United States Department of the Interior

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January 22, 2010

Ms. Liz Agapoa
Regional Forester
U.S. Forest Service, Southern Region
1720 Peachtree Road, NW
Atlanta, Georgia 30309

Dear Ms. Agapoa:

Subject: FWS 2009-B-0084; Biological Opinion for the Land Between the Lakes National Recreation Area's Wildfire and Forest Vegetation Management Program

This document is the U.S. Fish and Wildlife Service's (Service) biological opinion based on our review of the U.S. Forest Service (USFS) Land Between the Lakes National Recreation Area's (LBL) proposed implementation of the Wildfire and Forest Vegetation Management (WFVM) program and its effects on the Indiana bat (*Myotis sodalis*) and Price's potato-bean (*Apios priceana*) under section 7 of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 *et seq.*). Your September 9, 2009 request for formal consultation was received on September 10, 2009.

This formal consultation and biological opinion is based on information provided in the August 18, 2009 Biological Assessment, other available literature, personal communications with experts on federally listed species that occur on LBL, and other sources of information. A complete administrative record of this consultation is on file at this office.

INTRODUCTION

The Service has reviewed the BA for implementation of the WFVM program and all of the above-referenced supporting and supplemental information. The BA evaluates the potential and actual effects of implementation of the WFVM program on four (4) federally listed species. This document represents our (a) concurrence with the "not likely to adversely effect" determination for the least tern (*Sterna antillarum athalassos*) and the gray bat (*Myotis grisescens*), and (b) biological opinion on the effects of that action on the endangered Indiana bat and Price's potato-bean in accordance with Section 7 of the Act. LBL's staff determined that the proposed action is "likely to adversely affect" the Indiana bat and Price's Potato-bean.

LBL considered potential effects to two additional listed species that are currently known to occur on LBL or historically occurred there. Assessment of effects to those species resulted in "not likely to adversely affect" determination for the least tern and gray bat. A "not likely to adversely affect" determination was made for the least tern because no action is planned to occur in suitable habitat for the species and because exposure from wildfire or vegetation management actions on LBL is extremely unlikely in adverse effects on this species. In addition, LBL has committed to apply the Area Plan's Standards to protect and conserve the species and its habitat, and will continue consulting with the KFO on actions not considered in the BA.

A "not likely to adversely affect" determination was also made for the gray bat because: (a) No suitable caves for gray bats are known to occur on LBL, so direct impacts to its roosting and hibernation habitat will not occur; (b) The proposed action will create canopy gaps that will be beneficial to the species and the temporary disturbances and activities associated with proposed WFVM program actions are unlikely to result in significant adverse effects or take of the species; and (c) Tobacco Port Cave, a known gray bat hibernacula approximately 1.3 air miles from LBL, will be treated as a smoke-sensitive target, so potential adverse effects to this known habitat can be avoided through properly planned prescribed fires. In addition, LBL has committed to apply the Area Plan's Standards to protect and conserve this species and its habitat, and will continue consulting with the KFO on actions not considered in the BA.

Consultation History

June 22, 2007 – LBL staff met with Lee Andrews and Alan Whited of the KFO to begin an informal discussion of this Biological Assessment.

November 2, 2007 – USFS Project leader Jim McCoy had a telephone conversation with KFO Fish and Wildlife Biologist Mindi Lawson regarding the need for subsequent, project-specific consultation on LBL's management actions.

January 8, 2008 – Jim McCoy had a telephone conversation with Mindi Lawson to discuss a timeline for consultation on the BA.

February 25, 2008 – Jim McCoy submitted a draft of the BA to the KFO for comment.

March 5, 2008 – Jim McCoy, Lee Andrews, and Mindi Lawson had a conference call to discuss format and content of a draft version of the BA.

March 10, 2008 – Mindi Lawson mailed a hardcopy of the KFO's comments regarding the draft BA to Jim McCoy.

May 30, 2008 – Jim McCoy notified the KFO of the USFS's intention to deliver the final BA and to request Formal Consultation.

June 2008 – A draft of the BA was submitted to Dennis Krusac, the USFS's Regional Threatened and Endangered Species Specialist, for review.

October 20, 2008 – A revised draft of the BA was submitted to the KFO.

November 24, 2008 – Carrie Lona emails the KFO's comments on the revised draft BA to Jim McCoy.

August 3, 2009 – The final BA was submitted to the KFO.

August 18, 2009 – The final BAE with corrections to page 50 was mailed to the KFO.

September 10, 2009 – The KFO receives a request from the USFS requesting initiation of formal consultation for the Indiana bat and Price's potato-bean.

September 10, 2009 - The KFO initiates formal consultation.

January 22, 2010 – The KFO issues the final Biological Opinion for the LBL Wildfire and Vegetation Management program.

BIOLOGICAL OPINION

DESCRIPTION OF THE 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. This biological opinion addresses only those actions for which the Service believes adverse effects may occur. In their BA, LBL outlined those activities in the proposed WFVM program that would affect the Indiana bat and Price's potato-bean. This biological opinion addresses whether implementation of the WFVM program is likely to jeopardize the continued existence of the Indiana bat and/or Price's potato-bean.

Proposed Action

The 2004 Land and Resource Plan (Area Plan) is LBL's guide for management of multiple uses, such as outdoor recreation, education, and the sustainable management of LBL's natural resources. The proposed action is LBL's use of the WFVM program to implement the Area Plan, specifically Goal 5. Goal 5 addresses natural resource management and forms the basis of for resource stewardship for species of viability concern on LBL. Goal 5 states that LBL will "use a collaborative approach to maintain and restore: 1) a diversity of plant and animal communities that support viability of associated plants, fish, and wildlife; and 2) sustainable levels of habitat and wildlife populations to support public demand for wildlife-related recreation. The following objectives are the measurable, planned results to implement Goal 5 of the Area Plan:

• OBJ5a: In mature oak forests, provide open forest structure on approximately 19,000 acres by the end of the first decade with a long-term objective of 31,000 acres.

• OBJ5b: In mature oak forests, provide woodland structure on approximately 6,000 acres by the end of the first decade with a long-term objective of 30,000 acres.

• OBJ5c: Provide a sustained supply of regenerating forest habitats totaling approximately 5,400 acres at any point in time. Regenerating forest will be treated predominantly within oak forest although other forest types and natural disturbances will be included.

• OBJ5d: Increase the abundance of mature forest habitats toward achieving the long-term objective of approximately 123,000 acres of mature forest, of which 52,000 acres will meet old growth criteria.

• OBJ5e: In mature forests on moist sites, provide canopy gaps on a minimum of 1,600 acres by the end of the first decade with a long-term objective of a minimum of 9,000 acres.

• OBJ5f: Create and maintain at least 250 acres of shortleaf pine forest by developing desired mature open forest and woodland structural conditions over the first decade with a long-term objective of 450 total acres of shortleaf pine forest.

• OBJ5g: Restore 50 acres of canebrake over the first 10 years of Area Plan implementation, with a long-term objective of 240 total acres of canebrake.

• OBJ5h: In addition to the approximately 600 acres of open lands currently in native grasses, restore native grasses and forbs to another 750 acres of current open lands within the first 10 years of Area Plan implementation, with a long-term (50-year) objective of 2,600 total acres of native grassland.

• OBJ5i: Maintain approximately 10,600 acres in open lands - cultivated and grassland cover types to - support game species, early successional species, and watchable wildlife. Approximately 1,100 acres of this 10,600 will be converted from cultivated field to grassland within riparian corridors over a 10-year period to improve riparian functions.

• OBJ5j: Restore and maintain fire regimes and fire return intervals in fire dependent communities by prescribed burning an average of approximately 10,000 acres per year by the end of the first decade, with a long-term objective of 21,000 acres per year on average. Some acres will incur repeat fire application during the planning period.

The proposed WFVM program actions are designed and intended to implement Goal 5, to meet the objectives listed above, and to provide habitat for species associated with the following habitats: Upland Forest Associates, Forest Opening Associates, Pine Forest Associates, Xeric and Dry Open Forest Associates, Calcareous Cliffs and Talus Associates, Xeric and Dry Grassland and Woodland Associates, Interior Forest Associates, Regenerating Forest Associates, Den Tree Associates, Mesic Forest Opening Associates, Snag Associates, Downed Wood Associates, and Riparian Forest Opening Associates.

In order to implement the Area Plan, LBL is proposing the following actions:

1. Wildland fire (prescribed fire and wildland fire use) on no more than 27,000 acres annually.

2. Forest vegetation management on no more than 2,200 acres annually.

Wildland Fire Management

LBL proposes prescribed fire and Wildland Fire Use (WFU) in both the dormant season and the growing season on no more than 27,000 acres in scattered project areas across LBL. Wildland Fire management actions for prescribed burning include:

- No more than 18,000 acres of prescribed fire annually during the dormant season (September 16th through March 31st), including no more than 5,000 acres within the 5-mile radius of Tobaccoport Cave during the Indiana bat swarming season.

- No more than 9,000 acres of prescribed fire annually during the growing season (April 1st through September 15th).

Most acres will be burned on a two to seven year rotation. However, some rotations may be as short as annual burning while other areas may only receive fire once or not at all. The average burn rotation will be three years and the size of prescribed fires may vary from a few to several thousand acres. The total expected wildland fire average is 27,000 acres annually. WFU will be counted in conjunction with prescribed fire. For example, if WFU is allowed on 7,000 acres in any given year, then an additional 20,000 acres could be burned using prescribed fire in that same year.

The Wildland Fire management action for WFU includes allowing wildfires to burn within a maximum management area, or MMA, with minimal intervention. This means that WFU would allow fires to burn wherever and whenever they occur and when feasible at the same dormant season and growing season rates as the prescribed fire levels listed above. However, LBL will not allow all wildfires to burn as many may or will ignite under conditions which will result in unacceptable resource impacts or which may result in unacceptable smoke impacts to the surrounding area. The choice to allow a wildfire to burn within predetermined boundaries will be based on parameters contained in wildland fire use plans that are maintained by LBL.

Forest Vegetation Management

LBL proposes a suite of forest vegetation management actions on no more than 2,200 total acres per year. These actions are fully described in the BA and include:

- Conversion of planted loblolly pine plantations to native pine or hardwoods – This action will be achieved by (a) clear-cutting scattered loblolly pine stands, which average 10 acres in size, on approximately 200 acres annually, (b) conducting site preparation with chainsaws, prescribed fire, or machine grinding/chopping on approximately 200 acres annually, and (c) planting shortleaf pine, Virginia pine, or hardwoods on approximately 200 acres annually.

- Imazapyr herbicide application on approximately 100 acres annually – This action will be achieved by (a) spraying herbicide onto cut stumps to control hardwood competition (stump sprouts) in shortleaf pine and hardwood stands, (b) injection of herbicide into selected trees for stand improvements (thinning from below) in shortleaf pine and hardwood stands, (c) injections of herbicide into loblolly pine stems to control (kill) pines in forest stands, and (d) injections of herbicide into tree stems to create canopy gaps and snags.

- Restore woodland and savanna structure in short-leaf pine on xeric, dry, and dry-mesic sites – This action will use the seed-tree with reserves regeneration method on approximately 500 acres of mixed shortleaf pine forest types. Seed-tree cuts are an even-aged regeneration method in which an area is clear cut except for certain trees (seed trees), which will be left standing singly or in groups for the purpose of furnishing seed to restock the cleared areas. Generally, the most dominant shortleaf pines with the best crowns and seed producing ability will be retained along with some oaks for mast production, den availability, and overall species diversity. A typical seed tree with reserves harvest would leave 12-18 large pines and 2-5 large hardwoods per acre.

- Restore mixed oak-pine woodland – This action will involve restoration of mixed pine-oak stands using a modified group selection regeneration method that has a maximum opening size of 1 acre. This action will occur in shortleaf pine or upland oak stands and on approximately 250 acres annually.

- Restoration of oak woodland – This action proposes a combination of shelter-wood with reserves treatment and oak woodland restoration treatment on approximately 1,000 acres annually on xeric, dry, and dry mesic sites across LBL. This process involves selecting trees for removal that beginning with the smallest size class present then also removing some larger trees with weak crown development until the desired basal area is reached. Both treatments seek to create diffuse light conditions under which oak regeneration can have a competitive advantage over both relatively shade tolerant and less shade tolerant seedlings.

- Creation of canopy gaps – This action will be achieved by cutting/girdling/injection (with imazapyr) of approximately 225 trees per year on mesic and alluvial site types. This action will consist of removing small groups of 1-4 trees with an average of 1 group per 4 acres. LBL estimates that 1,600 trees will be removed over the next 10 years to create canopy gaps.

- Salvage/sanitation harvesting on no more than 250 acres annually in scattered project areas across LBL – This action will be achieved through the (a) removal of downed trees where the main stem is less than six feet from the ground, (b) removal of uprooted trees with more than 20 percent of the root system exposed to the air, (c) removal of weakened trees with signs of partial root upheaval, twisted stems, broken tops, or excessive lean that may contribute to tree mortality, and (d) removal of severely damaged trees with broken stems or 20 percent or more of the live crown broken. No healthy trees will be marked for removal except for salvage access or safety concerns.

- Construction of approximately 4 miles of temporary logging roads annually – This action will be achieved using bulldozers and other heavy equipment to clear trees for other management actions. These roads will be closed and rehabilitated by Area Plan standards when not needed. These trails will be closed and rehabilitated by Area Plan standards when not needed.

- Use of approximately 8 miles of skid trails annually – This action involves the movement of logs, by dragging, from the stump to a log landing typically using heavy, rubber-tire equipments. These trails will be designed to avoid the additional cutting of timber.

Action Area

The Land Between the Lakes NRA covers approximately 170,000 acres of federal land located in western Kentucky and Tennessee and is administered by the U.S. Forest Service. LBL is an inland peninsula bordered on the west by Kentucky Lake and on the east by Lake Barkley. LBL ranges from 6 to 8 miles wide and is approximately 40 miles long. There are approximately 110,000 acres in Kentucky (Lyon and Trigg counties) and 60,000 acres in Tennessee (Stewart County).

For the purposes of this analysis, the entire land base of LBL is the action area. LBL is in the Western Mixed Mesophytic forest region, a transition zone between the Eastern Mesophytic forest region and the Western Oak-Hickory forest region (Franklin and Fralish, 1994). LBL is part of the Western Highland Rim subsection of the Interior Low Plateau Physiographic Province and the Coastal Plain Physiographic Province (Fralish and Crooks, 1989; Franklin and Fralish, 1994; NatureServe, 2004). Most of the area consists of highly dissected uplands. Approximately 92 percent of LBL is forested, with mostly second and third-growth hardwoods comprised mainly of oak species (Franklin and Fralish, 1994). Approximately 8 percent of LBL is in open land cover types. Oak forest types contain numerous hardwood species including white oak, northern and southern red oak, post oak, blackjack oak, chestnut oak, black oak, and pignut hickory. Mesophytic forest species on LBL include sugar maple, American beech, mockernut hickory, pignut hickory, sweet gum, yellow poplar and elm. Oak forests cover 82 percent of LBL, with mesophytic/riparian forests comprising 7 percent, and pine forest (mostly planted) on the remaining 3 percent.

Since about 1950, wildland fire has largely been excluded from LBL. Wildfires have and do still occur, but the extent of these fires is typically small. Prescribed fire has been used for many years to manage native warm season grass openlands, and, more recently (since the FS assumed management of LBL), prescribed fire has been used on an average of 3,000 acres per year in forested areas. However, landscape scale fire on which the ecosystem is dependent has been largely excluded.

Across LBL, regeneration of oak species is failing due to forest densification, as a result of fire exclusion, which has allowed oak forests to begin to succeed to more mesophytic forest types.

The herbaceous layers that were historically a part of this community, and which provided habitat for many species of viability concern, are also suppressed (Franklin et al. 2002). Upland areas that consisted of scattered prairie, savanna, woodland, and other fire-mediated sub-climax communities have, as a result of natural forest succession from fire exclusion, become closed canopy forests with a depleted herbaceous layer (Martin and Taylor 2002; Guyette et al. 2008).

The cool, moist microclimate of the closed canopy forest has allowed for the invasion and succession to more mesophytic species, especially sugar maple (*Acer saccharum*) and American beech (*Fagus grandiflora*) (Franklin et al. 2002). This transition is occurring in alluvial, mesic, and dry-mesic forest cover types. There are relict stands of shortleaf pine (*Pinus echinata*) on Devil's Backbone, Tennessee; however, they are rapidly succeeding to several species of oak (Franklin et al. 2002).

INDIANA BAT: STATUS OF THE SPECIES/CRITICAL HABITAT

Species/Critical Habitat Description

Species Description

The Indiana bat is a medium-sized bat in the genus *Myotis*. Its forearm length is 13/8-15/8 in), and the head and body length ranges from 15/8-17/8 in. 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).

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. 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.

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 non-hibernation 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).

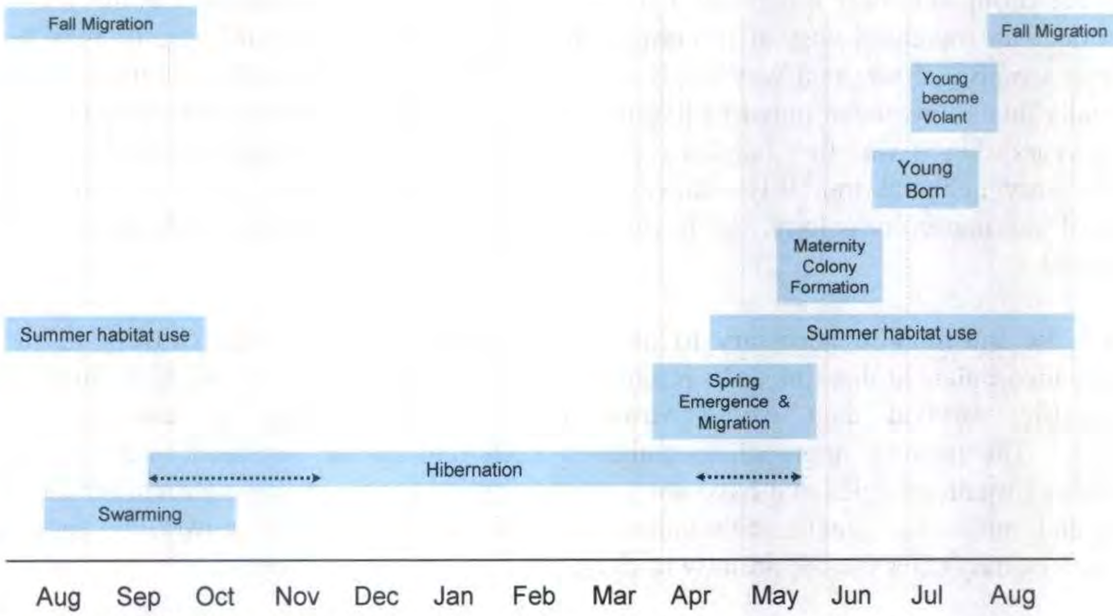


Figure 1. Indiana bat annual chronology.

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 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 (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.

Hibernation

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 radio tagged 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).

Maternity Roosts

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).

Foraging Behavior

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.

Home Range

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 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.

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

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.

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 percent) 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.

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 from 7 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).

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).

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.

<u>Landscape Structure and Macrohabitat</u>

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).

Status and Distribution

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).

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).

Based on these records, they described the species' distribution (Figure 3) as the "eastern United States from the central Mississippi Valley and northern Alabama to the western part of New England". 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).

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 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.

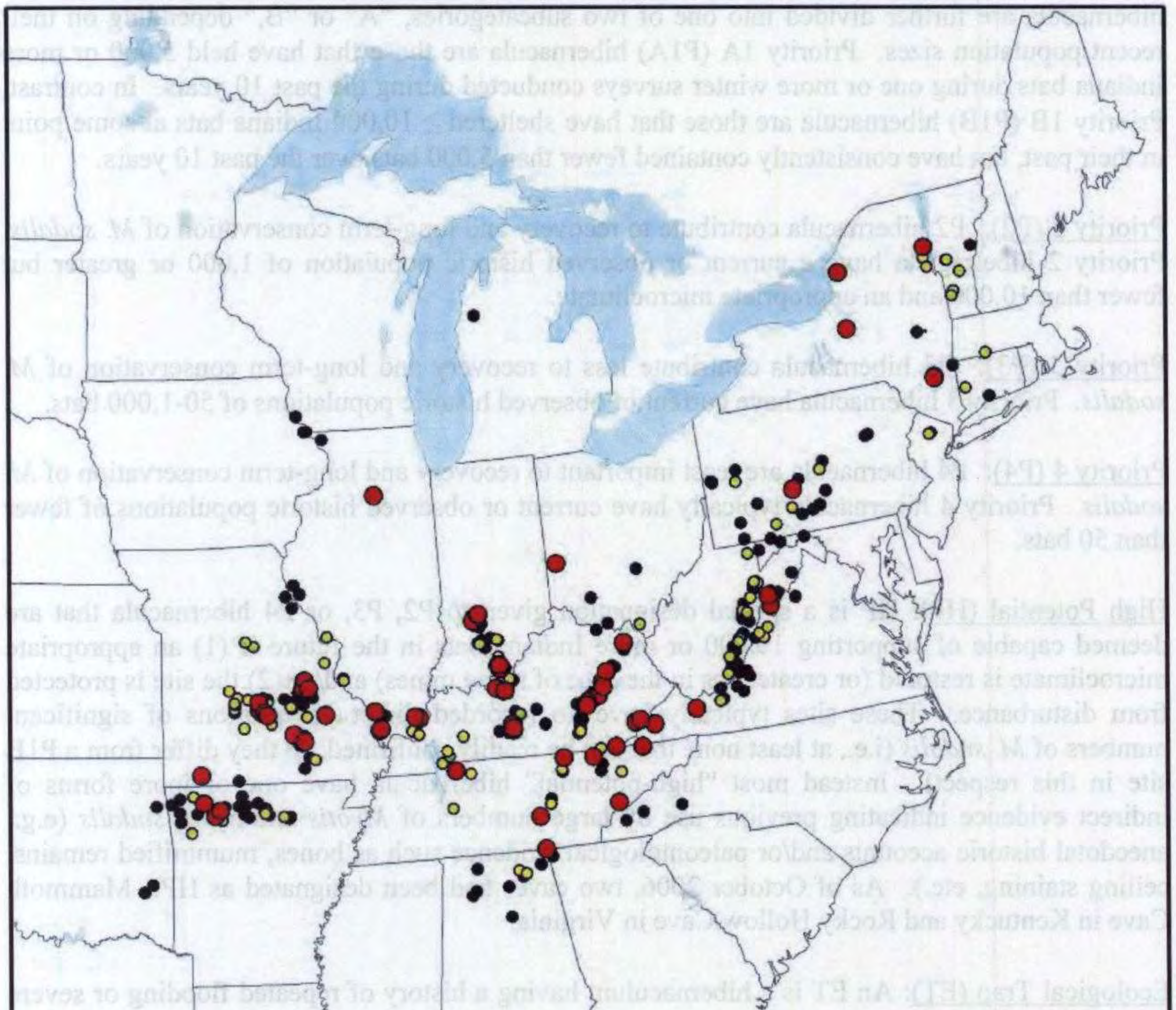
For example, abundance of hibernating bat populations almost certainly declined after settlers discovered large deposits of nitrates or saltpeter, essential for making gunpowder, and began year-round mining operations within some of the major hibernacula. Saltpeter mining operations at Mammoth Cave, 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[1]

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.

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

Figure 4. Distribution of known Indiana bat hibernacula and their current priority status (Service 2007). Source: Andrew King, Service, Bloomington, Indiana.



- **Priority 1 & 2 IBat Hibernacula Sites (to be surveyed in 2009)**
- **Priority 3 (may or may not be surveyed in 2009)**
- **Priority 4 (many will not be surveyed in 2009)**

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 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

The following is a summary from the Indiana Bat Draft Recovery Plan and unpublished data (Service 2007, Service 2008 unpublished data); additional information from the Plan is incorporated by reference. As of October 2008, the Service has winter records of extant winter populations (i.e. positive winter occurrence since 1995) of the Indiana bat at approximately 281 different hibernacula located in 19 states. Likewise, based on the 2005 winter surveys, there were a total of 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). A total of 53 Priority 2 hibernacula are known from the aforementioned states, as well as Arkansas, Ohio, Pennsylvania, and Virginia. A total of 150 Priority 3 hibernacula have been reported in 16 states. A total of 213 Priority 4 hibernacula have been reported in 23 states. Winter surveys in 2006-2007 found hibernating Indiana bats dispersed across 15 states. However, over 90 percent of the estimated range-wide population hibernated in five states – Indiana (46.4 percent), Missouri (12.6 percent), Kentucky (13.4 percent), Illinois (10.5 percent), and New York (10.3 percent) (Table 4, Service 2008).

Current Winter Population Groups

The following summary is from the Indiana Bat Draft Recovery Plan (Service 2007). M.J. Vonhof and G.F. McCracken's statistical analysis of genetic samples (mtDNA extracted from wing membrane punches) 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 (Service 2007).

For more information on wintering bat distribution, abundance, and potential genetic variation, see the Indiana Bat Draft Recovery Plan (Service 2007). The 2007 Recovery Plan is available at (http://www.fws.gov/midwest/Endangered/mammals/inba/index.html).

Current Summer Distribution

Summer distribution of the Indiana bat occurs throughout a wider geographic area than its winter distribution (Figure 5). Most summer occurrences are from the upper Midwest including southern Iowa, northern Missouri, much of Illinois and Indiana, southern Michigan, Wisconsin, western Ohio, and Kentucky. Recently, many summer maternity colonies have been found in the northeastern states of Pennsylvania, Vermont, New Jersey, New York, West Virginia, and Maryland. Maternity colonies extend south as far as northern Arkansas, southeastern Tennessee, and southwestern North Carolina (Britzke et al. 2003, Service 2007). Non-reproductive summer records for the Indiana bat have also been documented in eastern Oklahoma, northern Mississippi, Alabama, and Georgia.

Table 4. Indiana Bat Revised* Range-wide Population Estimate

Estimates are based on winter surveys conducted at all known Priority 1 and 2 hibernacula throughout the species' range. Additional data from Priority 3 and 4 hibernacula has also been included when available.

USFWS Region	State	2001	2003	2005	2007	% Change from 2005	% of 2007 total
Region 2	Oklahoma	0	5	2	0	-100.00%	0.0%
Region 3	Indiana	173,111	183,337	206,610	238,009	15.2%	50.8%
	Missouri	18,999	17,722	16,102	15,895	-1.3%	3.4%
	Illinois	21,677	43,646	55,166	54,095	-1.9%	11.6%
	Ohio	9,817	9,831	9,769	7,629	-21.9%	1.6%
	Michigan	20	20	20	20	0.0%	0.0%
	Total	223,624	254,556	287,667	315,648	9.7%	67.4%
Region 4	Kentucky	51,053	49,544	64,611	71,250	8.6%	15.2%
	Tennessee	9,564	9,802	12,074	8,906	-26.2%	1.9%
	Arkansas	2,475	2,228	2,067	1,829	-11.5%	0.4%
	Alabama	173	265	296	258	-12.8%	0.1%
	Total	63,625	61,839	80,048	82,243	2.7%	17.6%
Region 5	New York	29,671	32,981	41,727	52,803	26.5%	11.3%
	Pennsylvania	702	931	835	1,038	24.3%	0.2%
	West Virginia	9,714	11,444	13,417	14,745	9.9%	3.1%
	Virginia	969	1,158	769	723	-6.0%	0.2%
	New Jersey	335	644	652	659	1.1%	0.1%
	Vermont	246	472	313	325	3.8%	0.1%
	Total	41,637	47,630	57,713	70,293	21.8%	15.0%
Rangewide Total:		328,526	364,030	425,430	468,184		100.00%
	2-yr. Net Increase of:		35,504	61,400	42,754		
	% Increase of:		10.8%	16.9%	10.0%		

Missouri's 2001-2007 estimates had previously assumed 50,550 Indiana bats in Pilot Knob Mine (PKM) based on external fall capture rates at the mine's primary entrance, but a February 2008 internal survey of this mine documented a total population of 1,678 Indiana bats (Elliott and Kennedy 2008, unpublished technical report; available at http://www.utexas.edu/tmm/sponsored_sites/biospeleology/pdf/index.htm). The Service considers this new data to more closely estimate the true population within the mine and adjusted the Missouri estimates accordingly. Some other, smaller adjustments were made based upon the discovery of new hibernacula in Kentucky and New York in 2008 (i.e., we assumed the same number of Indiana bats that we found at these new sites in 2008 were also present in 2007). Compiled by Andy King, U.S. Fish and Wildlife Service, Bloomington, Indiana, Ecological Services Field Office from data gathered from bat biologists throughout the species' range. (andrew_king@fws.gov)

Maternity Colonies
The first Indiana bat maternity colony was not discovered until 1971 in east-central Indiana (Cope et al. 1974). As of the publication of the Indiana Bat Draft Recovery Plan (Service 2007), we have records of 269 maternity colonies in 16 states that are considered locally extant. Of the 269 colonies, 54 percent (n=146) have been found, mostly during mist-netting surveys, within the past 10 years (i.e. since 1997). This number is an underestimate as additional colonies were discovered in New York and probably found elsewhere in 2007. 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.

In New York, there are approximately 35 documented maternity colonies across the landscape in 8 counties – Cayuga, Dutchess, Essex, Jefferson, Onondaga, Orange, Oswego, and Ulster. Many of these colonies have been located by tracking females as they emerge from hibernation to their spring roosting areas using radio telemetry. Each documented roost tree was recorded using a handheld Global Positioning System unit. Many of the radio transmitter batteries lasted into "summer" season (after May 15, or approximately 30 days) documenting the use of these sites by potential colonies. Many sites had large exit counts in spring either before or after May 15 and many sites were documented as colonies by subsequent mist-netting and radio telemetry efforts.

Adult Males
Male Indiana bats are found throughout the range of the species, but in summer are most common in areas near hibernacula (Gardner and Cook 2002).

Current Abundance
The range-wide population estimate had been increasing since at least 2001 (Figure 6), indicating that the species' long-term decline had perhaps been arrested and possibly reversed (Service 2007 and Service, unpublished data, 2007). The population increase was largely attributed to population growth at hibernacula in Illinois, Indiana, Kentucky, New York, and West Virginia (Service, unpublished data, 2009).

However, since the April 2007 release of the Draft Recovery plan, the Service's Bloomington (Indiana) Field Office has collated the population data gathered during the range-wide 2007 and 2009 biennial winter hibernacula surveys. Based on this data, the Service has preliminarily determined that the Indiana bat's 2009 range-wide population estimate stands at approximately 391,000 bats, which is a 16.5 percent decrease over the 2007 range-wide population estimate of 468,000 bats (Service, unpublished data, 2009). The observed decline in 2009 is partly attributable to the disease White-nose Syndrome (see discussion below), specifically for decreased population estimates in the Northeast. The species' range-wide, regional, State, and hibernacula specific population trends are being closely monitored by the Service.

Given the 2009 range-wide Indiana bat population estimate of 391,000, it is assumed that there are approximately 2,445 to 3,260 maternity colonies throughout the species' entire range [assuming a 50:50 sex ratio (Humphrey et al. 1977]) and an average maternity colony size of 60 to 80 adult females (Whitaker and Brack 2002)].

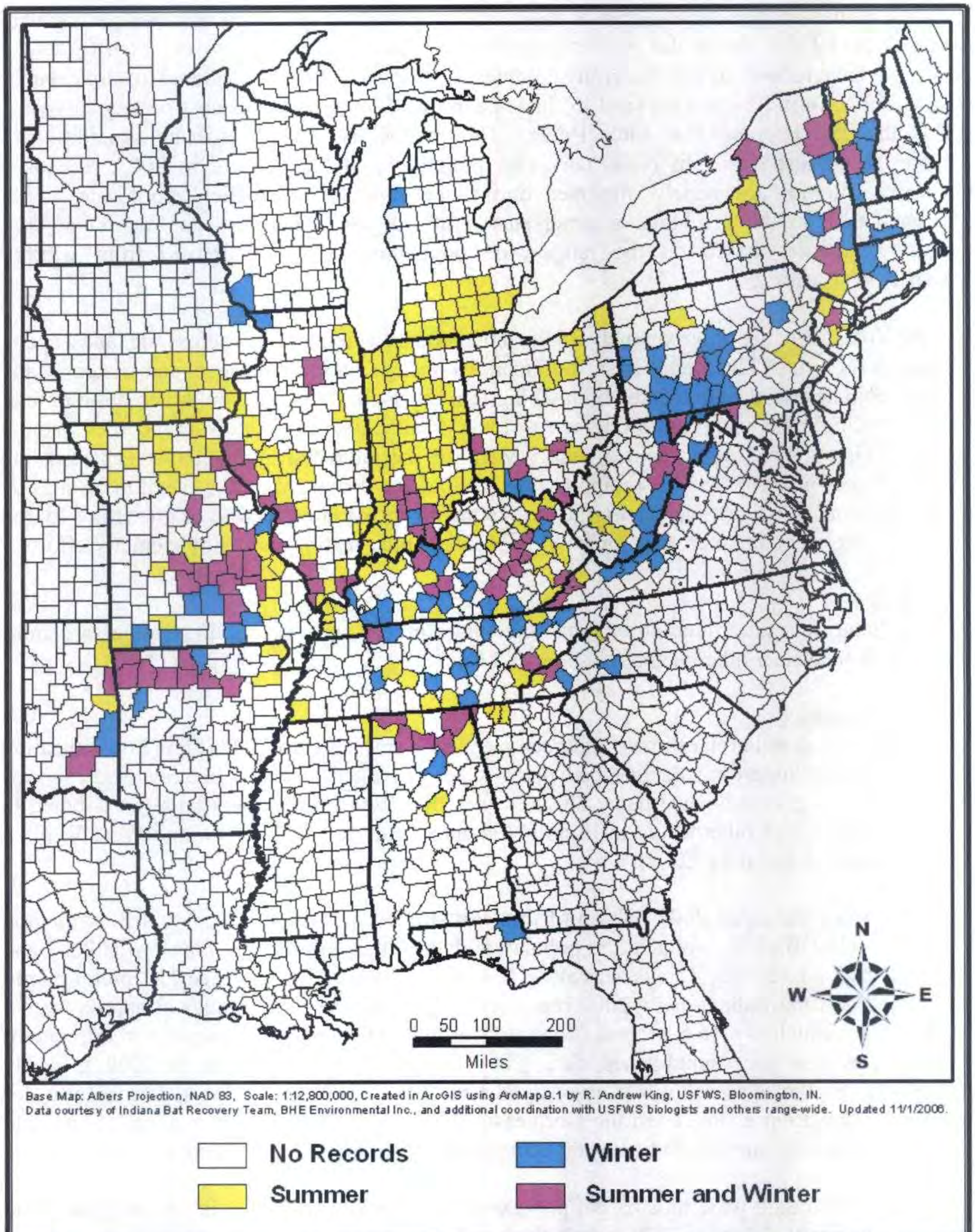


Figure 5. Distribution of counties with known summer and winter records of the Indiana bat as of publication of the Indiana Bat Draft Recovery Plan (Service 2007).

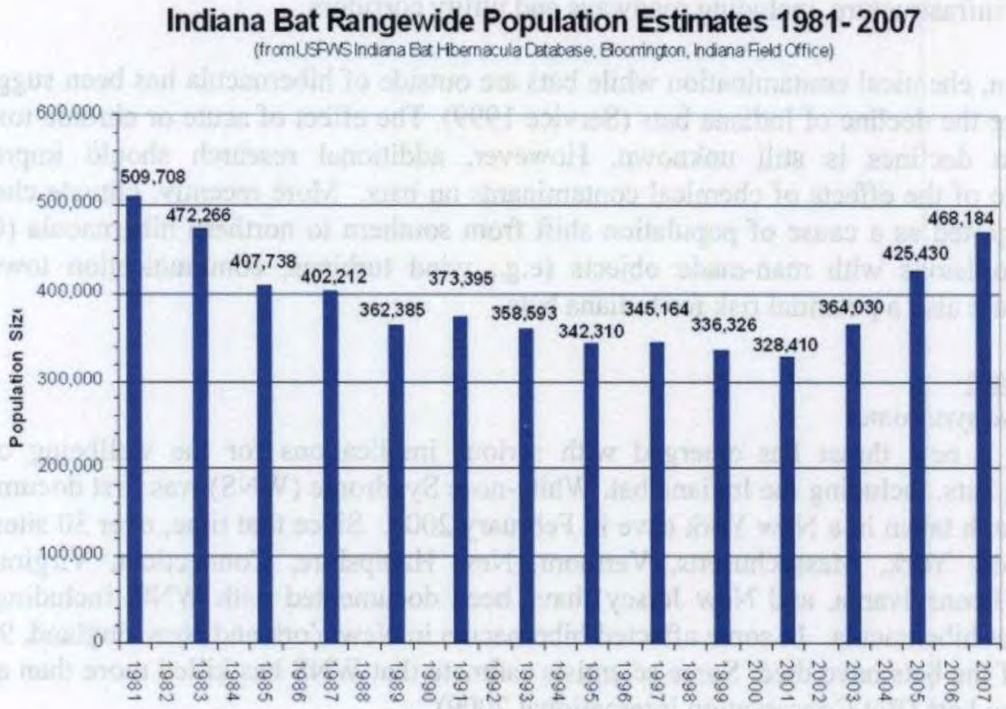


Figure 6. Indiana Bat Rangewide Population Estimates 1981-2007 (Service, unpublished data, 2009)

Reasons for Listing/Threats

From 1965-2001, there was an overall decline in Indiana bat populations, with winter habitat modifications having been linked to changes in populations at some of the most important hibernacula (Service 2007). Most of these modifications were human-induced for either commercialization of the cave, control of cave access, or for mining. Improper gating and other structures have rendered many historical hibernacula unavailable to Indiana bats. Other documented threats involving hibernacula include human disturbance, vandalism, indiscriminate collecting, handling, and/or banding of hibernating bats, flooding of caves for reservoirs, and destruction by limestone quarries. Natural alterations of hibernacula can include flooding, entrance and passage collapse, and blocked sinkholes which can all alter the temperature regime within the cave and even prevent entry by bats. Natural and human-induced changes to hibernacula can alter the climate required by Indiana bats which adversely affects the population.

Summer habitat modification is also suspected to have contributed to the decline of bat populations; however, it is difficult to quantify how forest management or disturbance may affect Indiana bats. Forests used by foraging and roosting Indiana bats during spring, summer, and autumn have changed dramatically from pre-settlement conditions. Forests have been fragmented in areas, fire has been suppressed, and much of the vegetation in flatlands (i.e. prairie) has been converted for agricultural purposes (Service 1999). Summer habitat can include small woodlots connected by hedgerows or extensive forests. The removal of such habitats is occurring rapidly in some portions of the Indiana bat's range due to urban development, mining, and other infrastructure, including roadways and utility corridors.

In addition, chemical contamination while bats are outside of hibernacula has been suggested as a cause for the decline of Indiana bats (Service 1999). The effect of acute or chronic toxicity on population declines is still unknown. However, additional research should improve our knowledge of the effects of chemical contaminants on bats. More recently, climate change has been suggested as a cause of population shift from southern to northern hibernacula (Clawson 2002). Collisions with man-made objects (e.g., wind turbines, communication towers, and vehicles) are also a potential risk for Indiana bats.

New Threats

White-nose syndrome

Recently, a new threat has emerged with serious implications for the wellbeing of North American bats, including the Indiana bat. White-nose Syndrome (WNS) was first documented in a photograph taken in a New York cave in February 2006. Since that time, over 30 sites in nine states (New York, Massachusetts, Vermont, New Hampshire, Connecticut, Virginia, West Virginia, Pennsylvania, and New Jersey) have been documented with WNS, including known Indiana bat hibernacula. In some affected hibernacula in New York and New England, 90 to 100 percent of the bats have died. Some scientists estimate that WNS has killed more than a million hibernating bats (Bat Conservation International 2009).

WNS has been characterized as a condition primarily affecting hibernating bats. Affected bats usually exhibit a white fungus on their muzzles and often on their wings and ears as well (Blehert et. al. 2009). Some affected bats may display abnormal behavior including flying during the day and in cold weather (before insects are available for foraging) and roosting toward a cave's entrance where temperature and humidity are less stable. Many of the affected bats appear to have little-to-no remaining fat reserves which are necessary for a bat to survive until spring emergence. Recently, the fungus associated with WNS has been identified as a previously undescribed species of the genus *Geomyces* (named *G. destructans*) (Gargas et al. 2009). The fungus thrives in the cold and humid conditions of bat hibernacula. It is unclear at this point if the fungus is causing the bat deaths, or if it is secondary to the cause of death. The mode of transmission is currently unknown, although biologists suspect it is primarily spread by bat-to-bat contact. In addition, people may unknowingly contribute to the spread of WNS by visiting affected caves and transferring the fungus to other sites.

Currently, WNS appears to be restricted to sites primarily within the proposed Northeast Recovery Unit for the Indiana bat, as well as several sites within the proposed Appalachian Mountain Recovery Unit. The fungus has been confirmed in eastern pipistrelle, little brown, small-footed, northern long-eared, big brown and Indiana bats. There are many factors regarding WNS that are unknown at this point including if there are species' differences in susceptibility and mortality, how long symptoms may take to manifest, and the long-term effects. Meanwhile, the FWS, States wildlife agencies, and multiple researchers are continuing to learn more about the disease and options for minimizing its impacts. To date, no WNS has been documented in the proposed Midwest Recovery Unit where LBL lies.

Climate Change

It is important to consider the possibility that climate change may be driving some changes in Indiana bat populations. 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 is unknown but needs 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.

Recovery

The existing recovery program for the Indiana bat focuses on protection of hibernacula (Service 1983). The proposed recovery program has four broad components: 1) range-wide 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 (Service 2007). This recovery program continues to have a primary focus on protection of hibernacula but also increases the focus on summer habitat and proposes use of Recovery Units.

Recovery Units

The Service's proposed delineation of Recovery Units relied on a combination of preliminary evidence of population discreteness and genetic differentiation, differences in population trends, and broad-level differences in macrohabitats and land use. When Recovery Unit delimitations suggested by these factors were geographically close to state boundaries, the Recovery Unit borders were shifted to match the state boundaries in order to facilitate future conservation and management. The revised draft Indiana Bat Recovery Plan proposes four Recovery Units for the species: Ozark-Central, Midwest, Appalachian Mountains, and Northeast (Figure 7) (Service 2007). Population estimates for the proposed Midwest Recovery Unit, which includes Kentucky, in 2008-2009 were near 262,000; this accounts for two-thirds of the Indiana bat population.

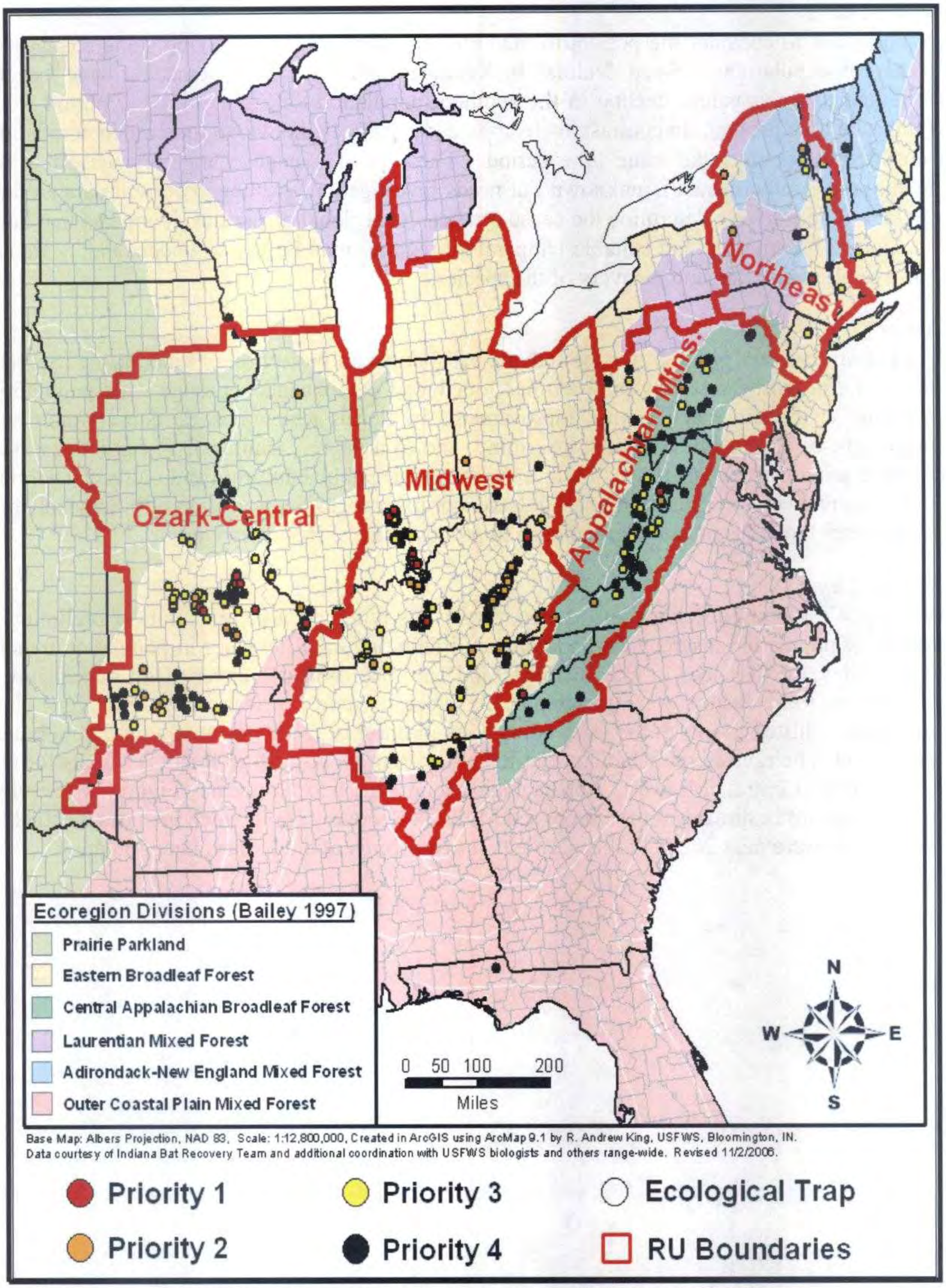


Figure 7. Proposed Indiana bat Recovery Units (Service 2007).

Previous Incidental Take Authorization

All previously issued biological opinions involving the Indiana bat have been non-jeopardy. These formal consultations have involved a variety of action agencies including: (a) the USFS for activities implemented under various Land and Resource Management Plans on National Forests in the eastern United States, (b) the Federal Highway Administration (FHWA) for various transportation projects, (c) the Corps for various water-related projects, (d) the Department of Defense for operations at several military installations, and (e) others. 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 table of previous consultations can be found at: http://www.fws.gov/midwest/endangered/mammals/inba/inbaBOs.html.

It is important to note that in many of these consultations, survey information was lacking. As Federal agencies are not required to conduct surveys, often the Service relied on a host of valid factors in helping the Federal agency determine whether Indiana bats were likely to be present. To ensure the Federal agency and Service meet the mandates of the Act, if the best available information suggested that Indiana bats may be present, the assumption was often made that one or more maternity colonies occurred within the action area. We believe this approach is fully justified; however, it is a conservative approach and likely resulted in an over-estimate of the number of individuals or colonies that may have been taken by previous Federal actions.

Take has primarily been authorized in the form of harm through habitat loss because of the difficulty of detecting and quantifying take of Indiana bats. This is due to the bat's small body size, widely dispersed individuals under loose bark or in tree cracks/crevices, and unknown spatial extent and density of much of their summer roosting population range. For some incidental take statements, take has also been extrapolated to include an estimated number of individual Indiana bats. Previous habitat impacts have been both temporary (e.g., USFS timber management) and permanent (e.g., FHWA road alignments). Some of these projects were certain to impact known Indiana bat habitat. To minimize the effects of these previous projects, the action agencies agreed to implement various conservation measures including seasonal tree clearing restrictions, protection of roost trees, minimization of project footprints and retention of adequate roosting and/or foraging habitat to sustain maternity colonies into the future, and permanent protection or restoration of off-site habitat to provide future roosting and foraging habitat opportunities.

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 anticipated the loss of a maternity colony. Required monitoring for three formal 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. Only with long-term monitoring will we definitely be able to determine the true effectiveness of our conservation measures, but that monitoring is typically not undertaken by the action agency.

Overall, we believe the take exempted to date via Section 7 consultations has resulted in short-term effects to Indiana bats. As many of these consultations necessarily made assumptions about Indiana bat presence, we are confident that the number of maternity colonies actually exposed to the environmental impacts of the Federal actions is far less than anticipated. Furthermore, although not definitive, monitoring of several maternity colonies pre- and post-project implementation preliminarily suggests that our standard conservation measures, when employed in concert, appear to be effective in minimizing adverse effects on the affected Indiana bats, including maternity colonies.

Analysis of the Species/Critical Habitat Likely 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. LBL contains no suitable winter hibernacula; however Tobaccoport Cave, which supports a winter population of Indiana bats (310 in 2002), is 1.3 air miles east of LBL. To date, no Indiana bats have been detected on LBL, most likely because of limited survey efforts. However, LBL does contain suitable habitat for foraging, roosting, maternity sites. Due to the close proximity to Tobaccoport Cave and the amount of suitable habitat present, it is likely that Indiana bats occur on LBL – at least periodically during the spring and fall swarming periods and during migration to and from winter habitat.

The proposed action would allow wildland fire on approximately 27,000 acres annually and forest vegetation management on 2,200 acres annually. Of the 27,000 acres of fire, wildland fire would only occur on 9,000 acres during the summer roosting period and only on 5,000 acres during the fall swarming period, when Indiana bats may be present across LBL. As a result, the Service agrees with LBL's determination that some of the actions proposed in the WFVM program may adversely affect the Indiana bat due to the loss or alteration of roosting and foraging habitat and potential impacts to individuals from tree clearing and smoke/obscurants. These effects are expected to occur during the periods when summer and swarming habitat could be occupied by Indiana bats on LBL. Critical habitat has been designated for the Indiana bat, but none of those critical habitat areas occur within the action area, so the proposed project is not likely to adversely modify critical habitat for the species.

PRICE'S POTATO-BEAN: STATUS OF THE SPECIES/CRITICAL HABITAT

Species/Critical Habitat Description

Listing Status

Price's potato-bean (*Apios priceana*) is a perennial vine often found in mixed hardwoods or in associated forest clearings. The species was proposed as threatened on May 12, 1989 and federally listed as a threatened species by the Service on January 5, 1990 (NatureServe 2008).

Eleven populations, including the only known populations from Illinois, have not been relocated and are considered to be extirpated (Service 1993). The Recovery Plan for Price's Potato-Bean was published in 1993. The Recovery Priority of Price's potato-bean is 8, which means that the species has a moderate degree of threat and high recovery potential.

Critical Habitat

Critical habitat has not yet been designated for Price's potato-bean.

Species Description

A detailed species description for Price's potato-bean is provided in the species recovery plan (Service 1993). Price's potato-bean, a member of the pea family (Fabaceae), is a twining, perennial vine that grows from a stout, thick, round-like tuber often 7.2 inches (in.) or 18 centimeters (cm) in diameter (Robinson 1898; Kral 1980; Woods 1988; Isely 1990). The stem is round in cross section, somewhat twisted and slightly ridged. During early growth stages, the stem is finely hairy, but later becomes smooth. Leaves of the main stem are 8 to 12 in. or 20-30 cm long, alternate, and pinnately compound with 5 to 9 leaflets. The upper leaflet surface is smooth at maturity, and the lower surface is pale, slightly hairy, and veiny. Leaves and leaflets of branches are smaller than those of the main stem.

Taxonomy

The genus *Apios* was described by Cornut in 1633; however, Linnaeus called the genus *Glycine* in 1753. In 1905, at the botanical congress in Vienna, *Apios* was conserved over *Glycine* (pro parte). The genus consists of three Asian species and two North American species (Woods 1988). Common names for *Apios priceana* include Price's potato-bean, Sadie Price's potato-bean, potato-bean, and Price's ground nut. Type specimens are in the Gray Herbarium, Cambridge Massachusetts.

Price's potato-bean is distinguished from ground nut (*Apios americana)* by their tuber morphology. Ground nut grows from a string of small tubers, while Price's potato-bean grows from one large spheroidal tuber, 18 cm in diameter (Robinson 1898).

Life History and Population Dynamics

A detailed life history of Price's potato-bean (*Apios priceana)* can be found in the Price's Potato-Bean Recovery Plan (Service 1993). Price's potato-bean flowers from late mid-July through mid-August and produces fruit in August and September. The flowers are pollinated by the long tailed skipper (*Urbanus proteus*), honey bees (*Apis mellifera*), and bumble bees (Subfamily Apinae, Tribe Bombini), although bees are reported to have some difficulty accessing the nectar (Robinson 1898). Flowers in the genus *Apios* have a tripping mechanism that causes the keel to coil when triggered by an insect. When the keel coils, it exposes the anthers and pistil, allowing pollination to occur (Bruneau and Anderson 1988).

Price's potato-bean is the only species of *Apios* in which the keel bends backwards after tripping rather than coiling (Woods 1988). This tripping mechanism prevents automatic self-pollination of the flowers. Price's potato-bean plants have been observed to produce few seeds (Robinson 1898; Chester and Holt 1990; P. Olwell, Center for Plant Conservation, personal communication, 1992). Several factors could explain this low seed set including shading of the plants by trees and shrubs (Medley 1980, Woods 1988, Service 1989), drought, and insect damage to flowers and fruits. Observations of a Mississippi population suggest that water availability may limit seed set as greater seed set has been observed in years with higher rainfall (Service 1993). However, more studies are needed to determine the reasons for low seed production.

When seeds are produced, they germinate readily with scarification (Service 1993). In a small germination test, 18 of 20 seeds germinated after scarification (Service 1993). There is limited information regarding the germination process in the wild, however temperature fluctuations probably act to break the impermeable seed coat (Service 1993). It is thought that having a single tuber limits dispersal and vegetative reproduction of Price's potato-bean. Tubers and seeds of the plant are frequently found near streams and may be dispersed by water.

Plants do not flower during their first year of growth, but they can grow as much as five to six feet in their first season (Service 1993). Observations also indicate that the tuber can remain dormant during a growing season yet still show vigorous growth the following year (Service 1993).

Habitat

Price's potato-bean thrives in open, wooded areas, often in forest gaps or along forest edges (Medley 1980). The species seems to prefer mesic areas and is often found in open, low areas near a stream or along the banks of streams and rivers. The species is sometimes found near the base of small limestone bluffs (Medley 1980, Kral 1983). Most populations are located in cleared areas associated with power line or roadside rights-of-way. The plant often grows in well drained loams or old alluvium over limestone on rocky, sloping terrains (Kral 1983) and can survive a broad range of soil pH levels from less than five (Duke 1983) to greater than eight (Walter et al. 1986).

Common associates, present on at least half of the sites where information is available, include: sugar maple (*Acer saccharum*), hog peanut (*Amohicaroa bracteata*), bluebell (*Camnanula americana*), redbud (*Cercis canadensis*), spicebush (*Lindera benzoin*), chestnut oak (*Quercus muhlenberaii*), basswood (*Tilia Americana*), poison ivy (*Toxicodendron radicans*) and slippery elm (*Ulmus rubra*).

Status and Distribution

Distribution

Price's potato-bean is found within the Coastal Plain, Interior Low Plateaus, and Appalachian Plateaus physiographic provinces of the United States (Fenneman 1938). The species was originally found in 1896 by Sadie Price in open woods near Bowling Green, Warren County, Kentucky (Robinson 1898). This population was last seen in 1920. Since its discovery, Price's potato-bean has been found in five States – Alabama, Illinois, Kentucky, Mississippi, and Tennessee (Figure 8) – but is now thought to be extirpated from Illinois (Service 1993).

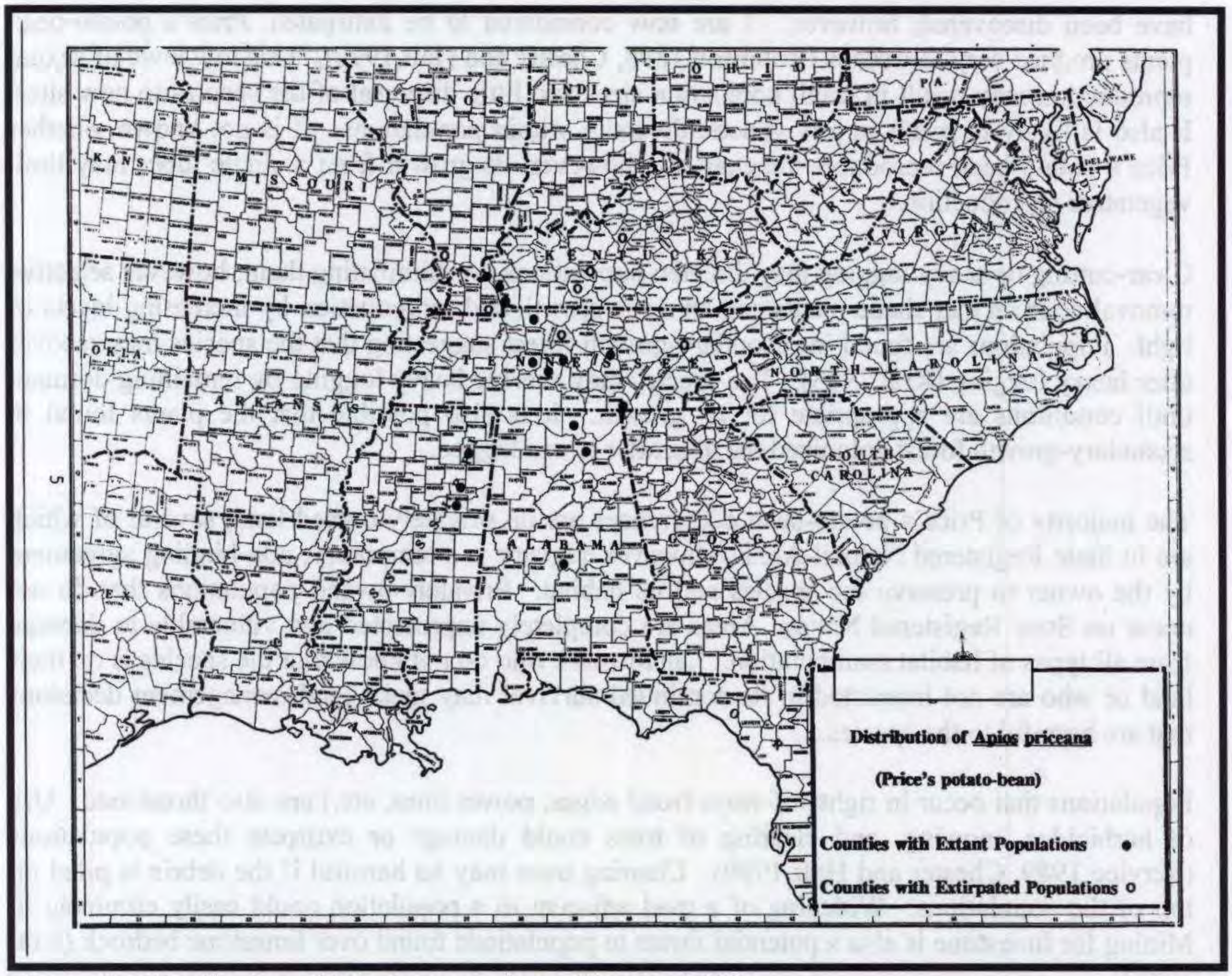


Figure 8. Distribution of Price's potato-bean (Service 1993)
*Since the publication of the Recovery Plan the range has expanded to include additional counties in TN and AL.

At the time of the Recovery Plan (1993), 25 populations were found within 15 counties in Tennessee, Alabama, Kentucky, and Mississippi. Since that time, additional occurrences have been discovered, including six in Tennessee and one in Alabama, in 2009 (Service, pers. comm., 2009). The Service is currently drafting the 5-year review for this species and it is expected that a more accurate range and distribution will be available upon publication.

It is very likely that undiscovered populations of Price's potato-bean exist in open woods, forest edges, road edges (in low areas near a creek) and stream-banks within its known range and in adjacent States. The species does not flower every year and is difficult to identify without flowers; therefore, populations have probably been passed over in their vegetative state.

Reasons for Listing/Threats

A number of factors threaten the continued survival of Price's potato-bean, including aspects of its biology, human disturbances, and interactions with other species. There are only 25 known populations of the species with approximately 1,500 to 1,700 vines. A total of 36 populations have been discovered; however, 11 are now considered to be extirpated. Price's potato-bean plants produce very few seeds (Robinson 1898, Chester and Holt 1990). This low level of sexual reproduction may result in small population sizes and little dispersal of the species to new sites. It also is likely to result in low genetic diversity within populations. It is not known whether Price's potato-bean reproduces vegetatively; however, its growth from a single tuber may limit vegetative reproduction.

Clear-cutting or heavy logging may threaten populations, by eliminating them; however selective removal of trees that shade plants can enhance growth and reproduction by increasing levels of light. Populations are found in secondary-growth forest suggesting that the species may recover after heavy logging (Kral 1983). The species may survive heavy logging by remaining dormant until conditions are appropriate for its growth. It is also possible that the plants found in secondary-growth forest colonized the area after it was logged.

The majority of Price's potato-bean occurrences are on privately-owned land, several of which are in State Registered Natural Areas. However, registry is a temporary, non-binding agreement by the owner to preserve the species and its habitat. Privately-owned populations that do not occur on State Registered Natural Areas are completely unprotected and vulnerable to damage from all types of habitat manipulation. Landowners who do not know that the species is on their land or who are not interested in its continued survival may make land management decisions that are harmful to the species.

Populations that occur in rights-of-ways (road edges, power lines, etc.) are also threatened. Use of herbicides, mowing, and clearing of trees could damage or extirpate these populations (Service 1989, Chester and Holt 1990). Clearing trees may be harmful if the debris is piled on top of the populations. Widening of a road adjacent to a population could easily eliminate it. Mining for limestone is also a potential threat to populations found over limestone bedrock (Kral 1983).

Several species interactions also damage populations of Price's potato-bean including shading by canopy trees that may result in reduced growth and reproduction (Medley 1980, Woods 1988, Service 1989) and erosion of soil that results from heavy grazing and trampling by cattle (Medley 1980). A variety of pests are reported to cause damage, including spider mites (Service 1993), a powdery mildew virus, and root-knot nematodes (Blackmon and Reynolds 1986), and an unidentified insect that has been observed to damage the flowers and fruits (Service 1993). Further, crown vetch (*Coronilla varia*), an introduced, invasive plant, is threatening to outcompete one Kentucky population (Chester and Holt 1990). Other exotic species are reported to be competing with populations in Mississippi (Service 1993).

Recovery

Price's potato-bean will be considered for delisting when there are at least 25 geographically distinct, self-sustaining, protected populations that have been maintained for ten years (Service 1993). A population is considered self-sustaining if the population size is stable and there is evidence of successful reproduction. The requirements of delisting may change as more information about the biology of the species is discovered.

Analysis of the Species/Critical Habitat Likely to be Affected

Price's potato-bean occurs in a variety of situations on LBL, including adjacent to lake shorelines, limestone outcrops, and road right-of-ways. Five populations of Price's potato-bean are known to occur on LBL. Four of these populations are in Kentucky: Hematite Lake, Laura Furnace, Mammoth Furnace, and Pisgah Bay. One population, near Lake Barkley, is located in Tennessee. All known populations are components of a local flora that is associated with limestone outcrops. Additional populations may exist within LBL, but have yet to be discovered due to limited survey efforts.

Historic and current habitat loss and interactions with other species have been identified as the primary threats to the species survival. However, LBL's proposed actions may ultimately provide beneficial effects on populations of Price's potato-bean by opening up dense forest canopies, which would enhance reproduction, and by controlling invasive/exotic species.

The Service agrees with LBL's determination that some of the actions proposed in the WFVM program may adversely affect individual Price's potato-bean plants because the probability of exposure from forest management actions and/or fire cannot be avoided.

Critical habitat has not been designated for Price's potato-bean. Therefore, the proposed project is not likely to adversely modify critical habitat for the species.

INDIANA BAT: ENVIRONMENTAL BASELINE

Status of the Species within the Action Area

Depending on local weather conditions, hibernation for Indiana bats typically lasts from October through April. LBL contains no suitable winter hibernacula (such as caves, rock shelters, abandoned mines, etc.) for Indiana bats (Gardner 1992); however, Tobaccoport Cave lies about 1.3 miles east of the LBL shoreline, provides a winter hibernaculum for the Indiana bat, and has a wintertime Indiana bat population estimated at 140 in 1999 (TWRA 2005) and 310 in 2002 (TWRA 2005). The Service reports that up to 310 Indiana bats have utilized this cave, thus making it a P3 hibernacula. Given the proximity to this cave, forested habitats on LBL could be important summer habitat for the Indiana bats that hibernate in Tobaccoport Cave. There is also an estimated 12,300 acres of swarming habitat on LBL (Kentucky and Tennessee) that is associated with Tobaccoport Cave that may be affected by the proposed action.

The non-hibernation 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 non-hibernation seasons); (Service 2007). Indiana bats may be present on LBL only during the growing season (April 1st through September 15th). Although no Indiana bats have been detected on LBL during surveys that were conducted from 1993 to 2002 (Harvey and Britzke 2000; Moyer et al. 1996; Palmer Engineering 2003; Rebar and Hendricks 1994), LBL does contain a sizable amount of suitable habitat for foraging, roosting, and summer maternity habitat.

During the summer of 2007, one Indiana bat was potentially detected during an Anabat™ survey in a forest stand that was being treated with prescribed fire to develop oak woodland habitat. Due to the close proximity of Tobaccoport Cave, and their documented occurrence there, it is reasonable to assume that Indiana bats are using habitat, and may eventually be documented, on LBL. Monitoring of bat populations will continue on a periodic basis unless otherwise determined in consultation with the KFO.

Factors Affecting Species Environment within the Action Area

LBL covers approximately 170,000 acres of federal land located in western Kentucky and Tennessee and is administered by the U.S. Forest Service. The entire action area falls within federally-owned lands. Therefore, all activities within the action area would have a federal nexus and would be routinely evaluated by the Service to determine adverse effects on the Indiana bat. As a result, there are no State, tribal, local, and private actions within the action area that are affecting the Indiana bat.

PRICE'S POTATO-BEAN: ENVIRONMENTAL BASELINE

Status of the Species within the Action Area

Price's potato-bean occurs in a variety of situations on LBL, including adjacent to lake shorelines, road rights-of-way, and limestone outcrops. Several LBL-wide surveys for Price's potato-bean have been conducted on LBL by Kentucky State Nature Preserves Commission, Dr. Edward Chester from Austin Peay State University, and others. Five populations are known to occur on LBL at the present time. Four populations are in Kentucky: Hematite Lake, Laura Furnace, Mammoth Furnace, and Pisgah Bay. One population is located in Tennessee near Lake Barkley. All known populations occur with other plant species characteristic of dry to dry-mesic conditions, with the possible exception of the Pisgah Bay population, which is characterized as dry-mesic or mesic. All known populations are components of a local flora that is associated with limestone outcrops. Additional populations may exist in other areas of potential habitat on LBL but have not yet been discovered. Excessive shade, ground disturbance, and dense shrubby/herbaceous competition threatened the existing populations on LBL prior to protection. The Kentucky State Nature Preserves Commission (KSNPC) located a total of 52 stems on LBL in 2001, and four of the five sites were recommended for shade removal (the fifth site appeared to be receiving sufficient light). Monitoring of known populations will continue on an annual basis unless otherwise determined in consultation with KFO.

Factors Affecting Species Environment within the Action Area

LBL covers approximately 170,000 acres of federal land located in western Kentucky and Tennessee and is administered by the U.S. Forest Service. The entire action area falls within federally-owned lands. Therefore, all activities within the action area would have a federal nexus and would be routinely evaluated by the Service to determine adverse effects on Price's potato-bean. As a result, there are no State, tribal, local, and private actions within the action area that are affecting Price's potato-bean.

EFFECTS OF THE ACTION

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 of the disturbances – We describe where the proposed action will occur and the likely impacts of the activities;
- Timing of the effects – 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 of effects – 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; and
- Disturbance intensity – We describe the effect of the disturbance on a population or species as a function of the population or species' state after the disturbances.
- Disturbance severity – We describe how long we expect the adverse effects to persist and long it would it take a population to recover.

Indiana Bat

Proximity of the Action

Indiana bats are not known to occur on LBL during the summer maternity season. The nearest summer records of the species occur approximately 9 miles east of LBL on Fort Campbell. Past survey efforts have been limited in scope, and no Indiana bats have been detected on LBL during surveys that were conducted from 1993 to 2002 (Harvey and Britzke 2000; Moyer et al. 1996; Palmer Engineering 2003; Rebar and Hendricks 1994). During the summer of 2007, one Indiana bat was potentially detected during an Anabat™ survey in a forest stand that was being treated with prescribed fire to develop oak woodland habitat, but this occurrence has not been substantiated. However, suitable summer habitat exists throughout LBL and could be occupied by the species. Previous and proposed management actions are expected to improve summer habitat on LBL, which may lead to future occupation of LBL by the species during the summer months.

In addition, LBL contains no suitable winter hibernacula (such as caves, rock shelters, abandoned mines, etc.) for Indiana bats (Gardner 1992). The nearest winter records of the species come from Tobaccoport Cave which lies approximately 1.3 miles from LBL. Tobaccoport Cave typically contains 100-300 hibernating Indiana bats. These bats are, therefore, likely to use an approximate 12,300-acre portion of LBL as swarming habitat during the fall swarming period. In addition, it is also possible that migrating Indiana bats use LBL if LBL lies between their summer and winter habitat areas.

No critical habitat for the Indiana bat occurs within the action area.

Distribution of Disturbances

The distribution of disturbances from wildland fire and forest vegetation management will vary depending on the location of project-specific impacts, but may occur anywhere within the action area. The disturbances associated with the proposed action will vary in size from single tree removal to small timber harvests of various types to prescribed and wildland fires that may exceed 1,000 acres (as described in the Description of the Proposed Action section). Impacts associated with the proposed action will occur in areas where Indiana bats are expected to occur during the growing season.

Timing of the Effects

Adverse effects to Indiana bats, as a result of wildland fire and forest vegetation management, are expected to occur during the growing season (April 1 to September 15) when Indiana bats are likely to utilize forested habitats on LBL for summer roosting and during the portion of the dormant season (September 16 to November 15) when Indiana bats are likely to utilize the forested habitat on LBL within 5 miles of Tobaccoport Cave as swarming habitat. 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/alteration of habitat, and other indeterminable habitat-related effects.

Adverse effects to Indiana bat hibernacula/hibernating bats are not anticipated because no suitable hibernacula exist within LBL. The closest known hibernacula is Tobaccoport Cave (1.3 air miles from LBL), which will be treated as a smoke-sensitive target.

Nature of the Effects

Wildland fire and forest vegetation management could have a variety of effects on individual Indiana bats, maternity colonies, and foraging habitat including: elimination of potential foraging and roosting habitat (e.g., removal of maternity roost trees, summer roost trees, and foraging habitat); alteration and/or modification of normal Indiana bat behaviors; and/or the mortality and/or injury of individual bats. Critical habitat for the Indiana bat will not be impacted by the proposed action and primary constituent elements of Indiana bat critical habitat areas have not been defined. Over time, the proposed action should benefit Indiana bats by creating forest openings and potential roost trees.

Duration of the Effects

Disturbances associated with wildland fire and forest vegetation management will generally be short-term and temporary.

Disturbance Frequency

The need for wildland fire and forest vegetation management will be determined on a project-specific basis. Therefore, the disturbance frequency cannot be accurately determined. However, the maximum amount of habitat that will be impacted on an annual basis is limited to 27,000 acres (only 9,000 acres of which will occur when Indiana bats are expected to be present on LBL during the summer roosting period and 5,000 acres of which will occur when Indiana bats are expected to be present on LBL during fall swarming for wildland fire and 2,200 acres for forest vegetation management.

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.

Disturbance Severity
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 temporary disturbance associated with wildfire and forest vegetation management and/or the loss of roost trees and foraging areas. 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 roost trees and/or foraging areas within the action area. Under a worst-case scenario, a primary maternity roost tree could be felled or consumed by fire 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.

Price's Potato-Bean

Proximity of the Action
There are currently five known populations of Price's potato-bean within the action area. The Kentucky State Nature Preserves (KSNPC) located a total of 52 stems within those populations on the LBL in 2001. Undiscovered populations may exist within the action area where suitable habitat is present.

No critical habitat for the Price's potato-bean occurs within the action area.

Distribution of Disturbances
The distribution of disturbances from wildland fire and forest vegetation management will vary depending on the location of project-specific impacts, but may occur anywhere within the action area.

Timing of the Effects
Adverse effects to Price's potato-bean may occur during any time of the year as a result of wildland fire and/or forest vegetation management. However, the most significant effects are expected during the growing season or during actions that could cause serious effects on the tubers that result in mortality of individual plants.

Nature of the Effects
Wildland fire and forest vegetation management could damage and/or kill individual plants and/or populations by crushing above-ground parts of the plant or underground tubers as a result of soil disturbance or heat exposure. Further, portions of the plant that occur above-ground could also be adversely affected by heat exposure from wildland fire or crushing from falling trees or large equipment.

Critical habitat for the Price's potato-bean will not be impacted by the proposed action. Over time, the proposed action should benefit Price's potato-bean by reducing excessive shading and controlling invasive species.

Duration of the Effects

Disturbances associated with wildland fire and forest vegetation management will generally be short-term and temporary.

Disturbance Frequency

The need for wildland fire and forest vegetation management will be determined on a project-specific basis. Therefore, the disturbance frequency cannot be accurately determined. However, the maximum amount of habitat that will be impacted on an annual basis is limited to 27,000 acres for wildland fire and 2,200 acres for forest vegetation management.

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 the species within these areas.

Disturbance Severity

In most cases, it is unlikely that a project will result in the loss of an individual Price's potato bean plant or population because LBL will avoid soil disturbance within 200 feet of limestone outcrops and will survey all areas for Price's potato bean prior to herbicide treatment. Therefore, most adverse effects will be the result temporary disturbance associated with wildfire and forest vegetation management.

Indiana Bat: Analysis of Effects

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. There are no beneficial effects to the Indiana bat that would result from wildland fire or forest vegetation management.

Direct Effects

Wildland Fire

Wildland fire (prescribed fire and wildland fire use) during the growing season (April 1 to September 15) and during a portion of the dormant season (September 16 to November 15) when Indiana bats are swarming may result in a number of activities that could directly impact the Indiana bat. Some of these activities, by themselves, may not result in the take of an Indiana bat (i.e., See "a" from the list below.); however, when they are considered as one programmatic action, take may occur.

These associated activities, which are discussed in detail in the BA, include:

(a) Burn Plan Preparation/Layout;
(b) Fire Line Construction;
(c) Ignition of the Burn; and
(d) Mop-Up after the burn is completed.

Activity (a) is unlikely to independently cause adverse effects on Indiana bats, but we believe that the remaining activities (i.e., b-d) may each cause adverse effects as they each involve the alteration of habitat that could result in harm, harassment, and/or mortality of Indiana bats.

The direct effects that may occur because of wildland fire could result from fire line construction, ignition of the burn, and/or mop-up after burn is completed. These effects can be separated into the felling of trees associated with the construction of the fire line and/or mop-up of the site once the burn is completed and the smoke and heat produced from the fire. Trees within and adjacent to the fire line are either felled through the selection and subsequent cutting or removal of that tree or the accidental felling of an adjacent tree.

As stated in the BA, fire line layout and construction measures will attempt to avoid the removal of any large trees, including snags. However, in some instances related to fire control and/or human safety, the direct or accidental removal of trees that may be suitable for Indiana bat roosting, including snags, may occur. If the removal of these trees is not avoided or completed when the bats are hibernating (i.e., during the non-roosting season), then adverse effects may occur. Additionally, standing snags that are on fire or smoldering could be felled during mop-up operations if they pose a threat to human safety or pose a threat to losing control of the prescribed fire outside the fire lines. If an Indiana bat remained in such trees, then the felling of such trees, or the accidental felling of an adjacent tree, could also result in take of an Indiana bat.

Summer roosting and/or fall swarming Indiana bats have the potential to be harmed and/or harassed by both the smoke and fire associated with prescribed burns. Summer roosting and/or fall swarming bats may flush from trees in response to smoke or the heat from the fire, but flushing may not occur if certain situations (i.e., the bats are roosting high in a tree and are not affected by smoke or heat). This flushing activity could result in harm and harassment to the Indiana bat by altering its normal behavior pattern, making it more susceptible to various predators during the daylight hours, or result in injury or mortality. However, it should be noted that fire is part of the natural disturbance regime for forest communities on LBL, as are rain and windstorms. Prescribed burning is an action that attempts to restore a natural disturbance that Indiana bats have evolved with over time. If Indiana bats do not flush from their roosting sites, they may become subject to both heavy smoke and high heat conditions. Either condition could result in the take of an Indiana bat due to harm and/or harassment.

During the portion of the year that young Indiana bats are flightless, the potential for take of these bats would increase. Juvenile bats would be incapable of flushing from a roost tree and would not have the opportunity or option of minimizing the effects of smoke and fire by flying away. The likelihood of harming and/or harassing a bat would depend on several factors including how high the bat was roosting, the smoke characteristics for the site on that date, the intensity of the fire, and/or the density of the smoke in that location. Radio-telemetry data that was conducted on the Daniel Boone National Forest (DBNF) in eastern Kentucky indicates that Indiana bats roost at various heights ranging from as low as six feet to over 50 feet from the ground (K. Huie, DBNF, Personal Communication 2003), with higher roosting possible, depending on the physical condition of the roost tree.

Additional direct effects that may occur as a result of wildland fire could result from the disturbance of summer roosting and/or fall swarming Indiana bats. The noise or disturbance is typically generated by a variety of activities ranging from human presence in the area to the loud noises associated with the use of equipment on or near the roosting bat (e.g., axes, chain saws, bulldozers). Noise associated with activities within a burn unit may cause a bat to flush. T his flushing activity could result in harm and/or harassment of the Indiana bat by altering its normal behavioral pattern or making it more susceptible to various predators during the daylight hours, which could result in injury or mortality.

In addition, spot fires can and do occasionally occur outside of planned fire lines. These spot fires usually result from burning embers blowing across the fire lines. During the prescribed burn and mop-up operations, fire crews are in the immediate area and these unplanned burn areas seldom exceed ¼ acre. Should these spot fires continue to grow in size, they are declared a wildfire and additional resources brought into the area to bring the escaped fire under control. In such occurrences, the loss of roost trees could cause additional harm, harassment and/or mortality to the Indiana bat. Indiana bats flushed from trees could be harmed and/or harassed by (a) alteration in normal behavior patterns, (b) making them more susceptible to various predators during the daylight hours, or (c) increasing the probability of mortality.

There is no potential for Indiana bats to be exposed to dormant season prescribed fire or WFU on LBL because there are no suitable hibernacula on LBL. Further, the closest known hibernacula, Tobaccoport Cave, is treated as a smoke sensitive target, which does not allow any wildland fire within two miles of the cave entrance if winds are expected to transport smoke over the cave entrance.

Forest Vegetation Management

Forest vegetation management during the growing season (April 1 to September 15) and a portion of the dormant season (September 16 to November 15) if done within occupied swarming habitat may result in a number of activities that could directly impact the Indiana bat. Some of these activities, by themselves, may not result in the take of an Indiana bat (i.e., See "a" from the list below.); however, when they are considered as one programmatic action, take may occur. These associated activities, which are described in detail in the BA, include:

(a) Timber Appraisal, Advertisement, Bidding, Award of Sale and Closing the Sale;
(b) Sale Area Layout/Designation of Timber to be Harvested;
(c) Felling of Trees;
(d) Skidding of Cut Trees;
(e) Decking/Landing of Cut Trees; and
(f) Transporting of Logs.

Activities (a) and (b) are unlikely to independently cause adverse effects on Indiana bats, but we believe that the remaining activities (i.e., c-f) may each cause adverse effects as they each involve the alteration of habitat that could result in harm, harassment, and/or mortality of Indiana bats. Although the proposed actions are designated to improve Indiana bat habitat, these activities may involve the removal of occupied roost trees and/or the modification of occupied foraging habitat where proposed forest vegetation management and summer home ranges of Indiana bats within the action area overlap. This has the potential to cause direct adverse effects on Indiana bats by altering their necessary summer habitat characteristics.

The direct effects that may occur will typically result from the felling, skidding, decking/landing, and/or transport of trees. These effects can be separated into the felling of a tree and the removal operations that occur once the tree has been cut and is on the ground. Trees are either felled through the selection and subsequent dropping of that tree or the accidental felling of an adjacent tree. Regardless of the felling method (i.e., direct or accidental), a maternity colony or individual Indiana bat could be harmed, harassed, and/or killed as a result of the felled tree striking the ground or due to being dislodged from the roost tree (i.e., falling to the ground). Although any mature Indiana bat can likely fly away from a tree prior to or during the felling process, females may be less likely to leave if they have flightless (i.e., non-volant) young present (usually between May 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 felling of a tree in which they are roosting likely increases. While this type of disturbance can occur, we believe that this potential adverse effect is unlikely to occur but cannot be discounted.

Another direct 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. This type of adverse effect could result from any of the activities mentioned previously, excluding the administrative activities. The noise and vibration generated from the proposed activities and equipment 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 vegetation management may initially be startled by unusual noises in the distance but may habituate to the noises if they are of low volume and a 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 vegetation management 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 they were displaced from. 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). While we do not know if Indiana bats will return to roosting areas subjected to harvests after the harvest is completed, research conducted on the DBNF suggests that they have done so in the past when appropriate conservation measures where applied.

Conversely, 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 2007). Therefore, we cannot say definitively that Indiana bats will shift or abandon their roosts as a result of the proposed harvesting actions.

We do not anticipate that vegetation management will affect the availability of foraging habitat, because there is a surplus of potentially suitable foraging habitat within the action area. This surplus is based on the facts that (a) forests cover the majority of the action area; (b) Indiana bats do not occupy all available habitats; and (c) the forested area within the action area is not expected to decrease significantly through the year 2020 (USFS 2002). However, we expect that foraging habitat will be modified. These modifications may temporarily degrade the available foraging habitat in situations where the habitat is optimum, but this is expected to be a minor, short-term effect. In most cases, we expect that the proposed activities will provide significant long-term benefits to Indiana bat summer foraging and roosting habitat. The implementation of vegetation management would open up the forest by creating additional small (on localized and landscape scales) gaps in the forest canopy and by altering the structure of the forest, thus facilitating use of those stands by Indiana bats for foraging and roosting.

Summer habitat research conducted on the DBNF over the last decade or more has documented Indiana bats foraging within and often roosting adjacent to those areas where harvest and burn activities have occurred. Similar results have been demonstrated in other parts of the Indiana bat's range and would also be expected on LBL. The *A Summary of Characteristics of a Typical Primary Roost*, *Other Factors Affecting Access and Sunlight*, and *Foraging Habitat* sections highlight much of what is known with regard to the habitat preferences of Indiana bats, and that knowledge leads us to believe that Indiana bats prefer semi-open habitat (although they will use other habitat types).

After the fall swarming period, there is no potential for Indiana bats to be exposed to dormant season forest vegetation management because Indiana bats do not hibernate on LBL. Further, timber appraisal, advertisement, bidding, award of sale and closing the sale activities are administrative in nature and will have no effect on Indiana bats.

While the types of adverse effects discussed above can, theoretically occur, we anticipate that they would only occur for a relatively short period of time and would represent a minor risk to the Indiana bat due to the low probability that any individual maternity or other roost tree will be consumed by fire or accidentally knocked down; however, these activities can result in adverse effects to an Indiana bat and cannot be discounted. Our determination that the adverse effects would be of short duration and minor in effect is based on:

(a) A lack of published evidence showing that wildland fire or forest vegetation management causes adverse effects to Indiana bats;
(b) LBL will apply the Area Plan's Standards, which contain measures to protect and conserve Indiana bats and their habitat; and
(c) Wildland fire and/or forest vegetation management that occurs in occupied summer habitat is unlikely to result in consistent and predictable adverse effects due to differences in fire prescriptions (i.e., some fires burn hotter and produce more smoke than others due to wind direction, fuel loads and fuel moisture, relative humidity, and other factors) or forest vegetation management activities (i.e., some harvests will leave more roost trees than others, thus not felling immediate roost trees) and Indiana bat roosting characteristics (i.e., the physical location of bats that are affected will often determine if adverse effects will occur and the intensity or severity of the adverse effects).

In summary, we have taken a cautious, conservative approach in determining that adverse effects will occur.

If wildland fire were implemented at the proposed maximum thresholds, a maximum of 27,000 acres, or 15 percent of LBL's acreage, would be affected each year. However, only 9,000 acres would be affected during the growing season and only 5,000 acres would be affected during a portion of the dormant season when Indiana bats are likely to be found across LBL's landscape. Therefore, incidental take is only required for the 9,000 acres, or 5 percent of LBL's acreage, to be treated with wildland fire during the growing season and 5,000 acres, or 3 percent of LBL's acreage, to be treated during a portion of the dormant season. If forest vegetation management was implemented at the proposed maximum threshold, approximately 2,200 acres, or percent of the total LBL acreage, would be affected each year.

LBL has asked for incidental take authorization for 9,000 acres annually as a result of wildland fire during the growing season, 5,000 acres annually as a result of wildland fire during a portion of the dormant season, and 2,200 acres annually as a result of forest vegetation management. However, we believe that this assumption significantly overestimates potential adverse effects to Indiana bats, because it assumes that:

(a) All wildland fire and forest vegetation management activities occur in forest types that can be immediately occupied or are occupied by Indiana bats;
(b) All of the habitat within a wildland fire or forest vegetation management area is potentially suitable and/or occupied habitat; and
(c) All wildland fire and forest vegetation management activities are completely deleterious to Indiana bats and their habitat resulting in a complete loss of Indiana bats and/or their habitat within a project area.

Even though potential adverse effects to summer roosting, swarming, and foraging bats may occur when proposed wildland fires occur, the overall potential adverse effects resulting from wildland fire are significantly reduced by several important factors:

(a) Not all habitat within the action area is suitable Indiana bat habitat. Habitat within many of the areas where wildland fire or forest vegetation management would be conducted is comprised of several communities (i.e., forest habitat types), not all of which are expected to be suitable Indiana bat habitat. In addition, some habitat that will be treated is too young, too dense, or has other characteristics that would limit its use by Indiana bats. However, burning is expected to improve those habitats;

(b) As described in detail within the BA, implementation of the Area Plan Standards will minimize potential adverse effects to Indiana bats on those areas that are proposed for wildland fire or forest vegetation management;

(c) The proposed action will not cause adverse effects in every situation. Indiana bats do not roost in every potential roost tree within the action area, so the potential removal of unoccupied trees and trees by prescribed fires in unoccupied habitat will be inconsequential. The available survey and life history information for the species show that Indiana bats do not use all potential roost trees within their home ranges. Therefore, the probability that any single occupied roost tree will be lost during wildland fire or forest vegetation management is low.

(d) Despite survey efforts, Indiana bats have never been documented on LBL. Therefore, if they occur, Indiana bats are unlikely to occur ubiquitously or in a uniform distribution across LBL. The limited surveys efforts for the species on LBL also support this.

(e) Management of certain forest stands as proposed would improve roosting and foraging habitat for Indiana bats both locally and as a whole within the action area. Indiana bats tend to use forested habitats that are semi-open or that have edges. The proposed use of wildland fire and/or forest vegetation management would encourage this type of habitat throughout LBL while also creating potential roost trees; and

(f) None of the proposed actions would involve the complete removal of suitable Indiana bat habitat. They would, instead, involve the gradual modification of forest stands while maintaining suitable roosting and foraging habitat conditions.

Interrelated and Interdependent Effects

An interrelated activity is an activity that is part of the proposed action and depends on the proposed action for its justification (Service and National Marine Fisheries Service [NMFS] 1998). An interdependent activity is an activity that has no independent utility apart from the action under consultation (Service and NMFS 1998). A determination of whether other activities are interrelated to, or interdependent with, the proposed action under consultation is made by applying a "but for" test. That is, it must be determined that the other activity under question would not occur "but for" the proposed action under consultation (Service and NMFS 1998).

There is no justification for claiming that other wildland fires or forest vegetation management on adjacent lands would occur because of the implementation of the WFVM; therefore, actions outside the boundaries of LBL cannot be considered as an interrelated or interdependent action that should be considered in this biological opinion. Further, any unforeseen activity that may occur because of the proposed actions would receive a project-specific analysis and subsequent section 7 consultation with the Service through the BA/BE process.

Indirect Effects

The Service has identified several likely indirect effects of the proposed action. All of these indirect effects relate to improvements in Indiana bat foraging, swarming, and roosting habitat that would result from implementation of the proposed action and are listed below:

(a) Indiana bats should benefit from increased foraging opportunities and increased insect populations following prescribed burns. Burned areas tend to have more herbaceous biomass due to reduced competition from trees and shrubs and the removal of leaf litter from the forest floor. In turn, this increase in herbaceous biomass will support more Indiana bat prey items (i.e., insects and other arthropods) and more species of prey items. We would expect this increase in food availability to have positive effects on Indiana bat reproduction, adult fitness, and juvenile survival.

(b) Harvests and burning may improve Indiana bat foraging efficiency by opening dense stands that may hamper foraging and other movements or by maintaining open stands for such movements.

(c) Habitat improvements, such as increasing or maintaining sufficient numbers of potential roost trees and opening the forest canopy, mid-story, and understory, may cause additional Indiana bats to begin using the action area and/or may result in improved reproductive success. These increased numbers of Indiana bats, if they occur, would increase the probability of adverse effects resulting from the proposed action over current conditions.

Price's Potato-Bean: Analysis of Effects

Price's potato-bean occurs at five known sites within LBL. However, additional populations may exist in other suitable habitat on LBL, but these populations have not yet been discovered. All known populations of Price's potato-bean will be avoided during the proposed actions; therefore, only direct effects that could impact undiscovered populations were evaluated for this biological opinion.

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. There are no beneficial effects to Price's potato-bean that would result from wildland fire or forest vegetation management.

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.

Wildland Fire

Wildland fire (prescribed fire and wildland fire use) may include a number of activities that could directly impact Price's potato-bean. It is likely that Price's potato-bean plants may be impacted by the use of dozers when fire control lines are constructed in any season. Construction of control lines with dozers, although estimated at only one mile annually, is proposed on dry and dry-mesic sites across LBL, where undiscovered populations of Price's potato-bean may exist. Dozers could crush/kill individual plants, resulting in mortality of plants, reduced flowering, and/or seed production. The dozer lines could also encourage invasive species recruitment that could compete with Price's potato-bean, resulting the same adverse effects.

Direct impacts form heat/fire could also cause adverse effects to Price's potato-bean. The potential exists for the above-ground parts of Price's potato-bean to be consumed and/or exposed to heat damage from wildland fire during the dormant and growing seasons; however these effects are temporary as long as the tubers are unaffected. Even extreme wildland fires are unlikely to generate heat powerful enough to penetrate the soil deep enough to affect its tubers. Price's potato-bean may be top-killed by heat/fire during the growing season. The top-kill effect after a growing season fire may eliminate any potential for individual plants to flower and produce seed during that growing season, but the plants themselves are expected to resprout.

Forest Vegetation Management

Direct effects to Price's potato-bean as a result of forest vegetation management can occur during any season, assuming Price's potato-bean exists in an area where forest vegetation management is planned. Individual plants could be destroyed by logging activity if the activity disturbs the soil more than a few inches below the surface. This can uproot and kill plants and tubers.

Individual plants could also be adversely affected by Imazapyr application, if plants are exposed to the herbicide. However, LBL will survey all treated areas for Price's potato-bean prior to treatment to significantly reduce the potential for accidental applications of herbicides on the species.

Other forest vegetation management activities that do not disturb soil would have little impact on this species, and may be of actual benefit (NatureServe 2008). However, it is also possible that skidding a single large tree over a population could kill all the plants in a population, since many populations are typically small, localized populations containing a few individuals.

While the types of adverse effects discussed above can, theoretically, occur, we anticipate that non-mortality adverse effects would only occur for a relatively short period of time (i.e. immediately after proposed actions) and would represent a minor risk to Price's potato-bean due to the low probability that any individual plant or population will be directly impacted and then lost; however, on a programmatic level these activities could result in adverse effects to Price's potato-bean and cannot be discounted.

Our determination that the adverse effects would be of short duration and minor in effect is based on:

(a) A lack of published evidence showing that the wildland fire and forest vegetation management activities cause short- or long-term adverse effects to Price's potato-bean; and

(b) The fact that all wildland fire and forest vegetation management activities will be undertaken using prescriptions that avoid and minimize the potential for adverse effects to Price's potato-bean through incorporation of the Area Plan.

In summary, we have taken a cautious, conservative approach in determining that adverse effects will occur, including accounting for adverse effects that may not occur.

If the proposed action was implemented at the proposed maximum thresholds, 27,000 acres, or 15 percent of LBL's acreage, would be affected each year as a result of wildland fire; and 2,200 acres, or 1 percent of LBL acreage, would be affected each year as a result of forest vegetation management. However, we believe that this assumption significantly overestimates potential adverse effects to Price's potato-bean, because it assumes that:

(a) All activities occur in habitat that is suitable for Price's potato-bean;

(b) All of the habitat within a project area is potentially suitable and/or occupied habitat; and

(c) All wildland fire and forest vegetation management activities are completely deleterious to Price's potato-bean and it's habitat resulting in a complete loss of populations, individual plants, and/or habitat within a project area.

Even though potential adverse effects may occur when proposed wildland fire and forest vegetation management occur, the overall potential adverse effects are reduced significantly by several important factors:

(a) <u>Not all habitat within the action area is suitable Price's potato-bean habitat.</u> Habitat within the management areas are comprised of several communities (i.e., forest habitat types), not all of which are suitable. The species is also unlikely to be present in all potential habitat areas.

(b) <u>The proposed action will not cause adverse effects in every situation</u>. Fire/heat may cause growing season top-kill, but tubers are typically deep in the soil and protected by heat. Individual plants are likely to re-sprout and flourish after a fire (Neumann and Dickman 2001). Further, trees falling on individual plants or dozers crushing plants may occur, but is unlikely due to the typically limited distribution of the species on LBL and range-wide.

(c) <u>LBL will avoid soil disturbance within 200 feet of limestone outcrops.</u> Limestone outcrops will be identified and surveyed during the planning phases of any soil-disturbing activity, as all known populations of Price's potato-bean are also components of a local flora that is associated with limestone outcrops.

(d) <u>None of the proposed wildland fire or forest vegetation management actions would involve the complete removal of suitable Price's potato-bean habitat</u>.

Interrelated and Interdependent Effects

An interrelated activity is an activity that is part of the proposed action and depends on the proposed action for its justification (Service and National Marine Fisheries Service [NMFS] 1998). An interdependent activity is an activity that has no independent utility apart from the action under consultation (Service and NMFS 1998). A determination of whether other activities are interrelated to, or interdependent with, the proposed action under consultation is made by applying a "but for" test. That is, it must be determined that the other activity under question would not occur "but for" the proposed action under consultation (Service and NMFS 1998).

There is no justification for claiming that other wildland fires or forest vegetation management on adjacent lands would occur because of the implementation of the WFVM program; therefore, actions outside the boundaries of LBL cannot be considered as interrelated or interdependent actions that should be considered in this biological opinion. Further, any unforeseen activity that may occur because of the proposed actions would receive a project-specific analysis and subsequent section 7 consultation with the Service through the BA/BE process.

Indirect and Beneficial 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 to Price's potato-bean that could occur because of the proposed action. All of these indirect effects relate to improvements in Price's potato-bean habitat that would result from implementation of the proposed action and are listed below:

(a) Protection of limestone outcrops and increased sunlight from the combined effects of fire and tree removal is expected to benefit Price's potato-bean, thus improving its recovery potential by maintaining, increasing, and/or creating new populations.

(b) Individual plants that are exposed to and then survive soil disturbance would likely benefit from higher light levels brought about as a result of the forest vegetation management. In the past, trees have been removed from areas surrounding known populations of Price's potato-bean on LBL to successfully increase light levels (NatureServe 2008). In addition, research within the action area has shown that known populations appear to be flourishing in response to silvicultural treatments conducted in the dormant season of early 2009. This benefit should last for many years, allowing individuals to flower and seed with a high likelihood of new plant growth and population expansion.

(c) Individual plants are likely to resprout and flourish after a growing season top-kill. It is likely that growing season top-kill would not kill individual plants since tubers are usually deep in the soil and protected from heat. A close cousin of Price's potato-bean, *Apios americana* or American hog peanut, is known to re-sprout and flourish after fire (Neumann and Dickmann, 2001).

(d) Growing season fire will significantly reduce leaf litter and understory shading for several years.

Response to the Proposed Action

Numbers of Individuals in Action Area

Indiana Bat: To date, no Indiana bats have been documented within the action area, but presence is assumed during fall swarming and summer roosting. Therefore, it is difficult to quantify the numbers of Indiana bats within LBL. However, because potential adverse affects from the proposed action would be localized, we do not expect the affects of the proposed action to impact a large number of individuals.

Price's Potato-bean: There are currently five known populations of Price's potato-bean within the action area. However, undiscovered populations may exist within the action area where suitable habitat is present. LBL intends to avoid and minimize adverse effects to both known and undiscovered populations of Price's potato-bean by avoiding soil disturbance within 200 feet of limestone outcrops and surveying areas for the plant species prior to herbicide treatment. Because potential adverse effects are localized and temporary in nature, we do not expect the affects of wildland fire or forest vegetation management to impact any of the known populations or a large number of individual plants and/or populations that are currently unknown.

Sensitivity to Change

Indiana Bat: The Indiana bat does not appear to be particularly sensitive to change within its summer and swarming habitats. 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, which are the primary reasons cited for the species' historic population losses.

Price's Potato-bean: Additional information/studies are needed to better understand Price's potato-bean's sensitivity to change. Populations have been shown to decline when invasive/exotic species move into an area or when excessive shading limits the amount of sunlight (See Life History). However, changes associated with wildland fire and forest vegetation management are anticipated to be largely beneficial to the plant due to reduced shading and competition from invasives and other competitors.

Resilience

Indiana Bat: For the proposed action, the disturbances for both wildland fire and forest vegetation management will be relatively small compared to the action area, temporary in nature, and minor in severity. The species' resiliency to natural and anthropogenic disturbances has been demonstrated in a variety of contexts. 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. We do not believe that the types of disturbances associated with the proposed action will significantly affect the specie's populations even though it has a relatively low reproductive rate.

Price's Potato-bean: Disturbances for both wildland fire and forest vegetation management will be relatively small compared to the species' range within the action area, temporary in nature, and minor in severity. Price's potato-bean has been documented to flourish within the action area after silviculture treatments (LBL, pers. comm., 2009) and similar species are documented to flourish after fire.

Recovery Rate

Indiana Bat: 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 pre-project levels to be short (i.e., < 1 year until recovery). Most adverse effects associated with the proposed action are of temporary and/or of short duration as discussed elsewhere in the Analyses for Effects of the Action section.

Price's Potato-bean: Most adverse effects associated with the proposed action are of temporary and/or of short duration (i.e., < 1 year until recovery) (See Analyses for Effects of the Action section). We expect the time required for individual plants and/or populations with the action area to return to (or exceed) pre-project levels to be negligible.

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. This biological opinion only addresses those activities that are authorized by the Area Plan on lands that are under the jurisdiction of the Forest Service. Thus, any future State, local, or private actions that could potentially occur on LBL would require a permit from the Forest Service and will require compliance with the consultation provisions of Section 7 of the ESA as a second level, site-specific analysis of an individual project. There are no additional State, local or private actions reasonably certain to occur on LBL. Therefore, cumulative effects, as defined by the ESA, will not occur.

CONCLUSION

After reviewing the current status of the Indiana bat and Price's potato-bean, the environmental baseline(s) for the action area, the effects of the proposed WFVM program, and the cumulative effects, it is the Service's biological opinion that the wildland fire and forest vegetation management activities proposed in the WFVM program are not likely to jeopardize the continued existence of the Indiana bat or Price's potato-bean. Critical habitat has been designated for the Indiana bat, however, this action does not affect any Indiana bat critical habitat areas, and no destruction or adverse modification of that critical habitat is expected. No critical habitat has been designated for Price's potato-bean; therefore, none will be affected.

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 or Price's potato-bean by reducing the reproduction, numbers, or distribution of these species (50 CFR 402)." In fact, we believe that neither survival nor recovery will be reduced appreciably for reasons summarized later in this section.

The expected outcome of LBL's proposed management direction under the Area Plan would be beneficial to Indiana bats and its habitat in many ways, especially (a) the improvement and maintenance of maternity, summer roosting, and foraging habitat across LBL through proposed management activities, and (b) the continual replacement of potentially suitable forested habitat on LBL (i.e., habitat alteration/loss will not be permanent). Furthermore, the expected outcome of LBL's proposed management direction under the Area Plan is also expected to be beneficial to Price's potato-bean and its habitat by protecting limestone outcrops and improving habitat conditions (reducing shading) so that populations of this species can be maintained or increased and/or new populations established or enhanced.

For the proposed action to "reduce appreciably" Indiana bat or Price's potato-bean recovery, the proposed action would have to impede or stop the process by which the species' ecosystems are restored and/or threats to Indiana bats or Price's potato-bean 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 management actions, while potentially resulting in the incidental take of some individuals, are not a significant threat to the species as a whole and, therefore, do not rise to the level of jeopardy.

(b) 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. To the contrary, we expect that the proposed action to improve reproduction, numbers, and distribution of Indiana bats within the action area, which would have corresponding positive effects on its recovery. For example, we expect Indiana bats within the action area to find a greater amount of suitable foraging and roosting habitat and improved foraging conditions in those areas managed by harvests and prescribed fire than currently exists. This would result in a number of positive effects for Indiana bat population numbers and distribution. These benefits include, but are not necessarily limited to, increased reproductive success (i.e., better maternity roost sites can improve the survival and health of young); increased food availability (i.e, opening the forest canopy and mid-story by harvesting or burning will result in improved foraging areas, increased food item availability for adults and juveniles due to increases in leafy vegetation, and increased year-to-year survivorship of adults and juveniles because they enter hibernation in a healthier state); and a wide range of suitable habitat conditions throughout the action area that were created and maintained through management (i.e., a variety of habitat types and structures would be available and some of those would be previously unsuitable or marginal habitats into which Indiana bats could expand their local distributions).

(c) 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.

We do not believe the proposed project impedes or stops the recovery process for Price's potato-bean because:

(a) We believe that the proposed management actions, while potentially resulting in adverse effects on some individuals, are not a significant threat to the species as a whole and, therefore, do not rise to the level of jeopardy.

(b) No component of the proposed action is expected to result in adverse effects or mortality at a level that would reduce appreciably the reproduction, numbers, or distribution of Price's potato-bean on LBL or range-wide. To the contrary, we expect that the proposed action (1) will not cause the loss of any known populations, (2) will improve reproduction and numbers of currently-unknown Price's potato-bean populations within the action area, and (3) will create opportunities for the establishment of new Price's potato-bean populations on LBL in areas where habitat for the species is improved through implementation of the proposed action. All of these are expected to have corresponding positive effects on the recovery of the species.

(c) The primary threats to Price's potato-bean recovery are human disturbance, aspects of its biology, and interaction with other species (Service 1993). The proposed action may cause temporary adverse effects to Price's potato-bean individuals or populations, but should, in the long-term, improve recovery efforts by eliminating exotic/invasive species and excessive shading.

For the reasons listed above, we believe that Indiana bat and Price's potato-bean recovery and survival will not be reduced appreciably by the short-term adverse affects associated with the WFVM program.

INCIDENTAL TAKE STATEMENT

Section 9 of the Act and Federal regulation under section 4(d) of the Act prohibit the take 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 to attempt to engage in any such conduct. Harm is further defined by Service to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Harass is defined by 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 which 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 taking under the Act provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

Section 7(b)(4) and 7(o)(2) of the Act generally do not apply to listed plants species. However, limited protection of listed plants from take is provided to the extent that the Act prohibits the removal and reduction to possession of federally listed endangered plants or the malicious damage of such plants on areas under federal jurisdiction, or the destruction of endangered plants on non-federal areas in violation of state law or regulations or in the course of any violation of a state criminal trespass law. This action is being conducted entirely on federal lands.

AMOUNT OR EXTENT OF TAKE ANTICIPATED

Price's Potato-bean

Price's potato-bean is a plant; therefore, no take is identified.

Indiana Bat

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 summer habitat on LBL is unknown;
5. Implemented actions will not affect the entire available habitat within a project area (i.e., implementation of the Area Plan and avoidance measures that LBL will implement on a project-specific basis will minimize the amount of incidental take); 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 occupied and suitable roosting trees and habitat (a direct effect);
2. Modification and alteration of occupied and suitable roosting trees and habitat (a direct effect);
3. Modification and alteration of occupied and suitable foraging and/or swarming habitat (a direct effect);

4. Harm and harassment of Indiana bats resulting from activities associated with proposed WFVM program activities that will be conducted within suitable and/or occupied Indiana bat habitat (a direct effect); and

5. Mortality associated with the loss, modification, and/or alteration of occupied roost trees and occupied foraging and/or swarming habitat resulting from WFVM program activities that will be conducted within occupied Indiana bat habitat (a direct effect).

The level of take identified below may result, because LBL anticipates and has estimated that up to 27,000 acres of wildland fire and 2,200 acres of forest vegetation management may occur per year. These activities will likely occur within forest stands that may contain suitable habitat for Indiana bats. 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 wildland fire and forest vegetation management on an annual basis.

Therefore, the level of take anticipated in this biological opinion is 9,000 acres of wildland fire when accomplished during the summer roosting period (April 1 to September 15), 5,000 acres of wildland fire when accomplished during the fall swarming period, and 2,200 acres of forest vegetation management that may occur during any time of the year. Take is only expected to occur as a result of forest vegetation management during the summer roosting and fall swarming period for Indiana bats, however due to the difficulty in anticipating when forest vegetation management will occur, take is being requested for the entire 2,200 acres. No take is anticipated during wildland fire events that occur during the winter (November 16 to March 31).

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 as detailed in the "Analysis of Effects" section of this biological opinion. Collectively, the factors listed in the "Analysis of Effects" section 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 wildland fire and forest vegetation management activities as described in LBL's BA. 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 timber harvest; temporary road, skid-trail, fire line, and log landing construction and maintenance; smoke and fire resulting from prescribed burning; disturbance from equipment operators and machinery used during the preparation and implementation of these activities; and inter-related activities that are necessary to plan and implement these activities. Although mortality is the least likely form of take to occur due to implementation of these activities, adult or juvenile Indiana bats may be killed (a) due to the felling of trees, (b) by the effects of smoke and fire during wildland fire, or (c) by other activities that are associated with wildland fire and forest vegetation management. 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 roost trees 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, smoke and heat resulting from wildland fire and noise and other disruptions (e.g., operations of personnel and equipment) within occupied habitat. Potential foraging habitat and potential summer roost trees for the Indiana bat are believed to be well-distributed across LBL. Thus, we believe that harassment has the potential to occur in association with any prescribed burn occurring between April 1 and November 15.

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

Price's Potato-bean

Because Price's potato-bean is a plant, no reasonable and prudent measures are required.

Indiana Bat

The Service believes the following reasonable and prudent measures (RPMs) are necessary and proper to minimize impacts of incidental take of the Indiana bat associated with the WFVM program. These non-discretionary measures include, but are not limited to, LBL's implementation of standards within the Area Plan and the terms and conditions outlined in this biological opinion.

RPM 1 – LBL must plan, evaluate, and implement the proposed management activities associated with wildland fires and forest vegetation management in a manner that is consistent with the WFVM program and Area Plan to protect the Indiana bat. Specific implementation of the measures designed to maintain, improve, or enhance habitat for Indiana bats will help avoid impacts to Indiana bats and their habitat and minimize incidental take of Indiana bats.

RPM 2 – LBL must monitor its activities associated with the WFVM program to determine if the Area Plan and the Terms and Conditions of this biological opinion are being implemented and provide an annual report of those activities to the Service.

TERMS AND CONDITIONS

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

Price's Potato-bean

Because Price's potato-bean is a plant, no terms or conditions are required.

Indiana Bat

1. LBL will implement the proposed actions in a manner that is consistent with the Area Plan as they apply to forest management practices associated with WFVM projects that will be implemented annually on LBL between April 1 and September 15 of each year:

a. LBL will ensure that suitable Indiana bat roost trees are present within WFVM treatment areas by conducting surveys of the available Indiana bat roosting habitat prior to the implementation of specific projects. If immediate roost trees are not available within a proposed treatment area, or if immediate roost trees will not be available within the area after treatment, or if immediate roost trees are not and/or will not be available adjacent to a proposed treatment area, LBL must create an immediate roost tree (e.g. girdle) per ten acres of proposed harvest area, but no fewer than two created roost trees must be available per 50 acres of treatment area. If created roost trees are necessary, these habitat improvements must be implemented at least one year in advance of treatment and must be implemented as close as possible to the treatment area, but must not be located within the treatment area in order to avoid luring Indiana bats into areas that will be subsequently treated. This will ensure that immediate roosting habitat is available if Indiana bats are dislocated due to a proposed action and associated activities. This Term and Condition supports RPM 1.

b. As part of the WFVM program, LBL will take necessary precautions to protect designated trees and snags that are to be retained as Indiana bat roosting habitat and any tree known to be occupied by one or more Indiana bats. Further, all known roost trees will be protected until such time as they no longer serve as an Indiana bat roost (e.g., loss of exfoliating bark and/or cavities, blown down, or decay). This does not apply to any tree (live or dead) considered to be an immediate threat to human safety. This Term and Condition supports RPM 1.

c. LBL will develop specific guidelines for use by LBL personnel and contractors that provide guidance and instruction on marking or otherwise designating trees to be harvested and/or trees that will be retained in stands subject to the WFVM program. These guidelines will focus on ensuring that Indiana bat habitat trees, especially primary roost trees, are retained or created within affected forest stands and that known, occupied roost trees are protected. This Term and Condition supports RPM 1.

2. LBL will monitor its implementation of the WFVM program to ensure that the standards within the Area Plan are appropriately implemented and must provide the Service with an annual report of its monitoring activities by January 31 of each year:

a. LBL will monitor selected project areas for characteristics associated with potential Indiana bat roost trees pre- and post-project implementation. Relative to Indiana bat roost trees, LBL will determine (i) if potential roost trees are present within project areas, (ii) potential roost tree densities within project areas, and (iii) retention and creation rates of potential roost trees within project areas. Relative to habitat conditions and habitat quality, LBL will provide information on the canopy closure, tree species composition, and understory density, and the stand age and distance to water. This information is necessary to show that the Area Plan standards and related provisions are having the expected effects on Indiana bat habitat by reducing the amount and effect of the take associated with Indiana bat habitat. This Term and Condition supports RPM 2.

b. LBL will annually monitor the number of acres that are subjected to wildland fire during the summer roosting season (April 1 to September 15) and fall swarming period of the Indiana bat (September 16 to November 15). All acres that are subject to forest vegetation management will be monitored, with those acres treated during the summer roosting season of the Indiana bat accounted for separately. LBL will then use these data to determine if the amount of authorized incidental take was exceeded. This Term and Condition supports RPM 2.

c. LBL will use the following table and annually provide the Service with this table in the annual report:

Table 5. Estimate of Indiana bat incidental take occurred during [Insert Year] due to implementation of LBL's WFVM Program

Species	**Habitat (Acres)**	
	Authorized Level of Habitat Alterations	**Actual Level of Habitat Alterations**
Indiana Bat - Growing Season Wildland Fire (April 1 to September 15)	9,000	
Indiana Bat - Dormant Season Wildland Fire (September 16 to November 15)	5,000	
Indiana Bat - Forest Vegetation Management (April 1 to September 15)	2,200	
Indiana Bat - Forest Vegetation Management (September 15 to March 31)		

This Term and Condition supports RPM 2.

LBL 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, LBL 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 to the Service's Kentucky Ecological Services Field Office at 330 West Broadway, Room 265, Frankfort, Kentucky 40601 (Telephone: 502/695-0468).

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 9,000 acres due to wildland fire and no more than 2,200 acres due to forest vegetation management annually. 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. LBL must immediately provide an explanation of the causes of the taking and review with the Service the need for possible modification of the Reasonable and Prudent Measures

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Endangered Species Act (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. Conservation recommendations are discretionary activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information.

1. LBL should pursue additional funding and partnership opportunities to complete any additional research, inventory, and monitoring work that is necessary to better understand the ecology of the Indiana bat and Price's potato-bean on LBL. In particular, selected project areas should be selected and monitored for habitat use prior to project implementation and after project completion, which will provide information to compare and evaluate the effects of management activities on Indiana bat and Price's potato-bean occurrence and habitat use of project areas compared to non-project areas.

2. LBL hosts many visitors each year. The Service encourages the installation of informational/educational displays regarding endangered bats and plants. The Service believes that such information would be valuable in informing the public.

3. LBL should provide training for appropriate LBL staff and contractors on the bats (including the Indiana bat) and rare plants (including Price's potato-bean) that occur on LBL. Training should include sections on identification, biology, and habitat requirements, as well as sampling techniques for bats (including instructions on applicability/effectiveness of using mist-netting surveys versus acoustical monitoring (i.e., Anabat) detectors to accurately determine the presence of various bat species). The proper training of LBL staff and contractors on bat and plant identification will enable the USFS to better monitor the status of these species.

4. LBL should continue to control the spread of invasive species where invasion of such species is likely to result in the loss of suitable Indiana bat habitat or Price's potato-bean habitat.

5. LBL should investigate the potential for restoration or introduction of additional Price's potato-bean populations within suitable habitat areas on LBL.

In order for the Service to be kept informed of actions minimizing or avoiding adverse effects or benefiting listed species or their habitats, the Service requests notification of the conservation recommendations carried out.

REINITIATION NOTICE

This concludes formal consultation on the implementation of the WFVM program for LBL and its effects on the Indiana bat and Price's potato-bean. As stated in 50 CFR 402.16, reinitiation of formal consultation is required where discretionary LBL 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 LBL'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) LBL'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 of 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 following take monitoring parameters are exceeded:

1) 9,000 acres of wildland fire per year during the summer roosting period of the Indiana bat (April 1 to September 15), including no more than 5,000 acres within the 5-mile radius of Tobaccoport Cave during the Indiana bat swarming season, or
2) 2,200 acres of forest vegetation management per year.

These are the amounts of habitat that are exempted on an annual basis from the prohibitions of section 9 of the Act by this biological opinion. The Service appreciates the cooperation of LBL's staff during this consultation.

If you have any questions concerning this consultation, please contact me at (502) 695-0468 x 108 or Ms. Carrie Lona at (502) 695-0468 x 103.

Sincerely

Virgil Lee Andrews, Jr.
Field Supervisor

cc:

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