an incidental take permit has been issued under section 10 of the ESA to an Interagency Taskforce for expansion and related development at the Indianapolis Airport in conjunction with the implementation of a Habitat Conservation Plan (i.e., Six Points Road Interchange HCP).

A summary of the formal consultations completed over the past 10 years is discussed below and provided in Appendix C. Formal consultations on the Indiana bat completed prior to 1998 were omitted from this analysis. This was done, because the incidental take provided prior to 1998 would not be expected to affect the current environmental baseline for the proposed action. This is due to several reasons, including:

(a) The effects of the take occurred in the past and current population and other data are available that give us a better estimate of the environmental baseline;

(b) The authorized take in many biological opinions has been superseded by new biological opinions; and

(c) The relationship of the take in these older biological opinions and the applicability of such take to this biological opinion is tenuous, at best, because of the difficulty in drawing meaningful comparisons and conclusions for projects that may be geographically separated and not similar in their effects on the Indiana bat.

In conducting many of these consultations, Indiana bat presence/absence survey information was unavailable, so the Service often relied on a variety of factors to assist the action agency in determining if Indiana bats could be present. For example, if survey information indicated that Indiana bats were present in nearby areas, the action agency often assumed that Indiana bats were present in the action area and could be subject to incidental take. Further, if the best scientific and commercial data available indicated that an Indiana bat maternity colony could be present, a maternity colony was generally assumed to be present within the action area. This type of conservative approach is generally protective of Indiana bats because it tends to over-estimate the incidental take that may occur. In most such cases, including the proposed action, the Service analyzes the effect of the worst case for incidental take on the proposed action but acknowledges that the worst case is unlikely to occur. The fact that the worst case is unlikely to occur is primarily due to implementation of project-related conservation measures and other actions by the action agency to avoid and/or minimize incidental take.

Previous consultations have addressed impacts to hibernating or swarming bats, known maternity areas, or summer habitat that was assumed occupied. Due to the various life stages affected, the types of conservative assumptions made (as discussed above), and the difficultly in documenting actual take to Indiana bats (as more fully described in each biological opinion and the Incidental Take Statement section of this biological opinion), different methods have been used to estimate the amount of actual and/or potential take. Depending on the consultation, take has been measured either by estimating numbers of affected roost trees, individual bats or maternity colonies, or acres of potentially suitable and/or occupied habitat. However, the Service typically has determined the incidental take measure that was used based on the most accurate and reasonable means available for each site-specific analysis. For example, Appendix C shows that biological opinions have exempted take of Indiana bats on about 6,093,890 acres of potentially occupied habitat. However, new information that became available after the issuance of some of the biological opinions resulted in subsequent "not likely to adversely affect" determinations for activities on about 2,810,094 acres of that total acreage.

In addition, over 552,716 acres have been superseded by new biological opinions, which reduce the total take acreage to 5,491,079 acres range-wide. It is important to subtract out the acreage of incidental take exempted in those biological opinions which are no longer in affect as failure to so would result in potential double counting of the affected acres. An example of this would be the 2004 and 2007 biological opinions for the Daniel Boone National Forest Revised LRMP. Both biological opinions exempt take on 54,350 acres of the forest. However, these are the same acres and failure to subtract out the 2004 incidental take amount (which is superseded by the 2007 revised biological opinion) would result in double counting of the exempted take.

Of the 2,731,080 acres of exempted take currently active, approximately 2,671,031 acres (97.8 percent) are for the U.S. Forest Service, primarily for National Forests' land and resource management plans (LRMP) which are typically valid for a 10-year period. In assessing the acreage of incidental take exempted in these biological opinions, the Service multiplied any per year incidental take issued for an LRMP by 10 (standard effective period for an LRMP) to obtain the total exempted incidental take. This provides a very conservative estimate of exempted incidental take as many of the acres are not geographically distinct from one another and may be double counted.

A good example of this relationship exists for the biological opinion for the Northeast Research Station, where forest stands are harvested multiple times over many years, with each entry being counted as a separate acre of annual take (Service 2005b). Prescribed fire is another activity common on National Forests that while being given an annual acreage of exempted take, this take does not occur on geographically distinct locations each year, rather it often involves replicated burns on the same sites at re-occurring intervals. Therefore, it is difficult, for the reasons discussed previously in this section, to measure the effects of previously authorized take without knowing the details of each biological opinion and closely evaluating the outcome of each consultation. Furthermore, even when we have the details of a biological opinion and are able to evaluate the outcome, we may not be able to draw realistic conclusions regarding the short- and/or long-term effect of any incidental take that has occurred due to the difficulty in monitoring and estimating incidental take of Indiana bats.

For example, several National Forests and one Forest Service Research Station within the range of the Indiana bat have recently completed consultation at the programmatic level. Consultation under section 7 of the ESA is necessary to ensure Federal agency actions are not likely to jeopardize the continued existence of listed species or result in the destruction or modification of critical habitat of such species. The Service concluded that the proposed Forest Plans were unlikely to jeopardize the continued existence of the Indiana bat and issued biological opinions with associated incidental take statements. Although these incidental take statements anticipated the potential take of reproductive females, we have not confirmed the loss of any maternity colonies on a National Forest (NF).

The reasons for the lack of confirmed take of an Indiana bat maternity colony are likely two-fold. First, notwithstanding the conservative assumption that a maternity colony existed in the action area, to date, only fourteen maternity colonies have been actually confirmed to exist on the affected National Forests [i.e., the Daniel Boone NF (7), Hoosier NF (2), Mark Twain NF (1), Monongahela NF (1), Nantahala NF (1), and Shawnee NF (2)]. Surveys to identify and confirm other maternity colonies on the DBNF and other National Forests are ongoing but are not systematic. The National Forests covered by these biological opinions generally conduct some form of Indiana bat population monitoring, including mist net surveys, acoustical monitoring, and hibernacula surveys, as appropriate. These surveys have served to document either: (a) the continued presence of Indiana bats on the forests; (b) the discovery of new maternity colonies on the subject forest; or (c) the continued lack of presence of Indiana bats even though the conservative assumption of potential presence was made. Second, each Forest Plan includes conservation measures (i.e., standards and guidelines) that are protective of Indiana bats and their habitat and the reasonable and prudent measures required by each biological opinion that are applicable to each proposed action. These conservation measures and reasonable and prudent measures are designed to protect all known or newly discovered maternity colonies and to ensure an abundance of suitable Indiana bat habitat on the National Forests.

Incidental take exempted on National Forests is typically monitored and reported by acres of habitat lost, altered, or otherwise affected by a covered project. Based on the anticipated levels of take provided in the biological opinions for National Forest LRMPs, over 95 percent of these acres are affected by varying degrees of temporary loss as a result of timber management activities or prescribed burns (Service 2005a). However, much of this incidental take is take that is assumed to occur and based on a conservative assumption of take. Recording of actual incidental take is difficult, if not impossible, in most situations due to the difficulties in knowing if Indiana bats are actually present within an affected area and whether they are actually harmed, harassed, or killed. The Service or a federal action agency seldom has complete information when initiating a proposed project that could adversely affect Indiana bats and even more seldom is able to document that an actual take has occurred (e.g., a dead Indiana bat is found after implementation of the project).

Additionally, this exempted incidental take does not account for the expected habitat gains (beneficial effects) associated with many of these National Forest projects. Prescribed burning on National Forests operating under programmatic biological opinions is likely to improve foraging and roosting habitat for Indiana bats by increasing the number of snags, creating scattered canopy gaps, opening up the understory, and increasing the available prey base. Many of the management plans include standards that focus on avoiding the cutting of trees that are most likely to contain a maternity colony or a roosting bat. For example, the Monongahela National Forest plan calls for retaining all shagbark hickories with a dbh of five inches or more within its timber harvest areas as well as retaining a minimum number of snags per acre. The habitat gains associated with these measures do not reduce the amount of incidental take exempted but avoid or minimize long-term adverse effects of these actions on the Indiana bat.

In order to ensure that the anticipated level of take is not exceeded, however, each National Forest provides annual reports of the actual level of take that has been implemented. Although reported levels have not been compiled for all the Forests, the actual incidental take used has been less than the level exempted in the biological opinions for many Forests. If incidental take is exceeded, re-initiation of consultation is necessary.

A number of incidental take statements have also been issued to other Federal agencies conducting activities that were determined not likely to jeopardize the Indiana bat. Unlike the incidental take statements issued for the National Forest Land and Resource Management Plans, some of these other Federal agency actions were certain to impact known, occupied habitat for Indiana bats. To minimize the effect of these projects, the Federal action agencies agreed to implement various conservation measures and to implement the reasonable and prudent measures (if any) contained in the respective biological opinions for those projects. Some of the measures implemented in these proposed actions included: (a) seasonal clearing restrictions to avoid disturbing female Indiana bats and young; (b) protection of all known primary and alternate roost trees with appropriate buffers; (c) retention of adequate roosting and foraging habitat to sustain the maternity colony into the future; and (d) permanent protection of areas and habitat enhancement or creation measures to provide future roosting and foraging habitat opportunities. The acreage of exempted take within the last 10 years for non-U.S. Forest Service projects (including other Federal agencies and one HCP) is estimated at 60,049 acres or approximately 0.016 percent of the range.

With the exception of three (Fort Knox, Great Smoky Mountains National Park, and Laxare East and Black Contour Coal Mining projects), none of the biological opinions and associated incidental take statements issued for non-Forest Plan activities anticipated the loss of a maternity colony. The Fort Knox biological opinion [1999] exempted the take of two potential maternity colonies and individual Indiana bats. However, the biological opinion did not specify whether the "take" consisted of loss of the colonies or take in the form of harm and harassment. Surveys in 2004 and 2006 in the immediate area where the take was provided on Fort Knox have shown that at least one maternity colony (and possibly two) exists (Hawkins, et. al 2008). We have no data that tracks the take of maternity colonies for the GSMNP biological opinion, but additional monitoring of the maternity colony following the completion of the 2004 BO for the Laxare East and Black Castle Contour projects, documented a colony much larger than previously anticipated. Additional project modifications subsequent to that discovery resulted in the retention of all known roost trees and protection of some potential foraging areas. Reinitiation of that consultation in 2006 concluded that while the colony would experience adverse effects, the colony should be able to persist through the life of the project.

Required monitoring for three additional consultations (Camp Atterbury, Newport Military Installation, and Indianapolis Airport) has confirmed that the affected colonies persisted through the life of the project and continue to exist today. We recognize that given the philopatric nature of Indiana bats and the long lifespan, the full extent of the anticipated impacts may not yet have occurred. Nonetheless, these monitoring results, and the lack of data to suggest otherwise, indicate that the conservation measures to avoid and minimize the impacts of Federal projects appear to be effective.

In summary, we believe the take exempted to date via section 7 consultation has resulted in temporary effects to Indiana bat habitat and, in limited circumstances, Indiana bat maternity colonies. As many of these consultations necessarily made conservative assumptions about Indiana bat presence, we believe that the number of Indiana bats actually exposed to the environmental impacts of the Federal actions is less than anticipated. Furthermore, pre- and post-project implementation monitoring of several maternity colonies preliminarily suggests that proposed conservation measures, when employed in concert, appear to be effective in minimizing adverse effects on the affected Indiana bats, including maternity colonies, although this information cannot be considered definitive.

For reasons stated above, and not withstanding that range-wide survey results on a two-year interval indicate that the overall population of Indiana bats is increasing, the Service concludes that the aggregate effects of the activities and incidental take covered in previous biological opinions on the Indiana bat have not degraded the overall conservation status (i.e., environmental baseline) of the Indiana bat.

Analysis of the species/critical habitat to be affected

The Indiana bat occurs in suitable summer and winter habitat across the Commonwealth of Kentucky. Historic and current habitat loss, fragmentation and degradation and more recently, disease, have been identified as the primary threats to the species survival. The proposed action will provide a recovery-focused conservation benefit for the Indiana bat while allowing the removal of up to 40,000 acres of known and/or potential habitat for the Indiana bat throughout Kentucky. Based on the likelihood that proposed projects authorized by MOAs may impact Indiana bats or habitat, the Service has determined that the proposed action may affect and is likely to adversely affect the Indiana bat. However, the Service has incorporated a number of conservation efforts as part of the proposed action that will avoid and/or minimize these adverse effects.

While critical habitat (Coach Cave and Bat Cave) occurs within the action area, there are provisions within the Indiana Bat Mitigation Guidance (part of the proposed action) that specifically excludes projects resulting in adverse effects to hibernacula, including the two designated critical habitat area. Additionally, projects with potential impacts to Indiana bats within one mile of and including priority 1 and 2 hibernacula require project-specific evaluation by the Service to determine if it would be appropriate for the Service to enter into a MOA or if adequate conservation measures could be developed that would minimize likely adverse effects. If adverse effects were likely and if those adverse effects could not be sufficiently minimized, the Service would not enter into the MOA. Therefore the proposed action would not adversely modify critical habitat for the Indiana bat.

The Indiana bat is the only species considered in this biological opinion; all other federally listed species in Kentucky that could occur within the action area and within project areas covered by the proposed Conservation Agreements and conservation measures will continue to be covered by the Act. Potential adverse effects to these species will be addressed under the Service's authorities under section 7(a)(2) for federal projects and section 10(a)(1)(B) for private actions, respectively.

ENVIRONMENTAL BASELINE

Under section 7(a)(2) of the Act, when considering the "effects of the action" on federally listed species, the Service is required to take into consideration the environmental baseline. The environmental baseline includes past and ongoing natural factors and the past and present impacts of all Federal, State, or private actions and other activities in the action area (50 CFR 402.02), including Federal actions in the area that have already undergone section 7 consultation, and the impacts of State or private actions that are contemporaneous with the consultation in process. As such, the environmental baseline is "an analysis of the effects of past and ongoing human and natural factors leading to the current status of the species, its habitat (including critical habitat), and ecosystem, within the action area (Service and NMFS 1998, page 4-22)." The environmental baseline is, therefore, a "snapshot" of the species' health at a given point in time, but it does not include the effects of the proposed action. The environmental baseline for this biological opinion considers these "past and ongoing human and natural factors", which includes (a) all projects approved prior to the initiation of formal consultation with the Service, (b) any human and natural factors for which the Service has information that pertains to this consultation, and (c) any other Federal, State, or private actions for which the Service has information that pertains to this consultation.

Previous biological opinions and incidental take statements were discussed in a previous section. Fourteen of these biological opinions include at least a portion of the action area for this biological opinion. Additionally, the Service completes, on average, 700 informal consultations on the Indiana bat each year. These formal and informal consultations are discussed in detail in the "Factors affecting the species' environment within the action area" section below.

Status of the species within the action area

According to the known and suspected range of the Indiana bat (Service 1983), the Indiana bat ranges over an area of about 580,550 square miles in the eastern one-half of the United States. The action area's surface land area is approximately 39,728 square miles, which represents approximately 7 percent of the total range of the species. However, the occupied range of the species within both the known range and the action area is unknown but is likely to be considerably smaller than the known range and action area, respectively, due to the presence of unsuitable habitats within both of those areas and the lack of a uniform distribution for the species. According to our records, the Indiana bat is known from a number of locations within the action area.

The Commonwealth of Kentucky lies near the center of the species range and numerous records of the species occupying summer and winter habitat within Kentucky exist. Occurrences of the species are clearly tied to the availability of the suitable summer and winter habitat. Potential winter habitat is static in the landscape because the caves and other underground features the species relies on for winter habitat do not change locations. However, the species will move from one winter habitat area to another to take advantage of better conditions in hibernacula, to take advantage of new hibernacula (e.g., mines), or to abandoned hibernacula that humans or other factors have altered or disturbed. Populations of Indiana bats that use Kentucky hibernacula have demonstrated population trends that are similar to the range-wide trends, and the species has been observed using hibernacula in each of the karst regions of Kentucky. The 2007 Rangewide Population Estimate for the Indiana bat lists Kentucky's population at 68,668 individuals, which constitutes nearly 15 percent of the total rangewide population (USFWS 2008).

The Service considers the Indiana bat to occur statewide within the Commonwealth of Kentucky. Five caves within Kentucky are identified as Priority 1 hibernacula (defined as harboring current or historic winter populations greater than 10,000 individuals, and not identified as an ecological trap) in the draft, revised Indiana bat recovery plan (USFWS 2007) and two of these are designated as critical habitat (USFWS 2007). Three of the five Priority 1 hibernacula occur within the Mammoth Cave System, located in the Pennyrile region of the state. This includes Coach Cave, which is designated as critical habitat, and Dixon Cave and Long Cave. Cave researchers have suggested that the Mammoth Cave System historically may have provided winter roosts for millions of Indiana bats (Tuttle 1997; Toomey et al. 2002). The two other Priority 1 hibernacula are found in Kentucky's Eastern Coalfields with Bat Cave (designated critical habitat) in the northeast portion of Kentucky and Line Fork Cave in the southeast. Bat Cave and Coach Cave are the only designated critical habitat within the action area.

The expansive karst within much of Kentucky's limestone geology results in numerous caves that historically and currently provide winter habitat for Indiana bats. Over 100 caves (5 P1 and 15 P2 (harboring winter populations less than 10,000 but at least 1,000 individuals)) within the state have historic Indiana bat records and 77 of these caves have extant winter populations. Many of these caves occur within areas of existing conservation ownerships, both private and public. Of particular note are the Daniel Boone National Forest that is managed by the U.S. Forest Service, Mammoth Cave National Park that is managed by the National Park Service, Carter Cave State Resort Park that is managed by the Kentucky Department of Parks, and several parcels along Pine Mountain that are owned by a variety of state agencies.

Indiana bat summer habitat in Kentucky is typically ephemeral and is affected by factors such as land use, forest age structure, and other factors that deal with the quality, location, and availability of potential summer habitat. A 2004 Forest Inventory and Analysis published by the U.S. Forest Service and the Kentucky Division of Forestry (Turner et. al 2004) reported that 12 million acres of Kentucky's land base (47 percent) is forestland. This was a six percent decrease since 1988 but still greater than those acreages reported in 1949 and 1963. Kentucky's forests are most heavily concentrated in the eastern third of the state with the remaining 50 percent distributed across central and western Kentucky. The predominant forest type is oak-hickory, which constitutes 72 percent of the total forestland acreage. The stand-size distribution has seen a steady increase in sawtimber-size stands since 1975 with a seven percent increase in acreage since 1988. In spite of the reduction in total forestland acreage between 1988 and 2004, Kentucky saw an increase in growing-stock volume and the percentage of hardwood board-foot volume for tree grades 1 and 2 for the same period.

These data appear to show that the acreage of potentially available forest habitat for Indiana bats has slightly declined over the past 20 years in Kentucky, but the habitat has become larger and likely more suitable for use by Indiana bats. The number of acres in seedling and poletimber-size stands decreased while acres in sawtimber-sized stands increased. Sawtimber has a minimum diameter at breast height (d.b.h.) of 9 inches, and the greatest growth has been seen in the volume of trees with a d.b.h. of 12 or more inches (Turner et. al 2004). This is important as larger-diameter trees presumably provide thermal advantages and more spaces for more bats to roost. As with most tree-roosting bats (Hayes 2003, Barclay and Kurta, 2007), female Indiana bats probably select trees, especially primary roosts, that are larger in diameter than nearby, apparently suitable, but unoccupied trees (Kurta et al. 1996, 2002; Britzke et al. 2003; Palm 2003; Sparks 2003).

Summer records for the species occur across Kentucky, and 35 maternity colonies have been documented along with a number of locations for solitary males. Like the hibernacula, these known maternity colonies are scattered throughout the state with notable clusters of maternity colonies occurring near the Fort Knox Military Reservation, Mammoth Cave National Park, Daniel Boone National Forest, Pine Mountain, the Eastern Coalfields, and along the Ohio River floodplain in the Pennyrile (Mississippian Plateaus) and Jackson Purchase (Mississippi Embayment) regions of the state. An assessment of available forested habitat surrounding 32 known maternity records (USFWS 2008, unpublished data) yielded varied results with a steady gradient ranging from 16.6 to 94.3 percent forest within a 2.5 mile (roost trees) or 5.0 mile (mist-net sites) radius of the record (See Figure 12 below). Percent forest cover was determined by evaluating the 2001 National Land Cover Dataset (Harp et al. 2006) for the 2.5- or 5-mile buffer (as appropriate) around each determined maternity area. Forest cover includes deciduous forest, evergreen/coniferous forest, mixed forest, and forested wetlands.

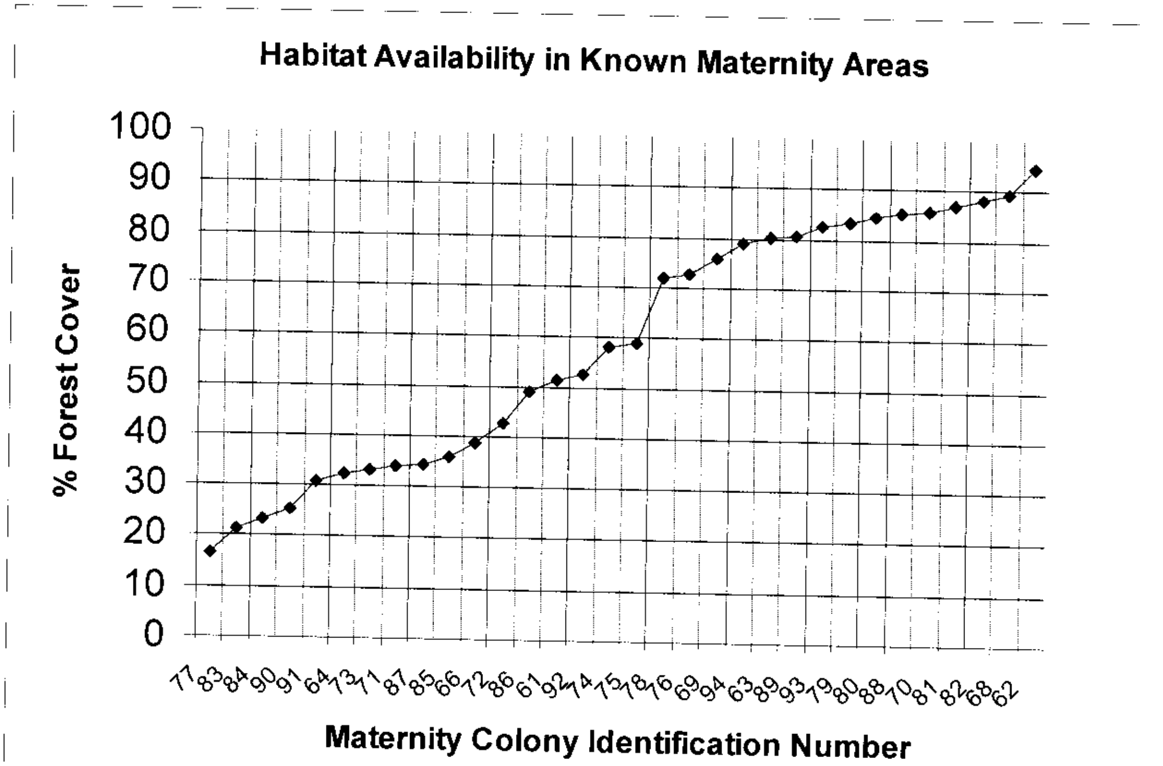


Figure 13. Assessment of available forest habitat surrounding 32 known maternity colonies (Service 2008, unpublished data).

In general, the habitat availability at known maternity sites appears to reflect the overall distribution of forest cover for the state. The figure below (Turner et. al 2004) shows the percent of land in forest, by county, for Kentucky as of 2004. Outside of the maternity colonies found on Fort Knox Military Reservation and Mammoth Cave National Park, those maternity areas with an availability of at least 80 percent forest cover occur in the eastern third of the state where forestland cover frequently exceeds 75 percent. Similarly, in the western third of the state where percent of land in forest is typically below 50 percent, the availability of forested habitat for known Indiana bat maternity colonies is also below 50 percent. Based on the wide distribution and availability of summer habitat across Kentucky, Indiana bats can be expected to occur at any location where its habitat needs can be met.

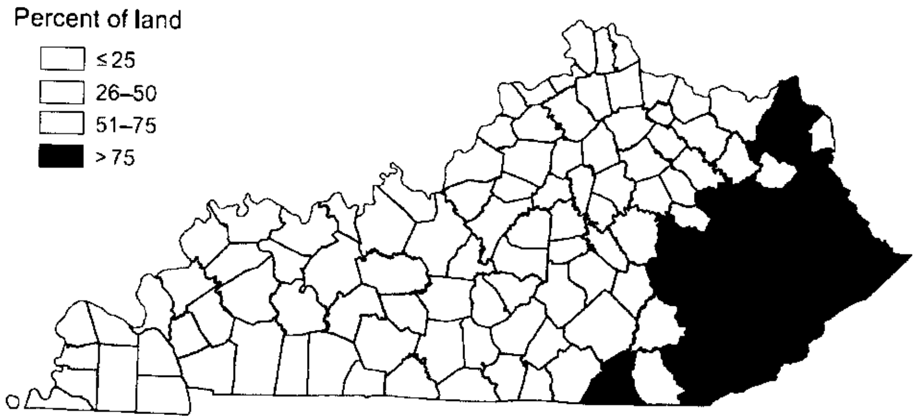


Figure 14. Percent of land in forest by county (Turner et. al 2004).

Factors affecting species environment within the action area

It is difficult to identify specific factors affecting the species environment within the action area, because the action area has been defined as the entire state of Kentucky and this biological opinion is based on analysis at a programmatic level rather than a specific project level. However, we are able to determine that there are a number of current and long-term land use and demographic trends could affect the Indiana bat within the action area. As a result of these trends, an increase in conversion of forested land to agricultural and/or residential development can be expected to further fragment and eliminate forested blocks of habitat that could be used by the Indiana bat. The extent to which this effect will be offset by new forest regeneration is unknown. In addition, natural factors such as, but not limited to, loss and/or lack of suitable maternity roost trees, reduction in the prey base, or loss and/or reduction in foraging acreage due to invasive species could negatively affect the Indiana bat. As previously discussed in the status of the species section, an unidentified ailment (i.e., "white-nose syndrome")is resulting in high percentage bat mortality at hibernacula in the Northeast.

Within the Northeast Recovery Unit (USFWS 2007), specifically New York, Vermont, Connecticut and Massachusetts, biologists and/or cavers have documented a mysterious illness that is causing widespread mortality of the wintering bat populations in the affected hibernacula. This illness has been dubbed "white-nose syndrome" due to the white fungus found on the noses of many of the affected bats. At this time, researchers do not know what is causing the illness or how it is spread. Affected species include *Myotis lucifugus* (little brown bat), *Myotis sodalis* (Indiana bat), *Myotis leibi* (eastern small-footed bat, *Myotis septentrionalis* (northern long-eared bat), and *Pipistrellus subflavus* (eastern pipestrelle bat). Kentucky populations of the Indiana bat fall within the Midwest Recovery Unit (USFWS 2007) and with the exception of Jamesville Quarry Cave, have distinct genetic differences from the northeastern populations found in New York (Vonhof, pers. comm., 2006). This indicates that these are discrete population groups. Symptoms associated with white-nose syndrome have not been observed in Kentucky and may not affect Kentucky's population of Indiana bats. With regard to the Jamesville Quarry Cave, as of 23 January 2008, inspections of hibernating bats showed no evidence of white-nose syndrome (Hicks 2008).

Numerous land use activities that affect the Indiana bat and that likely occur within the action area include: timber harvest, ATV recreational use, recreational use of caves, underground and surface coal mining, gas production, and development associated with road, residential, industrial, and agricultural development and related activities. These private actions are likely to occur within the action area, but the Service is unaware of any quantifiable information relating to the extent of private timber harvests within the action area, the amount of use of off-highway vehicles within the action area, or the amount of recreational use of caves within the action area. Similarly, the Service does not have any information on the amount or types of residential, industrial, or agricultural development that have or will occur within the action area. Therefore, the Service is unable to make any determinations or conduct any meaningful analysis of how these actions may or may not adversely and/or beneficially affect the Indiana bat. All we can say is that it is possible that these activities, when they occur, may have direct, indirect, and/or cumulative effects on Indiana bats and their habitat in certain situations (e.g., A private timber harvest during summer months within an unknown maternity colony may cause adverse effects to that maternity colony.). In stating this, however, we can only speculate as to the extent or severity of those effects, if any.

Actions with a federal nexus are routinely evaluated by the Service for potential impacts to federally listed species. As the Indiana bat is considered to occur statewide, all projects reviewed by the Service are evaluated for the potential to adversely affect the Indiana bat. Primary projects types reviewed by the Service in Kentucky include coal mining, transmission/pipeline, communication (e.g. cell towers), development (commercial, residential, institutional) and transportation. Examining data from 2004-2007, the Kentucky Field Office (KFO) estimates that it reviews nearly 700 projects annually. Nearly all of these projects are either covered under an existing biological opinion or result in a determination of not likely to adversely affect the Indiana bat.

For those projects in Kentucky that were likely to adversely affect the Indiana bat, the Service has issued six programmatic and eight project-specific biological opinions exempting incidental take of the Indiana bat. The programmatic opinions cover surface coal mining activities, implementation of the Daniel Boone National Forest's land and resource management plan (four iterations) and minor road construction projects. The project-specific biological opinions are for the Fort Knox Military Reservation (3), Daniel Boone National Forest (1), Federal Highway Administration (2), Mammoth Cave National Park (1) and Army Corps of Engineers (1). The amount of incidental take exempted by these opinions is shown in Appendix C and further discussed in the Previous Incidental Take Authorization portion of the Status Of The Species section. The following is a brief discussion of those impacts covered under the existing programmatic biological opinions that are active in Kentucky.

The Kentucky Department of Natural Resources issues surface and sub-surface coal mining permits. Surface coal mining occurs in the Eastern and Western Coalfields of the Commonwealth. As of 2006, there were 1,764,200 acres in Kentucky under coal mining permits (OSMRE 2006). This includes both surface and subsurface acres. The Service is provided an opportunity to review all Kentucky Department of Natural Resources mining permit applications, and all such applications and issued permits are subject to the 1996 Programmatic Biological Opinion for Surface Coal Mining Regulatory Programs Under the Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87) (USFWS 1996). Therefore, any potential adverse effects that may result from coal mining activities within the action area have been accounted for through a separate formal consultation with the Service and, if adverse effects are likely to occur, the subsequent implementation of an Indiana bat protection and enhancement plan by the mining permittee to avoid and minimize impacts to Indiana bats as required by the 1996 biological opinion.

The Daniel Boone National Forest (DBNF) manages approximately 700,000 acres within its proclamation boundary. This accounts for approximately 2.8 percent of land within the action area and not more than 6 percent of Kentucky's forestlands. As per the Terms and Conditions of the 2007 revised biological opinion on the implementation of the revised Land and Resource Management Plan (USFWS 2007), the DBNF must monitor and report annually to the Service the number of acres that are subjected to green tree harvests, salvage/sanitation harvests, and prescribed burns during the summer roosting season of the Indiana bat (April 1 to September 15). The DBNF's 2007 incidental take report showed that only 8 percent of annually authorized take (in the form of habitat alternation) actually occurred; previous incidental take reports showed 16 percent, 21 percent, and less than 1 percent. An analysis of exempted take on national forestlands is more thoroughly discussed in the Previous Incidental Take Authorization portion of the Status Of The Species section.

The Kentucky Transportation Cabinet (KYTC) is responsible for the construction and maintenance of state and federal roads across the Commonwealth. As the Indiana bat has potential to occur statewide, projects implemented by KYTC have the potential for adverse effects. That does not mean, however, that these projects actually resulted in adverse effects to Indiana bats. In many cases, surveys were conducted and/or the habitat was removed during the winter months when Indiana bats were not present. In a programmatic biological opinion issued to the Federal Highway Administration, the Service has exempted incidental take of the Indiana bat for minor, Federal road construction projects in the Commonwealth where KYTC is likely to adversely affect the Indiana bat.

For fiscal years 2006 and 2007, incidental take in the form of habitat removal was exempted up to 600 acres in 2006 and 720 acres in 2007. Of these 1320 acres exempted, only 176 acres (or 13 percent) were actually removed. For those projects not qualifying for the programmatic biological opinion or those constructed prior to its issuance, we are unable to determine the acreage of any past or future habitat losses as KYTC does not keep such records. However, most of these projects are subject to independent section 7 consultations, because they typically have a federal nexus (e.g., Federal Highway Administration funding or a Clean Water Act section 404 permit from the U.S. Army Corps of Engineers). As a result, it is unlikely that any adverse effects would result from these projects without first undergoing the Service's review and consultation. Further discussion on the factors affecting the species environment within the action area is provided in the Status of the Species/Critical Habitat (Threats) portion of this biological opinion.

EFFECTS OF THE ACTION

Factors to be considered

This section includes an analysis of the direct and indirect effects of the proposed action on the species and/or critical habitat and its interrelated and interdependent activities. While analyzing direct and indirect effects of the proposed action, the Service considered the following factors:

- Proximity of the action – We describe known species locations and designated critical habitat in relation to the action area and proposed action;
- Distribution – We describe where the proposed action will occur and the likely impacts of the activities;
- Timing – We describe the likely effects in relation to sensitive periods of the species' lifecycle;
- Nature of the effects – We describe how the effects of the action may be manifested in elements of a species' lifecycle, population size or variability, or distribution, and how individual animals may be affected;
- Duration – We describe whether the effects are short-term, long-term, or permanent;
- Disturbance frequency – We describe how the proposed action will be implemented in terms of the number of events per unit of time;
- Disturbance intensity – We describe the effect of the disturbance on a population or species; and
- Disturbance severity – We describe how long we expect the adverse effects to persist and how long it would it take a population to recover.

Proximity of the action: The Commonwealth of Kentucky lies near the center of the species range and numerous records exist documenting that the species occupies summer and winter habitat within Kentucky. Winter habitat is generally limited to the karst regions of Kentucky where suitable caves can be used for hibernacula, but summer habitat is widely distributed throughout Kentucky where suitable forested habitat exists. Two designated critical habitat areas are located in Kentucky – Coach Cave in Edmonson County and Bat Cave in Carter County. No summer habitat has been designated as critical habitat in Kentucky or elsewhere within the range of the species.

The Service's participation in Conservation Agreements will result in two primary effects: (1) protection (through acquisition or deed restriction) and management of Indiana bat habitat throughout the bat's range in the Commonwealth as part of the implementation of the Guidance (i.e., the positive effects) and (2) the destruction and/or degradation of forested Indiana bat habitat as a result of project-specific impacts (i.e., the detrimental impacts). The positive effects are indirect effects intended to minimize and mitigate the detrimental impacts of qualified project impacts covered by Conservation Agreements. These positive effects are expected to provide a variety of results including, but not necessarily limited to, (a) the protection of known summer and winter Indiana bat habitat, (b) the management and conservation of known summer and winter Indiana bat habitat, and (c) the protection and/or restoration of suitable summer and winter Indiana bat habitat that is currently not occupied by the species.

While the detrimental impacts are likely to occur across the Commonwealth, the Guidance specifically excludes impacts to hibernacula and requires project-specific evaluation of projects that may impact areas indentified by the Service as sensitive or that impact more than 250 acres of known or potential habitat for the Indiana bat. The areas identified as sensitive include: the one mile radius surrounding priority one and two hibernacula (which would include both designated critical habitat areas in Kentucky), the one-half mile radius surrounding priority three and four hibernacula, impacts within ten miles of any hibernacula identified as having less than 60 percent forest cover, and impacts within any known maternity areas with less than 45 percent forest cover. Additionally, project-specific evaluations will be required for proposed impacts within known maternity areas during the period when the young are non-volant. The exclusions described above and the requirement for project-specific reviews under certain circumstances serve to minimize the potential for adverse effects by projects implementing the Guidance and to ensure that improvement to Indiana bat conservation and recovery can be realized to mitigate any losses that occur.

Distribution: The effects of the proposed action will vary depending on the location of the Cooperator's qualified project-specific impacts and the selected avoidance, minimization and mitigation measure(s). Impacts associated with the implemented mitigation will typically occur in areas where Indiana bats are known or are expected to occur while those impacts associated with project-specific impacts will typically occur within the project footprint. However, it is certain that the proposed action, project-specific impacts and mitigation measures approved under the proposed action, will occur within the geopolitical boundaries of the Commonwealth of Kentucky. The positive effects associated with the selected minimization and mitigation measures will typically occur within the Recovery and Mitigation Focus Area (RMFA) closest to the impact site. The convergence of the minimization and mitigation efforts from one or more projects will maximize the recovery-focused conservation benefits for the Indiana bat in Kentucky.

Timing: Adverse effects related to the timing of the proposed action cannot be quantified, because the projects which might trigger implementation of the Guidance are driven by external factors (such as market forces) that cannot be predicted. However, we expect the impacts will occur during the following sensitive periods: the maternity period (mid-April through mid-August, see Status of the Species section) and fall swarming (late-August through mid-November). Detrimental impacts during these periods are expected to result in harm and harassment due to the removal of roost trees that may cause mortality of adults and young, degradation of habitat, alteration of travel and foraging areas, and other indeterminable habitat-related effects. During the non-volant period (June 1 through July 31) for juvenile Indiana bats, habitat removal in known maternity areas will require project specific review and may require additional minimization and mitigation measures.

During the spring staging period (early to mid-April), Indiana bats are still concentrated around the hibernacula. The bats have just awoken from hibernation and have depleted fat reserves. This is also the period when Indiana bats are preparing to migrate to their summer roosting areas. For females, this migration may be hundreds of miles (see Status of the Species section).

Impacts to Indiana bats during this sensitive period will be minimized by placing a one-mile buffer around all priority one and two hibernacula and a one half-mile buffer around all priority three and four hibernacula. Staging is not expected to occur beyond this buffer and negative impacts within this buffer will require project-specific under the proposed action to determine the appropriateness of the mitigation and minimization measures.

Indiana bats are most sensitive to disturbance during hibernation (mid-November through March). Adverse effects to Indiana bats covered under Conservation Agreements will not authorize impacts to hibernacula or hibernating bats. So impacts during this sensitive period are avoided and/or minimized, except for removal of some potential and known forested summer and swarming habitat during the hibernation period. The winter removal of forested summer and swarming habitat may have an indirect adverse effect on the Indiana bats that use those habitats. However, the resulting harm and harassment (e.g., alteration of normal behavior patterns) will not result in the mortality of any Indiana bats but may degrade its habitat through the loss of potential roost trees, the alteration of travel and foraging areas, and other indeterminable habitat-related effects.

Nature of the Effect: It is likely that the proposed action, resulting in project-specific impacts and associated minimization and mitigation measures, will have a variety of effects on individual Indiana bats, maternity colonies and wintering populations. In particular, the project-specific impacts are expected to (a) eliminate occupied and potential foraging and roosting habitat through removal and/or conversion of that habitat (e.g., removal of maternity roost trees, summer roost trees, and foraging habitat); (b) alter habitat (e.g., fragmentation of foraging habitat, modification of travel corridors); (c) result in alteration and/or modification of normal Indiana bat behaviors (e.g., reproduction effects, foraging effects, and sheltering behaviors); and (d) potentially cause the mortality and/or injury of individual bats. Additionally, the minimization and mitigation measures associated with the project-specific impacts are expected to result in (a) protection of previously unprotect winter habitat, (b) protection of maternity habitat, (c) protection of swarming habitat, and (d) funding of priority Indiana bat research and monitoring needs. Critical habitat for the Indiana bat will not be impacted by the proposed action and primary constituent elements of Indiana bat critical habitat area have not been defined.

Duration: The positive effects of the proposed action will be permanent, as will most of the adverse effects associated with each qualified project-specific impacts as defined within a Conservation Agreement. We expect protected lands will be protected and managed in perpetuity, and we expect that most impacts will also result in the permanent loss of forested Indiana bat habitat. However, there may be qualified project-specific impacts that only temporarily impact forested Indiana bat habitat. These would include forest management projects where forest stands are thinned or allowed to regenerate over time.

Disturbance Frequency: The frequency at which qualified project-specific impacts are implemented and associated impacts occur cannot be accurately determined. While the disturbance frequency cannot be determined, the amount of habitat that we have proposed will be impacted on an annual basis is limited to 8,000 acres. Additionally, individual projects can only disturb up to 250 acres of suitable habitat. Based on these limits, and assuming that these maximum limits actually occur, there will be as few as 32 projects per year. As individual project acreages decline, the number of disturbances per year can increase. The disturbance frequency cannot be predicted with accuracy because the Service does not control the implementation of qualified project-specific impacts.

Disturbance Intensity: The intensity of the disturbance is difficult to estimate, because we do not know how much of the habitat that may be removed is occupied and the density of Indiana bats utilizing these areas. While the proposed action will result in some incidental take of Indiana bats, previous discussions (see Status of the Species and Environmental Baseline) indicate the likelihood that bats will adjust to qualified project-specific impacts and occupy similar habitats within the action area without significant reductions in population size. The proposed action will, at a maximum, affect less than one half a percent of the potential habitat available within the action area and no more that 0.06 percent of potentially available habitat in a given year.

Disturbance Severity: The Service has deliberately restricted those qualified project-specific impacts that can be implemented under the executed Conservation Agreements in order to limit the severity of disturbance to the Indiana bat. This is accomplished by excluding projects that impact hibernacula and by requiring project-specific evaluations for those impacts that exceed 250 acres of impact, occur in known maternity areas during the period when young are non-volant (June 1- July 31), or occur in sensitive areas. The areas identified as sensitive include: the one mile radius surrounding priority one and two hibernacula, the one half mile radius surrounding priority three and four hibernacula, impacts within ten miles of any hibernacula identified as having less than 60 percent forest cover and impacts within any known maternity areas with less than 45 percent forest cover. These minimization measures reduce the disturbance severity of the proposed by identifying disturbances that would have the most adverse affect and either excluding them from this process or requiring project-specific evaluations of the proposed impacts. For those projects that are accepted for inclusion in the proposed action but required project-specific reviews, additional minimization and mitigation measures may be required, as appropriate, in the Conservation Agreement.

In most cases, it is unlikely that a project will result in the loss of an individual bat; most adverse effects will be the result of a loss of roost trees, foraging areas and/or travel corridors. In these situations, it is anticipated that based on the wide availability of suitable habitat within the action area, the affected bats will be able to shift to other primary and secondary or alternate roost trees. Under a worst-case scenario, a primary maternity roost tree would be felled during a period when the pups were non-volant. Since it is unlikely that an entire maternity colony would be roosting in the same tree and a majority of adults in the affected tree would be able to fly out, it is unlikely that the entire maternity colony would be lost. Belwood (2002) anecdotally describes the effects of such a worst-case scenario as summarized below.

On July 8, 1996, in a residential suburb of Cincinnati, Ohio, private landowners felled a dead maple tree a risk of falling on their house. After felling the tree, the landowners notice 34 Indiana bats that had scattered across the yard, including one dead lactating female and 33 non-volant young (16 males and 17 females), three of which were dead. The surviving young were placed in either a man-made bat house near the fallen tree or under loose bark on the downed maple. The placement of young was completed at dark and almost immediately adult bats, presumably Indiana bats, began circling over the downed tree and bat house. The site was revisited the following morning and two dead juveniles were found in the bat house. A thorough examination of the bat house, the felled maple tree (all loose bark was removed) and the surrounding yard revealed no other carcasses indicating that the adult females returned for the non-volant young. Reproductive females were caught in the vicinity a few weeks later suggesting that the colony relocated nearby after this catastrophic event (Belwood 2002).

Although this description is anecdotal, Belwood (2002) provides some important information that can be used to evaluate the effects of such a catastrophic event: (1) the majority of the bats (60 out of presumably 66) survived the felling of a primary maternity roost during a period of non-volancy in the young; (2) the adults and young responded differently, the adults flew out and the young scattered on the ground after the felling, which allowed the adults to retrieve and relocate the non-volant young; and (3) the colony appeared to have persisted in the area, with what is assumed to be the same colony being discovered in a new roost tree only 20 meters from the original roost tree just five weeks after the initial discovery. This is important as such a catastrophe is considered to be potentially the most severe disturbance that may occur as a result of the proposed action. Based on this information, the recovery rate for the affected maternity colony would be relatively short, perhaps 2-3 maternity seasons (Service 2006b) and is unlikely to have a measurable effect on the population as a whole.

Analyses for effects of the action

Private and Federal entities who enter into Conservation Agreements with the Service will be required to implement the minimization and mitigation measures described in the Guidance. These measures will be part of the effects that projects have on Indiana bats and their habitat. Consequently, the positive effects of implementing the Guidance must be weighed against the anticipated impacts associated with each project-specific impact that chooses to implement the Guidance. Generally speaking, if the positive effects outweigh the adverse effects, a recovery-focused conservation benefit can be expected. However, in some cases, recovery-focused conservation benefits may not be realized immediately, so any assessment must also consider the biological value of both the impacted and conserved habitat over time (e.g., temporal effects). In some instances, implementation of the Guidelines may result in a short-term loss of conservation value, but ultimately result in a net long-term gain in conservation value for the species.

Beneficial Effects

Beneficial effects are those effects of an action that are wholly positive, without any adverse effect, on a listed species or designated critical habitat. While the Service anticipates that the proposed action will indirectly provide a recovery-focused conservation benefit to the Indiana bat; this action cannot be considered wholly beneficial. Cooperators entering into Conservation Agreements with the Service will be implementing avoidance, minimization, and mitigation measures in response to adverse affects to the Indiana bat caused by qualifying projects. An example of this would be the fee-simple purchase and protection of a known Indiana bat hibernaculum in order to minimize and mitigate the adverse affects to the Indiana bat associated with the clearing of suitable swarming habitat.

Direct Effects

Directs effects are the direct or immediate effects of the agency action on the species or its habitat. Direct effects include the effects of any interrelated or interdependent actions. Interrelated actions are part of the proposed action and depend on the proposed action for justification. Interdependent actions are those actions that have no independent utility apart from the action under consultation. Future federal actions that are not a direct effect of the action under consideration are not considered in this biological opinion.

Because the proposed action has been defined as the Service's participation in and approval of voluntary Conservation Agreements with Federal and non-Federal entities, there are no direct effects of this action on the Indiana bat, because the act of entering into a Conservation Agreement does not directly cause adverse effects to Indiana bats. The project-specific impacts implemented by the Service's Cooperators under voluntary Conservation Agreements would occur with or without the opportunity to enter into the Conservation Agreements with the Service. Where there is an existing federal nexus, consultation with the Service is available under section 7 and those actions that would occur without a federal nexus could seek an incidental take permit under section 10 of the ESA from the Service but would not be required to do so. Similarly, federal or non-federal Cooperators could choose to implement the minimization and mitigation measures set out in the Guidance without entering into a Conservation Agreement with the Service.

Although it is not a direct effect, the Service's participation in these Conservation Agreements will provide recovery-focused conservation benefits (through the implementation of avoidance, minimization, and mitigation measures) for the Indiana bat while allowing the removal of up to 40,000 acres of known and/or potential habitat throughout the Commonwealth of Kentucky over a five-year period. No more than 8,000 acres may be removed in a given calendar year. The effects of habitat removal and implementation of minimization and mitigation measures are indirect from the proposed action, because they occur later in time from the approval of the voluntary Conservation Agreement and are considered in the following section.

Indirect Effects

Indirect effects are caused by or result from the proposed action, are later in time and reasonably certain to occur. The Service has identified several likely indirect effects of the proposed action. These indirect effects relate to the adverse affects to Indiana bats from qualified project-specific impacts as identified in the Conservation Agreements and recovery-focused conservation benefits that result from the implementation of minimization and mitigation measures as required by the Conservation Agreements. These indirect effects are discussed in greater detail in the following sections and in the text of previous sections.

Habitat Removal - General

The Conservation Agreements entered into by the Service under the proposed action would allow the loss, degradation and fragmentation of up to 40,000 acres of known and potential Indiana bat habitat over a five year period. These 40,000 acres represent approximately 0.3 percent of the 12 million acres of forestland in Kentucky. No more than 8,000 acres of habitat loss will be authorized under this biological opinion in a given year. Under the Guidance, which must be followed by entities entering into these Conservation Agreements with the Service, a single project-specific impact may impact up to 250 acres. Project-specific impacts affecting more than 250 acres will require individual evaluations by the Service before the project(s) can be covered under a Conservation Agreement.

Qualified project-specific impacts implemented under these Conservation Agreements have the potential to cause adverse effects on Indiana bats by altering their necessary summer habitat characteristics. During the summer roosting season, Indiana bats, especially females, often roost in live, damaged, and/or dead trees with naturally exfoliating bark (e.g., oaks, elms, and hickories). With regard to the damaged and/or dead trees, it is the physical condition of the tree, not the tree species, which make these trees suitable for Indiana bat roosting. Stochastic events, such as lightning strikes or pest outbreaks, and other disturbances create and distribute trees in this condition within forested tracts and across the available forestlands in Kentucky.

Regardless of how the habitat is removed, Indiana bats in a maternity colony or individually-roosting Indiana bats (i.e., non-reproductive females and males) could be harmed, harassed, or killed as a result of the tree or branch striking the ground or due to being dislodged from the roost tree (i.e., falling to the ground). Although any volant Indiana bat can likely fly away from a tree prior to or during the direct impact, females may be less likely to leave if they have flightless (i.e., non-volant) young present (usually between June 1 and July 31). Flightless young would not be capable of leaving their roost tree and, therefore, may be harmed, harassed, and/or killed. Once the young bats become volant, their likelihood of surviving the removal of the habitat in which they are roosting likely increases.

Another adverse effect that may occur is the disturbance of a roosting bat that causes the bat to flush from the roost tree during daylight or otherwise modify its normal behavior. The noise and vibration generated from habitat removal will likely occur during daylight hours and at variable distances from occupied roost trees. The novelty and intensity of these perturbations will likely dictate the range of Indiana bat responses to them. For instance, Indiana bats roosting at some distance from the disturbance or habitat removal may initially be startled by unusual noises in the distance but may habituate to the noises if they are of low volume or if some distance is maintained between the roost and the disturbance. At closer distances and increasing noise or vibration levels, Indiana bats may be startled to the point of fleeing from their roosts, which may increase the risks of injury, mortality, predation, abandonment of non-volant young, and other adverse effects. Non-volant young that are abandoned permanently are unlikely to survive.

Alternatively, Indiana bats that roost within or close to habitat removal areas will likely be subjected to increased levels of disturbance frequency and intensity. As a result, Indiana bats displaced by these activities may be forced to use different roost trees. These roost trees may be more or less suitable (e.g., easily accessed by predators) than the roosts from which they were displaced. Habitat conditions surrounding the disturbance area will likely determine the quality of any alternative roosts that are used.

We also anticipate that Indiana bats may change roosting areas by temporarily or permanently abandoning their current roosts and seeking roosts that are further away from the active disturbance area. This has been supported by a few accounts in the literature. For example, Callahan (1993) noted that the likely cause of the bats in his study area abandoning a primary roost tree was disturbance from a bulldozer clearing brush adjacent to the tree, and female bats in Illinois used roosts at least 1640 ft (500 m) from paved roadways (Garner and Gardener 1992). However, there are also studies that show that some amount of shifting roost tree usage is a normal behavior (Kurta et al. 2002, Kurta 2005, Barclay and Kurta 2007, Foster et al. 2007).

Some literature has reported that Indiana bats used roosts close to significant disturbance. In one study near I-70 and the Indianapolis Airport, a primary maternity roost was located 1,970 ft (0.6 km) south of I-70. This primary maternity roost was not abandoned despite constant noise from the Interstate and airport runways. However, the roost's proximity to I-70 may be related to a general lack of suitable roosting habitat in the vicinity and due to the fact that the noise levels from the airport were not novel to the bats (i.e., the bats had apparently habituated to the noise) (Service 2002). Therefore, we cannot say definitively that Indiana bats will shift or abandon their roosts as a result of any adjacent disturbances.

The Indiana bat does not appear to be particularly sensitive to change within its summer and swarming habitats (See Previous Incidental Take Authorizations and Status of the Species in the Action Area sections above). Most Indiana bat maternity colonies occur in disturbed landscapes and forest habitat areas of low to moderate canopy cover, and a preponderance of the data on summer roosting and foraging habitat show that Indiana bats appear to select roost trees based on proximity to natural or anthropogenic disturbances. Some examples of this include, among others, (a) the selection of primary roost trees that are in canopy openings that will provide solar exposure and radiant heat for maternity colonies, (b) the preferential use of roost trees within various types of timber harvests in many areas, and (c) the use of edges and tree corridors for travel and foraging.

In addition to habitat loss, project-specific impacts authorized under the proposed action may result in a decrease in the quality of habitat remaining within the action area. Factors that may lead to a loss in the quality of the remaining habitat include increased habitat fragmentation, loss of foraging areas and travel corridors, and the degradation of these habitats. Over time, it is expected that fragmentation of habitat in the action area will increase as cumulative effects continue to occur.

Habitat Removal – Summer

Summer habitat for the Indiana bat occurs throughout Kentucky and qualified project-specific impacts implemented under the proposed action may occur anywhere within the action area, with the exception of those areas specifically excluded in the Guidance. Impacts to summer habitat may occur during periods of occupation by the Indiana bat (April 1 through October 14) or during periods when the habitat is unoccupied. In most cases, the death of an individual bat from summer habitat removal would require that the bat be present in the specific tree being removed at the time it is felled. Additionally, the bat must be struck either during the felling or the subsequent fall. If not struck during the felling, volant Indiana bats would have the opportunity to escape the falling tree. The probability that all of these factors would occur, combined with the minimization measure requiring project-specific analysis during the non-volant period, results in a correspondingly low probability of death of an individual Indiana bat.

The more common adverse effect associated with the removal of summer habitat will be the harassment of bats that are disturbed from their roost(s), abandoning higher quality habitat in order to distance themselves from the disturbance, and loss of suitable roosting, foraging, and/or travel habitat. This harassment is not limited to the periods when the bats are present at the impact sites. The loss of suitable summer habitat during the period of inoccupation (while the bats are hibernating) cannot be discounted for this action. Indiana bats returning to summer roosting areas have low fat reserves after hibernation and migration. Additionally, the many females are pregnant which increases their energy needs. Habitat removal results in increased habitat fragmentation, loss of foraging areas and travel corridors. The degradation of these habitats will harass Indiana bats that are presumably stressed already. The proposed action will authorize the loss of up to 40,000 acres of potentially suitable and known Indiana bat habitat. Therefore, we believe this acreage, combined with the cumulative effects of future State, tribal, local and private actions, may adversely affect the Indiana bat even if the removal occurs when the bat is not physically present.

Habitat Removal - Maternity

The Service analyzed the available forest habitat data for known maternity colonies in Kentucky and found that maternity colonies in Kentucky occur in areas with percent forest cover ranging from 16.6 percent to 94.3 percent (Figure 13). While the maternity colonies appeared to occur in the habitat is available in their range, the Service has no mechanism or available data for determining the fitness of a given maternity colony relative to the amount of habitat available to each colony. In order to be protective of the Indiana bat, project-specific impacts occurring in maternity areas with less than 45 percent cover will require project-specific evaluation by the Service before the project(s) can be covered under a Conservation Agreement.

The maternity area for a given colony is evaluated as a 2.5-mile radius from known roost trees or as a 5-mile radius from the capture site, if roost trees are unknown. For a maternity areas defined by the 2.5-mile radius with at least 45 percent available forest cover, the 250-acre project-specific limit for impacts to Indiana bat habitat will result in no more than a 4.4 percent loss of potentially available habitat. If a maternity area is defined by a larger area, has a higher percent cover, and/or the impact is less than 250 acres, those impacts to the potentially available habitat are further reduced. Those maternity colonies with less than 45 percent forest cover will receive extra protection from the Service by the requirement for project-specific evaluations of proposed impacts. This project-specific review will allow the Service to determine if minimization and mitigation measures are appropriate for the proposed impacts and, if minimization and mitigation is appropriate, what level is needed. These determinations and any additional minimization measures that may be needed will be included in the individual Conservation Agreements.

This conservative approach will allow the Service to more closely monitor impacts to maternity areas where available habitat may be, but cannot be definitively shown to be, limited. Of the 35 known maternity colonies in Kentucky, this threshold will affect 12 colonies or approximately one-third of the known maternity colonies. The Service will re-evaluate the 45 percent habitat availability threshold on an annual basis or more frequently if new colonies are discovered to determine which maternity colonies will trigger the additional Service review of projects covered by Conservation Agreements.

Adverse effects to the Indiana bat from the removal of maternity habitat may occur as previously described under the general discussion on the effects of habitat removal. However, the removal of maternity roosting habitat between June 1 and August 1, while the young are non-volant, is when the likelihood of mortality is highest. Given the available acreage within maternity areas and the small project sizes approved under this action, it is unlikely that any of the projects implemented under these Conservation Agreements would result in the loss of an entire maternity colony. While the loss of an occupied primary maternity roost would result in the greatest immediate impact, the loss of multiple alternate roost trees could cause displaced individuals to expend increased levels of energy while seeking out replacement roost trees. If this increased expenditure occurred during a sensitive period of a bat's reproductive cycle (e.g., pregnancy) it is assumed that spontaneous abortion or other stress-related reproductive delays or losses in fecundity may be a likely response in some individuals, particularly those that may have already been under other environmental stresses. It has been hypothesized that these stresses and delays in reproduction could also cause lower fat reserves and ultimately lead to lower winter survival rates (USFWS 2002). For example, females that do give live birth may have pups with lower birth weights or their pups may have delayed development (i.e., late into the summer). This could in turn affect the overwinter survival of the young-of-the-year bats if they enter fall migration and winter hibernation periods with inadequate fat reserves. These stresses are anticipated, though to a lesser extent, even when the habitat is removed when the bats are not present.

Habitat Removal – Fall

There are 115 known hibernacula in Kentucky with historic (38) or extant (77) Indiana bat populations. This includes two caves designated as Critical Habitat, Bat Cave and Coach Cave. The Guidance specifically excludes impacts to caves and other potential hibernacula. In addition to avoiding impacts to hibernacula, the Service has identified those areas within a one mile radius of priority one and two hibernacula as sensitive areas that require additional, project specific evaluations before qualified project-specific impacts could occur under a Conservation Agreement. The same is true for the one-half mile radius around priority three and four hibernacula. In addition to limiting impacts to hibernacula and within their immediate vicinity, impacts proposed by Conservation Agreement cooperators that occur within a swarming area where the percent of available forest cover falls below 60 percent will require project-specific evaluations by the Service before the project(s) can be covered under a Conservation Agreement.

The swarming habitat for a given hibernaculum includes the 10-mile radius surrounding the entrance. Qualified project-specific impacts with impacts within identified swarming habitat are limited to a maximum single project impact of 250 acres, which amounts to approximately 0.4 percent of the available potential habitat assuming the minimum 60 percent forest cover. For impacts within swarming areas with higher percent forest cover and/or that impact less than 250 acres, the percent of potential habitat lost decreases. Those projects with impacts in swarming habitat with less than 60 percent cover will be individually evaluated by the Service to determine the appropriateness of the mitigation and minimization measures for that project. As with the maternity areas, these additional provisions/restrictions will allow the Service to more closely monitor impacts to swarming areas where available habitat may be, but cannot be definitively shown to be, limited. The Service will re-evaluate the 60 percent habitat availability threshold on an annual basis or more frequently if new hibernacula are discovered to determine which hibernacula will trigger the additional Service review of projects covered by Conservation Agreements.

Swarming is a sensitive period for Indiana bats when mating occurs and when bats are busy foraging to store sufficient fat reserves to survive winter hibernation. While all bats are volant during this period, and therefore less likely to be killed during the felling of a tree, the removal of suitable habitat during periods of occupation will certainly result in disturbance to roosting bats and additional energy expenditures if time must be spent seeking out new roosting sites. During a period when weight gain is critical to survival, additional energy spent searching for new roost trees also results in less time for foraging, both of which could result in reduced weight gain. It can be expected that lower weight gains during fall swarming could result in lower fitness in those stressed individuals by reduced survival and/or reproductive success. These stressors are anticipated, though to a lower extent, even when the bats are not present on site during the removal of the habitat.

These impacts will be minimized in those project-specific impacts implemented under Conservation Agreements with the Service through the use of the Guidance which requires individual review of projects with impacts within one mile of priority one and two hibernacula and within one half mile of priority three and four hibernacula. As previously discussed, proposed impacts within swarming areas with lower habitat availability will require project-specific review.

Habitat Removal – Winter

No winter habitat will be removed or impacted under the proposed action.

Habitat Removal – Spring Staging

During the spring staging period (early to mid-April), Indiana bats are still concentrated around the hibernacula. The bats have just awoken from hibernation and have depleted fat reserves. This is also the period when Indiana bats are preparing to migrate to their summer roosting areas. For females, this migration may be hundreds of miles (see Status of the Species section). Impacts to Indiana bats during this sensitive period will be minimized by placing a one mile buffer around all priority one and two hibernacula and a one-half mile buffer around all priority three and four hibernacula. Staging is not expected to occur beyond this buffer and negative impacts within this buffer will require project-specific review by the Service under the proposed action to determine the appropriateness of the mitigation and minimization measures.

Global Climate Change

Qualified projects that are implemented under the proposed action are likely to result (directly and/or indirectly) in the emission of greenhouse gases (GHG). While it is likely that the observed increase in global average temperatures is due to the observed increase in human-induced GHG concentrations, the best scientific data available today does not allow us to draw a causal connection between specific GHG emissions and effects posed to the Indiana bat, nor is there sufficient data to establish that such effects are reasonably certain to occur.

At present, there is a lack of scientific or technical knowledge to determine a relationship between activities that produce, distribute or facilitate production or distribution of petroleum products and the effects of the ultimate consumption of these products. Furthermore, there is no traceable nexus between the ultimate consumption of petroleum products and any particular effect to listed species or their habitats. Consequently, the GHG emissions resulting from the consumption, production and/or distribution of that petroleum do not constitute an indirect effect to the Indiana bat as a result of this proposed action.

Implementation of the Mitigation Guidance

The Service expects the recovery-focused conservation benefits provided by the Conservation Agreements and Guidance to be greater than the minimization measures typically implemented during section 7 consultations in two ways. First, section 7 consultations only require minimization of adverse effects, which typically is for habitat loss that occurs during the period of occupation by Indiana bats. Most commonly, this involves the removal of suitable roosting and foraging habitat during the summer months. The Guidance supports this minimization approach but also includes provisions for mitigation of adverse effects. Second, impacts to Indiana bat summer roosting and foraging habitat were typically minimized through the use of "seasonal cutting restrictions". These seasonal cutting restrictions avoided direct impacts (e.g., mortality) to Indiana bats and habitats by requiring project proponents to remove forested habitat during the Indiana bat's winter hibernation period (i.e., the habitat is removed while the species is not present). However, seasonal cutting restrictions do not address indirect and/or cumulative effects on the species and its summer habitat. The Guidance addresses these indirect and/or cumulative effects issues by ensuring that winter removal of habitat also requires mitigative conservation measures.

The measures identified as appropriate for use in Kentucky are based on the priority recovery actions contained in the revised draft recovery plan, the Indiana bat location and demographic information for Kentucky available to the Service, and relevant Service regulations, policy, and guidance. The measures include: (1) protecting known and previously unprotected Indiana bat hibernacula, (2) protecting known and previously unprotected Indiana bat maternity and/or swarming habitat, and (3) contributing funding to the Indiana bat Conservation Fund sufficient to achieve identified mitigation needs if other measures are impractical or will be of limited value to Indiana bat conservation and/or recovery. Implementation of these measures will support the conservation strategy and general minimization and mitigation goals for Indiana bats in Kentucky. As human disturbance to hibernacula and other suitable habitat is one potential threat to Indiana bats that can be limited (as compared to natural disasters such as flooding) the protection of suitable Indiana bat habitat is believed to be an effective mitigation measure to offset impacts to known or potential habitat.

Protection of Hibernacula

The Guidance lists protection and management of known P1 and P2 hibernacula as its primary conservation focus. This supports two of the recovery actions listed in the draft revised recovery plan (Service 2007): (1) Conserve and manage hibernacula and their winter populations (Recovery Action 1.1); (2) Reduce threats by purchasing from willing sellers or leasing at-risk privately owned P1 and P2 hibernacula to assure long-term protection (1.1.3). Of the 20 P1 (five) and P2 (15) hibernacula found in Kentucky, ten of these are in private ownership, including one P1 hibernacula and nine P2 hibernacula (Service, unpublished data). Overall, of the 77 caves in Kentucky with extant wintering populations of Indiana bats, 54 are in private ownership, and of these 54, only six have any cave gating with an additional four having some sort of seasonal restrictions to avoid or minimize human disturbance to hibernating bats. For most of the others, the primary threat to the hibernating bats is disturbance from recreational cavers.

Protection and management of currently unprotected hibernacula is one of the three habitat mitigation measures available to Cooperators participating in Conservation Agreements with the Service. The protection and management of these important habitats will avoid or minimize the threat of human disturbance to the Indiana bats. Hibernation is widely considered to be the most sensitive period for Indiana bats. Disturbances during hibernation that cause arousal of the bats are likely to increase metabolic rates, thus increasing the fat stores required for hibernation (Thomas et. al 1990). If the bats are disturbed repeatedly or for long periods of time, it is possible that the fat stores will be depleted prior to the end of hibernation and could result in death. Even if fat stores are sufficient for the hibernation period, the bats may emerge with poor body condition, which could reduce the likelihood of successful migration or result in reproductive failure for the females and reduced survivorship of young. Protection of these hibernacula from unrestricted disturbance will minimize the threat of winter disturbance and the associated risks to the hibernating bats.

Protection of Maternity and/or Swarming Habitat

Protection and management of existing forested habitat is the second minimization and mitigation goal listed by the Service in the Guidance. This goal will support several recovery actions listed in the draft, revised recovery plan (Service 2007): (1) Conserve and manage areas surrounding hibernacula (Recovery Action 1.1.4); (2) Purchase from willing sellers or lease privately owned lands surrounding P1 and P2 hibernacula identified as having inadequate buffers (1.1.4.4); (3) Restoration and creation of hibernacula (1.2); (4) Conserve and manage summer habitat to maximize survival and fecundity (2.0); and (5) Monitor and manage known maternity colonies (2.4).

The protection of known maternity and/or swarming habitats is another habitat mitigation measure available to Cooperators to compensate for impacts to known and potential Indiana bat habitat. The protection of these areas will avoid many of the potential adverse affects to the Indiana bat from the destruction, alternation and fragmentation of habitat that is discussed in the earlier portions of this section regarding habitat removal. Directing these mitigation measures to Recovery Mitigation Focus Areas (RMFA) (see Guidance, Appendix A) will maximize the benefits of the habitat protection and management by linking them with areas in existing conservation ownerships and keeping the mitigation as close to the location of the project-specific impacts as makes biological sense. In some situations, the RMFA geographically closest to the impact site may not provide the best minimization or mitigation of the impacts.

Contributing to the Indiana Bat Conservation Fund

Cooperators in these Conservation Agreements who choose not to purchase or protect known hibernacula, maternity or swarming areas are provided with the opportunity to make a contribution to the Indiana Bat Conservation Fund (IBCF). While these funds are held by the Kentucky Natural Lands Trust (a non-profit land trust not directly affiliated with the Service), the expenditure of these funds requires approval from the Service and must be used to achieve the following objectives: (a) summer habitat protection, conservation and restoration; (b) winter habitat protection and enhancement; and (b) priority Indiana bat research and monitoring needs. These mitigation measures provide a recovery-focused conservation benefit for the Indiana bat by offsetting suitable habitat loss regardless of the timing of the impacts.

Species Response to the Proposed Action

Numbers of individuals/populations in the action area affected - According to our records, the Indiana bat is known from more than 170 locations within the action area, including 115 hibernacula and 35 maternity colonies. The action area harbored about 68,668 Indiana bats during the 2006-2007 winter hibernation periods. However, an unknown portion of those Indiana bats are known to migrate to summer habitat areas that are outside of Kentucky (KSNPC 2006), and Indiana bats that winter in other states are known to occupy summer habitat in Kentucky (KSNPC 2006). So, we cannot determine the number of Indiana bats that are present within Kentucky during the summer maternity season. Given the fact that the Indiana bats within the action area are all part of a single population (see related discussion in the Status of the Species section) and that the potential adverse affects from the project-specific impacts authorized under the proposed action would be localized, we do not expect the affects of the proposed action to impact a large number of individuals. This is due to many reasons including, but not limited to, (a) implementation of the minimization and mitigation measures prescribed in the Guidance, (b) limiting the total acreage of potential Indiana bat habitat to be affected by qualified project-specific impacts to 0.3 percent of that available within the action area, (c) requiring individual evaluations of impacts in areas of expected higher Indiana bat densities (e.g., those areas surrounding hibernacula), and (d) limiting individual project impacts to 250 acres (less than two percent of a 2.5-mile radius area).

Sensitivity to Change – The Indiana bat does not appear to be particularly sensitive to change within its summer and swarming habitats (See Previous Incidental Take Authorizations and Status of the Species in the Action Area sections above). Most Indiana bat maternity colonies occur in disturbed landscapes and forest habitat areas of low to moderate canopy cover, and a preponderance of the data on summer roosting and foraging habitat show that Indiana bats appear to select roost trees based on proximity to natural or anthropogenic disturbances. Some examples of this include, among others, (a) the selection of primary roost trees that are in canopy openings that will provide solar exposure and radiant heat for maternity colonies, (b) the preferential use of roost trees within various types of timber harvests in many areas, and (c) the use of edges and tree corridors for travel and foraging.

This is not true, however, for winter hibernation habitat. Indiana bats appear to be particularly sensitive to changes in microclimatic conditions within hibernacula and to disturbances during hibernation (See Historic Abundance, Ecological Trap, and Hibernation Habitat sections above), which are the primary reasons cited for the species' historic population losses. The Guidance to be implemented under the proposed action specifically excludes impacts to winter hibernation habitat.

Resilience - For the proposed action, the authorized disturbances from qualified project-specific impacts will be relatively small compared to the action area and the species' range, widely distributed within the action area, and minor in severity. The species' resiliency to natural and anthropogenic disturbances has been demonstrated in a variety of contexts (See Previous Incidental Take Authorizations and Status of the Species in the Action Area sections above). In most cases of which we are aware, Indiana bat maternity colonies have persisted after minor or significant disturbances occurred, and the species (both males and females) have shown a natural tendency to routinely shift roost trees and to take advantage of new roosting and foraging opportunities (See Status of the Species section, especially Apparent Regional Population Trends and Climate Change section and sections that discuss summer roosting habitat). We do not believe that the types of disturbances associated with the proposed action (i.e., relatively small compared to the action area and the species' range, widely distributed within the action area, and minor in severity) will significantly affect the species even though it has a relatively low reproductive rate.

Recovery Rate – We expect the time required for individual Indiana bats, the Indiana bat population with the action area, and the affected Indiana bat habitat to return to equilibrium after implementation of the proposed action to be negligible. Most adverse effects associated with the proposed action will be localized (i.e., at the project-specific impact site) within the action area, thus having an effect on a smaller percentage of bats known to occur within the action area. Similarly, the small percentage (less than 0.4 percent) of the available potential habitat within the action area that could be adversely affected by the proposed action minimizes the recovery time.

CUMULATIVE EFFECTS

Cumulative effects include the combined effects of any future State, local, or private actions that are reasonably certain to occur within the action area covered in this biological opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation under section 7 of the Act. Additionally, any future Federal, State, local, or private actions that are reasonably certain to occur in the action area, and which are considered in this biological opinion, will require compliance with section 7 of the Act. In particular, many of the large-scale activities that could occur in the action area, such as highway development and mining, would have a federal nexus that would require an independent consultation under section 7 of the Act. As such, they would not be included in this cumulative analysis.

Numerous land use activities that affect the Indiana bat and that likely occur within the action area include: timber harvest, ATV recreational use, recreational use of caves, and development associated with road, residential, industrial, and agricultural development and related activities. These private actions are likely to occur within the action area, but the Service is unaware of any quantifiable information relating to the extent of private timber harvests within the action area, the amount of use of off-highway vehicles within the action area, or the amount of recreational use of caves within the action area. Similarly, the Service does not have any information on the amount or types of residential, industrial, or agricultural development that have or will occur within the action area. Therefore, the Service is unable to make any determinations or conduct any meaningful analysis of how these actions may or may not adversely and/or beneficially affect the Indiana bat. All we can say is that it is possible that these activities, when they occur, may have cumulative effects on Indiana bats and their habitat in certain situations (e.g., a private timber harvest during summer months within an unknown maternity colony may cause adverse effects to that maternity colony.). In stating this, however, we can only speculate as to the extent or severity of those effects, if any.

It is important to consider that the Service expects that many of the Cooperators who enter into voluntary Conservation Agreements with the Service and consequently will be implementing the Guidance will be non-federal entities whose proposed actions would occur with or without the proposed action. Without the proposed action, these impacts could not be quantified and would not be mitigated for, because there would be no requirement for consultation under the Act.

CONCLUSION

After reviewing the current status of the Indiana bat; the environmental baseline for the action area; the effects of participating in Conservation Agreements with private and federal entities; and the cumulative effects of the proposed action, it is the Service's biological opinion that the proposed action is not likely to jeopardize the continued existence of the Indiana bat. Critical habitat for the Indiana bat has been designated at a number of locations throughout its range, however, this action does not affect any of those designated critical habitat areas, because proposed actions affecting those areas are excluded from the proposed action, and no destruction or adverse modification of that critical habitat is expected.

Because of our analysis, we do not believe that the proposed action "would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of [the Indiana bat] by reducing the reproduction, numbers, or distribution of [the Indiana bat] (50 CFR 402)." In fact, we believe that neither survival nor recovery will be reduced appreciably for reasons summarized later in this section. Furthermore, the expected outcome of entering into these Conservation Agreements would primarily be positive to Indiana bats and their habitat through the protection, enhancement and/or restoration of hibernacula, swarming and maternity habitats. In addition to those measures previously listed, contributions to the Indiana Bat Conservation Fund may also fund priority Indiana bat research and monitoring needs. These are all important aspects of the proposed action that are expected to provide conservation and recovery gains to the species, improve its chances for recovery, and ensure its survival within the action area and within its range as a whole.

For the proposed action to "reduce appreciably" the Indiana bat's recovery, the proposed action would have to impede or stop the process by which the Indiana bat's ecosystems are restored and/or threats to Indiana bat are removed so that self-sustaining and self-regulating populations can be supported as persistent members of native biotic communities (Service and NMFS 1998, page 4-35). We do not believe the proposed project impedes or stops the recovery process for the Indiana bat because:

(a) The species' resiliency to natural and anthropogenic disturbances has been demonstrated (See Previous Incidental Take Authorizations and Status of the Species in the Action Area sections above). We believe that the proposed action, while potentially resulting in the incidental take of some individuals, is not a significant threat to the species as a whole and, therefore, does not rise to the level of jeopardy. No component of the proposed action is expected to result in harm, harassment, or mortality at a level that would reduce appreciably the reproduction, numbers, or distribution of the Indiana bat. The project-specific impacts to the Indiana bat associated with the proposed action will have minor effects on Indiana bats and would most likely occur with or without the proposed action. Additionally, as a result of the proposed action, these project-specific impacts will be mitigated through the implementation of the Guidance, regardless of the season during which the impacts occur.

(b) The primary threats to the Indiana bat's recovery (Service 1983) are destruction and alteration of species' winter hibernation habitat and disturbance of Indiana bats while they occupy that winter habitat. The proposed action does not result in any adverse effects on Indiana bat winter habitat. Additionally, the implementation of the Guidance is likely to result in the removal of some threats through the protection of winter habitat.

(c) The proposed action is unlikely to result in the loss of Indiana bat maternity colonies. Because maintenance of existing maternity colonies and the creation of new maternity colonies (i.e., evidence of population growth and/or improved habitat conditions) are likely important factors that affect the species' recovery potential, we have identified a number of factors related to the proposed action and discussed in the Status of the Species and Analyses for Effects of the Action sections that lead us to believe that the proposed action will not result in significant losses of individual Indiana bats, and especially maternity colonies. The resiliency to disturbance shown by Indiana bat maternity colonies (See Previous Incidental Take Authorizations and Status of the Species in the Action Area sections above) is one such factor, which was discussed in (a) above. However, other factors that are designed to protect and/or conserve Indiana bat maternity colonies include incentives to Cooperators to time their impacts within maternity habitat during periods the bats are not expected to be present, mitigative conservation measures for impacts within maternity areas, the identification of maternity areas which have reduced availability of potential habitat, and site-specific evaluations of projects affecting these areas. Additionally, site-specific evaluations are required when the proposed impacts would occur in known maternity areas during the period when the young are non-volant.

For the proposed action to "reduce appreciably" the Indiana bat's survival, the proposed action would have to impede or stop the condition in which a species continues to exist into the future while retaining the potential for recovery (Service and NMFS 1998, page 4-35). We do not believe the proposed action impedes or stops the condition in which the Indiana bat continues to exist while retaining the potential for recovery.

We believe that neither the Indiana bat's recovery nor its survival will be reduced appreciably by the loss of up to 40,000 acres of potential habitat, which equals less than 0.4 percent of the potential habitat available within the action area. Where adverse effects will actually occur, the species' ability to persist in the face of these effects is well-documented.

The proposed action will authorize incidental take of Indiana bats associated with project-specific actions that may be private or Federal. Any private actions that would not require consultation with the Service and without the proposed action would likely occur, but without the implementation of the Guidance. Federal actions require consultation with the Service and would like include many of the minimization and mitigation measures discussed in this Opinion. However, most project proponents currently opt to minimize impacts to the Indiana bat by implementing the project-specific actions involving the removal or disturbance of summer and swarming habitat during periods when Indiana bats are hibernating. Project-specific actions implemented under the proposed action will require mitigation even for these impacts that are minimized through timing. As a result, the proposed action is unlikely to approve any impacts that would not otherwise occur. The proposed action will result in positive gains for the Indiana bat in the form of research, management, and habitat protection through the mitigation measures required by the proposed action. These gains would be less likely if the proposed action were not implemented.

INCIDENTAL TAKE STATEMENT

Section 9 of the Act and Federal regulations under section 4(d) of the Act prohibit the taking of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct. Harm is further defined by the Service to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns such as breeding, feeding, or sheltering. Harass is defined by the Service as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns that include, but are not limited to, breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited under the Act, provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below are non-discretionary, and must be undertaken by the Service so that they become binding conditions of any grant, contract, or permit issued to an applicant, contractor, or permittee, as proper, for the exemption in section 7(o)(2) to apply. The Service has the continuing duty to regulate the activity covered by this Incidental Take Statement. If the Service (A) fails to assume and implement the terms and conditions or (B) fails to require an applicant, contractor, or permittee to adhere to the terms and conditions of the Incidental Take Statement through enforceable terms that are added to the grant, contract, or permit document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, the Service must report the progress of the action and its impact on the species to the Service as specified in the Incidental Take Statement.

AMOUNT OR EXTENT OF TAKE ANTICIPATED

The Service anticipates incidental take of the Indiana bat will be difficult to detect for the following reasons:

1. The individuals are small and occupy summer habitats where they are difficult to find;

2. Indiana bats form small (i.e., 25-100 individuals), widely dispersed maternity colonies under loose bark or in the cavities of trees, and males and non-reproductive females may roost individually which makes finding the species or occupied habitats difficult;

3. Finding dead or injured specimens during or following project implementation is unlikely;

4. The extent and density of the species within its roosting and foraging habitat in Kentucky is unknown;

5. Implemented actions will not affect all of the available habitat within a project area or within the Commonwealth of Kentucky; and

6. Most incidental take will be non-lethal and undetectable.

However, incidental take of Indiana bats can be expected due to:

1. Loss of suitable roosting trees, foraging habitat and travel corridors;

2. Modification and alteration of suitable roosting trees, foraging habitat and travel corridors;

3. Mortality associated with the loss, modification, and/or alteration of occupied roost trees and occupied foraging habitat and travel corridors resulting from habitat removal activities that will be conducted within occupied Indiana bat habitat.

The level of take identified below may result, because the Service anticipates and has estimated that up to 40,000 acres of habitat removal within forest stands that may contain suitable habitat for Indiana bats will likely be authorized under Conservation Agreements entered into by the Service. Because of the difficulty in determining a level of take based on the number of Indiana bats that will be adversely affected, the Service has decided that it is appropriate to base the level of authorized incidental take on the acreage of suitable habitat that will be affected by project impacts authorized under Conservation Agreements entered into by the Service. Therefore, the level of take anticipated in this biological opinion is 40,000 acres over a five year period, with no more than 8,000 acres occurring in any calendar year.

It is important to note, however, that we do not expect actual adverse effects and incidental take to occur on all of these potential habitat acres, because we have taken a cautious, conservative approach when determining adverse effects to the species and the amount of incidental take that may occur. We expect this authorized level of incidental take to be a significant overestimate of the actual incidental take of Indiana bats, because it assumes that:

(a) All forest types can be immediately occupied by Indiana bats;
(b) All of the suitable habitat within a project area is being used by Indiana bat; and
(c) All activities are completely deleterious and result in complete loss of habitat values for Indiana bats within a project area.

In contrast, the Service knows that:

(a) Indiana bats do not occur ubiquitously or in a uniform distribution across the action area based on negative survey data;
(b) There are less than 200 known records for the species within Kentucky – many of which are hibernation records – and both the winter and summer sites are not uniformly distributed across the state; and
(c) Not all of the action area contains potentially suitable or occupied habitat - some potential habitat is too young, too dense, etc.

Collectively, these factors will mean that actual harm and/or harassment of Indiana bats will likely occur on less acreage.

This incidental take statement anticipates the taking of Indiana bats only from the actions associated with qualified projects implemented under Conservation Agreements between the Service and the respective project proponent(s). Incidental take of Indiana bats is expected to be in the form of mortality, harm, and/or harassment and is expected to occur as a result of habitat loss. Although mortality is the least likely form of take to occur due to implementation qualified projects authorized through Conservation Agreements between the Service and the respective project proponent(s), adult or juvenile Indiana bats may be killed during the felling of trees if the felling is done during the summer maternity period and if the species is present. Harm may occur through the habitat alterations that are anticipated to occur because of the action which include, but are not limited to, removal of potential roosting habitat and the accidental scarring or knocking down of potential or occupied roost trees by personnel or equipment. Harassment may occur because of any number of disturbance-related effects outlined in previous sections of this biological opinion. However, likely sources of harassment to Indiana bats include, but are not limited to removal of habitat during periods of inoccupation.

EFFECT OF THE TAKE

In the accompanying biological opinion, the Service determined that this level of expected take is not likely to result in jeopardy to the Indiana bat or destruction or adverse modification of critical habitat.

REASONABLE AND PRUDENT MEASURES

The Service believes the following reasonable and prudent measures are necessary and appropriate to minimize impacts of incidental take of the Indiana bat associated with the Service's participation in and approval of voluntary Conservation Agreements:

1. The Service shall implement the proposed action as described above in this biological opinion.

2. The Service will ensure the amount of incidental take provided to Federal and non-federal entities through their participation in voluntary Conservation Agreements with the Service does not exceed the 8,000 acre annual and 40,000 acre total habitat loss limits identified in the Incidental Take Statement above.

TERMS AND CONDITIONS

In order to be exempt from the prohibitions of section 9 of the Act, the Service must comply with the following Terms and Conditions, which carry out the Reasonable and Prudent Measures described above and outline required reporting/monitoring requirements. These Terms and Conditions are non-discretionary.

1. The Service shall only enter into Conservation Agreements that comply with the provisions of this biological opinion and the Indiana Bat Mitigation Guidance. This Term and Condition is associated with Reasonable and Prudent Measure 1.

2. The Service shall keep records of the level of incidental take granted under Conservation Agreements and the amount of Indiana bat habitat impacted. This Term and Condition is associated with Reasonable and Prudent Measure 2.

3. The Service shall keep records of the amount of habitat purchased, managed, and protected and the amount of funding contributed to the Indiana Bat Conservation Fund. This Term and Condition is associated with Reasonable and Prudent Measure 2.

4. The Service shall perform audits on select qualified projects implemented by Cooperators to ensure compliance with the Indiana Bat Mitigation Guidance, the respective Conservation Agreement(s), and the allowed incidental take. This Term and Condition is associated with Reasonable and Prudent Measure 2.

5. The Service shall create a map or other geographical tool to allow Cooperators to identify when proposed projects are located within known habitat. This map or tool shall be updated annually or more often as needed so that incidental take within known habitat areas can be tracked. This Term and Condition is associated with Reasonable and Prudent Measure 2.

6. The Service shall perform habitat analyses on known maternity and swarming areas annually or as new land cover data becomes available. These analyses shall be used to identify sensitive areas (e.g., swarming areas with less than 60 percent cover or maternity areas with less than 45 percent cover) where additional protective measures may need to be developed and/or additional impact avoidance must be incorporated into the Conservation Agreement(s). This Term and Condition is associated with Reasonable and Prudent Measure 2.

The Service and its contractors must take care when handling dead or injured Indiana bats or any other federally listed species that are found in order to preserve biological material in the best possible state and to protect the handler from exposure to diseases, such as rabies. In conjunction with the preservation of any dead specimens, the Service and its contractors have the responsibility to ensure that evidence intrinsic to determining the cause of death or injury is not unnecessarily disturbed. The reporting of dead or injured specimens is required in all cases to enable the Service to determine if the level of incidental take authorized by this biological opinion has been reached or exceeded and to ensure that the terms and conditions are appropriate and effective. Upon locating a dead, injured, or sick specimen of any endangered or threatened species, prompt notification must be made to the Service's Division of Law Enforcement at 1875 Century Blvd., Suite 380, Atlanta, Georgia 30345 (Telephone: 404/679-7057). Additional notification must be made by the Service's Kentucky Ecological Services Field Office at 330 West Broadway, Room 265, Frankfort, Kentucky 40601 (Telephone: 502/695-0468) to the Ecological Services program office at 1875 Century Boulevard, Suite 200, Atlanta, Georgia 30345 (Telephone 404/679-7085).

The Reasonable and Prudent Measures, with their Terms and Conditions, are designed to minimize the impact of incidental take that might otherwise result from the proposed action. The Service believes that an indeterminate number of Indiana bats will be incidentally taken as a result of the proposed action, with incidental take occurring on no more than 40,000 acres of potential and known forest habitat in Kentucky. If, during the course of the action, this level of habitat alteration (leading to incidental take of the Indiana bat) is exceeded, such incidental take represents new information requiring reinitiation of consultation and review of the Reasonable and Prudent Measures provided. The Service must immediately provide an explanation of the causes of the taking and review the need for possible modification of the Reasonable and Prudent Measures.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to use their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. The Service has not identified any conservation recommendations for this biological opinion.

REINITIATION NOTICE

This concludes formal consultation on the Service's participation in and approval of voluntary Conservation Agreements and their effects on the Indiana bat. As stated in 50 CFR 402.16, reinitiation of formal consultation is required where discretionary Service involvement or control over the action has been retained (or is authorized by law) and if: (A) the amount or extent of incidental take is exceeded, (B) new information reveals effects of the Service's action that may affect listed species or critical habitat in a manner or to an extent not considered in this consultation (e.g., range-wide monitoring shows, over a five-year period, a decline in hibernating Indiana bats), (C) the Service's action is later modified in a manner that causes an effect to the listed species or critical habitat not considered in this consultation, or (D) a new species is listed or critical habitat is designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease until reinitiation.

For this biological opinion, the authorized incidental take would be exceeded when the take exceeds 8,000 acres of Indiana bat habitat removal in any one year for a five-year period. The total amount of incidental take covered for this period is 40,000 acres. These are the amounts of habitat that are exempted from the prohibitions of section 9 of the Act by this biological opinion.

This consultation was assigned FWS ID #42431-2008-F-0496. Please refer to this number in any correspondence concerning this consultation.

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APPENDIX A

INDIANA BAT MITIGATION GUIDANCE
FOR THE
COMMONWEALTH OF KENTUCKY

Indiana Bat Mitigation Guidance for the Commonwealth of Kentucky

Introduction

This guidance is to be used when assessing minimization and mitigation needs for the endangered Indiana bat (*Myotis sodalis*) relative to development, forestry, and other land use or land management projects that have the potential to alter or otherwise affect Indiana bat habitat in Kentucky. The Service will pursue similar minimization goals and options for Indiana bat conservation and recovery during informal and formal consultations with Federal action agencies pursuant to section 7(a)(2) of the Endangered Species Act of 1973 (ESA), subject to the acceptability of the minimization measures to the Federal action agencies.

The intent of this guidance is to (1) provide direction to project proponents whose actions have the potential to adversely affect the Indiana bat and (2) enhance conservation and recovery of Indiana bat populations in Kentucky by providing minimization and mitigation for adverse effects to Indiana bats that occur in Kentucky. The guidance is subject to modification as new information relative to the species, its conservation status, and its conservation and recovery becomes available.

Kentucky, like most states, is experiencing significant growth. Projects associated with growth can cause the loss, degradation, and fragmentation of natural habitats as the alteration or development of these formerly natural to semi-natural habitats occur. These types of impacts have the potential to adversely affect the Indiana bat, so project proponents must often determine if potential adverse effects to Indiana bats are likely to occur and, if so, how they can avoid, minimize, and/or mitigate for those adverse effects. If avoidance of all likely adverse effects is not achievable, project proponents must follow these guidelines below to ensure compliance with the ESA and avoid an illegal "take" of Indiana bats, a federally listed species. "Take" of federally listed species is prohibited pursuant to section 9 of the ESA. As a result, the supporting rationale for this guidance is that future recovery, conservation, and mitigation efforts for the Indiana bat undertaken by the Service and others using this guidance will improve conservation and recovery of Indiana bat populations in Kentucky in spite of adverse effects that occur, as these adverse effects would require avoidance, minimization, and/or mitigation.

Background

Kentucky lies near the center of the Indiana bat's range and contains numerous caves and forestlands known to contain and provide habitat for the species. Five out of the 23 Priority 1 hibernacula identified in the draft, revised Indiana bat recovery plan[1] lie within Kentucky's borders. Three of these hibernacula occur within the Mammoth Cave System, located in the Pennyrile region of the state. Cave researchers have suggested that the Mammoth Cave System historically may have provided winter roosts for millions of Indiana bats.[2, 3] The two other Priority 1 hibernacula are found in Kentucky's Eastern Coalfields[4] with Bat Cave in the northeast portion of Kentucky and Line Fork Cave in the southeast. The expansive karst within much of Kentucky's limestone geology results in numerous caves that historically and currently provide winter habitat for Indiana bats. Over 100 caves (5 Priority 1 and 15 Priority 2) within the state have historic Indiana bat records and 77 of these caves have extant winter populations. Many of these caves occur within areas of existing conservation ownerships, both private and public. Of particular note are the Daniel Boone National Forest that is managed by the U.S. Forest Service, Mammoth Cave National Park that is managed by the National Park Service, Carter Cave State Resort Park that is managed by the Kentucky Department of Parks, and several parcels along Pine Mountain. Like the hibernacula, known maternity colonies are scattered throughout the state with notable clusters of maternity colonies occurring near the Fort Knox Military Reservation, Mammoth Cave National Park, Daniel Boone National Forest, Pine Mountain, the Eastern Coalfields, and along the Ohio River floodplain in the Pennyrile (Mississippian Plateaus) and Jackson Purchase (Mississippi Embayment) regions of the state.

Because Indiana bat records occur broadly across the Commonwealth, nearly any project with suitable habitat has the potential to adversely affect the Indiana bat. Excluding those state transportation projects that are evaluated under a programmatic biological opinion, the KFO reviews nearly 700 projects annually for impacts to Indiana bats. The majority of these projects involve the loss of suitable summer roosting and foraging habitat. Projects that impact known winter habitat are rare. Projects impacting known and potential summer and swarming habitats range from large block disturbances such as those associated with surface mining and development projects to linear impacts associated with transmission lines and pipelines. Additionally, the KFO annually reviews numerous impacts that vary in size. Although the small size of some of the disturbances makes direct adverse impacts to Indiana bats less likely, the cumulative and indirect effects of these projects as a whole are or can be detrimental to the species and limit the potential conservation and recovery of the species.

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[1] U.S. Fish and Wildlife Service. 2007. Indiana Bat (*Myotis sodalis*) Draft Recovery Plan: First Revision. U.S. Fish and Wildlife Service, Fort Snelling, MN. 258 pp.

[2] Toomey, R.S., III, M.L. Colburn, and R.A. Olson. 2002. Paleontological evaluation of use of caves: a tool for restoration of roosts. Pp. 79-85 *in* A. Kurta and J. Kennedy (eds.), The Indiana bat: biology and management of an endangered species. Bat Conservation International, Austin, TX.

[3] Tuttle, M.D. 1997. A mammoth discovery. Bats 15:3-5.

[4] Physiographic Regions of Kentucky. Kentucky Atlas and Gazetteer. 3/5/2007 (see Appendix A) http://www.uky.edu/Kentucky Atlas/kentucky-atlasp.html

Explanation of Terms

Throughout this document, certain terms are used repeatedly to describe Indiana bat habitat. For the purpose of this document the Service provides the following definitions:

- "Known habitat" refers to suitable summer or winter habitat located within 10 miles of a documented hibernacula, five (5) miles of a documented maternity capture record, or 2.5 miles of a documented maternity roost tree or non-maternity capture record.

- "Maternity habitat" refers to suitable summer habitat used by juveniles and reproductive (pregnant, lactating, or post-lactating) females.

- "Non-maternity habitat" refers to suitable summer habitat used by non-reproductive females and/or males.

- "Occupied" refers to suitable habitat that is expected or assumed to be in use by Indiana bats at the time of impact. For summer habitat, this applies from April 1 through October 14.

- "Potential habitat" occurs outside of known habitat but where suitable habitat for the Indiana bat exists.

- "Suitable habitat" refers to summer and/or winter habitat that is appropriate for use by Indiana bats.

    - Suitable winter habitat (hibernacula) is restricted to underground caves and cave-like structures (e.g. abandoned mines, railroad tunnels). These hibernacula typically have a wide range of vertical structures; cool, stable temperatures, preferably between 4°C and 8°C; and humidity levels above 74 percent but below saturation.

    - Suitable summer habitat for Indiana bats consists of the variety of forested/wooded habitats where they roost, forage and travel. This includes forested blocks as well as linear features such at fencerows, riparian forests and other wooded corridors. These wooded areas may be dense or loose aggregates of trees with variable amounts of canopy closure. Isolated trees are considered suitable habitat when they exhibit the characteristics of a suitable roost tree.

- "Suitable roost tree" refers to a tree (live or dead) with a diameter at breast height (DBH) of 5 inches or greater that exhibits any of the following characteristics: exfoliating bark, crevices or cracks. Indiana bats typically roost under exfoliating bark, and in cavities of dead, dying, and live trees, and in snags (i.e., dead trees or dead portions of live trees). Trees in excess of 16 inches diameter at breast height (DBH) are considered optimal for maternity colony roosts, but trees in excess of 9 inches DBH appear to provide suitable maternity roosting habitat. Male Indiana bats have been observed roosting in trees as small as 3 inches DBH.

- "Unoccupied" refers to suitable habitat not expected to be in use by Indiana bats at the time of impact. For summer habitat, this is the period from October 15 through March 31. For swarming habitat, it is from November 15 through March 31.

Conservation Strategy and General Minimization and Mitigation Goals for Indiana Bats in Kentucky

The Service's Kentucky Field Office will generally rely on the draft, revised Indiana Bat recovery plan and other literature and data available on the Indiana bat to support its conservation and recovery activities for the species. For example, the draft, revised recovery plan's primary recovery actions focus on protection and management of Priority 1 and Priority 2 hibernacula, which will also be the primary conservation focus in Kentucky. However, there are a number of other recovery actions that this guidance supports, including, but not limited to: (a) Conserve and manage hibernacula and their winter populations (Recovery Action 1.1); (b) Reduce threats by purchasing from willing sellers or leasing at-risk privately owned P1 and P2 hibernacula to assure long-term protection (1.1.3); (c) Conserve and manage areas surrounding hibernacula (1.1.4); (d) Purchase from willing sellers or lease privately owned lands surrounding P1 and P2 hibernacula identified as having inadequate buffers (1.1.4.4); (e) Restoration and creation of hibernacula (1.2); (f) Conserve and manage summer habitat to maximize survival and fecundity (2.0); (g) Monitor and manage known maternity colonies (2.4); and (h) Minimize adverse impacts to the Indiana bat and its habitat during review of Federal, state, county, municipal, and private activities under the ESA, National Environmental Policy Act, Fish and Wildlife Coordination Act, and Section 404 of the Clean Water Act (2.6). Collectively, these recovery actions address Indiana bat conservation and recovery needs in both winter and summer habitat. As a result, they provide the foundation that supports this guidance. The Service will use its existing authorities, especially those under the ESA, when implementing this guidance.

Based on the background information above and the available information on the species, its status, and conservation[5], the Service developed a list of general minimization and mitigation goals for Indiana bats in Kentucky. If achieved, these goals would (a) support the conservation strategy discussed above, (b) significantly contribute to Indiana bat conservation and recovery in Kentucky, and (c) act as a guide for determining the appropriateness of any proposed minimization and mitigation measures. The goals are listed below:

Tier 1

1. Protect and manage known Priority 1 (P1) and Priority 2 (P2) hibernacula.
2. Protect and manage existing forested habitat:
    a. Swarming habitat within 10 miles of a known hibernacula; and/or
    b. Summer habitat within 2.5 miles of a documented maternity roost tree or within 5.0 miles of a maternity capture (mist-net) record.
3. Protect and manage additional conservation lands for Indiana bats, especially habitat that is contiguous with or within the proclamation/acquisition/preserve boundaries of existing public and private conservation lands occupied by Indiana bats.

[5] The KFO relied heavily on the draft revised Indiana Bat Recovery Plan, state heritage information, and the knowledge of experienced Indiana bat biologists to derive this list, but a number of other sources of information, which are on file in our office, were used.

4. Restore winter habitat conditions in degraded caves that exhibit the potential for successful restoration such as, but not limited to, those caves identified as having High Potential (HP) in the draft revised Indiana bat Recovery Plan.

Tier 2

5. Protect and manage known P3 and P4 hibernacula.

6. Protect and manage additional conservation lands that are currently suitable for but unoccupied by Indiana bats.

7. Fund priority Indiana bat research and monitoring that support the six strategies above and/or Kentucky's Indiana bat populations.

Tier 1 goals would have priority over Tier 2 goals and are encouraged.

Indiana Bat Recovery and Mitigation Focus Areas

The Service's analyses also resulted in the delineation of Indiana Bat Recovery and Mitigation Focus Areas (RMFAs) within the Commonwealth of Kentucky (Figure 1). RMFAs were identified specifically to support the general minimization and mitigation priorities identified in the previous section and represent areas that:

1. Contain one or more public or protected private lands that are known to support Indiana bat populations;

2. Currently support populations of Indiana bats that are expected to support long-term recovery and conservation efforts of the species;

3. Contain adequate suitable habitat to support recovery and conservation efforts;

4. Provide opportunities for future protection, restoration, enhancement, and/or creation of additional summer and/or winter Indiana bat habitat; and/or

5. In the Service's estimation, contain conditions that generally are expected to contribute to the persistence of the Indiana bat population and habitat into the future.

The identified RMFAs can be categorized as Summer Habitat RMFAs, Winter Habitat RMFAs, or as both and are shown in Table 1. Collectively, these RMFAs are key landscapes for Indiana bat conservation and recovery in Kentucky. Therefore, RMFAs will be those areas where most Indiana bat minimization and/or mitigation efforts will be undertaken or attempted. The Service expects, however, that minimization and/or mitigation efforts may also be undertaken or attempted at locations outside of the Indiana bat RMFAs in circumstances where the conservation and/or recovery benefits to Indiana bats can be clearly identified and justified. The applicability of minimization and/or mitigation efforts outside of RMFAs will be determined on a case-by-case basis in coordination with the Service and will depend on a variety of factors including, but not necessarily limited to, (a) location of the site, (b) the type and quality of the conservation opportunities available, and (c) the existence of new information that would help justify the conservation effort. In addition, minimization and/or mitigation efforts will generally be directed to the RMFA closest to the impact site or to the RMFA that best minimizes and/or mitigates the specific impact(s).

Table 1: Table of Recovery and Mitigation Focus Areas (RMFAs) & Available Habitat Types

RMFA Name and Description	Summer Habitat RMFA	Winter Habitat RMFA
Tygarts Creek-Carter Caves SRP – the assemblage of caves along Tygarts Creek and within Carter Caves SRP, including caves on private lands within 10 miles of Tygarts Creek and/or Carter Caves SRP Primary Conservation Ownership – Carter Caves SRP	no	yes
Daniel Boone National Forest – the area within the DBNF proclamation boundary, including caves and maternity colonies on private lands within 10 miles of the proclamation boundary Primary Conservation Ownership – Daniel Boone National Forest	yes	yes
Pine Mountain – the assemblage of caves along Pine Mountain, including caves and maternity colonies on private lands within 10 miles of the crest of Pine Mountain Primary Conservation Ownership – Kentucky State Parks and Kentucky State Nature Preserves Commission	yes	yes
Mammoth Cave National Park – the assemblage of caves within MCNP, including caves and maternity colonies on private lands within Barren, Edmonson, Hart, and Warren counties Primary Conservation Ownership – Mammoth Cave National Park	yes	yes
Barrens-Fort Knox – the assemblage of caves and maternity colonies in Breckinridge, Bullitt, Hardin, Jefferson, Meade, and Spencer counties Primary Conservation Ownership – Fort Knox, Taylorsville Lake WMA	yes	yes
Big Rivers – the assemblage of caves and maternity colonies in Christian, Livingston, Lyon, Marshall, and Trigg counties Primary Conservation Ownership – Land Between the Lakes NRA, Fort Campbell, and Clarks River National Wildlife Refuge	yes[6]	yes
Lower Ohio River – the assemblage of maternity colonies in Daviess, Henderson, and Union counties Primary Conservation Ownership – Sloughs WMA	yes	no
Mississippi River – the assemblage of maternity colonies in Ballard, Carlisle, Hickman, and McCracken counties Primary Conservation Ownership – Ballard, Boatwright, Doug Travis, and West Kentucky WMAs	yes	no

[6] Maternity colony exists on Fort Campbell in Tennessee.

Types of Adverse Effects That Are Appropriate for Minimization and Mitigation

Based on the importance of hibernacula, the Service determined that development of minimization and mitigation measures would not be appropriate for projects resulting in adverse effects to hibernacula; avoidance of caves and other potential hibernacula is preferred. However, minimization and mitigation of certain adverse effects to hibernacula or potential hibernacula may be appropriate but must be coordinated with the Service. The reasons minimization and mitigation measures would be inappropriate at hibernacula include, but are not limited to:

1. P1 and P2 hibernacula are critical to Indiana bat recovery and conservation;
2. Adverse effects to P1 and P2 hibernacula have the potential to cause significant, (and likely irreversible) negative effects on Indiana bat populations range-wide;
3. Sufficient technology and funding does not currently exist to recreate the habitat conditions that exist in most hibernacula, especially P1 and P2 hibernacula; and
4. Current P3 and P4 hibernacula may have historically been P1 or P2 hibernacula, so allowing impacts to restorable P3 and P4 hibernacula could limit Indiana bat recovery.

Minimization and mitigation measures would be appropriate for most other adverse effects that typically occur in association with development projects in Kentucky. However, certain groups of impacts will require project-specific evaluation by the Service to assess the appropriateness of the minimization and mitigation measures. These groups include:

1. Projects resulting in the loss of more than 250 acres of Indiana bat habitat[7].
2. Projects occurring within 1 mile of a priority 1 or 2 hibernacula[8].
3. Project occurring within ½ mile of a priority 3 or 4 hibernacula[8].
4. Identified hibernacula with percent forest cover less than 60 percent in the ten mile radius surrounding the entrance.[7]
5. Identified maternity areas with percent forest cover less than 45 percent.[7]
6. Projects resulting in impacts to known maternity habitat between June 1 and July 31. Limited clearing during this time may be approved only after a detailed survey to ensure that no primary maternity roosts are removed during this sensitive period.

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[7] Analyses by the Service and KDFWR relating to the amount of potential summer habitat available to known Indiana bat maternity colonies in Kentucky has shown that percent forest cover ranges between 16.6 and 94.3 percent with no discernable break in records of occurrence (see Appendix B). Based on the data (unpublished USFWS data, 2008), the Service determined that projects that (a) were greater than 250 acres, (b) occurred within the swarming area of a hibernaculum with less than 60 percent forest cover, or (c) occurred within known maternity habitat areas containing less than 45 percent forest cover warranted a separate analysis relative to these guidelines in order to further minimize potential adverse effects to the maternity colonies.

[8] Separate analyses for projects within ½ or 1 mile of hibernacula will (a) ensure that impacts to occupied swarming habitat are not underestimated (i.e., Most bat activity occurs close to a hibernaculum entrance, so adverse effects are most likely to occur there.), and will help the Service better determine if direct impacts to known hibernacula are likely.

Determine Habitat Mitigation Need

The following mitigation needs have been identified in order of preference.

1. Protect known and previously unprotected Indiana bat hibernacula[9,10,11]

    a. Purchase or otherwise acquire fee title

    b. Secure perpetual conservation easements and land management agreements

2. Protect known Indiana bat maternity or swarming habitat [9,10,11]

    a. Purchase or otherwise acquire fee title (typically at an acre for acre ratio)

    b. Secure perpetual conservation easements and land management agreements (typically at a ratio of two acres protected for each acre impacted)

3. Contribute funding to the Indiana bat Conservation Fund (IBCF) sufficient to achieve identified mitigation needs.

Acceptability of Mitigation and Minimization Measures

The Service defined the terms used in the following table in Explanation of Terms section. Table 2 provides guidance on whether a minimization and mitigation measure can be used for a specific type of action or impact. In some cases, minimizing and mitigating impacts to summer habitat with the protection of winter habitat may be appropriate, but this must be determined on a case-by-case basis. Impacts to known Indiana bat hibernacula will require a project specific analysis of suitable mitigation options and may not be appropriate or allowed under these Guidelines at the Service's sole discretion.

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[9] Property acquired or protected must adjoin or be within the preserve design or acquisition boundary of an existing conservation ownership.

[10] Easement or fee simple lands shall include all surface and mineral rights to the property and clear an unencumbered ownership of these rights. The applicant shall pay for all fees and/or other costs associated with title work, recording, transferring, surveying, and/or acquiring of the easement or property.

[11] Mitigation and minimization measures that involve land acquisition or easement require the donation of the property (or easement) to a conservation organization approved by the Service. Accompanying the donation must be a cash endowment sufficient to provide perpetual management of the preserved lands and any other funds identified by the receiving conservation organization that may be necessary for that entity to accept title or easement (e.g. contaminants surveys, fencing, trash removal, etc.).

Table 2. Table of Project Actions/Impact Types & Types of Appropriate Habitat Mitigation Measures.

<table>
<tr><th>ACTION / IMPACT TYPE</th><th colspan="3">HABITAT MITIGATION MEASURE</th></tr>
<tr><td></td><td>Protect Hibernacula</td><td>Protect Maternity and/or Swarming Habitat</td><td>IBCF Contribution</td></tr>
<tr><td>Summer Habitat Loss</td><td rowspan="7">Contact the Service for review of the appropriateness of these measures.</td><td colspan="2" rowspan="12">These are appropriate minimization and mitigation measures for the impacts listed.</td></tr>
<tr><td>Known maternity habitat - occupied</td></tr>
<tr><td>Known other habitat - occupied</td></tr>
<tr><td>Potential habitat - occupied</td></tr>
<tr><td>Known maternity habitat - unoccupied</td></tr>
<tr><td>Known other habitat - unoccupied</td></tr>
<tr><td>Potential habitat - unoccupied</td></tr>
<tr><td>Swarming Habitat Loss</td><td rowspan="5"></td></tr>
<tr><td>P1 or P2 - occupied</td></tr>
<tr><td>P3 or P4 - occupied</td></tr>
<tr><td>P1 or P2 - unoccupied</td></tr>
<tr><td>P3 or P4 - unoccupied</td></tr>
</table>

Determination of Minimization and Mitigation Amounts

Table 3 below allows project proponents to determine the amount of minimization and mitigation needed to offset the specific impacts of a given project. The project's impact(s) should be divided into the actions or impact types described below and then quantified to yield the acreage of impact for each action. For impacts where suitable habitat is sparse, each suitable roost tree should be counted, and the number of suitable roost trees should be multiplied by 0.09 acres/tree to determine the acreage of suitable habitat loss (i.e., the single tree method). For impacts involving the loss or alteration of blocks of forested habitat, the acreage of the impact is determined by identifying the perimeter and area of the impact with Global Positioning System or Geographic Information System technology (i.e., the habitat block method). Once the acreage of habitat loss has been determined for each action using the single tree and/or habitat block method(s), the impact information should then be inserted into Table 3 and multiplied by the appropriate multiplier to yield the amount of mitigation required for each action or impact type. The Service will provide assistance to project proponents in determining how the single tree and habitat block methods for calculating impact acreages should be applied on their project(s) so that an accurate mitigation estimate can be determined.

The value of a particular hibernacula or maternity or swarming habitat depends on the circumstances applicable to that particular site. As such, standard multipliers are not provided but must be determined on a case-by-case basis by the Service. Factors that influence the value of a particular protection site include, but are not limited to: the relative significance of the site to the conservation and recovery of the Indiana bat, the quality of the habitat, the level of protection afforded, the degree of risk to the site without the proposed mitigation and minimization measure, and the site's position within the landscape and proximity to RMFAs.

Table 3. Table for Calculation of Impact Acres & Mitigation Acres.[12]

ACTION / IMPACT TYPE	IMPACT ACRES	MULTIPLIER	MITIGATION ACRES
Summer Habitat Loss			
Known maternity habitat - occupied		2.0	
Known non-maternity habitat - occupied		1.5	
Potential habitat - occupied		1.0	
Known maternity habitat - unoccupied		1.5	
Known non-maternity habitat - unoccupied		1.0	
Potential habitat - unoccupied		0.5	
Swarming Habitat Loss			
P1 or P2 - occupied		2.5	
P3 or P4 - occupied		2.0	
P1 or P2 - unoccupied		1.5	
P3 or P4 - unoccupied		1.0	
Overlapping Habitat Loss			
Known maternity habitat and swarming habitat occur together	Choose highest multiplier from above (maternity or swarming) appropriate for impact and add 1.0 to the multiplier[13]		
Minimization & Mitigation Measures			
Purchase or protect hibernacula	Value determined on a case by case basis		
Purchase or protect maternity or swarming habitat			
Contribute to IBCF		$2850/acre[14]	

[12] The Service determined that impacts to potential habitat during the occupied season require direct replacement of impacted acres. From that point, mitigation ratios were assigned based on the importance of the habitat type to the recovery of the Indiana bat and likelihood for direct versus indirect impacts. Direct impacts (occupied) require more mitigation than indirect impacts for each habitat type.

[13] The multiplier should be chosen based on the timing of the impact and the habitat affected. For example, winter tree clearing in known maternity habitat and within the swarming range (but not during the swarming period) of a P2 hibernaculum would have multipliers of 1.5 and 1.5, respectively. The adjusted multiplier for this overlapping habitat removal would be 2.5 (1.5 + 1.0). The same tree clearing in June would require a multiplier of 3.0 (2.0 + 1.0). For clarification on the appropriate multiplier for a specific site, please contact the Service.

[14] This dollar amount is subject to change based on Kentucky's average value of farm real estate as published annually by the University of Kentucky's Department of Agricultural Economics in the Agricultural Situation and Outlook. The current value is based on The 2007 Agricultural Situation and Outlook for Kentucky by Richard L. Trimble.

Summary

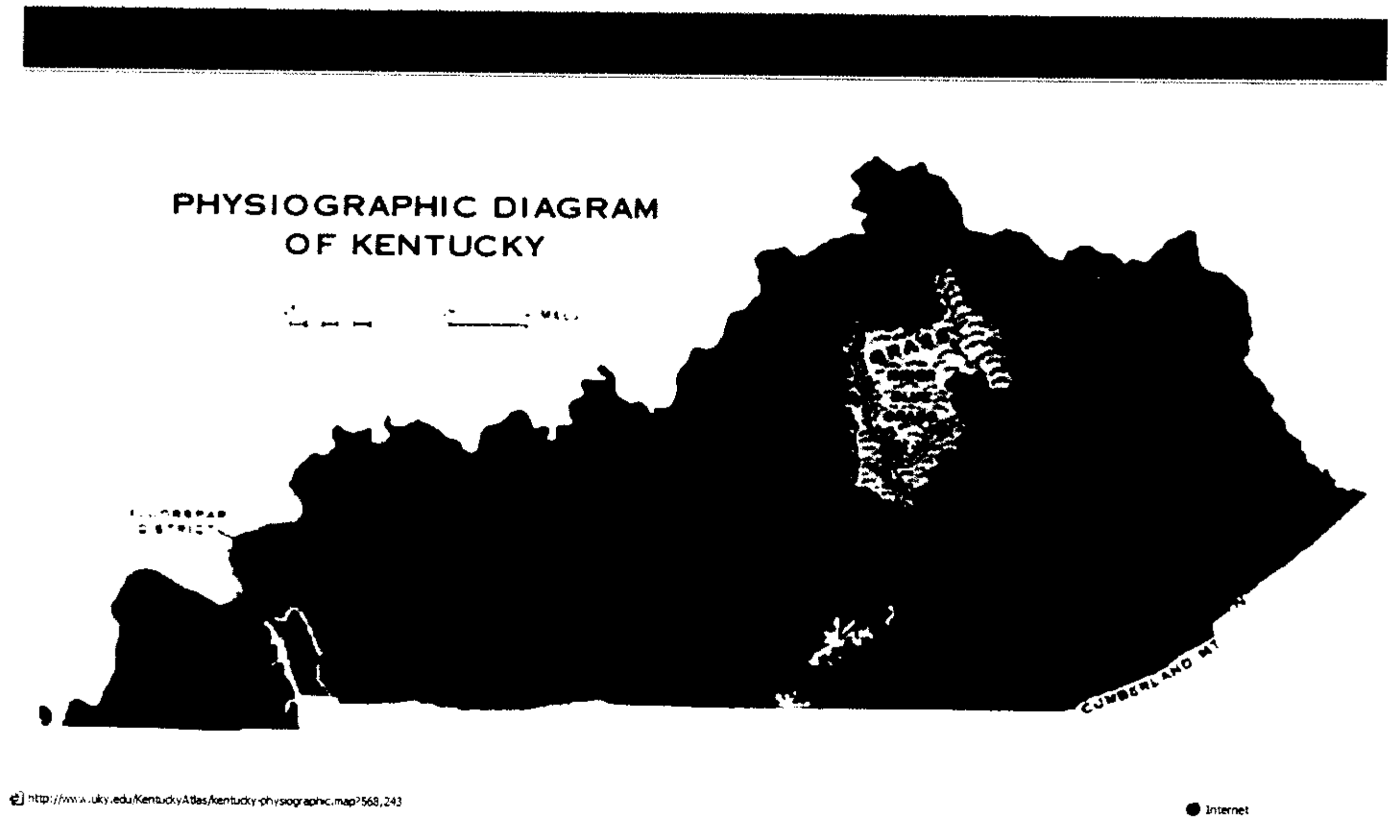
This Guidance has been developed by the Service to provide direction to project proponents whose actions have the potential to adversely affect the Indiana bat and to enhance the conservation and recovery of Indiana bat populations in Kentucky. This will be accomplished by the implementation of the minimization and mitigation measures set forth in this Guidance.

These measures were developed to support the recovery actions identified in the draft, revised recovery plan for the Indiana bat and address both summer and winter habitat. This document also establishes the conservation strategy that the Kentucky Field Office (KFO) will employ, which is the foundation for the Guidance.

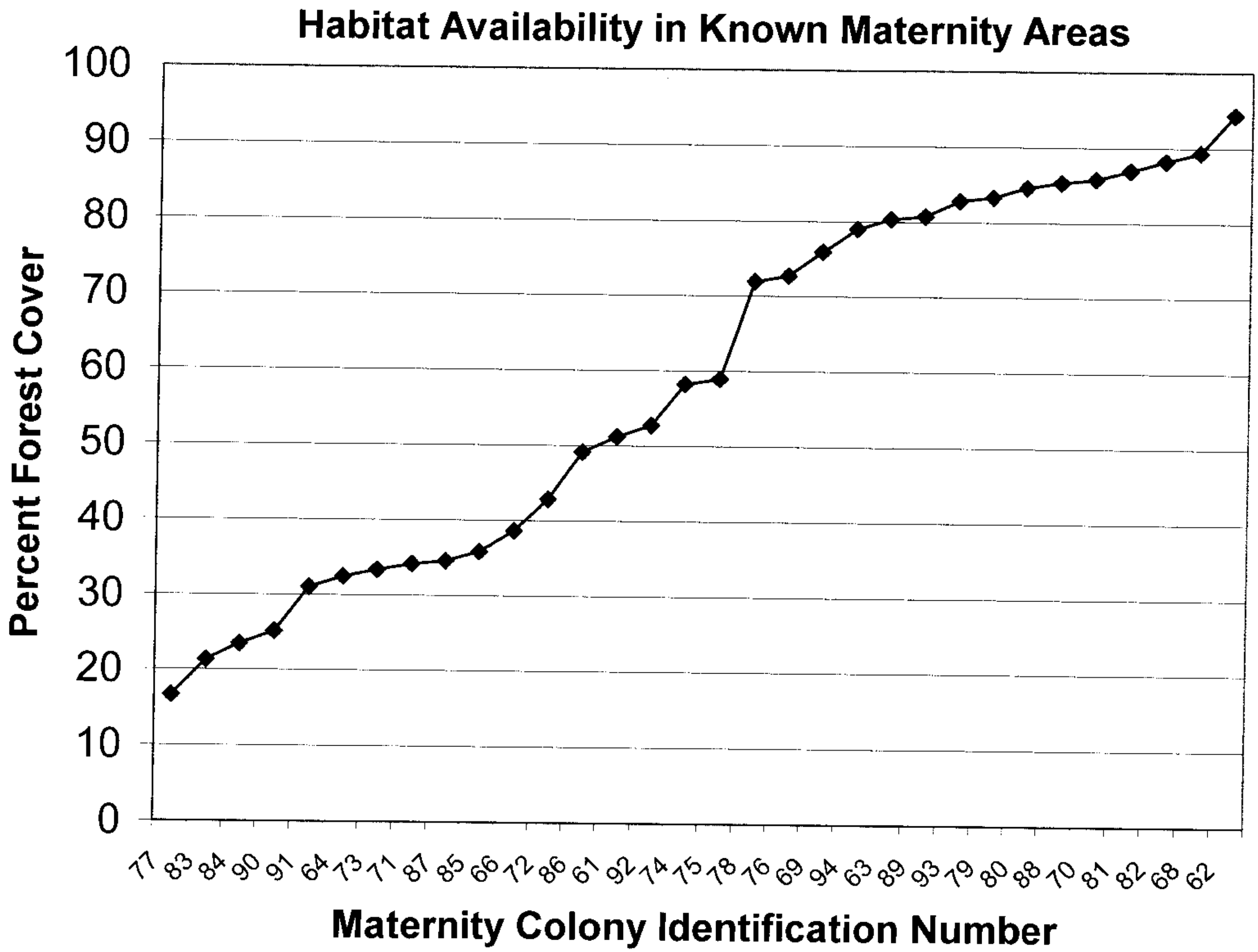
The KFO has identified those impacts to the Indiana bat where avoidance is more appropriate than minimization and mitigation as well as those projects that will need individual evaluations to determine if minimization and mitigation measures are appropriate. For any impacts that may be allowed, the level of minimization and mitigation that is established in the Guidance varies according to the relative importance of the habitat type that will be impacted to the conservation and recovery of the Indiana bat and likelihood of take. Recovery and Mitigation Focus Areas have been developed to support the identified minimization and mitigation measures as well as to ensure appropriate distribution and implementation of these measures relative to the locations of the impacts.

The protection of hibernacula, swarming and maternity areas is critical to ensuring the conservation and recovery of the Indiana bat. These guidelines set forth a process by which impacts that may directly or indirectly result in adverse effects to the Indiana bat can also help ensure the long-term survival of the species. The Service believes the implementation of this Guidance can help achieve that goal.

APPENDIX A

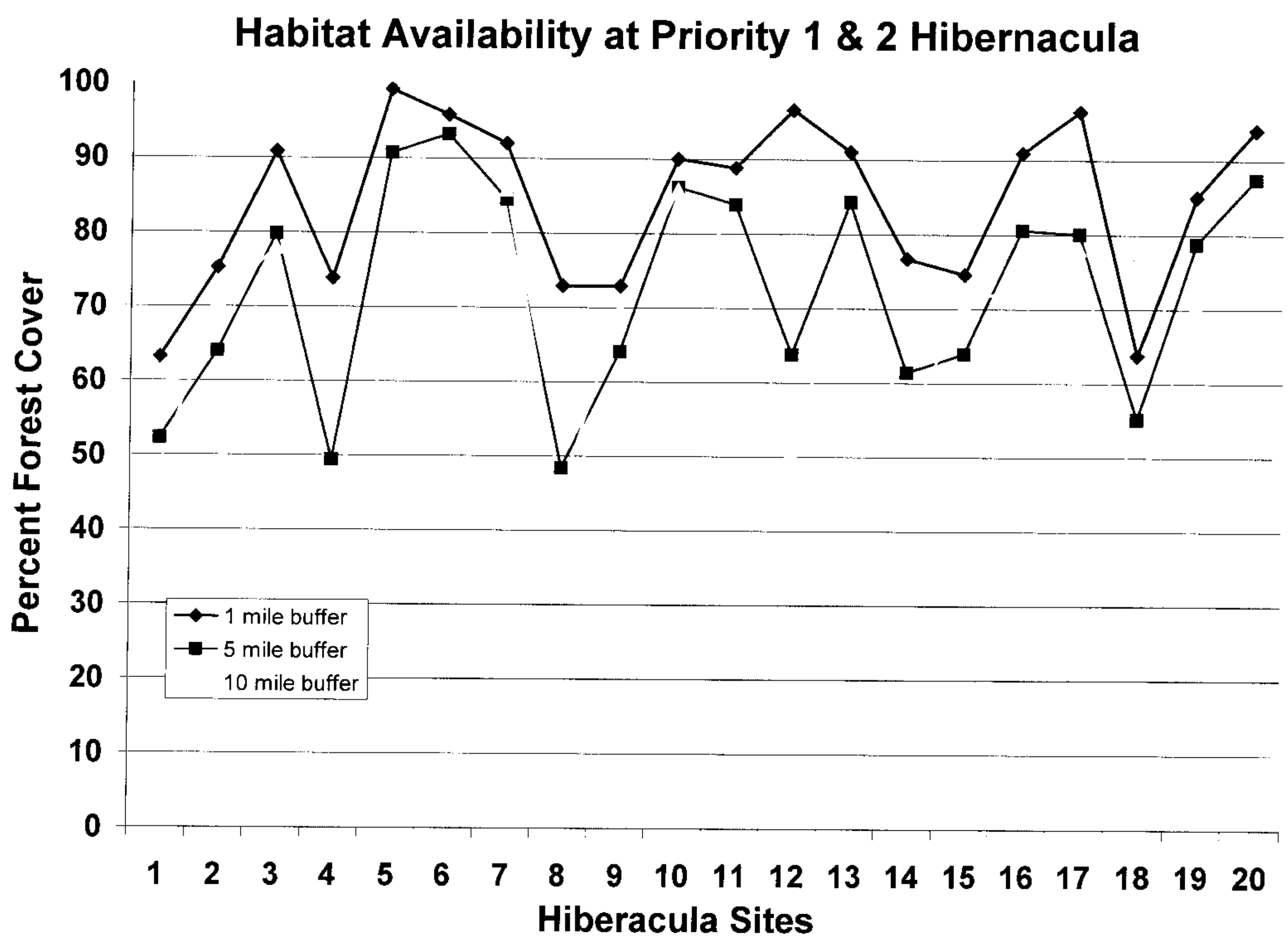

PHYSIOGRAPHIC DIAGRAM
OF KENTUCKY
CUMBERLAND MT
http://www.uky.edu/KentuckyAtlas/kentucky-physiographic.map?568,243
Internet

APPENDIX B



Habitat Availability in Known Maternity Areas
Percent Forest Cover
100
90
80
70
60
50
40
30
20
10
0
77 83 84 90 91 64 73 71 87 85 66 72 86 61 92 74 75 78 76 69 94 63 89 93 79 80 88 70 81 82 68 62
Maternity Colony Identification Number

APPENDIX C


Habitat Availability at Priority 1 & 2 Hibernacula
Percent Forest Cover
100
90
80
70
60
50
40
30
20
10
0
1 mile buffer
5 mile buffer
10 mile buffer
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Hiberacula Sites

APPENDIX B

MEMORANDUM OF AGREEMENT
FOR THE ESTABLISHMENT
OF THE
INDIANA BAT CONSERVATION FUND

MEMORANDUM OF AGREEMENT
BETWEEN
THE U.S. FISH AND WILDLIFE SERVICE
AND
THE KENTUCKY NATURAL LANDS TRUST
FOR
THE ESTABLISHMENT AND OPERATION OF THE
INDIANA BAT CONSERVATION FUND

I. PURPOSE

This Memorandum of Agreement (hereinafter "Agreement") is entered into between the United States Fish and Wildlife Service (hereinafter "USFWS"), represented by the Kentucky Field Office Supervisor and the Kentucky Natural Lands Trust (hereinafter "KNLT") represented by the Executive Director, for the purpose of establishing and operating the Indiana Bat Conservation Fund (hereinafter "IBCF"). The IBCF is intended to (a) serve as a mechanism for private individuals, companies, and other organizations to minimize the effects of authorized, project-related Indiana bat incidental take in Kentucky and (b) provide Indiana bat conservation and recovery benefits through the implementation of specific projects funded through the IBCF.

II. BACKGROUND

The Indiana bat was listed as an endangered species on March 11, 1967 (USFWS 1999). A recovery plan was approved on March 1, 1999, and the first revision of the recovery plan is currently in draft and undergoing public review. The historic range of this species consisted of the central and southeastern United States. Current records indicate that the Indiana bat occurs throughout the Commonwealth of Kentucky and may be present statewide at any location containing suitable summer or winter habitat. Within Kentucky, two caves – Bat Cave in Carter County and Coach Cave in Edmonson County – have been designated as critical habitat for the species.

Indiana bats hibernate during winter months in large, cool caves (winter hibernacula) where they form tight clusters, most often containing hundreds of individuals. Each spring the females emerge from the hibernacula and migrate to summer (maternity) habitat consisting of hardwood forests. Maternity colonies formed in these areas typically roost under the exfoliating bark of dead trees or loose bark of living trees. The migration of males is variable with a wider range of summer habitat characteristics. Some males do not migrate, others migrate only a short distance to smaller, warmer caves and others migrate to the same habitat as females.

Based on the characteristics of this life cycle, the intrinsic biological needs of this species include limiting use of fat during hibernation, obligate colonial roosting, high energy demands of pregnant and nursing females, and timely parturition and rapid development and weaning of young. Factors that may exacerbate the bat's vulnerability because of these constraints include energetic impacts of significant disruptions to roosting areas (both in hibernacula and maternity colonies), availability of hibernation habitat, and connectivity and conservation of roosting-foraging and migration corridors.

Major reasons for the decline in Indiana bat populations include channelization of streams, impoundment of waterways and associated flooding of bottomland forests, deforestation and fragmentation of forested habitat, application of insecticides, destruction or improper gating of winter habitat (e.g. mines, cisterns, and caves), commercialization of caves, and vandalism of cave habitat (Barbour and Davis 1974; USFWS 1999, 2004; Slone and Wethington 2001).

A variety of activities that are otherwise legal have the potential to cause direct, indirect, and cumulative adverse affects to the Indiana bat that could result in the illegal take of Indiana bats. Such take is prohibited by section 9 of the Endangered Species Act. The establishment of the Indiana Bat Conservation Fund will provide a mechanism to fund actions that will promote the conservation and recovery of the Indiana bat while minimizing the direct, indirect, and cumulative effects adverse effects that can occur as a result of development and other activities.

III. AUTHORITY

This Agreement is hereby entered into under the authority of the Endangered Species Act of 1973, as amended (hereinafter "Act"), (16 U.S.C. 1534 *et seq.*), wherein USFWS is responsible for the listing and recovery of wildlife listed under the Act, and cooperating with State and Federal agencies and others to achieve recovery of listed species. In addition, USFWS is authorized to provide assistance to, and cooperate with, private organizations in activities that provide for the management, conservation, and protection of fish, wildlife, and plant resources (Fish and Wildlife Act of 1956, 16 U.S.C. 742 f (a)-754, and the Fish and Wildlife Coordination Act, 16 U.S.C. 661-66c).

KNLT is a non-profit statewide land trust working with partners to secure funds for the protection of natural land and its long-term stewardship and to serve as a resource and partner to other land trusts and conservation groups. KNLT focuses on establishing protected migratory corridors in areas containing large concentrations on rare species, including the Indiana bat. KNLT is a "qualified organization" within the provisions of Section 170(h) of the Internal Revenue Code of 1986, as amended, is qualified under the laws of various states to acquire and hold conservation easements, and meets the requirements of the Internal Revenue Code as a 501(c)(3) exempt organization. KNLT is governed by a Board of Directors. KNLT's funding comes largely through donations from private charitable foundations and individuals as well as grants from government sources for specific projects.

IV. OBJECTIVES

A. Financial and other contributions to the IBCF are intended to provide a dedicated source of funding that will:
   i. Ensure that the direct, indirect, and cumulative adverse effects to Indiana bat, of otherwise legal activities are adequately addressed;
   ii. Result in tangible conservation and recovery benefits to the Indiana bat;

B. The IBCF shall be used to fund projects important to the conservation and recovery of the Indiana bat including, but not limited to:
   i. Summer habitat protection, conservation, and restoration;
   ii. Winter habitat protection and enhancement; and
   iii. Priority Indiana bat research and monitoring needs.

V. SPECIFIC OBLIGATIONS OF THE PARTIES

A. USFWS Obligations – USFWS will:

   i. Direct Deposits to the IBCF and provide KNLT with information that individually identifies the type of deposit and informs KNLT of the Recovery Unit to which the Deposit shall be credited.

   ii. Review projects proposed for funding by the IBCF and approve or disapprove proposed projects as appropriate and consistent with the purpose and objectives of the IBCF. KNLT shall not be excluded from proposing projects.

   iii. Where appropriate, provide information on the IBCF in its public wildlife education efforts.

B. USFWS Acknowledgements – USFWS hereby agrees and acknowledges that:

   i. The IBCF management fee described in Section VI.B represents reasonable consideration for KNLT's efforts under this Agreement. KNLT efforts shall include, but are not limited to: managing, investing and tracking the IBCF, attending meetings regarding oversight and management of the IBCF, and distribution of funds as directed by USFWS.

   ii. Notwithstanding anything contained herein to the contrary, third parties seeking incidental take permits or incidental take statements from USFWS remain ultimately and solely liable for satisfying all of the conditions under any permit or other regulatory document, and KNLT shall not be liable in any manner whatsoever to USFWS or those third parties, or any other individual or entity whatsoever with respect to satisfaction of any of the conditions or requirements of any permit or other regulatory document. In particular, USFWS acknowledges that, notwithstanding anything contained herein to the contrary, KNLT shall not be responsible for determining whether the acquisitions funded by the IBCF adequately minimize or mitigate for onsite impacts at any site or for determining the relative functional value of land to be acquired pursuant to this Agreement and that KNLT's acceptance of Deposits shall not constitute any direct or implied affirmation that Deposits are adequate mitigation and/or minimization for any purpose.

C. KNLT Obligations – KNLT will:

i. Subject to the terms of this Agreement, accept certified funds directed to KNLT as Deposits into the IBCF for use in achieving conservation projects described above in Section IV: Objectives.

ii. Appoint an individual, KNLT's Project Officer, who will represent KNLT to USFWS in carrying out KNLT's obligations under this Agreement.

iii. Distribute, at the sole direction of USFWS, funding from the IBCF for habitat acquisition, habitat management, monitoring, and research to governmental entities and nongovernmental organizations for USFWS approved Indiana bat projects. KNLT shall have no responsibility for determining the identity or adequacy of the recipient, amount, intended use, or results of any such distributions and this provision shall not be construed either as a direct funding or match requirement for KNLT. Upon receiving written notification from USFWS, KNLT shall have not more than 60 days to distribute those funds to the recipient(s).

iv. In the event any property transferred by KNLT results in proceeds, KNLT shall place all those proceeds into the IBCF to the extent they are attributable to the portion of the property purchased with the IBCF. KNLT is not, however, required to obtain proceeds from any transfer of property obtained pursuant to this Agreement.

VI. **FINANCIAL ADMINSTRATION AND DISTRIBUTION OF THE IBCF** - KNLT will have primary responsibility for administering the funding contained in the IBCF.

A. Certified funds designated for the IBCF shall be deposited into KNLT's general banking account or with an investment agent used by KNLT to manage its funds, subject to the following requirements:

i. KNLT shall open separate budget centers to track the IBCF;

ii. IBCF funding shall be tracked as specified by the USFWS; Deposits from the Kentucky Transportation Cabinet shall be tracked as specified by the USFWS and separate from Deposits made by other entities;

B. As compensation for the management of the IBCF, KNLT shall receive:

i. An annual principal fee of 0.75% that will be prorated and charged monthly, based on the market value of the IBCF.

ii. An annual management fee of 1.25% of the total account balance based on the average monthly value of the IBCF on the last day of that month. This management fee shall be waived to the extent necessary when income from the account is insufficient to cover the management fee.

C. If expenses are incurred by KNLT prior to the termination of this Agreement but are unpaid at the time of termination, KNLT shall be entitled to pay those costs from the IBCF prior to the return of the balance of the IBCF pursuant to Section IX: Modification and Termination.

D. USFWS has the discretion to direct KNLT to make distributions from the IBCF to governmental entities and nonprofit corporations. However, USFWS agrees to work closely with KNLT to ensure that USFWS does not direct disbursements which would adversely impact pending acquisitions, including pending negotiations, or which would result in insufficient funds being available to pay for incurred due diligence products or to pay one or more KNLT Management Fees which are due or which are reasonably expected to be due.

E. KNLT will furnish an annual report to USFWS in the form of a statement of income and expense and will include the total amounts of Deposits, interest income, and categorized disbursements, including but not limited to IBCF management fees, distributions, acquisition costs and expenditures. This report will be due within 30 days of each anniversary date of the effective date of this Agreement or within 30 days of the termination of this Agreement whichever first occurs.

F. KNLT shall maintain books, records and documents directly pertinent to performance under this Agreement in accordance with generally accepted accounting principles and make these available to the USFWS for review and auditing purposes upon the USFWS's written request.

VII. COOPERATION – Both USFWS and KNLT acknowledge that it is their desire to facilitate the processes set forth in this Agreement by open communication and cooperation. Both parties agree to exercise their rights and obligations under, this agreement in good faith. If at any time KNLT has questions regarding its application of the IBCF or selection of a project, USFWS agrees to make itself available for consultation in a timely fashion. Further, each of the parties hereto agrees whenever and as often as it shall be reasonably requested to do so by any other party hereto, execute, acknowledge, and deliver, or cause to be executed, acknowledged and delivered, any and all further instruments as may be reasonably necessary in order to consummate the transactions provide for in, or contemplated by, this Agreement, and to carryout the purpose and intent of this Agreement.

VIII. OTHER PROVISIONS

A. Each party hereto agrees that it shall be liable for the negligent or wrongful acts or omissions of its employees, agents and assigns only to the extent liable under applicable law. Nothing in this Agreement shall be interpreted or construed as constituting a waiver by any party of sovereign immunity or statutory limitations on liability.

B. This Agreement may not be assigned in whole or in part with out the written approval of the parties. Any such assignment or attempted assignment shall be null and void.

C. Each provision of this Agreement shall be interpreted in such a manner as to be effective and valid under applicable law, but if any provision of the Agreement shall be prohibited or invalid under applicable law, such provision shall be ineffective to the extent of such prohibition or invalidity, without invalidating the remainder of such provision or the remaining provisions of this Agreement.

D. The parties here to do not intend nor shall this Agreement be construed to grant any rights, privileges or interest to any person not a party to this Agreement.

E. No provision of this Agreement shall be interpreted as or constitute a commitment or requirement that either party take actions in contravention of applicable laws, either substantive or procedural.

F. Nothing in this Agreement shall be interpreted as or constitute a commitment or requirement that the USFWS obligate or pay funds in contravention of the Anti-Deficiency Act, 31 U.S.C. § 1341, or any other law or regulation.

G. This Agreement constitutes the full and complete agreement of the parties. No other promises, written or oral have been made by any party hereto.

IX. MODIFICATION AND TERMINATION

A. Modification - This Agreement may only be amended or modified with the written approval of all parties to this Agreement. Modifications may be requested by submitting a written request for such modifications to the other parties. If all parties approve these modifications in writing, they shall become binding terms of the Agreement.

B. Termination of Agreement - Any party may terminate this Agreement upon 30 days advance written notification to all signatory parties. Termination by KNLT will require the return of any unspent funds remaining in the IBCF to the Service or to the designee of the Service. If the Agreement is terminated, KNLT shall immediately transfer any and all funds in the IBCF to an account specified in writing by USFWS.

X. REFERENCES

A. Barbour, R.W. and W.H. Davis. 1974. Mammals of Kentucky. University Press of Kentucky, Lexington, Kentucky. 322 pp.

B. Slone, T. and T. Wethington (compilers). 2001. Kentucky's Threatened and Endangered Species. Kentucky Department of Fish and Wildlife Resources, Frankfort, Kentucky. 34 pp.

C. U.S. Fish and Wildlife Service. 1999. Agency Draft Indiana Bat (*Myotis sodalis*) Revised Recovery Plan. Fort Snelling, MN. 53pp.

D. U.S. Fish and Wildlife Service. 2004. An Assessment Framework for Conducting Jeopardy Analyses under Section 7 of the Endangered Species Act. Ecological Services Program, Washington D.C. 10pp.

XI. NOTICE

A. Any notice or other communication required or permitted hereunder shall be deemed to have been duly given if in writing and delivered personally or sent by Federal Express or similar next day nationwide delivery system or mailed by first-class, registered or certified mail, as follows:

If to USFWS:
U. S. Fish and Wildlife Service
c/o: State Field Office Supervisor
330 West Broadway, Suite 265
Frankfort, KY 40601

If to KNLT:
Kentucky Natural Lands Trust
c/o: Executive Director
433 Chestnut Street
Berea, KY 40403

B. A party may change the address to which such communications are to be directed by giving written notice to the other parties in the manner provided in this Article.

C. Any notice or other communication made pursuant to this Article shall be deemed to have been received by the addressee at the earlier of such times as it is actually received or seven calendar days after it is mailed.

XII. **EFFECTIVE DATE** - This Agreement shall be effective upon the date it is signed by all parties.

By: Virgil Lee Andrews
Field Supervisor
U.S. Fish and Wildlife Service

Date: 12/7/07

By: Hugh N. Archer
Executive Director
Kentucky Natural Lands Trust

Date: November 26, 2007

APPENDIX C

SUMMARY OF PREVIOUS
INCIDENTAL TAKE AUTHORIZATION

Indiana bat biological opinions including amount and form of incidental take exempted.

PROJECTS	SERVICE OFFICE AND DATE BO ISSUED	INCIDENTAL TAKE (IT) FORM	TAKE EXEMPTED or SURROGATE MEASURE TO MONITOR
1996 Programmatic Biological Opinion for Surface Coal Mining Regulatory Programs Under the Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87)	Washington DC October 1996	IT by harm, harassment, and killing of all current and future listed species	Unquantifiable
Cherokee National Forest LRMP; Note: As a result of new information, this Forest is now operating under a "not likely to adversely affect" determination, and this BO is no longer in effect.	Tennessee FO January 1997	IT by killing harming or harassing	1,300 acres annually
Spillway Rehabilitation at Tippy Dam, MI	East Lansing FO January 1997	IT by harming, harassing, or killing	3-65 individuals
Relocation of US Army Chemical School & US Military Police School to Fort Leonard Wood, Missouri	Missouri FO	IT by harming, harassing, or killing	56 hibernating bats from fog oil and TPA smoke pots; summer bats difficult to determine sub-lethal take
Daniel Boone National Forest LRMP; Note: This BO has been superseded by a March 2004 BO.	Tennessee FO April 1997	IT by killing, harming, or harassing	4,500 acres annually
Ozark-St. Francis National Forest LRMP;	Arkansas FO June 25, 1998	IT by killing, harming or harassing	Annually 8,000 acres of timber harvest in hardwoods, 11,000 acres harvest of pine and pine/hardwoods; 30,000 acres of prescribed burning
Construction of New Training Facilities at Fort Knox, KY	Tennessee FO October 1998	IT by killing, harming or harassing	2,000 acres
Construction of a Qualification Training Range at Fort Knox, KY	Tennessee FO October 1998	IT by killing, harming or harassing	80 acres
Construction & operation of the Multi-purpose training Range at the Camp Atterbury Army National Guard Training Site-Edinburgh Indiana NOTE: Superseded by November 2000 Amendment	Indiana FO December 4, 1998	IT by harm through habitat loss and exposure to toxic agents	1 maternity colony (200 bats total) and 99.7 ha of forest
Disposition of Lands Acquired by the Tennessee Valley Authority for the Columbia Dam Project, Maury County, Tennessee	Tennessee FO March 1999	No take provided	No take provided

Proposed stream bank stabilization at Yano Range and upgrade of the Wilcox Tank Range at Fort Knox, KY	Tennessee FO April 1999	IT by loss of summer roosting, foraging, and maternity habitat	1800 acres; 2 maternity colonies
Agricultural Pesticide Application Practices at Newport Chemical Depot, Newport IN	Indiana FO April 13, 1999	IT by harm through exposure to pesticides	2 maternity colonies with 74 bats total
Ouachita National Forest LRMP; Note: As a result of new information, this Forest is now operating under a "not likely to adversely affect" determination, and this BO is no longer in effect	Arkansas FO April 26, 1999	IT by killing, harming or harassing	Annually up to: 40,000 acres commercial harvest; 3,000 acres wildlife management & road construction/reconstruction; 24,000 acres thinning; 200,000 acres prescribed burning
Mark Twain National Forest LRMP; Note: This BO has been superseded by the September 2005 BO	Missouri FO June 23, 1999	IT by killing, harming, or harassing	Timber harvest – 20,000 acres per year; Prescribed fire - 12,000 acres/yr; Wildlife habitat improvement -2000 acres/yr; Timber stand improvement – 4000 acres/yr; Soil & water improvement – 150 acres/yr; Range management – 50 acres/yr; Mineral exploration & development – 50 acres/yr; Wildfire fire lines – 50 acres/yr; Special use – 50 acres/yr; Road construction – 25 acres/yr
Impacts of Forest Management and Other Activities to the Bald Eagle, Indiana Bat, Clubshell and Northern Riffleshell on the Allegheny National Forest, Pennsylvania; Note: As a result of new information, this Forest is now operating under a "not likely to adversely affect" determination, and this BO is no longer in effect.	Pennsylvania FO June 1999	IT by killing, harming, or harassing	Within a 5-year period (1999 to 2003), the disturbance of 45,594 acres
National Forests in Alabama; Note: As a result of new information, this Forest is now operating under a "not likely to adversely affect" determination, and this BO is no longer in effect.	Alabama FO December 10, 1999	IT by killing, harming or harassing	No more than 100 trees
Supplement for Proposed Bridges & Alignments Modifications to Kentucky Lock Addition Project	Tennessee FO January 2000	IT by killing, harming or harassing	No more than 20% of available suitable habitat
Green Mountain National Forest LRMP; Note: As a result of new information, this Forest is now operating under a "not likely to adversely affect" determination, and this BO is no longer in effect.	New England FO 2000	IT by harming or harassing	300 acres annually

White Mountain National Forest LRMP; Note: As a result of new information, this Forest is now operating under a "not likely to adversely affect" determination, and this BO is no longer in effect.	New England FO 2000	IT by harming or harassing	1,500 acres
Nantahala and Pisgah National Forests LRMP Amendment #5	Asheville (NC) FO 2000	IT by killing, harming, or harassing	4,574 acres per year
Daniel Boone National Forest LRMP and the Proposed Special Habitat Needs and Silviculture Amendment	Tennessee FO May 2000	No take provided	No take provided
Hazard Tree Removal and Vegetation Management Program at Mammoth Cave National Park	Tennessee FO June 2000	IT by loss of roosting habitat, direct mortality or by forcing bats to abandon tree	No take provided
Salvage Harvest Necessitated by 1998 Storm Damage on the Daniel Boone National Forest	Tennessee FO July 2000	IT by killing, harming, or harassing	3,100 acres
Revised: Construction & operation of the Multi-purpose training Range at the Camp Atterbury Army National Guard Training Site- Edinburgh Indiana	Indiana FO November 2000	IT by harm through habitat loss and exposure to toxic agents	121 ha of forest
North East research Station – Fernow Experimental Forest – Five year plan NOTE: Superseded by the December 2005 BO	West Virginia FO November 2000	IT by potential harm or mortality of roosting bats	210 acres timber harvest and 95 acres prescribed burn
Bankhead National Forest; Modification of 1999 BO for National Forests in Alabama	Alabama FO January 23, 2001	IT by killing, harming or harassing	Level of take changed for southern pine beetle suppression areas – upper limit of 65 suitable roost trees
Hoosier National Forest LRMP; Note: This BO has been superseded by a January 2006 BO.	Indiana FO June 13, 2001	IT by harm	Pine clear cuts – 578 acres; Pine shelterwood cuts – 391 acres; Pine thinning – 408 acres; Hardwood group selection cuts – 777 acres; HW single tree selection cuts – 100 acres; HW even aged salvage cuts – 518 acres; Prescribed fire treatment – 7000 acres; Forest openings maintenance – 3311 acres; Timber stand improvement – 2264 acres; Special use permits – 286 acres; Wildfire management – 250 acres; road construction – 16 acres; hazard tree removal – 100 trees; trail construction – 15 miles

Wayne National Forest LRMP; Note: BO has been superseded by a November 2005 BO.	Ohio FO September 20, 2001	IT by harm	Permanent loss of habitat – 2,504 acres; Habitat alteration – 8,102 acres plus 125 trees
Ozark-St. Francis National Forest Prescribed Fire Plan (an amendment to June 1998 LRMP BO).	Arkansas FO March 21, 2002	IT by loss of roost trees and potential roost trees	Prescribed fire - 153,000 acres/yr
1986 (as amended) Monongahela National Forest Land and Resource Management Plan (Forest Plan); Note – This BO has been superseded by a July 2006 BO.	West Virginia FO March 2002	IT by killing, harming, or harassing	A maximum of 6,125 acres annually and prescribed burning on a maximum of 300 acres annually.
BO for the Six Points Road interchange and Associated Development	Indiana FO March 2002	IT by killing, harming, or harassing	139 ha of roosting and foraging habitat [includes: 149 reproductive females & young; unquantifiable number of adult males and unreproductive females]
Huron-Manistee National Forest LRMP; Note: This BO has been superseded by a March 2006 BO.	Michigan FO June 13, 2003	IT by killing, harming, or harassing	0-65 bats; 3,150 ac (1,275 ha) of potential Indiana bat habitat may be harvested and 2,648 ac (1,071 ha) of habitat may be burned for fire management or wildlife habitat management activities for the duration of this proposed action
Great Smoky Mountains National Park Prescribed Burning	Tennessee FO August 12, 2003	IT by loss of suitable roosting or foraging habitat	One maternity colony
Big Monon Ditch Reconstruction Project	Indiana FO August 5, 2003	IT by harming and harassing	Permanent loss of 75 acres of occupied summer habitat
Proposed Construction, Operation, and Maintenance of Alternative 3C of Interstate 69 from Indianapolis to Evansville NOE: This has been replaced by a 2006 revised BO	Indiana FO December 3, 2003	IT by harming, killing	Summer action area: permanent direct & indirect loss of up to 1527 acres of forested habitat and 40 acres of non-forested wetlands. Winter action area: permanent loss of up to 947 acres of forest habitat around 10 known hibernacula. Death by vehicle collisions: 10 Indiana bats per year.
2003 Revised Jefferson National Forest Land and Resource Management Plan, Virginia, West Virginia, Kentucky	Virginia FO January 2004	IT by killing, harming, or harassing	16,800 acres total (15,000 fire; 1,800 other habitat manipulations) per year
Reinitiation: Wayne National Forest LRMP NOTE: Superseded by November 2005 BO	Ohio FO March 8, 2004	IT by harm	Additional 11,892 acres of habitat alteration
2004 Daniel Boone National Forest Revised LRMP Note: BO has been superseded by an April 2007 BO.	Kentucky FO March 20, 2004	IT by killing, harming, or harassing	Green tree harvest – 4000 acres; Salvage/sanitation – 350 acres; Prescribed burning during summer – 50,000 acres

Upper Mississippi River – Illinois Waterway System Navigation Feasibility Study	Rock Island (IL) FO August 2004	IT by injury, death, harming or harassing	511 acres of forested habitat annually for 50 years. Less than 20 bats per year.
Impacts of the Laxare East and Black Castle Contour Coal Mine Projects on the Indiana bat NOTE: BO has been superseded by the 2006 revised BO	West Virginia FO February 2005	IT by killing, harm and harassment	No more than 40 adult females & their pups; permanent loss of 2199 acres forested habitat; 917 acres of habitat fragmentation and degradation; 11.95 miles of stream loss
Department of the Army 88th Regional Readiness Command, US Army Reserve Center	Ohio FO April 14, 2005	IT by harming or harassing	18 acres of high quality roosting and foraging habitat
Construction, Operation, and Maintenance of the U.S. 33 Nelsonville Bypass	Ohio FO April 15, 2005	IT by harming, death, injury	No more than 10 Indiana bats
Mark Twain National Forest 2005 Forest Plan, Missouri; Note: Replaces June 1999 BO.	Missouri FO September 2005	IT through removal of roost trees	10 occupied roost trees , 19,400 acres and 240 miles of fire line over 10 years;
Construction .Operation, and Maintenance of the US 24 New Haven, Indiana to Defiance, OH Project	Ohio FO September 30, 2005	IT by harming, harassing, and killing	Not to exceed 10 individuals
BO on the Interstate 69 (I-69) preferred alternative #2 from Henderson, Kentucky to Evansville, Indiana, and its effects on the Indiana bat; Henderson County, Kentucky and Vanderburgh County, Indiana	Kentucky FO October 2005	IT through harm, harassment, and/or mortality	The level of take authorized is for those wooded areas of occupied and/or potentially occupied Indiana bat habitat within the construction limits of the proposed project that lie within the Indiana bat focus area identified in the BA, which was determined to be about 28 acres of wooded habitat and all of the potential Indiana bat roost trees contained within those 28 acres.
Wayne National Forest Land and Resource Management Plan; Note: Replaces September 20, 2001 BO.	Ohio FO November 2005	IT through removal of roost trees	No more than 4 occupied roost trees will be incidentally taken over the next ten years; Permanent Road Construction & Reconstruction -392 acres; Temporary Road Construction -146 acres; Skid Trails and Log Landings - 740 acres; Utility Development - 50 acres; Fire Lines - 74 miles

Shawnee National Forest LRMP	Illinois FO December 3, 2005	IT through harming, harassing, and killing	First 10 Years of plan: -- 11,565 acres of timber harvest/mgt. and minerals mgt. -- 5,630 acres of timber stand improvement and wetlands mgt. Second 10 Years of plan: -- 21,255 acres of timber harvest/mgt. and minerals mgt. -- 13,289 acres of timber stand improvement and wetlands mgt. Mortality of up to 2 individuals during research and monitoring.
North East Research Station – Fernow Experimental Forest – Five year plan; Note: Replaced November 2000 5-year BO.	West Virginia FO December 2005	IT by potential harm or mortality of roosting bats	124 acres timber harvest and 466 acres of prescribed burns (previous 210 acres timber harvest and 154 acres prescribed burn) over 5 years
Final Biological Opinion on implementation of the 2003 Ice Storm Recovery Project and it effects on the Indiana bat, Morehead Ranger District, Daniel Boone National Forest, Rowan County, Kentucky	Kentucky FO December 2005	IT through harm, harassment, and/or mortality	The level of incidental take authorized is 4,704 acres of commercial removal of damaged trees and restoration and creation of bat habitat when accomplished during the summer roosting period of the Indiana bat (April 1 to September 15).
Hoosier National Forest LRMP; Note: This BO replaced the June 2001 BO.	Indiana FO January 2006	IT by injury or death or harassing	No more than four (4) occupied roost trees/year and between four (4) and twelve (12) individuals injured or killed each year. 2956-acres; 60 hazard trees; 100 "accident" trees per year
Huron-Manistee National Forest LRMP NOTE: Replaces 2003 BO	Michigan FO March 2006	IT through harming, harassing, and killing	For first 10 years of revised Forest Plan: Thinning = 59,497 Clearcut = 45,144 Shelterwood = 8,261 Selection = 0

Biological Opinion – Impacts of the Laxare East and Black Castle Contour Coal Mining Projects on the Indiana bat; Note: Reinitiation of February 2005 BO.	West Virginia FO March 2006	IT in the form of harm due to habitat loss, degradation and fragmentation, Harassment during active mining, Permanent loss of foraging loss and roosting habitat, habitat fragmentation and degradation, permanent loss of streams and their associated watering and prey base for Indiana bats, long term alteration of streams	No more than 17 adult females and their pups; 912 acres of forested habitat and 5.0 miles of stream
Allegheny National Forest, West Branch Tionesta Site	Pennsylvania FO April 2006	IT through harming, harassing, and killing	574 acres of forested habitat loss or alternation from prescribed burning
Hoosier National Forest's Proposed Tell City Windthrow 2004 Salvage Timber Harvest	Indiana FO April 2006	Death and injury from direct felling of occupied trees; Harassment of roosting bats from noises/ vibrations/ disturbance levels causing roost-site abandonment and atypical exposure to day time predators while fleeing and seeking new shelter during the day-time; and Harm through the loss of primary and/or alternate roost trees	Project-wide Combined Total: 8,525 acres
Final Programmatic BO On Minor Road Construction Projects In Kentucky And Their Effects On The Indiana Bat	Kentucky FO June 2006	IT through harming, harassment, mortality	The level of take authorized is for those wooded areas of Indiana bat habitat within the construction limits of a proposed project covered by Tier 2 during KYTC FY 2006 through KYTC FY 2010, which was determined to be 500 acres of Indiana bat habitat as described in the HAM in KYTC FY06, 600 acres in KYTC FY07, 720 acres in KYTC FY08, 864 acres in KYTC FY09, 1,037 acres in KYTC FY10.

Programmatic Biological Opinion for the Monongahela National Forest 2006 Forest Plan Revision	West Virginia FO July 2006	IT through harming, harassment, and/or mortality	10,052 acres of suitable Indiana bat habitat annually
Revised BO on the Proposed Construction, Operation, and Maintenance of Alt. 3C of Interstate 69 from Evansville to Indianapolis	Indiana FO August 2006	Death/kill and/or injury/wound from direct felling of occupied trees, direct collision with vehicles, and other sources.	2,148 acres of forested habitat and 20 acres of non-forested wetlands within summer action area; 1,097 acres of forested habitat within winter action area; 11 individuals per year from collision with vehicles
Programmatic BO for the Crab Orchard National Wildlife Refuge	Illinois FO August 8, 2006	IT by harm, harass and kill	Loss of no more than 15 occupied roost trees plus up to 2 individual from research/monitoring
Meads Mill Project, Allegheny National Forest; USFWS Project #2006-1408	Pennsylvania FO September 2006	IT through harm, harassment, and/or death	549 acres of forested habitat by prescribed fire
BO on the Ohio DOT's Statewide Transportation Program for the Indiana bat	Ohio FO January 2007	IT through harm, harassment, and/or death	22,118 acres of suitable Indiana bat habitat over 5 years
2007 Daniel Boone National Forest Revised BO on implementation of the revised LRMP and its effects on the Indiana bat Note: Replaced March 20, 2004 BO.	Kentucky FO April 2007	IT by killing, harming, or harassing	Annually: Green tree harvest – 4000 acres; Salvage/sanitation – 350 acres; Prescribed burning during summer – 50,000 acres
BO and ITS for Indiana bat (*Myotis sodalis)* at the Herrington Place Subdivision, Reminderville, Summit County, Ohio	Ohio FO April 2007	IT through harm, harassment, and/or death	Permanent loss of 61.7 acres high quality roosting & foraging habitat and fragmentation of suitable habitat on the 125 acre site. Mortality of 1 adult male and 1 adult female
The Effects of the U.S. 6219, Section 019, Transportation Improvement Project (Meyersdale, Somerset County, Pennsylvania to I-68 in Garrett County, Maryland) on the Indiana bat	Pennsylvania FO October 2007	IT through harm, and/or harassment	All Indiana bats dependent on 375 acres of potential foraging and roosting habitat and near blasting/construction
Final Biological Opinion on the Reconstruction of US 119 from Partridge to Oven Fork in Letcher County	Kentucky FO November 2007	IT through harm, harass and/or death	456 wooded acres of occupied and/or potentially occupied Indiana bat habitat within the construction limits of the proposed project
Biological Opinion On The USDA Forest Service Application Of Fire Retardants On National Forest System Lands	Washington DC February 2008	No take provided	No take provided