United States Department of the Interior

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FISH AND WILDLIFE SERVICE
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Frankfort, Kentucky 40601

April 3, 2007

Mr. Charles L. Meyers
Regional Forester
U.S. Forest Service, Southern Region
1720 Peachtree Road, NW.
Atlanta, Georgia 30367-9102

Subject: FWS #07-B-0580; Revised Final Biological Opinion on implementation of the revised Land and Resource Management Plan and its effects on the Indiana bat, Daniel Boone National Forest, Kentucky

Dear Mr. Meyers:

This document sends the U.S. Fish and Wildlife Service's (Service) biological opinion based on our review of the U.S. Forest Service (USFS) Daniel Boone National Forest's (DBNF) proposed implementation of a revised Land and Resource Management Plan (LRMP) and its effects on the Indiana bat (*Myotis sodalis*) under section 7 of the Endangered Species Act (Act) of 1973, as amended (16 United States Code [U.S.C.] 1531 *et seq*.). On February 12, 2007, we requested re-initiation of formal consultation on implementation of the LRMP in order to (a) provide additional analysis with regard to range-wide incidental take issued for the Indiana bat in other biological opinions and (b) include new biological information on the Indiana bat's range-wide status and status within the action area that would clarify and support the Service's analysis of the proposed action. By letter dated February 12, 2007, you agreed to re-initiation of consultation. We initiated consultation as of February 12, 2007, the day we received your letter.

This biological opinion is based on information provided in the November 13, 2003, Biological Assessment (BA); the supplemental information to the BA that the Service requested on December 11, 2003, and that was received on February 4, 2004; the April 2003 Draft Environmental Impact Statement for the LRMP, the April 2004 Final Environmental Impact Statement and LRMP, other available literature, personal communications with experts on the Indiana bat, our previous (March 20, 2004) biological opinion and administrative record on implementation of the LRMP, new biological information (including the most recently available winter population estimates) on the Indiana bat, and other sources of information. A complete administrative record of this consultation is on file at this office.

The Service has reviewed the BA for implementation of the revised LRMP and all of the above-referenced supporting and supplemental information. The BA evaluated the potential and likely effects of implementation of the LRMP on 32 federally listed species and proposed critical habitat for the Cumberlandian combshell (*Epioblasma brevidens*), oyster mussel (*Epioblasma capsaeformis*), and Cumberland elktoe (*Alasmidonta atropurpurea*). One of these 32 species, Eggert's sunflower (*Helianthus eggertii*), has been removed from the Federal List of Endangered and Threatened Plants (Service, 2005), so there is no need to consider that species further in this biological opinion. In our March 20, 2004, biological opinion, we provided our concurrence with the USFS's determination that implementation of the revised LRMP would not result in the adverse modification of proposed critical habitat for the Cumberlandian combshell, oyster mussel, and Cumberland elktoe. A final rule designating critical habitat for those species was published (Service, 2004b). As a result, we concurred with the DBNF that implementation of the LRMP would not result in the adverse modification of designated critical habitat for the Cumberlandian combshell, oyster mussel, and Cumberland elktoe on September 30, 2004. Originally, we concurred with the USFS's effects determinations of not likely to adversely affect for the remaining 30 federally listed species addressed by the BA in our March 20, 2004 biological opinion; however, we reaffirmed those concurrences from the March 20, 2004 biological opinion in a separate February 12, 2007 concurrence letter to the USFS. This document, therefore, represents our biological opinion on the effects of that action on the endangered Indiana bat under section 7 of the Act. The Indiana bat was the only species for which the DBNF made a "may affect" determination in the BA relative to LRMP implementation.

Consultation History

Previous Consultation - On May 5, 2003, the DBNF hosted a meeting with our office where a summary presentation on and an advanced copy of the draft Environmental Impact Statement (DEIS) and draft revised LRMP were provided. The DBNF indicated at the time that the section 7 consultation would likely be handled informally for the revised LRMP since a site specific BA would be completed for all proposed projects prior to implementation. The Service suggested that informal consultation may be adequate for compliance with section 7 on certain parts of LRMP implementation, but formal consultation may be necessary for the Indiana bat.

On August 13, 2003, the Service provided written comments to the DBNF on the DEIS and LRMP. Our comments supported the approach the DBNF had taken to managing the more than 700,000 acres of federally owned lands and the preliminary selection of Alternative C1 as the preferred alternative for revising the 1985 forest plan. The Service also notified the DBNF that informal section 7 consultation would likely be necessary and that consultation should begin immediately or at the point the DBNF decided on the preferred alternative for the LRMP.

In August 25, 2003, the DBNF hosted a meeting to discuss the Service's written comments on the DEIS and LRMP. After some discussion of the comments, the dialogue quickly moved to what section 7 consultation approach would best serve the DBNF to address potential effects on federally listed species. Upon reviewing the draft EIS and LRMP, the Service suggested the DBNF enter formal consultation with all or a portion of the 32 federally listed species known to occur within or adjacent to the forest. This would allow the DBNF flexibility to manage the forest according to the revised forest plan to maintain and restore ecological processes and functions while providing for multiple public benefits.

On September 12, 2003, the DBNF held an internal meeting to discuss their consultation strategy for the LRMP. Because of this meeting, the DBNF notified us that formal consultation on the revised plan would be needed due to a "likely to adversely affect" determination for the Indiana bat. At the time, the rationale for the determination of effect was based on the potential tree cutting activities that would be conducted from May 1 thru July 15, or the period during which young Indiana bats are non-volant (i.e., unable to fly).

On October 7, 2003, the Service hosted a meeting in which the DBNF presented their proposed consultation strategy, the objectives of this strategy, and a detailed discussion of the management activities for which the DBNF was requesting formal consultation. Specifically the types of management activities included: green tree harvests, salvage harvests from stochastic events, and prescribed burning. The DBNF had estimated the total annual acreage of each of these activities that would likely occur during the April 1 thru September 15, or the period during which Indiana bats are most likely to be roosting in the DBNF each year. The meeting also included a discussion of how the standards of the revised LRMP might be modified given the increased flexibility provided the DBNF through the formal consultation.

On November 13, 2003, the DBNF hosted a meeting with us to present a draft copy of the BA and revised LRMP and to offer any assistance necessary toward the completion of the biological opinion. The DBNF explained that the USFS's Southern Regional Office would provide us with the final BA as soon as all signatures were obtained. To that end, the Service received the final BA for the revised LRMP that requested initiation of formal consultation on November 19, 2003.

On December 1, 2003, the DBNF e-mailed a document containing changes to the revised forest plan made since the receipt of the copy on November 13, 2003.

On December 11, 2003, the Service provided the DBNF with a letter requesting additional information on the types of activities that were associated with green tree harvests, salvage harvests from stochastic events, and prescribed burning and the likely effects of those activities on the Indiana bat.

From December 11, 2003, to February 3, 2004, the Service worked with the DBNF on information relating to the effects of the proposed action and the types of activities that would be undertaken by the DBNF in association with green tree harvests, salvage/sanitation harvests, and prescribed burns. This information would be provided in supplements to the November 19, 2003, BA.

On February 4, 2004, the DBNF provided supplemental information relating to the activities associated with green tree harvests, salvage harvests from stochastic events, and prescribed burning and the likely effects of those activities on the Indiana bat.

On February 5, 2004, the Service notified the DBNF that sufficient information to initiate formal consultation had been received, and formal consultation was initiated on that date.

On March 20, 2004, the Service issued the previous biological opinion on implementation of the LRMP and its effects on the Indiana bat.

Current Consultation - In January 2007 and February 2007, the Service and USFS began informal discussions about the possibility of re-initiating formal consultation for implementation of the DBNF LRMP.

On February 12, 2007, the Service provided a letter, by fax, to the USFS requesting re-initiation of formal consultation on the March 20, 2004 Final Biological Opinion on implementation of the revised Land and Resource Management Plan and its effects on the Indiana bat, Daniel Boone National Forest, Kentucky. The re-initiation was requested so that new information could be incorporated and considered.

On February 12, 2007, the USFS provided, through fax and e-mail, a letter agreeing with the Service's request for re-initiation.

On March 8, 2007, the USFS provided additional information, by a series of e-mails, on certain Indiana bat-related research projects and the DBNF's ranger district re-alignment.

On March 20, 2007, the Service provided a draft biological opinion to the USFS for review via e-mail.

This biological opinion was based on information provided in the November 13, 2003, biological assessment; the February 4, 2004, supplemental information documents; meetings with USFS staff; and other sources of information, including the administrative record for the March 20, 2004 biological opinion for implementation of the LRMP. A complete administrative record of this consultation is on file at the Service's Kentucky Field Office, J.C. Watts Federal Building, 330 West Broadway, Room 265, Frankfort, Kentucky 40601; telephone 502/695-0468; fax 502/695-1024.

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.

The proposed action is the USFS's implementation of the revised LRMP for the DBNF. In their BA on the proposed action, the DBNF outlined the activities in the revised LRMP (and projects predicated upon it) that may affect the Indiana bat. The Service and DBNF evaluated the proposed activities that would be undertaken during implementation of the LRMP and determined that three activities may cause adverse effects on the Indiana bat. These activities and projects include those associated with green tree harvests, salvage/sanitation harvests, and/or prescribed burning activities and was the subject of the USFS's BA and supplemental information documents. These actions were previously the subject of the March 20, 2004 biological opinion on implementation of the revised LRMP and its effects on the Indiana bat. In February 2007, the Service and USFS determined that the March 20, 2004 biological opinion needed updating to incorporate new information. This biological opinion contains that updated information and addresses whether continued implementation of the LRMP is likely to jeopardize the continued existence of the Indiana bat. Based on our analysis of the proposed activities in the LRMP, we believe that all other activities proposed by the LRMP will not result in adverse effects on the Indiana bat.

The LRMP does not contain a commitment to select any specific project. Instead, the LRMP establishes a framework of Desired Future Conditions with Goals, Objectives, and Standards to guide project proposals. Projects are proposed to solve resource management problems, move the DBNF's environments toward the Desired Future Conditions, and supply goods and services to the public. Further, these Goals, Objectives, and Standards dictate the conditions under which project-level activities (e.g., timber sales, wildlife habitat management, road construction, special uses, etc.) may be planned and implemented to meet the management direction of the DBNF. Future habitat conditions will depend on far-sighted management decisions as they are directed toward the attainment of the desired future conditions identified in the LRMP. Revision of the LRMP was needed by the DBNF to satisfy legal requirements and address new information about the forest and its uses.

Because the LRMP is a programmatic document and, as such, does not identify specific projects or actions that the DBNF will undertake, the DBNF has committed to placing limitations on its activities to protect the Indiana bats (and other species), enhance and conserve its habitat, assist with its recovery, and avoid adverse effects. These limitations involve the implementation of the Objectives, Standards, and Prescription Areas contained in the LRMP and the requirement for project-specific section 7 consultations. The implementation of these Objectives, Standards, and Prescription Areas are essentially ongoing conservation measures designed specifically to protect, maintain, or enhance summer or winter Indiana bat habitat as well as reduce or minimize adverse effects on the Indiana bat. Thus, impacts to Indiana bats resulting from the implementation of land management activities, such as green tree harvests, salvage/sanitation harvests, and prescribed burning, may be reduced through forest-wide standards and/or the implementation of standards and prescriptions for those activities.

However, in a subset of the DBNF's activities and/or projects, it is possible that incidental take and adverse effects to Indiana bats could occur, including activities associated with green tree harvests, salvage/sanitation harvests, and/or prescribed burning activities. Although the effects of these three activities, which are described in detail below, are addressed elsewhere in this biological opinion, the DBNF will continue to require compliance with the consultation provisions of section 7 of the Act by requiring a separate, project-specific analysis for each proposed project.

The BA and its supplements provide a description and analysis of green tree harvests, salvage/sanitation harvests, and prescribed burning, including the expected management actions, the anticipated levels of activity, and the likely effects of those actions on Indiana bats. The

Service used the information in the BA and revised LRMP and the other information in the administrative record to formulate this biological opinion and to evaluate the specific direct, indirect, and cumulative effects of these three types of management activities on the Indiana bat. The DBNF has determined that these activities may result in adverse effects on the Indiana bat if the activities are implemented during the Indiana bat's summer roosting period (April 1 to September 15). Therefore, this biological opinion focuses on those activities and their effects on the Indiana bat, as described below.

Action Area

The action area for this biological opinion is the land area encompassed by the proclamation boundary of the DBNF in Kentucky (see map in Appendix A). The DBNF is distributed across 21 counties in eastern Kentucky and contains two disjunct proclamation boundaries. The larger proclamation area is a relatively narrow strip running 140 miles along the western edge of the Cumberland Plateau from the Tennessee border to within 20 miles of the Ohio border. This area was proclaimed in 1937 as the Cumberland National Forest, which included all or part of Lewis, Fleming, Rowan, Bath, Menifee, Morgan, Powell, Wolfe, Estill, Lee, Jackson, Owsley, Rockcastle, Laurel, Pulaski, Wayne, McCreary, and Whitley counties. A second proclamation area, located to the east and separate from the original proclamation area and known as the Redbird Purchase Unit, was added in 1964 and includes all or part of Owsley, Breathitt, Clay, Laurel, Knox, Bell, Leslie, Perry, and Harlan counties. In 1966, the Cumberland National Forest was renamed the Daniel Boone National Forest.

Today, about one-third of the proclamation area's over two million acres, or nearly 700,000 acres, is federally owned and managed by the USFS. The BA for implementation of the revised LRMP submitted by the DBNF on November 13, 2003 discussed how the Forest was divided into six districts (i.e., Morehead, Stanton, Stearns, London, Somerset, and Redbird Ranger Districts). However, on December 27, 2005, the DBNF went through a transformation by consolidating two ranger districts (the Stanton and Morehead Ranger Districts) into one (the Cumberland Ranger District) and abolishing the Somerset Ranger District and allocating the land base between the London Ranger District and the Stearns Ranger District. Thus, the DBNF now consists of only four Ranger Districts as they relate to this biological opinion. The federally-owned tracts that comprise the DBNF are discontinuous and scattered within the two proclamation boundaries. The remaining land area within these proclamation boundaries is owned by individual private landowners, typically in small tracts of less than 300 acres.

This action area is appropriate for this biological opinion, because it "relates only to the action proposed by the action agency" (Service 1998, page 4-18) and includes "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 Code of Federal Regulations [CFR] 402.02). This action area allows the Service to take into consideration the fact that the land holdings of the DBNF are of various sizes and are often disjunct from each other, but all are geographically located within the two proclamation boundaries. The action area is also sizeable enough to provide meaningful analysis of any other direct, indirect, and cumulative effects that could result from the proposed action but that would occur on the non-DBNF land holdings within and bordering the DBNF.

Description of the Action Area
The DBNF lies mostly within the Northern Cumberland Plateau Section of the Eastern Broadleaf Forest (Oceanic) Province. The Northern Cumberland Plateau, an uplifted plateau, has been moderately dissected by weathering and stream action. Steep-sided, winding valleys and ridges mark the DBNF's hilly to mountainous terrain. Clifflines, caves, and geologic arches are prominent features that are widely scattered throughout the DBNF. Local relief varies from about 400 feet in the north to about 2,000 feet in the south. Thousands of miles of small streams dissect this area of flat-topped ridges and rolling hills.

More than 80 soil types are mapped on the DBNF. Acid sandstone, shale, and some siltstone and limestone underlie the area in alternating layers. Soils formed from these various materials are mostly of mixed mineralogy, generally acidic, and possess low to moderate fertility. Soil erosion losses range from an average low of about 0.1 ton per acre per year on undisturbed forested land, to10 tons per acre on cropland being cultivated under special-use authorization, to as much as 50 to 100 tons or more per acre at surface-mining, development, and road construction sites.

Three rivers, the Licking, Kentucky, and Cumberland, drain portions of the DBNF. Water quality is generally good to excellent, except in some smaller streams that are impacted by activities on adjacent or upstream private lands such as brine disposal from oil and gas drilling and acid discharges from abandoned surface and deep coal mines. However, streams with substandard water quality account for only three percent of the water flow.

Forested lands of the DBNF are generally classified as mixed mesophytic forest and Appalachian oak forest. A wide variety of species thrive in both the forest under- and over-stories, including more than 40 commercially valuable tree species. The DBNF is a mosaic of various developmental stages of ecological succession with mostly upland hardwood types. Oak-hickory is the most common forest type. Shortleaf pine-oak forest type was well represented on the southern end of the DBNF until a major outbreak of the southern pine beetle, which began in late 1999, destroyed or damaged a majority of the shortleaf pines within the DBNF.

The DBNF provides habitat for a wide variety of terrestrial and aquatic fauna. Some of these species are relatively rare, including a number that are federally listed as threatened or endangered. Most species are relatively abundant, including huntable populations of white-tailed deer, wild turkey, gray squirrel, and ruffed grouse. Recent efforts by the Kentucky Department of Fish and Wildlife Resources and other partners have resulted in the establishment in and near the DBNF of the largest elk herd in the eastern United States. Game fish are plentiful in the large lakes within the DBNF, and a number of streams are stocked annually with trout.

Five million annual visitors make recreation one of the DBNF's largest uses. There are also 18,000 acres of designated Wilderness and 19 miles of Wild and Scenic Rivers. The proclamation area is also home to three state parks and four Corps of Engineer-managed lakes. The Big South Fork National River and Recreation Area abuts the DBNF's southern boundary.

About 75 percent of subsurface mineral rights on the DBNF are either outstanding to third parties or reserved by the previous surface owners. Minerals currently being extracted include coal, petroleum, natural gas, and limestone.

Proposed Action
The proposed action is the continued implementation of the 2004 LRMP (Final Environmental Impact Statement [FEIS] Alternative C-1), which would take the place of the DBNF's 1985 Forest Plan. Implementation of the revised LRMP will provide programmatic management direction and guidance to all natural resource management activities on the DBNF to meet the objectives of federal law, regulations, and policy. The National Forest Management Act of 1976 (NFMA) requires that each national forest develop a LRMP that is revised every 10 to 15 years, or when conditions change significantly. A copy of the revised LRMP (USFS 2004) and the USFS's BA, which includes additional information on the proposed action, are included in the administrative record for this biological opinion.

Description of Green Tree Harvests - Cutting green (i.e., live) trees is a tool that will be used to meet some of the desired future conditions on the DBNF. Some of the green trees that will be harvested will be suitable for summer foraging and maternity roosting Indiana bats. Green tree cutting will occur across the forest (ref: appendix H, Revised Forest Plan) on up to 4,500 acres per year. Because of other programmatic limitations (such as seasonal equipment use restrictions), up to 4,000 acres of green tree harvest is anticipated to occur during the time of year that Indiana bats are using trees as roosts (April 1 to September 15). However, this harvest level is not expected to occur every year.

A green tree harvest is initiated by a management decision to implement a silvicultural prescription for a timber harvest. Detailed discussion of the silvicultural prescriptions and under what conditions they will be applied is provided in the BA, but about 90 percent of the proposed green tree harvests will use a two-aged silvicultural system (i.e., shelterwood with reserves and seed tree with reserves). The remaining 10 percent of the harvests will use either the even or uneven-aged silvicultural system. Regardless of system used, all green tree harvests are subject to the Standards in the LRMP to avoid and minimize impacts to Indiana bats as described in the BA and analyzed in this biological opinion. In particular, the Standards provided in Appendix B are considered protective of Indiana bats.

Green tree timber harvests on the DBNF typically include the following actions, which make up a harvest operation: administration, felling, skidding, decking, loading, and hauling of timber products from the sale area. A detailed description of these actions is provided in the BA.

Description of Salvage/Sanitation Harvests - Stochastic (random) events can cause unplanned alterations of the forest overstory. In the past, these events on the DBNF have been related to wind and/or ice/snow storms, insect and disease outbreaks, and wild fire. While the nature and occurrence of a stochastic event is unknown, management actions can occur in response to the changes in forest conditions caused by these events.

Based on 10 years of occurrence data, about 700 acres of the DBNF are impacted annually by stochastic events. This estimate does not include, nor is it intended to, large-scale events such as the southern pine beetle epidemic that recently killed most pine trees on the DBNF or the 2003 ice storm on the Cumberland Ranger District. Any large-scale stochastic events that result in effects that do not meet the criteria analyzed in this biological opinion will be analyzed separately in a separate section 7 consultation. In response to the tree damage brought about by these stochastic events and based on the likelihood that stochastic events will continue, DBNF resource managers anticipate salvage or sanitation harvests on roughly half of the 700 acres that is estimated to occur each year. This level of harvest may not occur every year, but, because of other programmatic limitations, the 350 acres of salvage and sanitation harvests may occur during the time of year that Indiana bats are using trees as roosts. However, all LRMP Standards associated with the Indiana bat, unless specifically exempted in the Standard itself, will apply to harvest actions associated with these projects. These exempted standards are DB-WLD-1 and DB-WLD-7 as defined in the BA.

Salvage/sanitation harvests typically include the same type of activities described for green tree timber sale actions, including the administration, felling, skidding, decking, loading, and hauling of timber products from the sale area. A detailed description of these actions is provided in the BA. While the activities associated with salvage/sanitation harvests are similar to green tree harvests, there is one primary difference between the green tree harvests and salvage/sanitation harvests. In salvage/sanitation harvests, it is typically the dead trees (i.e., snags) or damaged trees (i.e., potential roost trees for Indiana bats) that are the focus of the harvest.

Description of Prescribed Burning - Prescribed fire is a management tool that will be used to attain and maintain some of the Desired Future Conditions across the DBNF and may occur, depending on location and site-specific conditions, on a year-round basis. From a programmatic standpoint, the LRMP anticipates that between 15,000 and 50,000 acres will be burned using prescribed fire on an annual basis. However, this level of prescribed burning may not occur every year due to weather conditions and a variety of other factors. Further, the DBNF estimates that it will take nearly a decade for the upper goal of 50,000 acres burned annually to be achieved. Most of the prescribed burning that will occur on the DBNF will be for fuel reduction, but other purposes for prescribed burning include habitat improvement and site preparation. The DBNF believes that most burning in potential roosting habitat will take place during the winter-spring period with some occurring during the late summer and early fall, which is when Indiana bats are roosting (April 1st thru September 15th of any given year).

Prescribed burning projects on the DBNF typically include the following activities: burn plan preparation/layout, line construction, ignition, and mop-up. A detailed discussion of these activities is provided in the BA.

STATUS OF THE SPECIES/CRITICAL HABITAT

Species/critical habitat description

Listing status

The Indiana bat (*Myotis sodalis*) is a temperate, insectivorous, migratory bat that hibernates in mines and caves in the winter and summers in wooded areas. The species was originally listed as being in danger of extinction under the Endangered Species Preservation Act of 1966 (32 FR 4001, March 11, 1967), and is currently listed as endangered under the Act of 1973, as amended. Critical habitat for the Indiana bat was designated on September 24, 1976; it consisted of 11 caves and two mines in six states (September 24, 1976). The original recovery plan for the species was published in 1983 (Service 1983). An agency draft of a revised plan was published in 1999 but was never finalized. The Recovery Priority of the Indiana Bat is 8, which means that the species has a moderate degree of threat and high recovery potential.

Critical Habitat

Critical habitat was designated for the species on 24 September 1976 (Service 1976). Eleven caves and two mines in six states were listed as critical habitat:

> Illinois - Blackball Mine (LaSalle Co.);
> Indiana - Big Wyandotte Cave (Crawford Co.), Ray's Cave (Greene Co.);
> Kentucky - Bat Cave (Carter Co.), Coach Cave (Edmonson Co.);
> Missouri - Cave 021 (Crawford Co.), Caves 009 and 017 (Franklin Co.), Pilot Knob Mine (Iron Co.), Bat Cave (Shannon Co.), Cave 029 (Washington Co.);
> Tennessee - White Oak Blowhole Cave (Blount Co.); and
> West Virginia - Hellhole Cave (Pendleton Co.).

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

Species Description

The Indiana bat is a medium-sized bat in the genus *Myotis*. Its forearm length is $1^{3}/_{8}$-$1^{5}/_{8}$ in), and the head and body length ranges from $1^{5}/_{8}$-$1^{7}/_{8}$ 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).

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).

Population Distribution and Abundance

Prehistoric Distribution and Abundance

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

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

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).

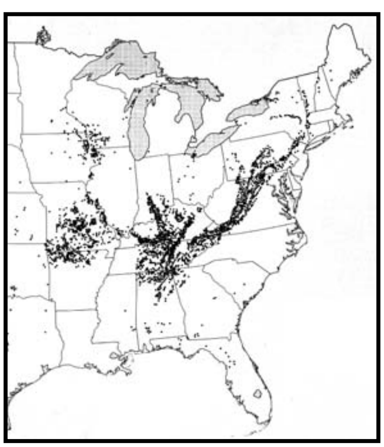
As a whole, existing paleontological evidence suggests that prehistoric abundance of Indiana bats may have exceeded most historic accounts and our current total population estimate by an order of magnitude. However, our degree of confidence in the accuracy of most prehistoric and historic population 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 1). Prior to and during much of the European settlement of the eastern United States, winter populations of Indiana bats likely occurred in karst regions of what would eventually become Alabama, Arkansas, Georgia, Illinois, Indiana, Iowa, Kentucky, Maryland, Massachusetts, Missouri, New Jersey, New York, North Carolina, Oklahoma, Pennsylvania, Tennessee, Vermont, Virginia, and West Virginia. Based on early accounts and other indirect evidence (Silliman et al. 1851, Blatchley 1897, Tuttle 1997, Tuttle 1999), some researchers have suggested that vast numbers, presumably the majority, of Indiana bats historically converged at a relatively small number of large complex cave systems to hibernate (e.g., Wyandotte Cave in Indiana; Bat, Coach, and Mammoth caves in Kentucky; Great Scott Cave in Missouri; and Rocky Hollow Cave in Virginia) and used other caves to a lesser extent (Olson 1996, Tuttle 1997, Tuttle 1999, Toomey et al. 2002, Whitaker et al. 2003).

When Miller and Allen first described *Myotis sodalis* in 1928, they had examined museum specimens originating from ten states including Alabama, Arkansas, Illinois, Indiana, Kentucky, Michigan, North Carolina, Pennsylvania, Tennessee, and Vermont (Miller and Allen 1928). Based on these records, they described the species' distribution as the "eastern United States from the central Mississippi Valley and northern Alabama to the western part of New England" (Figure 2). Because the majority of the specimens they had studied were collected from wintering localities, Miller and Allen (1928) noted that the species' summer distribution likely covered a more considerable area, which decades later proved to be true. By 1960, winter populations of Indiana bats had been reported from about 74 different hibernacula in 18 states (Service, unpublished data, 2006).



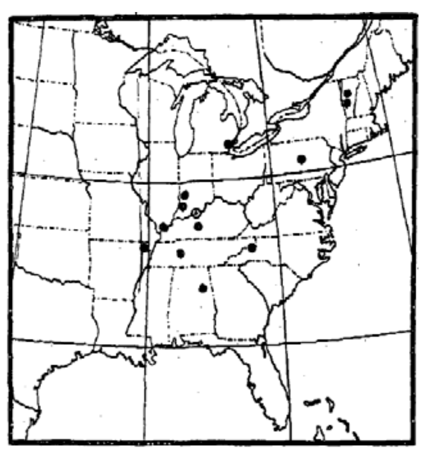


Figure 1. Cavern areas of the eastern United States (from Davies 1970) (on left).

Figure 2. Known distribution of *Myotis sodalis* in 1928 (from Miller and Allen 1928) (on right).

Historic Summer Distribution

The historic summer distribution and range for this species is poorly documented. The first maternity colony was not discovered until the summer of 1971 in east-central Indiana (Cope et al. 1974). Nonetheless, based on our knowledge of Indiana bat seasonal migration patterns and limits, and locations of historic and potential hibernacula, it is reasonable to assume that the species' historic summer distribution was more or less similar to its summer distribution (Figure 3).

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 Recovery Plan (Service 1983), Indiana bat hibernacula are assigned priority numbers based on the number of Indiana bats they contain. Originally a Priority 1 (P1) hibernaculum is 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

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

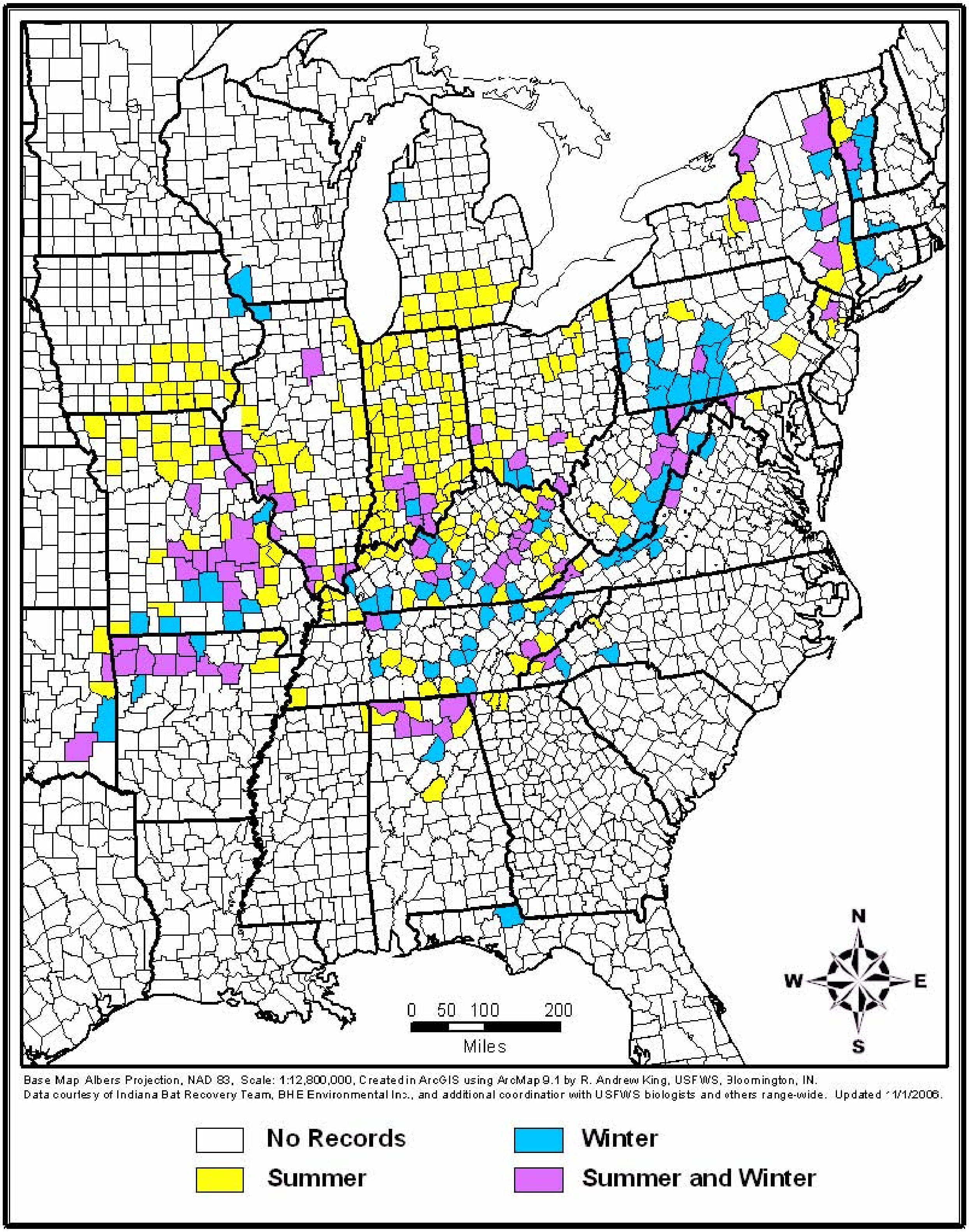


Figure 3. Distribution of counties with known summer and winter records of the Indiana bat.

2005, a decision was made to revise the existing hibernacula priority definitions in the forthcoming revised Indiana Bat Recovery Plan. Although not yet in effect, the hibernacula priority definitions that will be proposed will have the goal of achieving a wider and more even distribution of essential hibernation sites across the species' range. Until proposed, however, the current hibernacula categories will remain in-effect and are used in this biological opinion.

The P1 population criterion will be lowered from 30,000 bats to 10,000 and the "since 1960" part of all the hibernacula definitions will be omitted. These changes will effectively increase the number of P1 hibernacula from 11 sites in four states to 23 sites in seven states. Likewise, the population criteria will also be changed for Priority 2, 3, and 4 hibernacula. On a case-by-case basis, the Service may consider elevating a particularly important (i.e., "essential") Priority 2 (P2) hibernaculum (e.g., one that holds a key geographic location/distribution within the range or very high regional importance) to P1 status, even though it may not meet the P1 population criteria at that time. As of October 2006, no P2 hibernacula had been elevated to P1 status in this manner. The revised hibernacula priority numbers and other new subcategories are defined below. The Service expects to publish these categories in the revised recovery plan soon.

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

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

Even though hibernating Indiana bats were dispersed across 16 states in 2005, over 90 percent of the estimated range-wide population hibernated in five states: Indiana (45.2%), Missouri (14.2%), Kentucky (13.6%), Illinois (9.7%), and New York (9.1%) (Service, unpublished data, 2006). In 2005, 81.9 percent (374,653 bats) of the range-wide winter population hibernated in P1 hibernacula (n=23), while P2 (n=53), P3 (n=150), and P4 (n=213) sheltered 14.4%, 3.3% and 0.4% of the total population, respectively (Service, unpublished data, 2006). The ten most populous hibernacula in 2005 collectively held 71.6 percent of the range-wide total with Wyandotte Cave in southern Indiana leading the list with 54,913 bats (12.0% of total) (Service, unpublished data, 2006) (Table 2).

Table 1. Distribution and priority numbers of Indiana bat hibernacula by state.

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

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

Table 2. Winter population estimates through time for P1A (n=16) and P1B (n=7) Indiana bat hibernacula. All P1 hibernacula (n=23) have at some point in the recorded past had ≥10,000 hibernating Indiana bats and currently provide suitable winter habitat. P1A hibernacula have maintained a minimum of 5,000 Indiana bats during the last 10 years, whereas P1B hibernacula have not met this criterion in the last 10+ years.

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

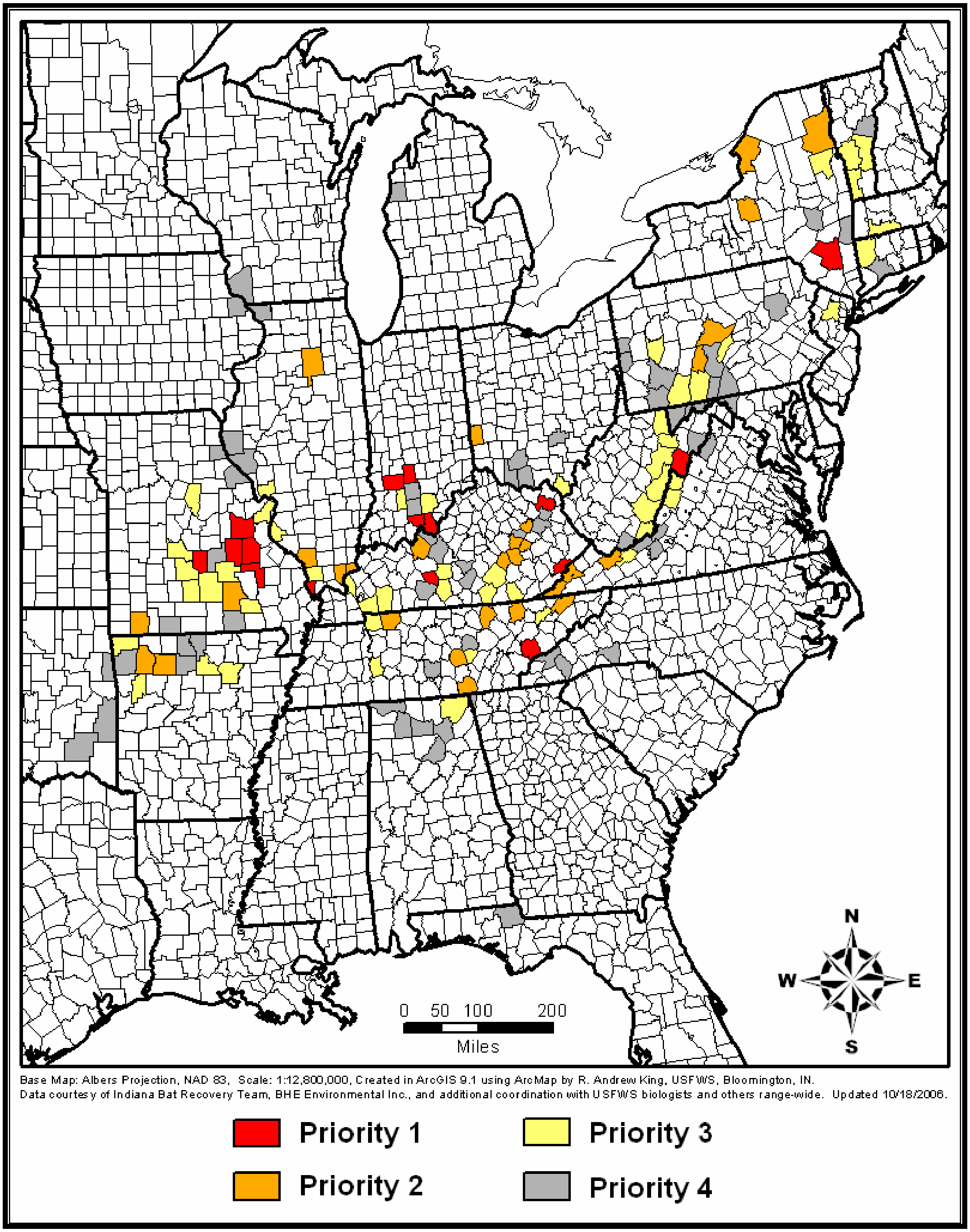


Figure 4. Distribution of counties with known Indiana bat hibernacula records and their current priority numbers. Note: For counties with multiple hibernacula with different priority numbers, only the color of the highest priority hibernacula is shown.

In the 1960s and 1970s, 75% of the known range-wide population hibernated in the southern portion of the species' winter range (i.e., Kentucky and Missouri) (Clawson 2002). However, by 2001 and through 2005, 60% of remaining Indiana bats occupied hibernacula in the (more or less) northern portion of the winter range (Table 3). Few specific drivers of this apparent population shift have been rigorously explored or identified, but inappropriate hibernacula temperatures (see Tuttle and Kennedy 2002) and regional climate change are either known or generally suspected in having had a role. We have an incomplete understanding of the links among *M. sodalis*' hibernation energetics, its biogeographical distribution, and climate change. However, the predictive modeling approach recently used by Humphries et al. (2002) for *M. lucifugus* could provide some insight into *M. sodalis*' potential winter distribution as global climate change occurs.

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

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

Current Winter Population Groups

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

Table 3. Size and distribution of hibernating populations of the Indiana bat by region and state, based upon estimates nearest to the year indicated.[1]

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

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

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

Vonhof and McCracken's other findings and conclusions included:

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

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

<u>Current Summer Distribution</u>

Maternity Colonies

The first Indiana bat maternity colony was not discovered until 1971 (in east-central Indiana, Cope et al. 1974). As of October 2006, we have records of 269 maternity colonies in 16 states that are considered locally extant (Table 4). 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) (Table 4, Figure 5). Because maternity colonies are widely dispersed during the summer and difficult to locate, it is presumed that all the combined summer survey efforts have found only a fraction of the maternity colonies based on the range-wide population estimates derived from winter hibernacula surveys. For example, based on the 2005 range-wide population estimate of 457,374 bats, and assuming a 50:50 sex ratio and an average maternity colony size of 50 to 80 adult females (Whitaker and Brack 2002), then the 269 maternity colonies in Table 4 may only represent 6 to 9 percent of the 2,859 to 4,574 maternity colonies we would assume exist. Regardless of reasonable disagreements on the average colony size, the geographic locations of the majority of Indiana bat maternity colonies remain unknown.

Table 4. States and counties with recorded Indiana bat maternity colonies.[1,2,3] These colonies are considered likely to be locally extant (within limits of data noted in footnote 3).

State	No. of Recorded Maternity Colonies	Counties with Recorded Maternity Colonies (if multiple colonies, then # is shown)
Arkansas	1	Clay
Illinois	28	Adams (2), Alexander, Bond, Cass, Ford, Henderson, Jackson (3), Jersey, Macoupin, Monroe (4), Pike (2), Pulaski, Randolf, Saline, Schuyler, Scott, St. Clair, Union, Vermilion, and Washington (2)
Indiana	83	Bartholomew (3), Clinton (2), Crawford, Davies (2), Dearborn, Gibson (2), Greene (3), Hendricks (2), Henry, Howard, Huntington, Jackson (3), Jasper, Jay, Jefferson (2), Jennings (2), Johnson (3), Knox, Koskiusko, LaPorte (2), Marion, Martin, Monroe (2), Montgomery (3), Morgan (4), Newton, Parke (2), Perry (2), Pike (2), Posey, Pulaski (2), Putnam (2), Randolph (3), Ripley (2), Rush, Shelby (2), Spencer, St. Joseph, Steuben, Tippecanoe (4), Vermillion, Vigo, Wabash (2), Warren (2), Warrick (2), Wayne, and Wells
Iowa	27	Appanoose (2), Davis, Decatur (2), Des Moines (2), Iowa, Jasper, Keokuk, Lucas (2), Madison (2), Marion (7), Monroe, Ringgold, Van Buren, Wapello, and Washington (2)
Kentucky	32	Ballard, Ballard/Carlisle, Bath (3), Breckinridge, Bullitt (4), Daviess, Edmonson (3), Floyd, Harlan (3), Henderson (2), Hickman (2), Jefferson (3), Logan, McCracken (2), Pulaski, Rowan, Spencer, and Union
Maryland	2	Carroll (2)
Michigan	11	Calhoun, Cass, Eaton, Hillsdale, Jackson, Lenawee (2), Livingston, St. Joseph (2), and Van Buren
Missouri	20	Chariton, Gasconade, Iron, Jefferson, Knox (2), Lewis, Linn, Macon, Madison, Marion, Mercer, Monroe, Nodaway, Pulaski, Scotland, St. Francois, St. Genevieve, Sullivan, and Wayne
New Jersey	7	Morris (5), Somerset, and Sussex
New York	31	Cayuga, Dutchess (5), Essex, Jefferson (9), Onondaga (4), Orange (8), and Oswego (3)
Ohio	11	Ashtabula, Butler, Clermont, Cuyahoga, Greene, Hocking, Lawrence, Paulding, Pickaway, Summit, and Wayne
Pennsylvania	2	Berks and Blair
Tennessee	3	Blount (2) and Monroe
Vermont	7	Addison (6) and Chittenden
Virginia	1	Lee
West Virginia	3	Boone (2) and Tucker
Total	**269**	

[1] Unpublished data obtained in response to a data request sent to Service Field Offices in February 2006.

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

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

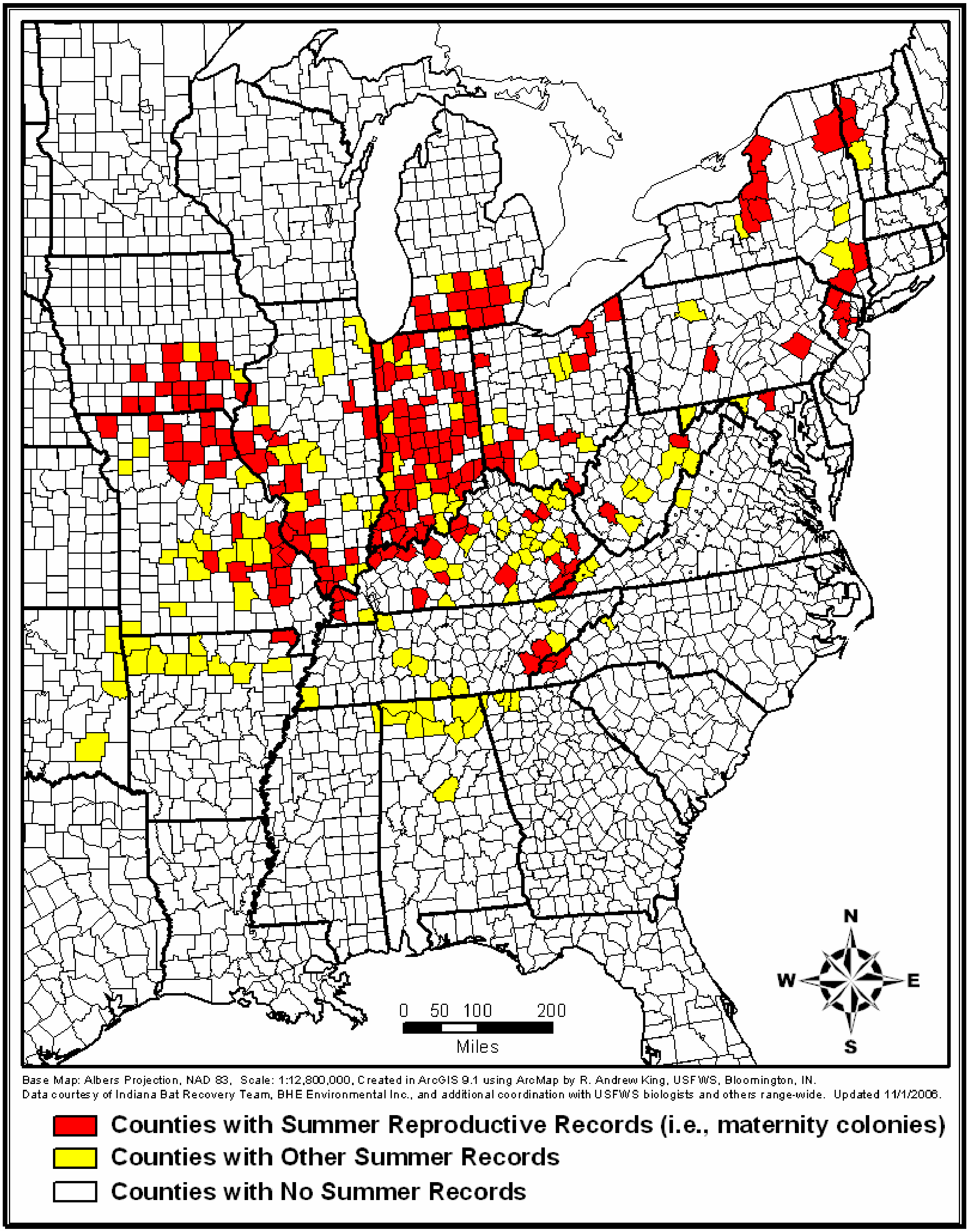


Figure 5. Distribution of counties with known summer reproductive records of Indiana bats (i.e., presence of reproductively active females and/or juveniles between 15 May and 15 August). Lack of records does not necessarily mean the species is not present.

Most capture records of reproductively active female and juvenile Indiana bats (i.e., evidence of a nearby maternity colony) have occurred in glaciated portions of the upper Midwest including southern Iowa, northern Missouri, much of Illinois, most of Indiana, southern Michigan, and western Ohio, and in Kentucky. However, a growing number of maternity records have been documented in New York, New Jersey, and Vermont recently due to spring emergence studies and mist netting efforts (Gardner and Cook 2002; Service, unpublished data, 2006) (Table 4; Figure 5). The more rugged, unglaciated portions of the Midwest (Ozarks/southern Missouri, parts of southern Illinois, and south-central Indiana), Kentucky, and most of the eastern and southern portions of the species' range appear to have fewer maternity colonies per unit area of forest than does the upper Midwest. Additional summer survey efforts and spring emergence studies will be needed in some areas, particularly along the periphery of the range, before conclusions may be reached on the extent of the species' summer range. Likewise, a comprehensive analysis of existing positive and negative summer survey data is warranted.

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

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

<u>Current Abundance</u>
By compiling individual population estimates from bat surveys conducted within 214 hibernacula during the winters of 2003-2004 and 2004-2005, the Service has estimated that the Indiana bat's 2005 range-wide population was approximately 457,000 bats (Service, unpublished data, 2006) (Table 3).

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

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

Population Trends in Hibernacula

<u>Background</u>

During the 1950s, biologists began conducting winter bat surveys at irregular intervals and recording population estimates for about a dozen Indiana bat hibernacula (Hall 1962; Service, unpublished data, 2006). Since that time, hundreds of additional populations of hibernating Indiana bats have been discovered, and our knowledge of the winter distribution and status of the species has expanded. Many hibernating populations have decreased in size since range-wide monitoring began (Figure 6), especially in Kentucky and Missouri (Table 3). By the time the status of the Indiana bat was officially recognized in 1967, it is assumed, the remaining populations represented a portion of historical numbers. These hibernating populations were often confined to smaller caves, which likely had less thermal stability, fewer and less optimal roosting options, and had a higher risk of predation than traditional hibernacula. By 1985, more than 85 percent of the known, range-wide population hibernated in just eight caves and one mine.

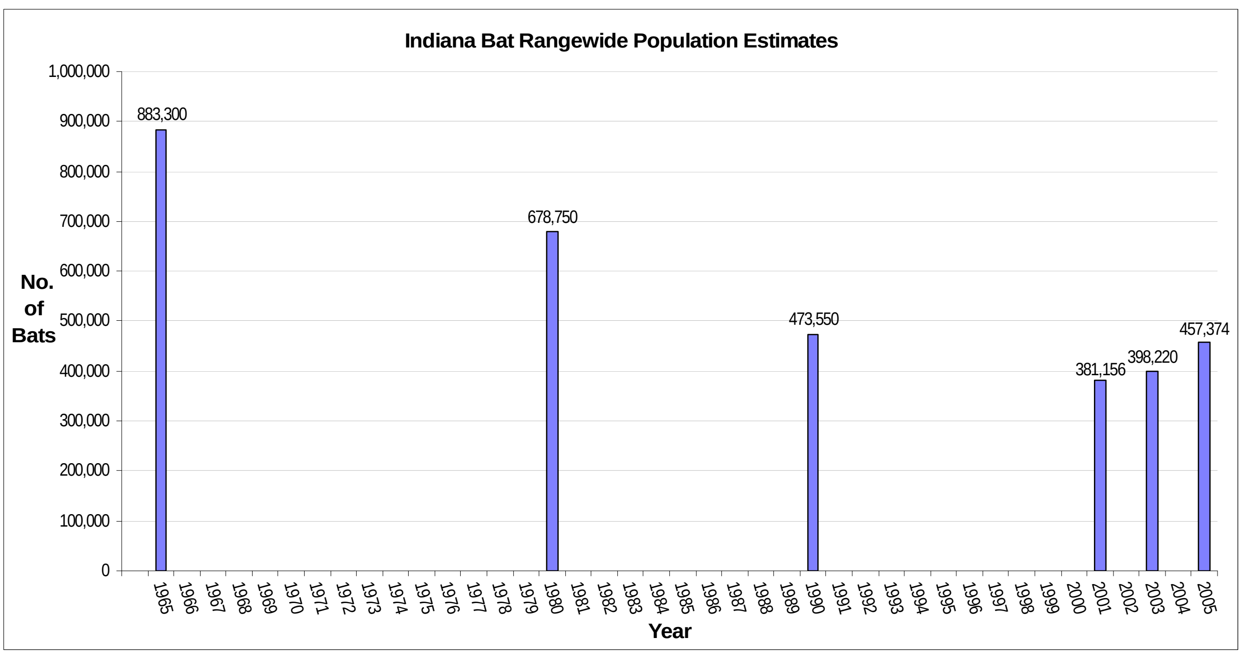


Figure 6. Indiana bat rangewide population estimates (Data sources: 1965-1990, Clawson 2002; 2001-2005, Service, unpublished data, 2006). Rangewide estimates calculated from all known hibernacula were not attempted or data was not available for most years prior to 2001.

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

Range-wide Population Estimates

Nearly all of the existing range-wide population estimates for the Indiana bat were generated by simply adding together all available estimates from traditional winter surveys of all known hibernacula during a specified period in time. However, if one looks at the actual proportion of the known hibernacula that were known and/or actually surveyed during previous decades, it is apparent that range-wide estimates calculated for any given year prior to about 1980 should be regarded as approximate. The uncertainty associated with these early range-wide estimates is relatively high (compared to recent estimates) due to large, irregular gaps of time between winter surveys, small number of surveys conducted in any given year, and asynchrony and non-standardization among the surveys that were conducted (Figure 6).

After standardized surveys of all known P1 hibernacula were initiated in the 1983, the quality of the range-wide estimates improved. Clawson (2002) made a reasonable and conservative effort to reduce the amount of error associated with calculating range-wide estimates (especially for decades with limited data) by forward- and/or backfilling in the missing data cells with the same estimates for each individual hibernaculum that had been recorded during its most recent survey. In a similar manner, when a "new" P1 or P2 hibernaculum was discovered, Clawson used its first post-discovery population estimate to backfill the blanks in the data set for each of the previous time periods being calculated (see Clawson 2002 for rationale for backward projection of estimates for newly discovered populations). Again, while such data manipulations were necessary and undoubtedly improved the accuracy of range-wide population estimates, the current estimates calculated for years prior to 1980 should be considered as approximate. As an example, more than half of the bats that were included in the calculation of the range-wide estimate for the year "1965" in Figure 6 were attributed to hibernacula that had not yet been discovered, but those bats were assumed to have been present in those hibernacula prior to discovery of the hibernacula.

Apparent Long-term Trend

Over the long term, from 1965 to 2001, there has been an overall decline in Indiana bat numbers, (Figure 6, Service 1983, Kurta and Kennedy 2002). Estimated numbers consistently declined through this period. Even with the discovery of many new, large hibernacula, the range-wide population estimate dropped about 57 percent from 1965 to 2001. Since the advent of systematic attempts to estimate population numbers, some specific drivers (e.g., changes in cave air flow/temperatures, human disturbance levels) have been linked to positive and negative trends in some of the most important hibernacula (see Tuttle and Kennedy 2002), but the underlying causes of population changes at other hibernacula remain unknown or incompletely known. The Service's confidence in apparent positive and negative population trends within individual hibernacula and collectively in the long-term, range-wide decline remains relatively high for the following reasons:

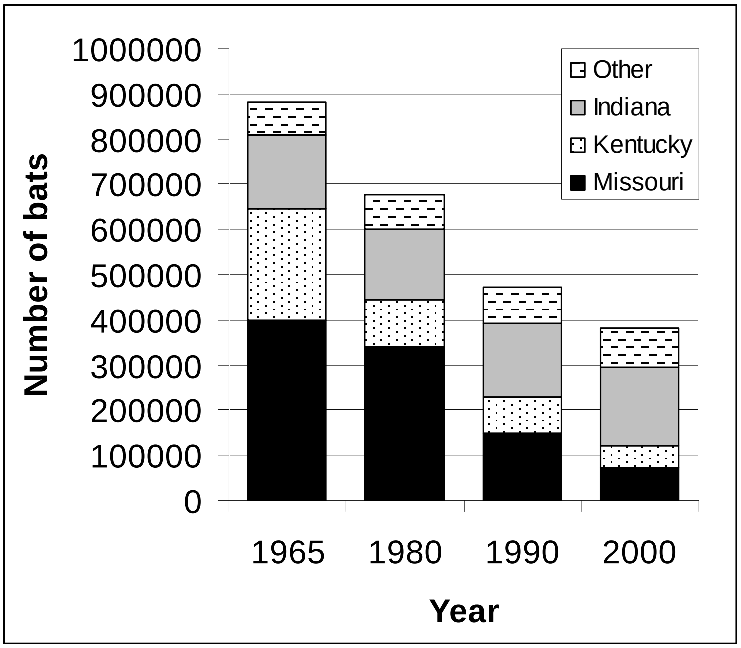
1) Continuity and consistency – with very few exceptions, the same small group of highly qualified biologists have been surveying the same caves/mines using consistent survey techniques since standardized surveys began in the 1983
2) Surveyors have demonstrated high levels of attentiveness, thoroughness,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

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

<u>Apparent Short-term Trend</u>
Range-wide estimates of species numbers over the three most recent biennial survey periods do not show the same declining trend seen in estimates spanning 1965-2000 (Figure 6). There was about a 16 % increase from the 2003 estimate of 393,000 bats to the rounded estimate of 457,000 bats Service in 2005 (USFWS, unpublished data, 2006) (Table 3; Figure 6). In spite of some changes in methodology over time and a general lack of data on the statistical accuracy and variability of hibernacula estimates, the Service believes that the apparent upward trend in recent years is real because the same biologists have been consistently conducting the winter surveys at all of the largest hibernacula over the past 20 years. This level of surveyor consistency, coupled with obvious, increases at some high-priority hibernacula in Indiana, Illinois, Kentucky and New York in recent years (see Table 3), provides us with some confidence that the long-term decline may have halted. We anticipate that planned improvements in hibernacula survey methodology will soon provide for a greater level of confidence in the overall population trend.

<u>Apparent Trends by Cave 1965-2005: Missouri, Indiana, and Kentucky</u>
Missouri, Indiana, and Kentucky have historically had the highest estimated numbers of hibernating bats (Figure 7); all had estimated populations of >100,000 bats in 1965. Over the period 1965-2005, estimated numbers of hibernating bats in Missouri and Kentucky clearly declined. Of Missouri hibernacula that were estimated to contain at least 10,000 bats at least once, all had estimates that declined since 1985, although two hibernacula showed strong increases before that time (Figure 8). Kentucky hibernacula that sheltered at least 10,000 (estimated) bats at least once had less consistent patterns (Figure 9). The total number of Indiana bats appears to have declined but trends at individual hibernacula is generally upward. Indiana bat hibernacula that had at least one estimate of >10,000 hibernating bats also showed little consistency (Figure 10). Four of seven hibernacula seem to show periods of increase and periods of decrease, including the three hibernacula with the highest one-time counts. The other three hibernacula show consistent increases, two of them reaching 10,000 in the 2003 survey.

Figure 7. States with the largest numbers of Indiana bats in hibernacula. For years in which a hibernaculum was not yet known, the first post-discovery survey results were used (V. Meretsky, pers. comm., 2006).



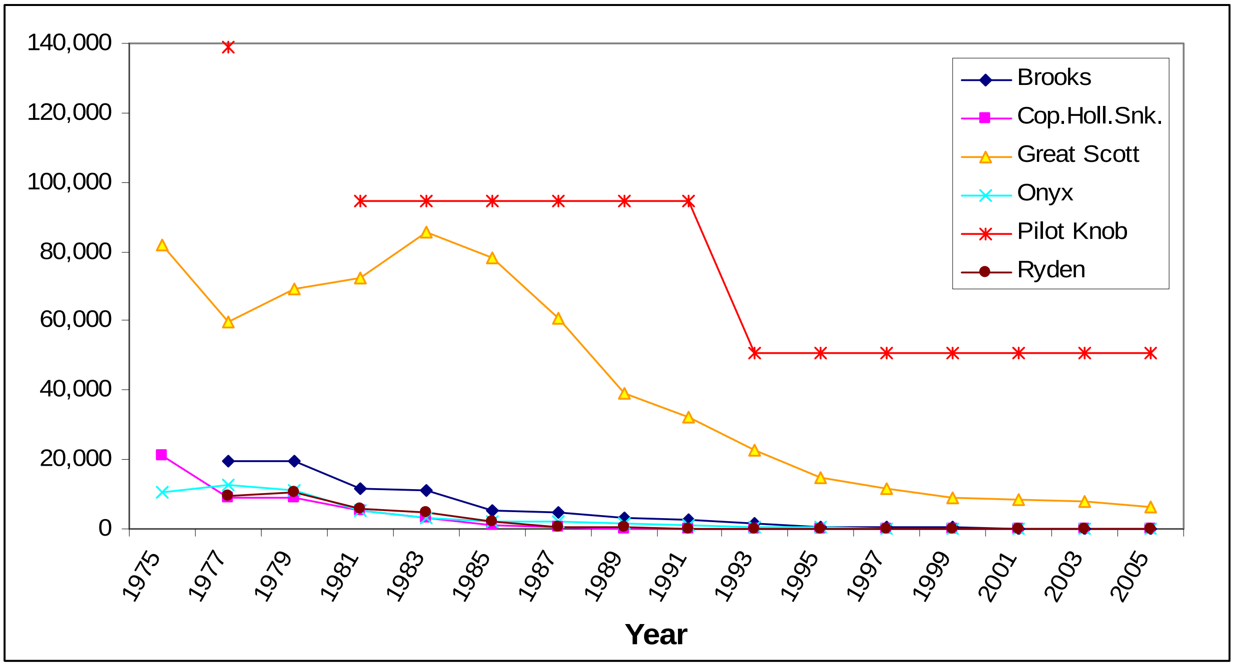


Figure 8. Estimated numbers of Indiana bats in P1A and P1B hibernacula in Missouri (Service, unpublished data, 2006).

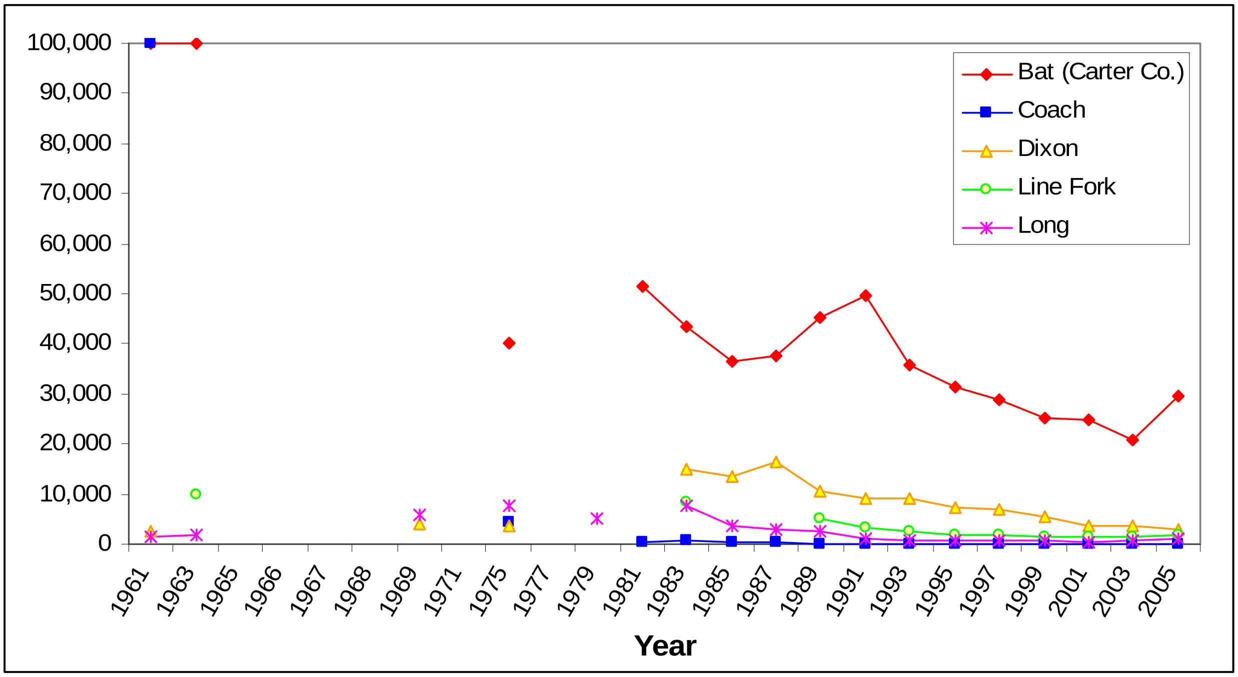


Figure 9. Estimated numbers of Indiana bats in P1A and P1B hibernacula in Kentucky (Service, unpublished data, 2006).

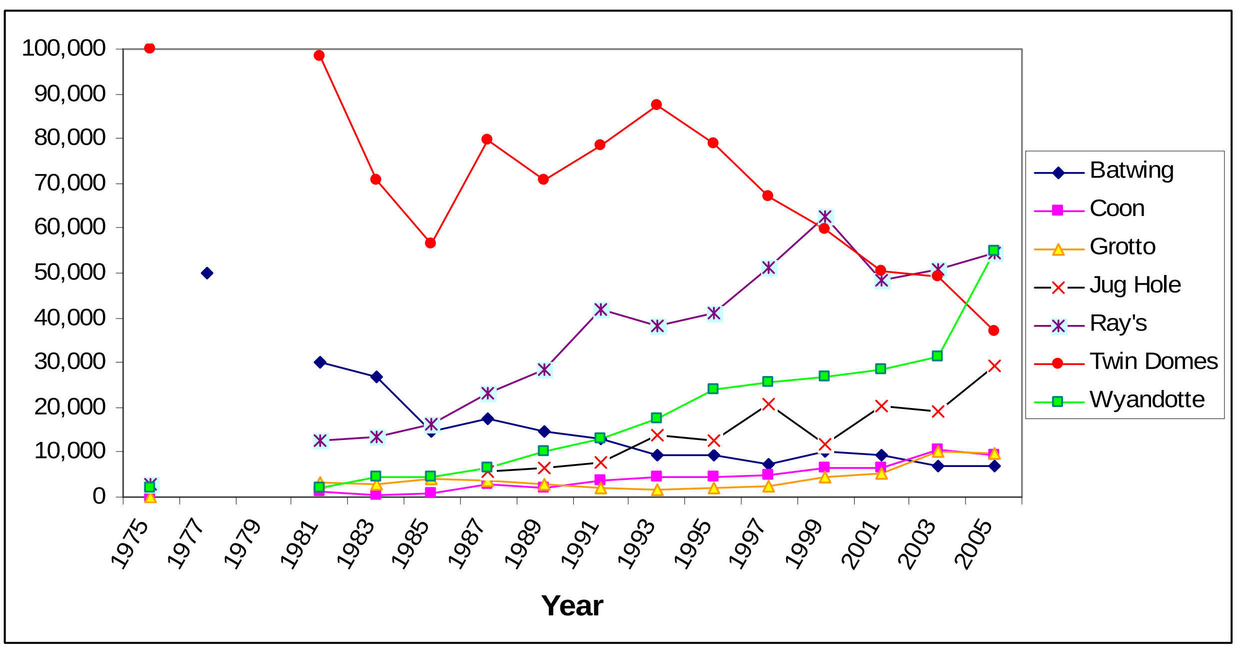


Figure 10. Estimated numbers of Indiana bats in P1A hibernacula in Indiana (Service, unpublished data, 2006).

Population Patterns in States with <100,000 Bats
Among the group of states in which aggregate hibernaculum surveys have never reached 100,000 bats, hibernaculum surveys in Arkansas, Tennessee, and Virginia have consistently declined from 1965 to 2000 (Figure 11). Hibernacula surveys in Illinois, New York, Ohio, and West Virginia are greater in 2000 than in 1965, but trends are not consistent through the period. Thus, the southern tier of states in the species' range shows declines in counts at hibernacula, whereas some states in the northern tier show increasing counts (Table 3). Connecticut and other states with very small populations were too small or too recently discovered to show graphically, and we do not discuss them here.

Apparent Regional Population Trends and Climate Change
It is nearly impossible to consider the geographic positions of states where Indiana bat populations are declining and states where they are stable or increasing without considering the possibility that climate change or other environmental issue is driving some changes in Indiana bat populations. Table 3 reveals a clear division in apparent population trends between states in the northern portion of the Indiana bat's range versus states in the southern portion of the range (Clawson 2002). Steep declines in Kentucky and Missouri hibernacula have largely contributed to the apparent decline in the southern population during the 45-year period from 1960 through the present. In contrast, there apparently has been an overall increase in population in northern states over the same time period. The role of climate change and its effect on temperatures in hibernacula need investigation. Although current data are not sufficient to definitively determine the cause of apparent regional disparities, it appears that both protection of hibernacula and suitable temperature regimes may be key to understanding trends in the overall population and recovery of the species.

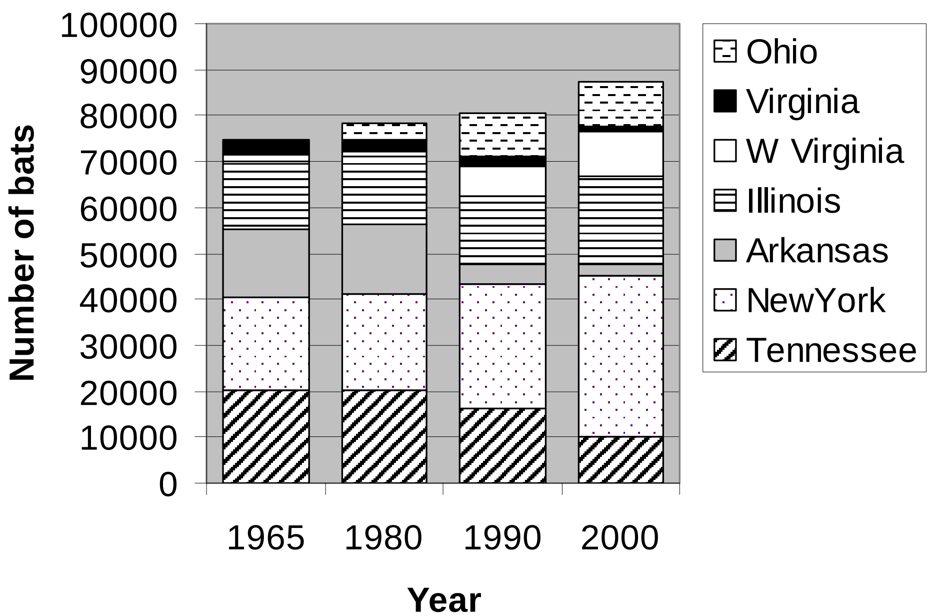


Figure 11. Estimated numbers of Indiana bats in states with counts always below 100,000 bats. For years in which a cave was not yet known, the first survey results for the cave are used. Counts for Alabama, Massachusetts, Pennsylvania, and Vermont were too small to show at this scale (Meretsky, pers. comm., 2006).

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% 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% for males. Following 10 years, the survival rate for females dropped to only 4%. Humphrey and Cope (1977) surmised that this lower rate may reflect an increased cost of migration and reproduction during old age, or may be attributable to sampling error, as a very small number of females remained alive after 10 years. However, individuals have been noted to live much longer, with the oldest known Indiana bat captured 20 years after it was first banded (LaVal and LaVal 1980). Humphrey et al. (1977) provided the only neonatal mortality estimate, 8 percent, based on one of two seasons of observation of one maternity colony. More research on differences in survival rate among life stages is needed.

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

Chronology

Depending on local weather conditions, hibernation for Indiana bats typically lasts from October through April (Hall 1962, LaVal and LaVal 1980), although it may be extended from September to May in northern areas including New York, Vermont, and Michigan (Kurta et al. 1997, Hicks 2004). The nonhibernation season, which includes spring emergence, migration, reproductive activities, and fall swarming, varies depending upon the sex (males may enter hibernation later than females) and the location (northern latitudes may have shortened nonhibernation seasons) (Figure 12). The following sections describe the annual life cycle for the Indiana bat, beginning with the fall mating season.

Fall Swarming and Mating

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

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

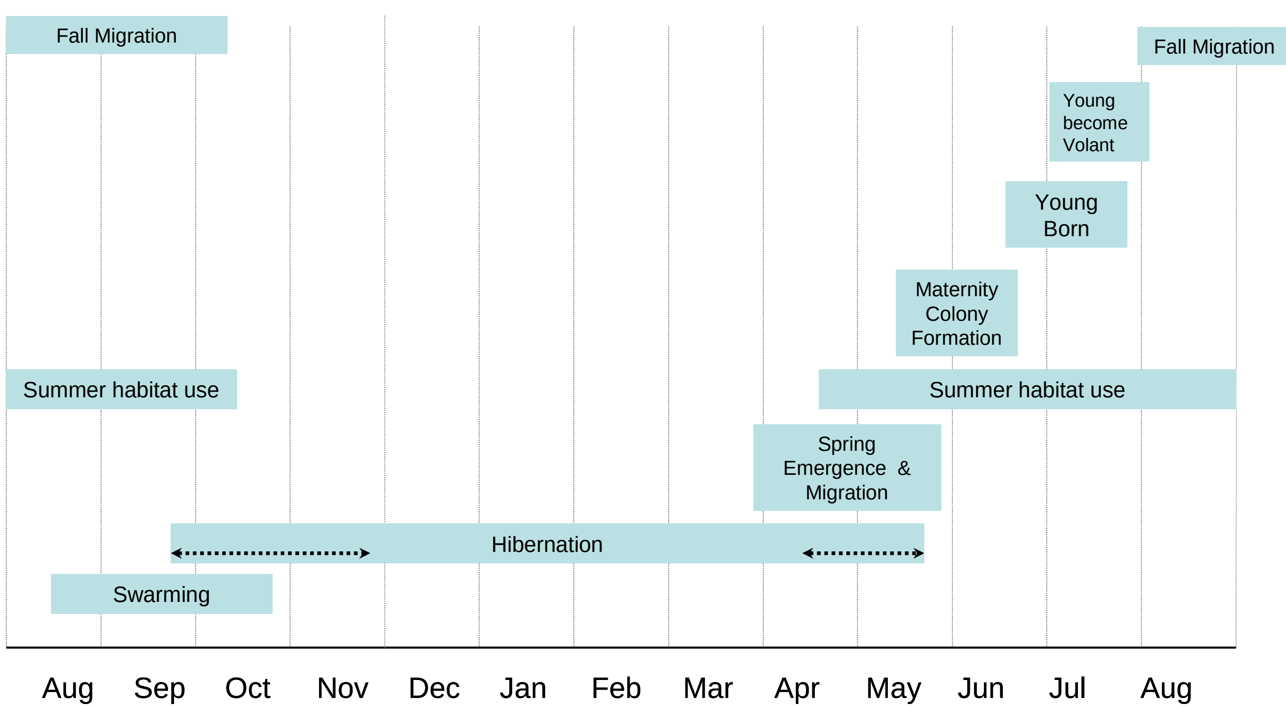


Figure 12. Indiana bat annual chronology.

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

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

Bat movement patterns in autumn often do not follow a simple linear pattern of migration from summer habitat to the hibernacula. Parsons et al. (2003) discussed the transitory nature of bats at this time of year, noting that bats may travel relatively long distances from a swarming site during the swarming season; they observed bats roosting up to 17 mi from swarming sites and completing the round trip between the swarming and roosting sites in one or two nights. Humphrey and Cope (1976) documented several little brown bats making movements up to 37 mi (away from the hibernaculum where they were captured during swarming). Indiana bats have also been found making relatively long trips from hibernacula during fall swarming. Butchkoski (pers. comm., 2006) documented a radio-tagged male Indiana bat in Pennsylvania making two trips between the hibernaculum where it was captured to a site 9 mi away over a period of two weeks. Hawkins et al. (2005) documented several Indiana bats radio-tagged at Wyandotte Cave in Indiana traveling long distances from the cave during fall swarming, including two females that were relocated over 19 mi from the cave. Brack (2006) suggested that competition for foraging resources may force bats to leave the immediate vicinity of the hibernacula to find prime foraging habitat to replenish their energy reserves, particularly at hibernacula that support large populations of Indiana bats and/or multiple species.

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

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; J. MacGregor, Kentucky Department of Fish and Wildlife Resources, pers. comm., 2005) 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, in press).

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 Microlimate section).

Spring Emergence

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

In spring when fat reserves and food supplies are low, migration provides an additional stress and, consequently, mortality may be higher immediately following emergence (Tuttle and Stevenson 1977). This increased risk of mortality may be one reason why many males do not migrate far from the hibernacula (Brack 1983, Gardner and Cook 2002, Whitaker and Brack

2002). Movements of 2.5-10 miles by radio-tagged male Indiana bats were reported in Kentucky, Missouri, and Virginia (Hobson and Holland 1995, Rommé et al. 2002). However, other males leave the area entirely upon emergence and have been captured throughout various summer habitats (Kurta and Rice 2002, Whitaker and Brack 2002).

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

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

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

<u>Summer Life History and Behavior</u>

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.

<u>Maternity Colony Formation</u>

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 (in press) 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 thermoregulators (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 (in press) 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, in press). 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 (in press) 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, in press). 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., in press), 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., in press). 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., in press). 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, in press; K. Watrous, pers. comm., 2005).

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 radiotracked 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 radiotracked 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 (in press) calculated a mean home range of 205 acres for 14 female Indiana bats in Vermont.

Hibernation Habitat

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

Hibernacula Microclimate

Ambient Temperature during Torpor

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

Researchers studying hibernacula temperature have used different temperature monitoring instruments and techniques, making it difficult to compare results of studies. For example, among long-term (>2 years) datasets, Henshaw (1965) left thermometers inside hibernacula and measured maximum and minimum temperatures once every two weeks; Brack and his colleagues usually measured temperatures near hibernating clusters of Indiana bats during occasional cave visits (e.g., Brack et al. 1984, Brack et al. 2003, Whitaker et al. 2003); and Tuttle and Kennedy (2002) took near-continuous temperature readings using data loggers left inside hibernacula. Standard (and thus comparable) protocols for quantifying the thermal profiles of hibernacula used by Indiana bats over ecologically meaningful periods (e.g., >5 years) have not been established, but continuous monitoring using data loggers is currently the most useful approach. Any protocol for monitoring with data loggers should be designed to maximize the likelihood that temperature measurements are taken in all areas of a hibernaculum used by bats during winter. Ideally, temperature measurements from data loggers would be temporally correlated to remotely-sensed information (e.g., images from infrared cameras) on the actual whereabouts of individuals or colonies within the hibernaculum. The second factor complicating the analysis of temperature data gathered by different researchers, that work in different geographic areas, is the relationship between temperature and the degree of gregariousness exhibited by Indiana bats.

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

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

There are few quantitative data pertaining to energy use by Indiana bats during hibernation. In laboratory experiments, Henshaw (1965) measured energy expenditure by Indiana bats as a function of ambient temperature. During torpor, Indiana bats consumed the least amount of energy at 5ºC, with energy use increasing at temperatures of both -5ºC and 10ºC (23.0ºF and 50.0ºF). However, Henshaw (1965) did not quantify energy expenditure by Indiana bats at intermediate temperatures (i.e., 1º to 4ºC and 6º to 9ºC (33.8º to 39.2ºF and 42.8º to 48.2ºF)). T. Tomasi (unpublished data, 2006) collected metabolic data for Indiana bats hibernating in a laboratory at 1°, 3°, 5°, 7°, and 9°C (33.8º, 37.4º, 41.0º, 44.6º, 48.2ºF) 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 (41.0ºF) treatment. V. Brack (pers. comm., 2004; 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., 3ºC versus 8ºC (37.4ºF versus 46.4ºF)) 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 2º to 4ºC), 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; R. Clawson, pers. comm., 1996). 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 (55.4ºF) 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 Habitat

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, in press), 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 5), 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, in press), 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 5), but some species are preferred under certain circumstances. Kurta et al. (1996), for example, demonstrated a preference by Indiana bats for green ash (*F. pennsylvanica*) over silver maple (*A. saccharinum*) in Michigan, and Carter (2003) showed that Indiana bats chose green ash and pin oak (*Q. palustris*) more often than expected based on availability in Illinois. Both studies occurred at sites with very high snag densities. However, if suitable trees are less abundant, other factors that influence roost selection (e.g., canopy cover, exposure to wind, distance to foraging sites) may mask preferences displayed by bats in areas of superabundant roosts.

Living or Dead Trees

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

Table 5. 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

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

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

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

Size of Tree

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

Average heights of roost trees range from 16 to 26 m (52 to 85 ft) (Tables 6 and 7). 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, in press, 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 6). Nevertheless, minimum exit height for a primary roost is 1.8 m (6 ft); for an alternate roost it is only 0.6 m (2 ft) (Callahan 1993). Height of the exit is correlated with height of the tree (Kurta et al. 2002).

Table 6. 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% 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 7. 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% of bats located were female) and by multiple counting of trees (9.2%) used in more than one season (spring, summer, autumn).
[d] Calculations of overall average and SE used the unweighted means from the various studies. Weighting each study, based on the number of trees, gave very similar results.

Other Factors Affecting Access and Sunlight

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

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

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

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

Amount of Bark Remaining

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

Primary vs. Alternate Roosts

Despite the number of studies of Indiana bats, few reports have statistically compared the attributes of primary roosts and alternate trees. In Missouri, primary trees were more likely to be in open situations, as opposed to the interior of the woods, and more likely to be dead trees, rather than living shagbark hickories; alternate roosts, in contrast, were more variable and could be either interior or open trees (Callahan et al. 1997). No other statistical differences were found between primary and alternate trees (Callahan et al. 1997). In Michigan, both primary and alternate roosts typically were in open sites, and there was no statistical difference between primary and alternate roosts in tree height, exit height, canopy cover, solar exposure, or amount of bark (Kurta et al. 1996, 2002). In addition, mean diameter did not differ, although diameter of primary trees was less variable than that of alternate roosts in Michigan (Kurta et al. 2002). One proposed function of frequent roost switching by tree-living bats is that individuals are evaluating new trees for future use (Barclay and Kurta, in press). 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 6) and average diameter of roosts used by adult males is 33 cm (13 in) (Table 7). 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, in press). 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 5). 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 6 and 7). 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 5). 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 5, suggesting that use of buildings by maternity colonies is uncommon.

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

Landscape Structure and Macrohabitat

Distance to Environmental Features

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

Insectivorous bats typically obtain 20 to 26 percent of their daily water from drinking (Kurta et al. 1989, 1990), and one might think that roost trees should be closer to water sources than random points. In upland areas lacking streams or lakes, Indiana bats, especially adult males, have been captured while flying over wildlife ponds and at water-filled road ruts (e.g., Wilhide et al. 1998), suggesting that the bats might be attracted to these artificial sources of water. However, water sources are ubiquitous in most areas where Indiana bat maternity roosts have been found. At one maternity site in Michigan, for example, average distance from a random point to a perennial stream is only 910 m (2,986 ft) and to a lake or pond, 541 m (1,775 ft) (Kurta et al. 2002). Such distances are energetically insignificant to a flying mammal (Barclay and Kurta, in press), 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 (Service2004a). 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).

Species Recovery

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

Previous Incidental Take Authorizations

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

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

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.

A summary of the formal consultations completed over the past 10 years is discussed below and provided in Appendix C. Formal consultations on the Indiana bat completed prior to 1997 were omitted from this analysis. This was done, because the incidental take provided prior to 1997 would not be expected to affect the current environmental baseline for the proposed action. This is due to several reasons, including:

(a) The effects of the take occurred in the past and current population and other data are available that give us a better estimate of the environmental baseline;
(b) The authorized take in many biological opinions has been superceded by new biological opinions; and
(c) The relationship of the take in these older biological opinions and the applicability of such take to this biological opinion is tenuous, at best, because of the difficulty in drawing meaningful comparisons and conclusions for projects that may be geographically separated and not similar in their effects on the Indiana bat.

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

Previous consultations have addressed impacts to hibernating or swarming bats, known maternity areas, or summer habitat that was assumed occupied. Due to the various life stages affected, the types of conservative assumptions made (as discussed above), and the difficultly in documenting actual take to Indiana bats (as more fully described in each biological opinion and the Incidental Take Statement section of this biological opinion), different methods have been used to estimate the amount of potential take. Depending on the consultation, take has been measured either by estimating numbers of affected roost trees, individual bats or maternity colonies, or acres of potentially suitable and/or occupied habitat. However, the Service typically has determined the incidental take measure that was used based on the most accurate and reasonable means available for each site-specific analysis. For example, Appendix C shows that biological opinions have exempted take of Indiana bats on about 916,500 acres of potentially occupied habitat. However, new information that became available after the issuance of some of the biological opinions resulted in subsequent "not likely to adversely affect" determinations for activities on about 517,600 acres of that total acreage. Thus, only 398,900 acres of the original take acreage exempted by these biological opinions remains authorized today.

In addition, over 81,000 acres of this 398,900-acre total has been superceded by new biological opinions, which further reduces the total take acreage to 317,900 acres range-wide (i.e., a very small proportion of the species' range) and would result in potential double counting of the affected acres if those acres were not subtracted from the total. A good example of this relationship exists for the biological opinion for the Northeast Research Station, where forest stands are harvested multiple times over many years, with each entry being counted as a separate acre of annual take (Service 2005c). Therefore, it is difficult, for the reasons discussed previously in this section, to measure the effects of previously authorized take without knowing the details of each biological opinion and closely evaluating the outcome of each consultation. Furthermore, even when we have the details of a biological opinion and are able to evaluate the outcome, we may not be able to draw realistic conclusions regarding the short- and/or long-term effect of any incidental take that has occurred due to the difficulty in monitoring and estimating incidental take of Indiana bats.

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

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

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

In order to ensure that the anticipated level of take is not exceeded, however, each National Forest provides annual reports of the actual level of take that has been implemented. Although reported levels have not been compiled for all the Forests, the actual incidental take used has been less than the level exempted in the biological opinions for many Forests, including the DBNF (See Table 8 below). If incidental take is exceeded, re-initiation of consultation is necessary.

A number of incidental take statements have also been issued to other Federal agencies conducting activities that were determined not likely to jeopardize the Indiana bat. Unlike the incidental take statements issued for the National Forest Land and Resource Management Plans, some of these other Federal agency actions were certain to impact known, occupied habitat for Indiana bats. To minimize the effect of these projects, the Federal action agencies agreed to implement various conservation measures and to implement the reasonable and prudent measures (if any) contained in the respective biological opinions for those projects. Some of the measures implemented in these proposed actions included: seasonal clearing restrictions to avoid disturbing female Indiana bats and young; protection of all known primary and alternate roost trees with appropriate buffers; retention of adequate roosting and foraging habitat to sustain the maternity colony into the future; and permanent protection of areas and habitat enhancement or creation measures 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 issued for non-Forest Plan activities anticipated the loss of a maternity colony. The Fort Knox biological opinion [1999] exempted the take of two potential maternity colonies and individual Indiana bats. However, the biological opinion did not specify whether the "take" consisted of loss of the colonies or take in the form of harm and harassment. Surveys in 2004 and 2006 in the immediate area where the “take” was provided on Fort Knox have shown that at least one maternity colony (and possibly two) exists (M. Gumbert, Personal Communication, 2007). A concerted effort is planned for 2007 to determine if the colony(ies) are indeed the same colony(ies) known to use the area in 1999 by capturing females banded in 1999. We have no data that tracks the take of maternity colonies for the GSMNP biological opinion, but additional monitoring of the maternity colony following the completion of the 2004 BO for the Laxare East and Black Castle Contour projects, documented a colony much larger than previously anticipated. Additional project modifications subsequent to that discovery resulted in the retention of all known roost trees and protection of some potential foraging areas. Reinitiation of that consultation in 2006 concluded that while the colony would experience adverse effects, the colony should be able to persist through the life of the project.

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

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

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

Analysis of the species/critical habitat likely to be affected

Based on the DBNF's need to remove green and damaged trees and conduct prescribed burns during the summer roosting period of the Indiana bat, the Service concurs with the DBNF's determination that the Indiana bat may likely be adversely affected by implementation of the revised LRMP. Our concurrence is based on the fact that conducting these activities during the summer roosting period could result in the harm, harassment, and/or mortality of Indiana bats due to the potential effects of timber harvest and burning activities on the Indiana bat and its habitat. Additionally, no critical habitat for the Indiana bat exists within the action area. Therefore, the Indiana bat is the only species that will be considered further in the remaining sections of this biological opinion.

The Service has reviewed the BA for implementation of the revised LRMP and all of the above-referenced supporting and supplemental information. The BA evaluated the potential and actual effects of implementation of the revised LRMP on 32 federally listed species and proposed critical habitat for the Cumberlandian combshell (*Epioblasma brevidens*), oyster mussel (*Epioblasma capsaeformis*), and Cumberland elktoe (*Alasmidonta atropurpurea*). One of these 32 species, Eggert's sunflower (*Helianthus eggertii*), has been removed from the Federal List of Endangered and Threatened Plants (Service 2005), so there is no need to consider that species further in this biological opinion. In our March 20, 2004, biological opinion, we provided our concurrence with the USFS's determination that implementation of the revised LRMP would not result in the adverse modification of proposed critical habitat for the Cumberlandian combshell, oyster mussel, and Cumberland elktoe. Subsequent to that date, a final rule designating critical habitat for those species was published (Service 2004b). As a result, we provided the DBNF with our concurrence that implementation of the LRMP would not result in the adverse modification of designated critical habitat for the Cumberlandian combshell, oyster mussel, and Cumberland elktoe in a letter dated September 30, 2004. Previously, we provided our concurrences on the DBNF's effects determinations that implementation of the revised LRMP would not likely adversely affect the remaining 30 federally listed species addressed by the BA in our March 20, 2004 biological opinion; however, we separated those concurrences from the March 20, 2004 biological opinion in a February 12, 2007 concurrence letter to the USFS. These concurrences were based on the fact that nine listed species are likely extirpated from the action area and 21 species and four critical habitat areas would continue to be subject to project-specific section 7 consultations. Thus, these 30 species will not be considered further in this biological opinion.

ENVIRONMENTAL BASELINE

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

Previous biological opinions and incidental take statements were discussed in a previous section. However, 6 of these biological opinions include at least a portion of the action area for this biological opinion. In addition, the Service has completed 140 informal consultations with the DBNF since completion of the 2004 biological opinion. These formal and informal consultations are discussed in detail in the "Factors affecting the species' environment within the action area" section below.

Monitoring data provided by the DBNF in support of the reasonable and prudent measures from March 20, 2004 biological opinion show that the actual acreages of burning and green tree or salvage/sanitation harvests implemented by the DBNF from March 20, 2004 to present are significantly less than authorized. The acreages for green tree harvests, salvage/sanitation harvests, and prescribed burning for the years 2004 to 2006 are shown in Table 8 below.

Table 8. Acreages of implemented harvests and prescribed burns in 2004 to 2006 on the DBNF.

Year	Green Tree Harvests	Salvage/Sanitation Harvests	Prescribed Burning
2004	0	102	0
2005	0	<2	11,362
2006	65	0	8,742

Status of the species within the action area

According to the known and suspected range of the Indiana bat (Service 1983), the Indiana bat ranges over an area of about 580,550 square miles in the eastern one-half of the United States. The action area's surface land area is approximately 3,191 square miles, which represents just over one-half of one percent (0.55 percent) of the total range of the species. However, the occupied range of the species within both the known range and the action area is unknown but is likely to be considerably smaller than the known range and action area, respectively, due to the presence of unsuitable habitats within both of those areas and the lack of a uniform distribution for the species. According to our records, the Indiana bat is known from a number of locations within the action area, with at least 64 known capture locations within the proclamation boundary. Most of the records are from caves, which harbor anywhere from a few occasional individuals to several thousand Indiana bats each winter, but 9 locations are summer records of males (n=3), females (n=3), unknown sex (n=3), and juveniles (n=4).

Although the action area does not contain any designated critical habitat or any Priority I hibernacula (defined as harboring 30,000 or more Indiana bats since 1960), it does contain 8 Priority II winter caves (harboring 500 to 30,000 bats), 16 Priority III caves (with < 500 bats) that regularly support 100 or more through each winter, and about 30 more Priority III caves that contain fewer than 35 Indiana bats in winter. Seven of the 8 Priority II caves and 7 of the 16 Priority III caves located within the action area are on National Forest System lands, and most of the others are on private tracts immediately adjacent to the Forest. No designated critical habitat for the Indiana bat is located within the action area.

Indiana bat winter populations are censused every second year in the hibernacula. Since 1990, the action area has harbored 20 to 25 percent of the known Indiana bat winter population in Kentucky, and the population numbers have remained relatively stable with a recent slight increase. The 2005 winter population estimate for Kentucky has the population to be about 62,380 individuals. Thus, the DBNF harbored about 15,600 Indiana bats during the winter of 2005. In comparison, the range-wide winter population estimate for 2005 was about 457,000 individuals. Based on these estimates, we estimate that the action area provides winter habitat for about 3 percent of the range-wide Indiana bat population.

Based on the number of summer capture records and the few known maternity colonies within the action area, the existing data indicate that most of the Indiana bats that hibernate within the action area migrate to locations outside of the action area in summer. We have little specific information on the numbers of Indiana bats that migrate outside of the action area, because few Indiana bats from the entire range-wide population are captured, banded, or radiotracked each year. However, a female that had been banded at a maternity site in northern Indiana was observed during two winters at a Lee County hibernaculum on the DBNF, and a male banded in Michigan in July 1998 was recorded in a hibernation cave on the DBNF in October 1999. We also have several records of male Indiana bats that were captured during summer near Pine Mountain (i.e., just south of the Redbird RD) hibernating in the hibernacula on Pine Mountain. As a result, we believe that it is reasonable to assume that other Indiana bats may use summer habitats near their hibernacula that lie within the action area; this would include areas both on and off the DBNF. So, we expect that other Indiana bats may remain within the action area year-round.

Summer maternity colonies, consisting of females and their young, have been documented by mist netting on the Cumberland (3 sites), Stearns (1 site) Ranger Districts (RD), and within the proclamation boundary of the Redbird RD (3 sites) and might be expected to occur anywhere within the action area where suitable summer habitat exists. However, most of the eastern and southern portions of the species' range, which would include the action area, appear to have fewer maternity colonies per unit area of forest than does the upper Midwest (Table 4). This leads us to believe that the action area is likely to contain fewer maternity colonies and a lower overall population level than we would expect relative to the size of the action area and the amount of forested land. When also faced with the facts that (a) most documented maternity colonies contain 100 or fewer adult females (Harvey 2002), (b) the available data show that some male and female Indiana bats that hibernate within the action area leave the action area during the summer (and would thus not be subject to adverse effects from the proposed action, and (c) only 7 maternity colonies are known from the DBNF and will be protected through the programmatic protections summarized in Appendix B, we believe that few, if any, maternity colonies will be adversely affected by the proposed action. Further, we do not believe that any maternity colonies will be lost due to the proposed action based on information we have from a number of areas showing that maternity colonies tend to persist in the face of even significant disturbances (e.g., see Fort Knox biological opinion).

We also believe that males are likely to be affected by the proposed action, because they may tend to remain near their hibernacula during the summer months (Hall 1962, Gardner and Cook 2002, Figure 5). However, males are more mobile, because they are not responsible for young; they tend to roost singly or in smaller numbers than females; and they typically use more and different roosts than females. We, therefore, expect these behavioral traits to minimize the effects of the proposed action on male Indiana bats. Summer resident male Indiana bats have been captured or observed on the Cumberland, London, Stearns, and Redbird RDs and a single Indiana bat was found in an abandoned coal mine in Big South Fork NRRA (near the Stearns RD) during the fall migration period (USFS *et al*. 1988, 1989, 1990, 1992, 1993; 1995; K. Huie, field notes; J. MacGregor, field notes).

Within the action area, suitable winter habitat for Indiana bats is largely confined to areas where limestone caves occur, which includes large sections of the Cumberland RD, the northern part of London RD, and smaller portions of the Stearns and Redbird RDs. Sandstone caves (rock shelters with well developed dark zones), underground workings in limestone quarries, and abandoned coal mines may also provide suitable winter habitat and can be found in varying numbers on all RDs.

In October 1996, following a 2-year study of autumn Indiana bat roosting and foraging habitat that took place on the London RD (Kiser and Elliott 1996), the DBNF began monitoring roost tree use by Indiana bats during the fall on the Stearns RD. The majority of the roost trees used by Indiana bats during the autumn months were located in stands greater than 50 years old with relatively closed canopies (80 to 93 percent canopy cover), in natural canopy gaps that had been formed by the death of one or more canopy trees (primarily from wind or ice damage), and in areas subjected to prescribed burns which had been conducted primarily for red-cockaded woodpecker habitat management. Indiana bats also roosted extensively in 2-age shelterwood harvest areas within which snags and other potential roost trees had been retained, and in high-graded stands with many snags and culls. Similar roost tree use was reported by Gumbert (2001) on the Stearns RD during the spring and summer months.

Beginning in 2006, the DBNF has initiated 2 studies to better understand the effects of silviculture practices (e.g., timber harvest) and prescribed burn activities on the Indiana bat. Results of these studies will provide managers with important information that can be incorporated into decisions regarding the application of shelterwood harvests, thinning, burning, and use of herbicide for forest management. For example, if all, or specific, bat species tend to avoid sites subjected to shelterwood harvests, mechanical thinning, mechanical thinning and burning, or mechanical thinning and herbicide treatment, then caution will need to be applied when considering the best management practice(s) to employ in order to achieve a stated forest management goal. However, if the post-treatment level of use by all, or specific species, of bats are similar to or greater than what was documented prior to treatment, then those species may not have to be considered when dealing with the implementation of the applicable silvicultural practice. Results of these studies will be published in referred journals such as the *Journal of Mammalogy* or *Forest Ecology and Management*.

Suitable roosting and foraging habitat and potential maternity habitat for the Indiana bat occurs throughout the action area, but this habitat is not evenly distributed. At least a portion of the Indiana bats that spend the winter in the large and medium-sized hibernacula on the Cumberland, London, and Stearns RDs are assumed to remain near these areas through the summer, but definitive data to support this contention is not available. Some of the Indiana bats from hibernating sites on Pine Mountain (i.e., adjacent to the Redbird RD), Carter Caves (i.e., near the Cumberland RD), and caves in Campbell and Fentress Counties in Tennessee (i.e., near the Stearns RD), and perhaps from other areas, may also occur on the DBNF in summer as a result of being near the action area. Recent work in Missouri (Romme et al. 2002) and Kentucky (Kiser and Elliott 1996; Gumbert 2001) have found that Indiana bats range up to 5 miles from hibernacula during autumn and spring swarming activity periods.

A number of land use and management activities occur on the non-federal in-holdings lying within the DBNF proclamation boundary that may affect the Indiana bat. The most likely activities to occur within this area include:

(a) timber harvest;
(b) off-highway vehicle (i.e., ATV) recreational use;
(c) recreational use of caves (i.e., potential adverse effect on hibernacula); and

(d) development associated with road, residential, industrial, and agricultural construction and related activities.

Long-term land use and demographic trends may also play a key role in any effects that may occur to the Indiana bat if these trends result in destruction and/or modification of Indiana bat habitat. Overall, we have determined that the effects of these past and ongoing human and natural factors leading to the status of the Indiana bat, its habitat, and ecosystem, within the action area are both qualitative and quantitative in nature and will be discussed further in the paragraphs that follow.

Factors affecting the species' environment within the action area

The DBNF owns and manages nearly 700,000 acres of the proclamation area's over two million acres. The federally owned tracts are discontinuous and scattered within the proclamation boundary. Individual landowners hold most of the privately owned land within this proclamation boundary, typically in small tracts of less than 300 acres. Additional description of the action area and the DBNF, specifically, is provided in the "Description of the Action Area" section above.

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

The Service does, however, have access to unpublished information regarding the extent of state and federal highway development (Kentucky Transportation Cabinet, unpublished data, 2007: This does not include county or local government road projects.) and surface coal mining (Kentucky Department of Natural Resources, unpublished data, 2007) within the action area. For highway projects, 232 highway projects have been implemented within the action area since January 1, 2002. Of these 232 projects, only 13 projects are known to have resulted in the removal of potentially suitable Indiana bat summer habitat. That does not mean, however, that these projects actually resulted in adverse effects to Indiana bats. In many cases, surveys were conducted and/or the habitat was removed during the winter months when Indiana bats were not present.

In addition, the Kentucky Transportation Cabinet currently estimates that 216 projects lie wholly or partially within the action area and may be implemented over the next six years. Of these 216 projects, 21 projects are expected to result in some removal of potential Indiana bat summer habitat, and another 26 projects may result in some summer habitat removal once final plans for these projects are determined. So, a total of 21.7 percent of planned, future road projects within the action area have at least some potential to cause adverse effects on Indiana bats. However, this does not take into account any avoidance or minimization measures that may be implemented or any surveys that will be done to determine presence/absence of the species. These factors would likely reduce or may eliminate the probability of adverse effects occurring because of these projects. This also does not take into account the fact that these projects typically undergo an independent section 7 review and consultation, if necessary.

We are also unable to determine the acreage of any past or future habitat losses from the road projects described above, because KYTC does not keep such records. However, most of these projects are subject to separate, independent section 7 consultations, because they typically have a federal nexus (e.g., Federal Highway Administration funding or a Clean Water Act section 404 permit from the U.S. Army Corps of Engineers). As a result, it is unlikely that any adverse effects would result from these projects without first undergoing the Service's review and consultation.

The Kentucky Department of Natural Resources issues surface and sub-surface coal mining permits. Their data indicate that 120,790.60 acres within the action area have been permitted for coal mining. Of that acreage, 91,249.9 acres (or 75.5 percent) is associated with 44 permits for underground mining, which would have only minor (i.e., typically less than 20 acres per permit or about 880 acres) surface impacts and may or may not involve the removal of potential Indiana bat summer habitat. The remaining acreage would involve surface disturbances, which again may or may not involve the removal of potential Indiana bat summer habitat. KDNR also provided us information showing that 15,407 acres of the 120,790.6 acres of coal mining within the action area was permitted after issuance of the March 20, 2004 biological opinion and that 120 new coal mining applications for an additional 28,511.93 acres (12,414.8 acres of underground mining and 16,097.13 acres of surface mining and other related disturbances) have been received for that area.

The Service is provided an opportunity to review all KDNR mining permit applications, and all such applications and issued permits are subject to the 1996 Programmatic Biological Opinion for Surface Coal Mining Regulatory Programs Under the Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87). Therefore, any potential adverse effects that may result from coal mining activities within the action area have been accounted for through a separate formal consultation with the Service and, if adverse effects are likely to occur, the subsequent implementation of an Indiana bat protection and enhancement plan by the mining permittee to avoid and minimize impacts to Indiana bats as required by the 1996 biological opinion.

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 severity – We describe how long we expect the adverse effects to persist and long it would it take a population to recover.

Analyses for effects of the action

Beneficial Effects

General – Beneficial effects are those effects of an action that are wholly positive, without any adverse effect, on a listed species or designated critical habitat. For this consultation, a number of activities proposed in the LRMP that, as a whole and on a programmatic basis, may have anticipated adverse effects may also have wholly beneficial effects in some project-specific circumstances. For example, management practices, such as timber harvests or prescribed burning, that create small forest openings may also foster the development of suitable roosting and foraging habitat (Krusic and Neefus 1996). These types of benefits have been reported to occur in a variety of instances (Gardner *et al.* 1991b, Callahan 1993, Romme *et al*. 1995). Activities that involve habitat manipulation, which could adversely affect Indiana bats if they are present, may at the same time improve foraging and/or roosting habitat conditions by opening the canopy and exposing potential roost trees to a greater amount of sunlight (see thermoregulatory needs in "Summer Habitats"). This would be considered a beneficial effect in situations where such management activities do not cause adverse effects. These situations may occur if Indiana bats are present, but we believe they are more likely to occur if Indiana bats are merely in the vicinity or are not present. For example, green tree harvest within forest stands not used by a nearby maternity colony may improve future foraging and roost tree availability and conditions for the maternity colony while at the same time not causing adverse effects to the maternity colony or its existing habitat.

Other situations where beneficial effects could occur include:

(a) Previous and planned pond/waterhole construction will increase the number of upland water sources available for Indiana bats;
(b) Persistence of early successional habitats and forests with an open understory and patchy overstory that would create insect-rich foraging areas and flight corridors leading to any potential roost trees;
(c) Harvests that produce a mosaic of regeneration areas intermixed with mature and late successional forests; and
(d) Prescribed fire that create snags and a mosaic of forest habitat conditions resulting from varying fire intensities and reduce the potential for catastrophic wild fires.

These would all indirectly benefit Indiana bats by providing feeding areas since bats are known to forage within the canopy openings of upland forests, over clearings with early successional vegetation, and over ponds. So, if these actions occurred but did not cause adverse effects, the effects would be beneficial. We believe that these types of beneficial effects are likely to occur. However, we cannot quantify or identify specific instances where they would occur due to the lack of distribution data on the species within the action area and the programmatic nature of the proposed action.

Current USFS Indiana Bat Conservation Measures - Conservation measures represent actions pledged in the project description that the action agency will implement to further the recovery of the species under review. Typically, such measures are closely related to the action and should be achievable within the authority of the action agency. The beneficial effects of conservation measures are, therefore, taken into consideration in our jeopardy/no jeopardy determination and in the analysis and quantification of incidental take. However, such measures must minimize impacts to listed species within the action area in order to be factored into our analyses.

The proposed action includes numerous, ongoing conservation measures that will be implemented through the standards and prescriptions outlined in the revised LRMP to reduce or minimize adverse effects on the Indiana bat. The DBNF has designed Objectives, Standards, and Prescription Areas specifically to protect, maintain, or enhance summer or winter Indiana bat habitat or prevent impacts to Indiana bats roosting in trees. Thus, impacts to Indiana bats resulting from the implementation of land management activities, such as green tree harvests, salvage/sanitation harvests, and prescribed burning, may be coincidentally reduced through forest-wide standards and/or the implementation of standards and prescriptions specific to those activities. Discussions of some of the more important conservation measures that will minimize impacts to Indiana bats are contained in the following paragraphs.

The direction contained in the revised LRMP, and in particular the creation of several Prescription Areas, is expected to provide programmatic, long-term benefits to Indiana bat populations on the DBNF. For example, the Cliffline Community (111,200 acres), Riparian Corridor (155,370 acres) and Significant Bat Cave (6,100 acres) Prescription Areas were created, in part, with habitat maintenance and/or improvements for the Indiana bats in mind. Generally, habitat management in these areas is limited and is primarily designed to improve conditions for species associated with these prescription areas. For example, an objective (1.J-Objective 1.B) within the Significant Bat Cave Prescription Area specifically limits the occurrence of prescribed burning within five miles of these cave openings during the fall swarming season (September 1 to December 1). Therefore, in the long-term, management actions in these areas should move the habitat conditions toward the desired future condition and provide beneficial effects to the Indiana bat. Standards (discussed below and listed in Appendix B) within these Prescriptions Areas are also expected to provide additional protective measures and/or habitat enhancement direction for the species.

Additionally, the Habitat Diversity Emphasis Prescription Area (376,000 acres) is an area of active forest management that should continue to provide for a mosaic of habitats that can be occupied by Indiana bats within the general forested community. Standards in the revised LRMP, particularly DB-WLF-1 through DB-WLF-15, are designed to retain and/or create habitat conditions particularly suitable for the Indiana bat and should provide long-term beneficial effects for the species. These Standards focus on avoiding the cutting of trees that are most likely to contain an Indiana bat maternity colony or a roosting Indiana bat.

Thus, the Standards are intended to minimize negative impacts to Indiana bats and their habitat and, in some cases, are also intended to improve Indiana bat habitat. These Standards and Prescription Areas were developed to meet specific resource objectives, to serve as avoidance, minimization, and/or mitigation measures, and to provide for population viability for native wildlife species, including the Indiana bat. Further, the Service believes that these Standards and Prescription Areas will contribute to Indiana bat recovery by (a) protecting important summer and winter habitat areas and/or characteristics, especially potential summer roost trees, foraging habitat, and known hibernacula; and (b) improve summer habitat and swarming habitat within the DBNF for extant Indiana bat populations on the DBNF (i.e., better habitat quality should result in improved Indiana bat demographic characteristics such as reproduction, survivorship, etc.). The Standards (i.e., conservation measures) that will most often pertain to the Indiana bat are listed in Appendix B.

<u>Direct Effects</u>
Direct Effects of Green Tree and Salvage/Sanitation Harvests – For this analysis, the direct effects of green tree and salvage/sanitation harvest are considered to be identical. This is because both activities involve the same basic process, result in the harvest, alteration, or other removal of living trees and other potentially suitable Indiana bat roost trees (e.g., snags), and would, therefore, be expected to have similar effects on the Indiana bat.

In any green tree and/or salvage/sanitation harvest the associated activities 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.

These activities are listed in the order in which they typically occur and are discussed in detail in the BA and its supplements. 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.

Implementation of these activities was described in detail in the Description of Green Tree Harvests and Description of Salvage/Sanitation Harvests sections above and in the BA. The major difference between green tree and salvage/ sanitation harvests is the condition of the individual trees that are selected for harvest. In salvage/sanitation harvests, it is the highly damaged trees that are selected for removal and, thus make up the majority of trees cut in a project area. These damaged trees usually meet the physical conditions defined and protected in the LRMP under Standard DB-WLD-7 as "immediate roost trees" and/or Standard DB-WLD-1 as "snags". Thus, salvage/sanitation harvest projects are designed to remove those trees that have desirable roosting characteristics for the Indiana bat, which is not typically the case for green tree harvests.

Nonetheless, these activities may involve the removal of occupied roost trees and/or the modification of occupied foraging habitat where proposed harvests 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. During the summer roosting season Indiana bats, especially females, often roost in live, damaged, and/or dead trees with naturally exfoliating bark (e.g., oaks, elms, and hickories). These trees are defined as Potential, Immediately Suitable, or Currently Suitable Roost Trees in the LRMP and as Potential Roost Trees in the BA. Of the 20 tree species commonly harvested on the DBNF, 13 species are considered potential roost tree species. Based on information provided in the BA (as supplemented) for an average timber harvest, these 13 species (e.g., mostly oaks, elm, and yellow poplar) would make up about 89 percent of the live trees that would be cut.

With regard to the damaged and/or dead trees, it is the physical condition of the tree, not the tree species, which make these trees suitable for Indiana bat roosting. Stochastic events, such as lightning strikes or pest outbreaks, and other disturbances create and distribute trees in this condition across the forest. The Standards (conservation measures) proposed by the DBNF differ depending upon whether the silviculture practice being implemented is a green tree harvest or salvage/sanitation harvest. As stated previously, salvage/sanitation harvest projects are designed to remove those damaged and/or dead trees that have desirable roosting characteristics for the Indiana bat, which is not typically the case for green tree harvests. Therefore, specific Standards do not apply to salvage/sanitation harvests that do apply to green tree harvests. For example, Forest-wide Standard DB-WLF-1 requires that all snags equal to or greater than 6 inches diameter-at-breast-height (dbh) and equal to or greater than 10 feet in height be retained within timber harvest, regeneration, and thinning projects, unless identified as an immediate threat to human safety. Although this Standard does not apply to salvage/sanitation harvests for reasons expressed above, other Standards (i.e., DB-WLF-2, 3, and 15, see Appendix B for detailed descriptions) are applied in these harvest units to ensure that adequate numbers of snags suitable for roosting by Indiana bats are retained, created, and appropriately shaded.

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 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 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.

With regard to the likelihood that non-target trees could be cut or otherwise removed (e.g., target tree or heavy equipment knocks down non-target tree), the DBNF's monitoring over the last four years (2000 – 2006) indicates that between 1 and 17 reportable roost trees are accidentally felled on an annual basis. Reportable roost trees are defined in the BA and LRMP. Inspection of these trees has determined that no known harm or mortality has occurred to Indiana bats. Similarly, project-level monitoring on the DBNF indicates that there is no known occurrence of Indiana bat mortality associated with the felling of trees during harvests. Based on this data, we believe that this potential adverse effect is minimal 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 harvest 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 harvest 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 harvest areas will likely be subjected to increased levels of disturbance frequency and intensity. As a result, Indiana bats displaced by harvesting 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 within the action area suggests that they have done so in the past when appropriate conservation measures where applied. More specifically, the DBNF documented in October 1996 that the majority of roost trees used by Indiana bats during the autumn months were located in stands greater than 50 years old with relatively closed canopies (80 to 93 percent canopy cover), in natural canopy gaps that had been formed by the death of one or more canopy trees (primarily from wind or ice damage), and in areas subjected to prescribed burns which had been conducted primarily for red-cockaded woodpecker habitat management. Indiana bats also roosted extensively in 2-age shelterwood harvest areas within which snags and other potential roost trees had been retained, and in high-graded stands with many snags and culls. Similar roost tree use was reported by Gumbert (2001) on the Stearns RD during the spring and summer months.

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 2002). 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 harvesting activities 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 habitat; and (c) the forested area within the action area is expected to increase 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 harvest activities will provide significant long-term benefits to Indiana bat summer foraging and roosting habitat based on the factors and analysis described below.

As stated elsewhere, most harvests and other management on the DBNF will occur within those areas identified as "Habitat Diversity Emphasis" Prescription Areas, which comprises about 375,900 acres of the DBNF. The "Dense Cove Forest" community comprises 112,800 acres or 30 percent of this Prescription Area. This community is described in the LRMP as having a high canopy, moderate to high basal area (70-120 or more square feet/acre) forest, some with and some without well developed vertical structure, mid to old age canopy trees with various components of sub-canopy, mid-story, and shrub layers. Forests meeting this description are typically marginal Indiana bat foraging and roosting habitat, because they are dense, over-stocked, and not easily used by Indiana bats for foraging and/or roosting, at least in large numbers. The implementation of harvest (and/or burning) activities within this community would open up the forest by creating additional small (on localized and landscape scales) gaps in the forest canopy and by simplifying the structure of the forest, thus facilitating use of those stands by Indiana bats for foraging and roosting.

Summer habitat research conducted within the action area over the last decade or more has documented that the Indiana bats utilizing the action area during the summer are found 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. 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).

While green tree and salvage/sanitation harvests have the potential to directly affect Indiana bats (as discussed previously in this section) utilizing trees in the immediate vicinity of their winter hibernacula as summer roosts, the intensity of disturbance to Indiana bats is greatly reduced through additional cave related standards provided in the LRMP. These standards serve to minimize adverse affects to Indiana bats by ensuring that:

(a) A large percentage of the forested habitat within 1 mile of a known significant bat cave is maintained (i.e., DB-WLF-11),
(b) Tree cutting is not conducted during the fall swarming season within 5 miles of a significant Indiana bat hibernacula (i.e., DB-WLF-12), and
(c) No mechanical site preparation and/or construction of new roads, skid trails, or log landings would occur within a minimum zone of 200 feet from any caves, abandoned underground mine portals and their associated underground workings, sinkholes, and cave collapse areas (i.e., DB-WLF-13).

It must be noted that there are a small number of caves within the action area that historically have harbored less than 50 Indiana bats during any single winter hibernation period. While these caves are documented hibernacula they are not classified as "Significant Bat Caves" by the LRMP. We anticipate similar direct effects to occur in the forest immediately surroundings these small hibernacula, as has been discussed previously in this section, and believe that the hibernacula is protected through Forest-wide Standard DB-WLF-13 or the Cliffline Community Prescription Area. Any affects to Indiana bats that would occur outside of the April 1 to September 15 summer activity period (e.g., during the fall swarming season around these unclassified hibernacula) would be identified and considered in the site-specific section 7 consultation with the DBNF and are not considered further in this biological opinion.

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 (i.e. immediately after the harvest, the forest begins to improve) 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 harvested by fire or accidentally knocked down; however, on a programmatic level these activities could 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 green tree and salvage/sanitation harvests cause adverse effects to Indiana bats;
(b) The fact that all green tree and salvage/sanitation harvests will be undertaken using a harvest prescription that avoids and minimizes the potential for adverse effects to Indiana bats through incorporation of the LRMP's Standards, Goals, and Objectives;
(c) All green tree and salvage sanitation harvests are unlikely to occur in occupied summer habitat; and
(d) Those harvests that do occur in occupied summer habitat are unlikely to result in consistent and predictable adverse effects due to differences in harvest prescriptions (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).

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

If green tree harvests and salvage/sanitation harvests were implemented at the proposed maximum thresholds, about 4,350 acres would be affected each year, and the DBNF has asked for incidental take authorization for that same acreage. We believe, however, that this assumption significantly overestimates potential adverse effects to Indiana bats, because it assumes that:

(a) All activities occur in forest types that can be immediately occupied or are occupied by Indiana bats;
(b) All of the habitat within a project area is potentially suitable and/or occupied habitat; and
(c) All harvest 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.

Obviously, this will not be the case, and, further, this acreage would represent less than 1 percent of the potentially suitable habitat (693,726 acres) on the DBNF if maximum management targets are achieved.

So, even though potential adverse effects to summer roosting and foraging bats may occur when proposed harvests occur, the overall potential adverse effects resulting from harvests are reduced significantly by several important factors:

(A) Nearly half of the DBNF would not have harvest as an objective under the LRMP due to Prescription Area restrictions. Most harvests would occur in the "Habitat Diversity Emphasis" Prescription Area, which comprises 375,900 acres or 54 percent of the DBNF (and a correspondingly smaller percentage of the action area). Other Prescription Areas, such as the "Cliffline", "Designated Old Growth", and "Riparian Area" Prescription Areas, would not be subject to regularly scheduled harvests except for up to 4 percent (or

5,514 acres) of the "Riparian Area" that has been identified as "Uneven-aged" or "Permanent Shrub-sapling Openings".

(B) Not all habitat within the action area and federally owned land comprising the DBNF is suitable Indiana bat habitat. Habitat within the "Habitat Diversity Emphasis" Prescription Area is comprised of several communities (i.e., forest habitat types), not all of which are 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.

(C) Implementation of the Standards will minimize potential adverse effects to Indiana bats on those areas that are proposed for harvest. The Standards in Appendix B will avoid and/or minimize adverse effects to Indiana bats by limiting the opportunity for adverse effects and by ensuring that Indiana bat summer and winter habitat is protected or provided. Standards DB-WLD-1 through 9, 11, and 12 protect, maintain and/or enhance Indiana bat habitat associated with green tree harvests, and Standards DB-WLD-2 through 5, 8, 11, and 12 are designed to protect the Indiana bat or enhance its habitat during salvage/sanitation harvests. Thus, suitable roosting habitat is retained within all green tree and/or salvage/sanitation project areas and is generally not considered to be a limiting factor for the Indiana bat on the DBNF.

(D) 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 removal of unoccupied trees and trees in unoccupied habitat will be inconsequential. The available survey and life history information for the species within the action area show that Indiana bats do not use all Potential Roost Trees within their home ranges. Therefore, Indiana bats will use only a very small proportion of the Potential Roost Trees that may be harvested, which means that potential adverse effects will be limited.

(E) Indiana bats do not occur ubiquitously or in a uniform distribution across the DNBF. There are only 64 known sites for the species within the action area and most of those sites are hibernation records. In addition, winter and summer site records are not uniformly distributed across the DBNF or even within individual RDs, which suggests that potential adverse effects will be localized.

(F) 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 harvest methodologies would encourage this type of habitat throughout the DBNF while simultaneously providing sufficient numbers of Potential Roost Trees.

(G) None of the proposed forest management actions would involve the complete removal of suitable Indiana bat habitat but would, instead, involve the gradual modification of forest stands to the Desired Future Condition while maintaining suitable roosting and foraging habitat conditions on affected stands. The DBNF estimates that (a) a high percentage of the DBNF will provide suitable snag habitat conditions, with a projected increase in the number of acres meeting suitable snag habitat conditions over the life of the LRMP; (b) at projected harvest rates, the creation of roosts through annual natural tree mortality will offset any subsequent loss of live potential or dead roost trees; and (c) the overall forest stand age of the DBNF is increasing, which indicates that, as stands get older, there will be a greater number of larger-diameter potential roost trees available, which are preferred by Indiana bats.

Direct Effects of Prescribed Burning - In any prescribed burn, a number of activities that occur may 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 include:

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

These activities are listed in the order in which they typically occur and are discussed in detail in the BA and its supplements and in the Description of Prescribed Burning section above. 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.

The direct effects that may occur because of prescribed burns could result from the 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. Similar to timber harvest actions discussed above, 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.

Roosting Indiana bats have the potential to be harmed and/or harassed by both the smoke and fire associated with prescribed burns. Roosting bats may flush from their roost 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 the DBNF, as are rain and windstorms. Historically, management actions have combined to suppress the occurrence of fire on the DBNF. 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.

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. To minimize the potential for this type of take to occur the LRMP has a Standard designed to protect young Indiana bats during their flightless period (DB-FIRE-8), which ensures that no prescribed burning will occur within known Indiana bat roosting areas from May 1 through July 31. 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 from the DBNF 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 (Tables 6 and 7).

The DBNF also attempts to avoid impacting roosting bats by determining if roosting occurs in the area. This monitoring is done as part of the project-specific analysis associated with each prescribed burning project from May 1 to July 31. Known roosting areas are determined in several ways prior to conducting burns in suitable roosting habitat during the above time period. If Indiana bats are present in the area, it is assumed that they are females and, during this period of the year, have young. Methods include, but are not limited to: (a) reviewing past research and monitoring records for Indiana bat roosting areas; (b) on-site review of the project area to determine if suitable roosting habitat is currently present; and (c) monitoring the area according to the Service's mist net survey protocols to determine if Indiana bats are using the area.

Additional direct effects that may occur as a result of prescribed fire could result from the disturbance of roosting 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. This 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.

Additionally, 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. Actions taken during wildfire control are not required to adhere to Standards established in the LRMP. 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 result in harm and/or harassment by altering its normal behavior pattern and possibly making it more susceptible to various predators during the daylight hours or result in mortality.

While prescribed burns have the potential to directly affect Indiana bats that are (a) males utilizing caves and/or abandoned underground mines as summer roosting habitat, (b) swarming around their hibernacula during the fall swarming season, and/or (c) hibernating during the winter within the hibernacula, the intensity of disturbance to Indiana bats is reduced through the inclusion of each "significant bat cave" and a one-half mile radius around each opening within the Significant Bat Cave Prescription Area, the general avoidance of conducting prescribed burns within 5 miles of significant Indiana bat hibernacula from September 1 to December 1 (i.e., 1.J-Objective 1.B.), and additional cave related standards provided in the LRMP. These standards serve to minimize adverse affects to Indiana bats by ensuring that the existing forest cover is left undisturbed by management activities unless the activity is designed to improve habitat for species like the Indiana bat (i.e., DB-VEG-1) and no tractor-constructed fire lines for prescribed fire would occur within a minimum zone of 200 feet from any caves, abandoned underground mine portals and their associated underground workings, sinkholes, and cave collapse areas (i.e., DB-WLF-13). Additionally, there are a small number of caves within the action area that historically have harbored less than 50 Indiana bats during any single winter hibernation period. While these caves are documented hibernacula they are not classified as "Significant Bat Caves" by the LRMP. We anticipate similar direct effects to occur in the forest immediately surroundings these small hibernacula as has been discussed previously in this section and believe that the hibernacula is protected through Forest-wide Standard DB-WLF-13. It is important to note that any affects to Indiana bats using any cave and/or habitat within 5 miles of the cave (whether it is designated as a Significant Bat Cave or not) as summer roosting habitat, fall swarming habitat, and/or a winter hibernacula would be identified and considered in the site-specific section 7 consultation with the DBNF and are not considered further in this biological opinion.

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 (i.e. immediately after the fire, the forest begins to improve) 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, on a programmatic level these activities could 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 prescribed fires cause adverse effects to Indiana bats;
(b) The fact that all prescribed burns will be undertaken using a burning prescription that avoid and minimizes the potential for adverse effects to Indiana bats through incorporation of the LRMP's Standards, Goals, and Objectives;
(c) All prescribed fires are unlikely to occur in occupied summer habitat; and
(d) Those fires that do occur in occupied summer habitat are 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) 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).

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

If prescribed fires were implemented at the proposed maximum thresholds, about 50,000 acres would be affected each year, and the DBNF has asked for incidental take authorization for that same acreage. We believe, however, that this assumption significantly overestimates potential adverse effects to Indiana bats, because it assumes that:

(a) All burning activities occur in forest types that can be immediately occupied or are occupied by Indiana bats;
(b) All of the habitat within a proposed burning area is potentially suitable and/or occupied habitat; and
(c) All burning 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.

Obviously, this will not be the case, and, further, this acreage would represent 7.5 percent of the potentially suitable habitat (693,726 acres) on the DBNF if maximum management targets are achieved.

So, even though potential adverse effects to summer roosting and foraging bats may occur when proposed prescribed burns occur, the overall potential adverse effects resulting from burning are reduced significantly by several important factors:

(A) Not all habitat within the action area and federally owned land comprising the DBNF is suitable Indiana bat habitat. Habitat within many of the Prescription Areas where burning would be conducted is comprised of several communities (i.e., forest habitat types), not all of which are 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) Implementation of the Standards will minimize potential adverse effects to Indiana bats on those areas that are proposed for burning. The Standard DB-FIRE-8 in Appendix B will avoid and/or minimize adverse effects to Indiana bats by limiting the opportunity for adverse effects and by ensuring that Indiana bat summer maternity habitat is protected. Thus, suitable roosting habitat is retained and improved within all burning project areas and is generally not considered to be a limiting factor for the Indiana bat on the DBNF.
(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 within the action area 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 prescribed fires is low.
(D) Indiana bats do not occur ubiquitously or in a uniform distribution across the DNBF. There are only 64 known sites for the species within the action area and most of those sites are hibernation records. In addition, winter and summer site records are not uniformly distributed across the DBNF or even within individual RDs, which suggests that potential adverse effects from fires will be localized where they may occur.

(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 prescribed fire would encourage this type of habitat throughout the DBNF while simultaneously providing sufficient numbers of Potential Roost Trees through the maintenance and/or creation of Potential Roost Trees (e.g., snags).

(F) None of the proposed forest management actions would involve the complete removal of suitable Indiana bat habitat but would, instead, involve the gradual modification of forest stands to the Desired Future Condition while maintaining suitable roosting and foraging habitat conditions. The DBNF estimates that (a) a high percentage of the DBNF will provide suitable snag habitat conditions, with a projected increase in the number of acres meeting suitable snag habitat conditions over the life of the LRMP that can be attributed to snag creation through the use of prescribed fires; and (b) the overall forest stand age of the DBNF is increasing, which indicates that, as stands get older, there will be a greater number of larger-diameter potential roost trees available, which are preferred by Indiana bats.

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). For example, private timber-harvesting or prescribed burning activities outside the DBNF but within the action area would only be considered as interrelated or interdependent if a determination was made that these activities would not occur but for implementation of the LRMP. There is no justification for claiming that other harvesting or burning activities on adjacent land occurred due to the implementation of the LRMP; therefore, these actions outside the boundaries of the DBNF 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 second level, 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 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.

Species response to a proposed action

Numbers of individuals/populations in the action area affected

The action area harbored about 15,600 Indiana bats during the 2005-2006 winter hibernation period. According to our records, the Indiana bat is known from a number of locations within the action area, with at least 64 known capture locations within the proclamation boundary. Most of the records are from caves, which harbor anywhere from a few occasional individuals to several thousand Indiana bats each winter, but 9 locations are summer records of males (n=3), females (n=3), unknown sex (n=3), and juveniles (n=4). However, based on the small number of summer capture records and the few known maternity colonies within the action area, we believe that most of the Indiana bats that hibernate within the action area and, therefore, are most likely to use the action area for summer habitat due to proximity, migrate to locations outside of the action area in summer. The available capture data also indicate that the bats are not uniformly distributed across the DBNF or even within individual RDs, which suggests that potential adverse effects from green tree harvests, salvage/sanitation harvests, and prescribed fires would be localized where they may occur.

Given the fact that the Indiana bats within the action area are all part of a single population (see related discussion in the Status of the Species section) and that the potential adverse affects from the proposed action would be localized, we do not expect the affects of the proposed action to impact a large number of individuals. This is due to many reasons including, but not limited to, (a) implementation of the standards (conservation measures) in the LRMP, (b) protection of summer habitat of all known maternity colonies within the action area, and (c) the low number of maternity colonies identified within the action area and anticipated to exist within the action area.

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

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

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

Recovery Rate – We expect the time required for individual Indiana bats, the Indiana bat population with the action area, and the affected Indiana bat habitat to return to equilibrium after implementation of the proposed action to be negligible. Most adverse effects associated with the proposed action are of temporary and/or of short duration as discussed elsewhere in the Analyses for Effects of the Action section. Longer-term effects tend to be largely beneficial to the species and its habitat within the action area.

CUMULATIVE EFFECTS

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

Most activities that are likely to occur on private lands within the action area would likely be small in scale, because most properties are less than 200 acres. There is substantial evidence that previous forestry-related activities have occurred within the action area and may continue to occur. However, the Service does not know of any specific actions in the action area that are reasonably certain to occur, and data from the National Forest Service (USFS 2002) indicates that the forested area within the Northern Cumberland Plateau (which contains the action area) is projected to increase through the year 2020. Based on the USFS's Southern Forest Resource Assessment (Figure 6.17(a) on page 169 and Figure 6.18 A and B on Page 170) (USFS 2002), the counties that constitute the action area are presently among the most heavily forested areas and contain the least fragmented forests in the United States. Furthermore, the USFS projects that this area is likely to remain heavily forested throughout the projected time period (2020). As a result, we anticipate that much of the action area, and potentially more of the action area, is expected to remain forested, which will likely benefit the Indiana bat by retaining and/or providing suitable habitat.

CONCLUSION

After reviewing the current status of the Indiana bat; the environmental baseline for the action area; the effects of the proposed forest management activities associated with green tree harvests, salvage/sanitation harvests, and prescribed burning; and the cumulative effects of the proposed action, it is the Service's biological opinion that implementation of the revised DBNF LRMP and the associated activities related to green tree harvests, salvage/sanitation harvests, and prescribed burning are not likely to jeopardize the continued existence of the Indiana bat. Critical habitat for the Indiana bat has been designated at a number of locations throughout its range, however, this action does not affect any of those designated critical habitat areas and no destruction or adverse modification of that critical habitat is expected.

Because of our analysis, we do not believe that the proposed action "would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of [the Indiana bat] by reducing the reproduction, numbers, or distribution of [the Indiana bat] (50 CFR 402)." In fact, we believe that neither survival nor recovery will be reduced appreciably for reasons summarized later in this section. Furthermore, the expected outcome of the DBNF's proposed management direction under the LRMP would primarily be beneficial to Indiana bats and their habitat through the protection of hibernacula, the improvement and maintenance of summer roosting and foraging habitat across the DBNF through proposed management activities, and the continual replacement of potentially suitable forested habitat on the DBNF (i.e., habitat alteration/loss will not be permanent). These are all important aspects of the proposed action that are expected to benefit the species, improve its chances for recovery, and ensure its survival within the action area and within its range as a whole.

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

(a) The species' resiliency to natural and anthropogenic disturbances has been demonstrated (See Previous Incidental Take Authorizations and Status of the Species in the Action Area sections above). We believe that the proposed 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. 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 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).

(b) The primary threats to the Indiana bat's recovery (Service 1983) are destruction and alteration of species' winter hibernation habitat and disturbance of Indiana bats while they occupy that winter habitat. The proposed action does not result in any significant adverse effects on Indiana bat winter habitat, but some minor adverse effects could occur near insignificant hibernacula (termed "unclassified hibernacula" as discussed in the Direct Effects of Green Tree and Salvage/Sanitation Harvests and Direct Effects of Prescribed Burning sections above). "Significant bat caves", as defined in the LRMP, contain or have contained at least 50 hibernating Indiana bats and are protected from adverse effects by several LRMP Standards as described in the Direct Effects of Green Tree and Salvage/Sanitation Harvests and Direct Effects of Prescribed Burning sections above. In addition, the Cliffline Community (111,200 acres) and Significant Bat Cave (6,100 acres) Prescription Areas were created, in part, with habitat maintenance and/or improvements for the Indiana bats in mind. Generally, habitat management in these areas is limited and is primarily designed to improve conditions for species associated with these prescription areas. For example, an objective (1.J-Objective 1.B) within the Significant Bat Cave Prescription Area specifically limits the occurrence of prescribed burning within five miles of these cave openings during the fall swarming season

(September 1 to December 1), and Standard DB-WLF-12 limits tree cutting with the same areas.

(c) The proposed action is unlikely to result in the loss of Indiana bat maternity colonies. Because maintenance of existing maternity colonies and the creation of new maternity colonies (i.e., evidence of population growth and/or improved habitat conditions) are likely important factors that affect the species' recovery potential, we have identified a number of factors related to the proposed action and discussed in the Status of the Species and Analyses for Effects of the Action sections that lead us to believe that the proposed action will not result in significant losses of individual Indiana bats, and especially maternity colonies. The resiliency to disturbance shown by Indiana bat maternity colonies (See Previous Incidental Take Authorizations and Status of the Species in the Action Area sections above) is one such factor, which was discussed in (a) above. However, other factors that are designed to protect and/or conserve Indiana bat maternity colonies include Forest-wide Standards DB-WLF-1 (i.e., most larger snags are retained except in salvage/sanitation harvests and for safety considerations), DB-WLF-2 (i.e., large snags are retained or created in all harvests), DB-WLF-3 (i.e., live trees are retained to partially shade snags), DB-WLF-4 (i.e., maintain a minimum amount of live potential roost trees), DB-WLF-5 (i.e., leave edges for foraging); DB-WLF-6 (i.e., retain large hickories as roost trees), DB-WLF-7 (i.e., retain any immediate roost trees), DB-WLF-8 (i.e., no cutting within 2.5 miles of a known Indiana bat maternity colony from May 1 to August 15), DB-WLF-9 (i.e., winter felling of suitable roost trees), DB-WLF-15 (i.e., create or retain at least 1 snag per acre), and DB-FIRE-8 (i.e., no burning while juvenile Indiana bats are non-volant).

For the proposed action to "reduce appreciably" the Indiana bat's survival, the proposed action would have to impede or stop the condition in which a species continues to exist into the future while retaining the potential for recovery (Service and NMFS 1998, page 4-35). We do not believe the proposed project impedes or stops the condition in which the Indiana bat continues to exist while retaining the potential for recovery, because any incidental take that may occur is typically not a loss of individuals (especially maternity colonies) or a loss of habitat. It is, instead, a modification of existing habitat that results in either more suitable habitat for Indiana bats within the action area or the short-term (i.e., marginal habitat is made suitable) or long-term (i.e., management sets the stage for the habitat to become suitable in the future) creation of improved habitat for Indiana bats. A couple of primary relationships are likely.

First, all currently suitable habitat that is treated, either through harvest or burning, is expected to continue to be suitable Indiana bat habitat because application of the DBNF's management actions will not remove the habitat, and all currently unsuitable habitat that is treated is expected to either become suitable habitat as a result of management actions or remain unsuitable habitat. Second, all currently occupied habitat that is treated is expected to remain occupied Indiana bat habitat because application of the DBNF's management actions will not result in significant or long-term losses of Indiana bats, and all currently unoccupied habitat that is treated is expected to either become occupied as a result of management actions or remain unoccupied habitat. Incidental take was anticipated in this case not because we knew that adverse effects would occur based on site specific occurrence or other data, but because of the potential that harassment, harm, and some mortality of the species might occur while implementing essentially minor habitat management and improvement projects scattered over a very large action area.

For the reasons listed above and due to the fact that the species' range-wide population numbers are increasing in spite of (a) the previous incidental take that has been allowed and (b) an environmental baseline that includes numerous activities that could result in adverse effects to Indiana bats, we believe that neither the Indiana bat's recovery nor its survival will be reduced appreciably by the short-term adverse affects associated with green tree harvests, salvage/sanitation harvests, and prescribed burns. Where adverse effects will actually occur, the species' ability to persist in the face of these effects is well-documented.

INCIDENTAL TAKE STATEMENT

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

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

AMOUNT OR EXTENT OF TAKE ANTICIPATED

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

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

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

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

4. The extent and density of the species within its summer habitat on the DBNF is unknown; and

5. Implemented actions will not affect all of the available habitat within a project area (i.e., implementation of protective Standards and avoidance measures that the DBNF will implement on a project-specific basis will minimize the amount of incidental take).

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 habitat (a direct effect);

4. Harm and harassment of Indiana bats resulting from activities associated with green tree harvests, salvage/sanitation harvests, and prescribed burning 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 habitat resulting from green tree harvests, salvage/sanitation harvests, and prescribed burning that will be conducted within occupied Indiana bat habitat (a direct effect).

The level of take identified below may result, because the DBNF anticipates and has estimated that up to 4,000 acres of green tree harvest, 350 acres of salvage/sanitation harvest, and 50,000 acres of prescribed burning may occur per year during the summer roosting period of the Indiana bat and because 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 green tree harvests, salvage/sanitation harvests, and prescribed burns on an annual basis. Therefore, the level of take anticipated in this biological opinion is 4,000 acres of green tree harvest, 350 acres of salvage/sanitation harvest, and 50,000 acres of prescribed burns annually when accomplished during the summer roosting period (April 1 to September 15).

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

(a) All activities occur in forest types that can be immediately occupied by Indiana bats,
(b) All of the habitat within a project area is potentially suitable and/or occupied habitat, and
(c) All activities are completely deleterious and result in complete loss of habitat values for Indiana bats within a project area.

In contrast, the Service knows that:

(a) Indiana bats do not occur ubiquitously or in a uniform distribution across the DNBF based on negative survey data;
(b) There are only 64 known sites for the species on the DBNF – most of which are hibernation records – and both the winter and summer sites are not uniformly distributed across the DBNF or even within RDs;
(c) Not all of the DBNF contains potentially suitable or occupied habitat - some potential habitat is too young, too dense, etc.;
(d) Management of certain forest stands as proposed by the LRMP would improve roosting and foraging habitat for Indiana bats both locally and as a whole within the action area; and
(e) None of the proposed forest management actions would involve the complete removal of suitable Indiana bat habitat but would, instead, involve the gradual modification of forest stands to the Desired Future Condition while maintaining suitable roosting and foraging habitat conditions on affected stands.

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

This incidental take statement anticipates the taking of Indiana bats only from the actions associated with green tree harvests, salvage/sanitation harvests, and/or prescribed burning activities as described in the DBNF's BA, as supplemented. 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 the LRMP's forest-wide standards, adult or juvenile Indiana bats may be killed (a) during green tree harvests and salvage/sanitation harvests due to the felling of trees, (b) by the effects of smoke and fire during prescribed burns, or (c) by other activities that are associated with green tree harvests, salvage/sanitation harvests, or prescribed burning. 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 prescribed burning 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 the DBNF. Thus, we believe that harassment has the potential to occur in association with any prescribed burn occurring between April 1 and September 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

The Service believes the following reasonable and prudent measures are necessary and proper to minimize impacts of incidental take of the Indiana bat associated with green tree harvests, salvage/sanitation harvests, and prescribed burning. These non-discretionary measures include, but are not limited to, the DBNF's implementation of the Standards found in the revised LRMP and the terms and conditions outlined in this biological opinion.

1. The DBNF must plan, evaluate, and implement the proposed management activities associated with green tree harvests, salvage/sanitation harvests, and prescribed burning in a manner that is consistent with Standards contained in the LRMP 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 associated with green tree harvests, salvage/sanitation harvests, and prescribed burns.

2. The DBNF must monitor its activities associated with green tree harvests, salvage/sanitation harvests, and prescribed burning to determine if the LRMP Standards 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, the DBNF 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 the DBNF associated with green tree harvests, salvage/sanitation harvests, and prescribed burning. These Terms and Conditions are non-discretionary.

1. The DBNF will implement the Standards in a manner that is consistent with the LRMP and as they apply to forest management practices associated with green tree harvests, salvage/sanitation harvests, and prescribed burns that will be implemented annually on the DBNF between April 1 and September 15 of each year:

    a. The DBNF will ensure that immediate roost trees are available either within a proposed harvest or burn area or adjacent to a proposed harvest or burn area by conducting surveys of the available Indiana bat roosting habitat prior to implementation of the harvest or burn. If immediate roost trees are not available within a proposed harvest or burn area, or if immediate roost trees will not be available within the harvest or burn area after treatment, or if immediate roost trees are not and/or will not be available adjacent to a proposed harvest area, the DBNF must either create an immediate roost tree (e.g. girdle) or install one artificial structure (e.g. rocket-style bat box) per ten acres of proposed harvest area, but no fewer than two created roost trees and/or artificial bat structures must be installed per harvest area. If created or artificial structures are used, these habitat improvements must be implemented at least one year in advance of the harvest or burn and must be implemented as close as possible to the harvest or burn area, but must not be located within the harvest or burn 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 harvest or burn and associated activities. The DBNF should monitor, at least three times each summer, the use of these created roost trees/artificial structures for use by Indiana bats for a period of five years beginning with the year of their installation so that monitoring will occur during the Indiana bat's early summer dispersal period, the maternity roosting period, and the late summer/early swarming period.

    b. The DBNF will ensure that the following Standards designed to protect and conserve the Indiana bat and its habitat are incorporated into each green tree harvest and each salvage/sanitation harvest: DB-WLF-1 to DB-WLF-8 and DB-WLF-11 to DB-WLF-12 for green tree harvests, and DB-WLF-2 to DB-WLF-6, DB-WLF-8, DB-WLF-11 to DB-WLF-12 for salvage/sanitation harvests. Further, the DBNF will ensure that the following LRMP provisions, which are designed to protect and conserve the Indiana bat and its habitat, are incorporated into each prescribed burn: DB-Fire-8 and 1.J-Objective 1.B.

    c. During green tree harvests, salvage/sanitation harvests, and prescribed burns, the DBNF 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.

    d. The DBNF will develop specific guidelines for use by DBNF 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 green tree harvests and salvage/sanitation harvests. These guidelines will focus on ensuring that trees that would be considered immediate Indiana bat habitat are retained or created within affected forest stands and that known, occupied roost trees are protected.

2. The DBNF will monitor its implementation of green tree harvests, salvage/sanitation harvests, and prescribed burns to ensure that the Standards are appropriately implemented and must provide the Service with an annual report of its monitoring activities by January 31 of each year:

   a. The DBNF 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, the DBNF 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, the DBNF 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 Standards and related provisions of the LRMP are having the expected effects on Indiana bat habitat by reducing the amount and effect of the take associated with Indiana bat summer roosting habitat. The information will be gathered provided to the Service consistent with the monitoring and reporting requirements set forth in the Service's September 27, 2004 letter.

   b. The DBNF will annually monitor the number of acres that are subjected to green tree harvests, salvage/sanitation harvests, and prescribed burns during the summer roosting season of the Indiana bat (April 1 to September 15). The DBNF will then use these data to determine if the amount of authorized incidental take was exceeded. The DBNF will use the following table and annually provide the Service with this table in the annual report:

Table X. Estimate of Indiana bat incidental take that occurred during [Insert Year] due to implementation of the Daniel Boone National Forest's Land and Resource Management Plan (2004)

<table>
<tr><th rowspan="2">Species</th><th colspan="2">Habitat (acres)</th></tr>
<tr><td>Authorized Level of Habitat Alteration</td><td>Actual Level of Habitat Alteration</td></tr>
<tr><td>Indiana bat - Green Tree Harvest (April 1 to September 15)</td><td>4,000</td><td></td></tr>
<tr><td>Indiana bat – Salvage or Sanitation Harvest (April 1 to September 15)</td><td>350</td><td></td></tr>
<tr><td>Indiana bat – Prescribed Burning (April 1 to April 30)*</td><td rowspan="2">50,000</td><td></td></tr>
<tr><td>Indiana bat – Prescribed Burning (August 1 to September 15)*</td><td></td></tr>
</table>

* Combined incidental take for prescribed burning from April 1 to April 30 and August 1 to September 15 cannot exceed 50,000 acres.

c. The above-listed Terms and Conditions do not take the place of the other Standards listed in the LRMP but are considered in addition to them.

The DBNF and its contractors must take care when handling dead or injured Indiana bats or any other federally listed species that are found in order to preserve biological material in the best possible state and to protect the handler from exposure to diseases, such as rabies. In conjunction with the preservation of any dead specimens, the DBNF 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 4,000 acres of green tree harvests, no more than 350 acres of salvage/sanitation harvest, and no more than 50,000 acres of prescribed burns 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. The DBNF 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 Act directs Federal agencies to use their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. The following conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help carry out recovery plans, or to develop information.

1. The DBNF 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 on the DBNF. In particular, selected project areas should be selected and monitored for Indiana bat roosting and foraging 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 habitat use of project areas compared to non-project areas.

2. Where possible, the DBNF should work with landowners, the public, and other agencies to promote education and information about endangered bats, their habitats, and their conservation.

3. The DBNF hosts many visitors each year. The Service encourages the installation of informational/educational displays regarding all bats occurring on the DBNF. The Service believes that such information would be valuable in informing the public about the value of this misunderstood group of mammals. The Service also encourages the DBNF to develop an educational slide program on Indiana bats and threats to its existence.

4. The DBNF should provide training for appropriate DBNF staff and contractors on the bats (including the Indiana bat) that occur on the DBNF. Training should include sections on bat identification, biology, habitat requirements, and sampling techniques [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 DBNF staff and contractors on bat identification and reliable methods for counting roosting bats will enable the USFS to better monitor the status of this species.

5. The demolition or removal of buildings or other manmade structures that harbor bats should occur while bats are hibernating. If public safety is threatened and the building must be removed while bats are present, a bat expert should examine the building to determine if Indiana bats are present. Consultation with the Service should be initiated if Indiana bats are found.

6. The DBNF should control the spread of invasive species where invasion of such species is likely to result in the loss of suitable Indiana bat habitat.

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

For this biological opinion, the authorized incidental take would be exceeded when the following take monitoring parameters are exceeded:

1) 4,000 acres of green tree harvests,
2) 350 acres of salvage/sanitation harvests, or
3) 50,000 acres of prescribed burning per year during the summer roosting period of the Indiana bat (April 1 to September 15).

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 the Daniel Boone National Forest during this consultation.

This consultation was assigned Project No. 07-B-0580. Please refer to this number in any correspondence concerning this consultation.

If you have any questions concerning this consultation, please contact me at (502) 695-0468 x108 or Mr. Mike Armstrong at (502) 695-0468 x101.

Sincerely,

Virgil Lee Andrews, Jr.
Field Supervisor

cc: Mr. Jerry Perez, Forest Supervisor-DBNF, Winchester, KY
Dr. Jon Gassett, Commissioner-KDFWR, Frankfort, KY
Regional Director, FWS, Atlanta, GA (Mr. Joe Johnston)

LITERATURE CITED

Anthony, E.L.P. 1988. Age determination. Pp. 47-57 *in* T.H. Kunz (ed.), Ecological and behavioral methods for the study of bats. Smithsonian Institution Press, Washington, D.C.

Bakken, G.S. and T.H. Kunz. 1988. Microclimate methods. Pp. 303-332 *in* T.H. Kunz (ed.), Ecological and behavioral methods for the study of bats. Smithsonian Institution Press, Washington, D.C.

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

Barclay, R.M.R. and L.D. Harder. 2003. Life histories of bats: life in the slow lane. Pp. 209-253 *in* T.H. Kunz and M.B. Fenton (eds)., Bat ecology. University of Chicago Press; Chicago, IL.

Barclay, R.M.R., J. Ulmer, C.J.A. MacKenzie, M.S. Thompson, L. Olson, J. McCool, E. Cropley, and G. Poll. 2004. Variation in reproductive rate of bats. Canadian Journal of Zoology 82:688-693.

Barclay, R. M. R. and A. Kurta. In press. Ecology and behavior of bats roosting in tree cavities and under bark. *In* M.J. Lacki, J.P. Hayes, and A. Kurta (eds), Bats in forests: conservation and management. Johns Hopkins University Press, Baltimore, MD. (Scheduled for publication in Summer 2007).

Batulevicius D., N. Pauziene, and D.H. Pauza. 2001. Dental incremental lines in some small species of the European vespertilionid bats. Acta Theriologica 46: 33-42.

Belwood, J.J. 2002. Endangered bats in suburbia: observations and concerns for the future. Pp. 193-198 *in* A. Kurta and J. Kennedy (eds.), The Indiana bat: biology and management of an endangered species. Bat Conservation International, Austin, TX.

Blatchley, W.S. 1897. Indiana caves and their fauna. Indiana Department of Geological and Natural Resources Annual Report 21:121-212.

Bowles, J.B. 1981. Ecological studies on the Indiana bat in Iowa. Central College, Pella, IA. 28 pp.

Bowles, J.B. 1983. The nonhibernating ecology of bats in Indiana with emphasis on the endangered Indiana bat, *Myotis sodalis*. Ph.D. Dissertation, Purdue University, Lafayette, IN. 280 pp.

Brack, V., Jr. 2005. The biology and life history of the Indiana bat: hibernacula. Pp. 7-14 *in* K.C. Vories and A. Harrington (eds.), The Proceedings of the Indiana bat and coal mining: a technical interactive forum Office of Surface Mining, U.S. Department of the Interior, Alton, IL. Available at: http://www.mcrcc.osmre.gov/PDF/Forums/Bat%20Indiana/TOC.pdf. (Accessed October 17, 2006).

Brack, V. Jr. 2006. Autumn activities of *Myotis sodalis* (Indiana bat) in Bland County, Virginia. Northeastern Naturalist 13(3):421-434

Brack, V., Jr. In press. Diet and foraging activity of the Indiana bat, *Myotis sodalis*, in Indiana. Northeastern Naturalist.

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

Brack, V., Jr. and J.O. Whitaker, Jr. 2004. Bats of the Naval Surface Warfare Center at Crane, Indiana. Proceedings of the Indiana Academy of Science 113:66-75.

Brack, V., Jr., A.M. Wilkinson, and R.E. Mumford. 1984. Hibernacula of the endangered Indiana bat in Indiana. Proceedings of the Indiana Academy of Science 93:463-468.

Brack, V., Jr., S.A. Johnson, and R.K. Dunlap. 2003. Wintering populations of bats in Indiana, with emphasis on the endangered Indiana myotis, *Myotis sodalis*. Proceedings of the Indiana Academy of Science 112:61-74

Brack, V., Jr., S. Johnson, and C. Stihler. 2005a. Winter hibernacula temperatures used by Indiana bats in: (1) caves in Indiana; (2) a mine in Preble County, Ohio; (3) caves in West Virginia; and (4) caves in Bland County, Virginia. Report prepared for the Indiana Bat Risk Assessment Workshop, Shepherdstown, West Virginia.

Brack, V., Jr., J.O. Whitaker, Jr., and S.E. Pruitt. 2004. Bats of Hoosier National Forest. Proceedings of the Indiana Academy of Science 113:76-86.

Brack, V., Jr., C.W. Stihler, R.J. Reynolds, C.M. Butchkoski, and C.S. Hobson. 2002. Effect of climate and elevation on distribution and abundance in the mideastern United States. Pp. 21-28 *in* A. Kurta and J. Kennedy (eds.), The Indiana bat: biology and management of an endangered species. Bat Conservation International, Austin, TX.

Brenner, F.J. 1973. Influence of daily arousal on body composition of two species of *Myotis* (Mammalia: Chiroptera). Proceedings of the Pennsylvania Academy of Science 47:77-78

Britzke, E.R. 2003. Spring roosting ecology of female Indiana bats (*Myotis sodalis*) in the Northeastern United States. Report prepared for the U.S. Fish and Wildlife Service, Concord, NH.

Britzke, E.R., M.J. Harvey, and S.C. Loeb. 2003. Indiana bat, *Myotis sodalis*, maternity roosts in the southern United States. Southeastern Naturalist 2:235-242.

Britzke, E.R., A.C. Hicks, S.L. von Oettingen, and S.R. Darling. 2006. Description of spring roost trees used by female Indiana Bats (*Myotis sodalis*) in the Lake Champlain Valley of Vermont and New York. American Midland Naturalist 155:181-187.

Butchkoski, C.M. and J.D. Hassinger. 2002. Ecology of a maternity colony roosting in a building. Pp. 130-142 *in* A. Kurta and J. Kennedy (eds.), The Indiana bat: biology and management of an endangered species. Bat Conservation International, Austin, TX.

Butchkoski, C.M. and G. Turner. 2006. Indiana bat (*Myotis sodalis*) summer roost investigations. Project 06714 Annual Job Report. Pennsylvania Game Commission, Bureau of Wildlife Management, Research Division, Harrisburg, PA.

Callahan, E.V., III. 1993. Indiana bat summer habitat requirements. M.S. Thesis, University of Missouri, Columbia, MO.

Callahan, E.V., R.D. Drobney, and R.L. Clawson. 1997. Selection of summer roosting sites by Indiana bats (*Myotis sodalis*) in Missouri. Journal of Mammalogy, 78:818-825.

Carter, T.C. 2003. Summer habitat use of roost trees by the endangered Indiana bat (*Myotis sodalis*) in the Shawnee National Forest of southern Illinois. Dissertation. Southern Illinois University, Carbondale, IL.

Carter, T.C. 2005. Summer habitat assessment. Pp. 81-87 *in* K.C. Vories and A. Harrington (eds.), The Proceedings of the Indiana bat and coal mining: a technical interactive forum Office of Surface Mining, U.S. Department of the Interior, Alton, IL. Available at: http://www.mcrcc.osmre.gov/PDF/Forums/Bat%20Indiana/TOC.pdf. (Accessed October 17, 2006).

Carter, T.C., G. Feldhamer, and J. Kath. 2001. Notes on summer roosting of Indiana bats. Bat Research News 42:197-198.

Chenger, J. 2003. Iowa Army Ammunition Plant 2003 Indiana bat investigations. Unpublished report. Iowa Army Ammunition Plant, Middletown, IA.

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

Clawson, R.L. 2002. Trends in population size and current status. Pp. 2-8 *in* A. Kurta and J. Kennedy (eds.), The Indiana bat: biology and management of an endangered species. Bat Conservation International, Austin, TX

Clawson, R.L., R.K. LaVal, M.L. LaVal, and W. Caire. 1980. Clustering behavior of hibernating *Myotis sodalis* in Missouri. Journal of Mammalogy 61:245-253.

Cope, J.B., and S.R. Humphrey. 1977. Spring and autumn swarming behavior in the Indiana bat, *Myotis sodalis*. Journal of Mammalogy 58:93-95.

Cope, J.B., A.R. Richter, and R.S. Mills. 1974. Concentrations of the Indiana bat, *Myotis sodalis*, in Wayne County, Indiana. Proceedings of the Indiana Acadamy of Science 83:482-484.

Cronin, J.T. 2003. Movement and spatial population structure of a prairie planthopper. Ecology 84:1179-1188.

Davies, W. E. 1970. Karstlands and cavern areas. The national atlas of the United States of America: United States Department of the Interior, Geological Survey

Dunbar, M.B. and T.E. Tomasi. In press. Arousal patterns, metabolism, and a winter energy budget of eastern red bats (*Lasiurus borealis*). Journal of Mammalogy.

Easterla, D.A., and L.C. Watkins. 1969. Pregnant *Myotis sodalis* in northwestern Missouri. Journal of Mammalogy 50:372-373.

Farmer, A.H., B.S. Cade, and D.F. Staufer. 2002. Evaluation of a habitat suitability index model. Pp. 172-179 *in*. Kurta and J. Kennedy (eds.), The Indiana bat: biology and management of an endangered species. Bat Conservation International, Austin, TX.

Fenton, M.B. and G.K. Morris. 1976. Opportunistic feeding by desert bats (*Myotis* spp.). Canadian Journal of Zoology 54:526-530.

Foster, R. and A. Kurta. 1999. Roosting ecology of the northern bat (*Myotis septentrionalis)* and comparisons with the endangered Indiana bat (*Myotis sodalis*). Journal of Mammalogy 80:659-672.

Gardner, J.E. and E.A. Cook. 2002. Seasonal and geographic distribution and quantification of potential summer habitat. Pp. 9-20 *in* A. Kurta and J. Kennedy (eds.), The Indiana bat: biology and management of an endangered species. Bat Conservation International, Austin, TX.

Gardner, J.E., J.D. Garner, and J.E. Hofmann. 1989. A portable mist netting system for capturing bats with emphasis on *Myotis sodalis* (Indiana bat). Bat Research News 30(1):1-8.

Gardner, J.E., J.D. Garner, and J.E. Hofmann. 1991a. Summer roost selection and roosting behavior of *Myotis sodalis* (Indiana bat) in Illinois. Final report. Illinois Natural History Survey, Illinois Department of Conservation. Champaign, IL.

Gardner, J.E., J.D. Garner, and J.E. Hofmann. 1991b. Summary of *Myotis sodalis* summer habitat studies in Illinois: with recommendations for impact assessment. Special report. Illinois Natural History Survey, Illinois Department of Conservation Champaign, IL.

Gardner, J.E., J.E. Hofmann, and J. D. Garner. 1996. Summer distribution of the Federally endangered Indiana bat (*Myotis sodalis*) in Illinois. Transactions of the Illinois State Academy of Science 89:187-196.

Garner, J.D., and J.E. Gardner. 1992. Determination of summer distribution and habitat utilization of the Indiana bat (*Myotis sodalis*) in Illinois. Unpublished Report. Endangered Species Coordinator, Region 3, Service, Twin Cities, MN.

Geiser, F. 2004. Metabolic rate and body temperature reduction during hibernation and daily torpor. Annual Reviews of Physiology 66:239-74.

Geiser, F. and R.L. Drury. 2003. Radiant heat affects thermoregulation and energy expenditure during rewarming from torpor. Journal of Comparative Physiology B 173:55-60.

Grindal, D.R. 1996. Habitat use by bats in fragmented forests. Pp. 260-272 *in* R. Barclay and R. Brigham (eds.), Bats and forests symposiums. British Columbia Ministry of Forest, Victoria, BC, Canada. 292 pp.

Grindal, S.D., T.S. Collard, R.M. Brigham, and R.M.R. Barclay. 1992. The influence of precipitation on reproduction by *Myotis* bats in British Columbia. American Midland Naturalist 128:339-344.

Gumbert, M.W. 2001. Seasonal roost tree use by Indiana bats in the Somerset Ranger District of the Daniel Boone National Forest, Kentucky. MS Thesis. Eastern Kentucky University.

Gumbert, M.W., J.M. O'Keefe, and J.R. MacGregor. 2002. Roost fidelity in Kentucky Pp. 143-152 *in* A. Kurta and J. Kennedy (eds.), The Indiana bat: biology and management of an endangered species Bat Conservation International, Austin, TX.

Gustafson, A.W. 1975. A study of the annual male reproductive cycle in a hibernating vespertilionid bat (*Myotis lucifugus*) with emphasis on the structure and function of the interstitial cells of Leydig. Ph.D. Dissertation. Cornell University, Ithaca, NY.

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

Hall, E.R. 1981. The Mammals of North America. Vol. I. John Wiley and Sons, New York.

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

Hanski, I. 1998. Metapopulation dynamics. Nature 396:41-49.

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

Harvey, M.J. 2002. Status and ecology in the southern United States. Pp. 29-34. *in* A. Kurta and J. Kennedy (eds.), The Indiana bat: biology and management of an endangered species. Bat Conservation International, Austin, Texas.

Hawkins, J.A. and V. Brack, Jr. 2004. Habitat Conservation Plan: 2003 telemetry study of autumn swarming behavior of the Indiana bat (*Myotis sodalis*). Report prepared for the Indiana Department of Natural Resources, Indianapolis, IN.

Hawkins, J.A., J. Jaskula, A. Mann, and V. Brack, Jr. 2005. Habitat Conservation Plan: 2004 telemetry study of autumn swarming behavior of the Indiana bat (*Myotis sodalis*). Report prepared for the Indiana Department of Natural Resources, Indianapolis, IN.

Hayes, J.P. 2003. Habitat ecology and conservation of bats in western coniferous forests. Pp. 81-119 *in* C.J. Zabel and R.G. Anthony (eds.), Mammal community dynamics in coniferous forests of western North America: management and conservation.

Henshaw, R.E. 1965. Physiology of hibernation and acclimatization in two species of bats (*Myotis lucifugus* and *Myotis sodalis*). Ph.D. Dissertation. University of Iowa, Iowa City, IA.

Henshaw, R.E. 1970. Thermoregulation in bats. Pp. 188-232 *in* B.H. Slaughter and D.W. Walton (eds.), About bats: a chiropteran biology symposium. Southern Methodist University Press, Dallas, TX.

Herreid, C.F. 1964. Bat longevity and metabolic rate. Experimental Genetics 1:1-9.

Hicks, A. 2003. Indiana Bat (*Myotis sodalis*): Protection and management in New York State. endangered species investigations performance report. Prepared for project number W-166-E Segment 2002-2003, New York Department of Environmental Conservation.

Hicks, A. 2004. Indiana Bat (*Myotis sodalis*): Protection and management in New York State. endangered species investigations performance report. Prepared for project number W-166-E Segment 2003-2004, New York Department of Environmental Conservation.

Hicks, A.C. and P.G. Novak. 2002. History, status, and behavior of hibernating populations in the northeast. Pp. 35-47 *in* A. Kurta and J. Kennedy (eds.), The Indiana bat: biology and management of an endangered species. Bat Conservation International, Austin, TX.

Hobson, C.R., and J.N. Holland. 1995. Post-hibernation and foraging habitat of a male Indiana bat, *Myotis sodalis* (Chiroptera: Vespertillionidae), in western Virginia. Brimleyana 23:95-101.

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

Humphrey, S.R. and J.B. Cope. 1976. Population ecology of the little brown bat, *Myotis lucifugus*, in Indiana and north-central Kentucky. Special publications of the American Society of Mammalogists 4:1-81.

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

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

Humphries, M.H., D.W. Thomas, and J.R. Speakman. 2002. Climate-mediated energetic constraints on the distribution of hibernating mammals. Nature 418: 313-316.

Kath, J.A. 2002. An overview of hibernacula in Illinois, with emphasis on the Magazine Mine. Pp. 110-116 *in* A. Kurta and J. Kennedy (eds.), The Indiana bat: biology and management of an endangered species. Bat Conservation International, Austin, TX.

Kerth, G. and B. König. 1999. Fission, fusion, and nonrandom associations in female Bechstein's bats (*Myotis bechsteinii*). Behaviour 136:1187-1202.

Kerth, G., M. Wagner, and B. König. 2001. Roosting together, foraging apart: information transfer about food is unlikely to explain sociality in female Bechstein's bats (*Myotis bechsteinii*). Behavioral Ecology and Sociobiology 50:283-291.

Kiser, J.D., and C.L. Elliott. 1996. Foraging habitat, food habits, and roost tree characteristics of the Indiana bat (*Myotis sodalis*) during autumn in Jackson County, Kentucky. Final Report, Kentucky Department of Fish and Wildlife Resources, Frankfort, KY.

King, A. 2006. Deep in the bat cave. Inside Region 3. U.S. Fish and Wildlife Service, Fort Snelling, MN. March 2006. Available at: http://www.fws.gov/midwest/InsideRegion3. (Accessed June 7, 2006).

Kiser, J.D. and C.L. Elliott. 1996. Foraging habitat, food habits, and roost tree characteristics of the Indiana bat (*Myotis sodalis*) during autumn in Jackson County, Kentucky. Report prepared for Kentucky Department of Fish and Wildlife Resources, Nongame Program, Frankfort, KY.

Kiser, J.D., C.L. Elliott, and J. MacGregor. 1996. The use of roost trees by Indiana bats, *Myotis sodalis*, during autumn. Presented at the 6th colloquium on the Conservation of Mammals in the Southern and Central United States.

Krusic, R.A., and C. Neefus. 1996. Habitat associations of bat species in the White Mountains National Forest. Pp. 185-198 *in* Bats and Forests Symposium, October 19-21, 1995, Victoria, British Columbia, Canada (R. M. R. Barclay and R. M. Brigham, eds.) Research Branch, British Columbia Ministry of Forests, Victoria, British Columbia, Working Paper 23/1996:1-292.

Kunz, T.H., J.A. Wrazen, and C.D. Burnett. 1998. Changes in body mass and fat reserves in pre-hibernating little brown bats (*Myotis lucifugus*). Ecoscience 5:8-17.

Kurta, A. 1985. External insulation available to a non-nesting mammal, the little brown bat (*Myotis lucifugus*). Comparative Biochemistry and Physiology 82A:413-420.

Kurta, A. 2000. The bat community in northwestern Lower Michigan, with emphasis on the Indiana bat and eastern pipistrelle. Report submitted to United States Forest Service, Huron-Manistee National Forests, Cadillac, MI.

Kurta, A. 2005. Roosting ecology and behavior of Indiana bats (*Myotis sodalis*) in summer. Pp. 29-42 *in* K.C. Vories and A. Harrington (eds.), Proceedings of the Indiana bat and coal mining: a technical interactive forum. Office of Surface Mining, U.S. Department of the Interior, Alton, IL. Available at: http://www.mcrcc.osmre.gov/PDF/Forums/Bat%20Indiana/TOC.pdf. (Accessed October 17, 2006).

Kurta, A. and R. Foster. 1995. The brown creeper (Aves: Certhiidae): a competitor of tree-roosting bats? Bat Research News 36:6-7.

Kurta, A. and J. Kennedy (eds.). 2002. The Indiana bat: biology and management of an endangered species. Bat Conservation International, Austin, Texas.

Kurta, A. and S.W. Murray. 2002. Philopatry and migration of banded Indiana bats (*Myotis sodalis*) and effects of radio transmitters. Journal of Mammalogy 83:585-589.

Kurta, A. and H. Rice. 2002. Ecology and management of the Indiana bat in Michigan. Michigan Academician 33:361-376.

Kurta, A., and J.A. Teramino. 1994. A novel hibernaculum and noteworthy records of the Indiana bat and eastern pipistrelle (Chiroptera: Vespertilionidae). American Midland Naturalist 132:410-413.

Kurta, A., and J.O. Whitaker, Jr. 1998. Diet of the endangered Indiana bat (*Myotis sodalis*) on the northern edge of its range. American Midland Naturalist 140:280-286.

Kurta, A., J. Caryl, and T. Lipps. 1997. Bats and Tippy Dam: species composition, seasonal use, and environmental parameters. Michigan Academician 24:473-490.

Kurta, A., T.H. Kunz, and K.A. Nagy. 1990. Energetics and water flux of free-ranging big brown bats (*Eptesicus fuscus*) during pregnancy and lactation. Journal of Mammalogy 71:59-65.

Kurta, A., S.W. Murray, and D.H. Miller. 2002. Roost selection and movements across the summer landscape. Pp. 118-129 *in* A. Kurta and J. Kennedy (eds.), The Indiana bat:

biology and management of an endangered species. Bat Conservation International, Austin, TX.

Kurta, A., K.J. Williams, and R. Mies. 1996. Ecological, behavioral, and thermal observations of a peripheral population of Indiana bats (*Myotis sodalis*). Pages 102-117 *in* Bats and Forests Symposium (R. M. R. Barclay and R. M. Brigham, eds.). Research Branch, British Columbia Ministry of Forests, Victoria, British Columbia, Canada, Working Paper 23:1-292.

Kurta, A., G.P. Bell, K.A. Nagy, and T.H. Kunz. 1989. Water balance of free-ranging little brown bats (*Myotis lucifugus*) during pregnancy and lactation. Canadian Journal of Zoology 67:2468-2472.

Kurta, A., J. Kath, E.L. Smith, R. Foster, M.W. Orick, and R. Ross. 1993b. A maternity roost of the endangered Indiana bat (*Myotis sodalis*) in an unshaded, hollow, sycamore tree (*Platanus occidentalis*). American Midland Naturalist 130:405-407.

Lacki, M. J., S. K. Amelon, and M. D. Baker. 2006. Foraging ecology of bats in forests. *In* M.J. Lacki, J.P. Hayes, and A. Kurta (eds), Bats in forests: conservation and management. Johns Hopkins University Press, Baltimore, MD. (Scheduled for publication in Summer 2007).

LaVal, R.K., R.L. Clawson, W. Caire, L.R. Wingate, and M.L. LaVal. 1976. An evaluation of the status of Myotine bats in the proposed Meramec Park Lake and Union Lake project areas, Missouri. Special Report. U.S. Army Corps of Engineers, St. Louis, MO.

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

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

Lee, Y.F. 1993. Feeding ecology of the Indiana bat, *Myotis sodalis*, and resource partitioning with *Myotis keenii* and *Myotis lucifugus*. Unpubl. M.S. Thesis, the University of Tennessee, Knoxville, TN.

Lewis, S.E. 1993. Effect of climatic variation on reproduction by pallid bats (*Antrozous pallidus*). Canadian Journal of Zoology 71:1429-1433.

Menzel, M.A., J.M. Menzel, T.C. Carter, W.M. Ford, and J.W. Edwards. 2001. Review of the forest habitat relationships of the Indiana bat (*Myotis sodalis*). USDA, Forest Service, Northeastern Research Station, General Technical Report NE-284:1-21.

Menzel, J.A., W.M. Ford, M.A. Menzel, T.C. Carter, J.E Gardner, J.D. Garner, and J.E. Hofmann. 2005. Summer habitat use and home-range analysis of the endangered Indiana bat. Journal of Wildlife Management 69:430-436.

Miller, G.S., Jr. and G.M. Allen. 1928. The American bats of the genus *Myotis* and *Pizonyx*. Bulletin of the United States National Museum 114:1-218.

Miller, N.E. 1996. Indiana bat summer habitat patterns in northern Missouri. Unpubl. M.S. Thesis, University of Missouri, Columbia, Columbia, MO.

Miller, N.E., R.D. Drobney, R.L. Clawson, and E.V. Callahan. 2002. Summer habitat in northern Missouri. Pp. 165-171 *in* A. Kurta and J. Kennedy (eds.), The Indiana bat: biology and management of an endangered species. Bat Conservation International, Austin, TX.

Mumford, R.E., and J.B. Cope. 1958. Summer record of *Myotis sodalis* in Indiana. Journal of Mammalogy 39:586-587.

Mumford, R.E. and L.L. Calvert. 1960. *Myotis sodalis* evidently breeding in Indiana. Journal of Mammalogy 41:512.

Mumford, R.E. and J.O. Whitaker, Jr. 1982. Mammals of Indiana. Indiana University Press, Bloomington, IN. 537 pp.

Munson, P. J. and J. H. Keith. 1984. Prehistoric raccoon predation on hibernating *Myotis*, Wyandotte Cave, Indiana. Journal of Mammalogy 65:152-155.

Murray, S.W. 1999. Diet and nocturnal activity patterns of the endangered Indiana bat, *Myotis sodalis*. M.S. Thesis. Eastern Michigan University, Ypsilanti, MI. 77 pp.

Murray, S.W. and A. Kurta. 2002. Spatial and temporal variation in diet. Pp. 182-192 *in* A. Kurta and J. Kennedy (eds.), The Indiana bat: biology and management of an endangered species. Bat Conservation International, Austin, TX.

Murray, S.W. and A. Kurta. 2004. Nocturnal activity of the endangered Indiana bat (*Myotis sodalis).* Journal of Zoology 262:197-206.

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

Nason, E.S. 1948. Morphology of hair of eastern North American bats. The American Midland Naturalist 39:345-361.

O'Donnell, C. 2000. Cryptic local populations in a temperate rainforest bat *Chalinolobus tuberculatus* in New Zealand. Animal Conservation 3:287-297.

Olson, R. 1996. This old cave: the ecological restoration of the historic entrance ecotone of Mammoth Cave, and mitigation of visitor impact. Pp. 87-95 *in* Proceedings of Mammoth Cave National Park's Fifth Science Conference. U.S. National Park Service, Mammoth Cave National Park, Mammoth Cave, KY.

Ormsbee, P.C., J. Kiser, and S.I. Perlmeter. In press. The importance of night roosts to the ecology of forest bats. *In* M.J. Lacki, J.P. Hayes, and A. Kurta (eds), Bats in forests: conservation and management. Johns Hopkins University Press, Baltimore, MD. (Scheduled for publication in Summer 2007).

Osgood, F.L., Jr. 1938. The mammals of Vermont. Journal of Mammalogy 19:435-441.

Palm, J. 2003. Indiana bat (*Myotis sodalis*) summer roost tree selection and habitat use in the Champlain Valley of Vermont. M.S. Thesis. Antioch University, Keene, NH.

Parker, G.R. and C. M. Ruffner. 2004. Current and historical forest conditions and disturbance regimes in the Hoosier-Shawnee Ecological Assessment area. Pp. 23-58 *in* F.R. Thompson III (ed.), The Hoosier-Shawnee Ecological Assessment. General Technical Report NC-244. U.S. Forest Service, North Central Research Station, St. Paul, MN.

Parsons, K.N., G. Jones, and F. Greenaway. 2003. Swarming activity of temperate zone microchiropteran bats: effects of season, time of night and weather conditions. Journal of Zoology(London) 261:257-264.

Racey, P.A. 1982. Ecology of bat reproduction. Pages 57-104 *in* T. H. Kunz (ed.), Ecology of bats. Plenum Press, New York, NY.

Racey, P.A. and A.C. Entwistle. 2000. Life history and reproductive strategies of bats. Pp. 363-414 *in* E.G. Chrichton and P.H. Krutzsch (eds.), Reproductive Biology of Bats. Academic Press, New York., NY.

Racey, P.A. and A.C. Entwistle. 2003. Conservation ecology of bats: reproduction. Pp. 680-743 *in* T.H. Kunz and M.B. Fenton (eds.), Ecology of bats. University of Chicago Press, Chicago, IL.

Ritzi, C.M., B.L. Everson, and J.O. Whitaker, Jr. 2005. Use of bat boxes by a maternity colony of Indiana myotis (*Myotis sodalis*). Northeastern Naturalist 12:217-220.

Rodrigue, J.L. 2004. Biological Asssement: Fernow Experimental Forest. Final Report, USDA Forest Service Northeastern Research Station, Parsons, WV. 105 pp. Available at: http://www.fs.fed.us/ne/parsons/Environmental_Impact_Statement/index.htm.

Romme, R.C., K. Tyrell, and V. Brack, Jr. 1995. Literature summary and habitat suitability index model: components of summer habitat for the Indiana bat, *Myotis sodalis*. Report submitted to the Indiana Dept. of Natural Resources, Division of Wildlife, Bloomington, Indiana, by 3D/Environmental, Cincinnati, Ohio. Federal Aid Project E-1-7, Study No. 8

Rommé, R.C., A.B. Henry, R.A. King, T. Glueck, and K. Tyrell. 2002. Home range near hibernacula in spring and autumn. Pp. 153-158 *in* A. Kurta and J. Kennedy (eds.), The Indiana bat: biology and management of an endangered species Bat Conservation International, Austin, TX.

Sanders, C., J. Chenger, and B. Denlinger. 2001. Williams Lake telemetry study: New York Indiana bat spring migration tracking study. Report for Bat Conservation and Management. Available at: www.batmanagement.com.

Scherer, A. 2000. A survey for the Federally listed endangered Indiana bat (*Myotis sodalis*), Picatinny Arsenal, Morris County, New Jersey. Report prepared for U.S. Army Tank, Automotive and Armaments Command, Armament Research Development and Engineering Center, Picatinny Arsenal, Morris County, NJ.

Schultes, K.L. 2002. Characteristics of roost trees used by Indiana bats (*Myotis sodalis*) and northern bats (*M. septentrionalis*) on the Wayne National Forest, Ohio. M.S. Thesis. Eastern Kentucky University, Richmond, KY.

Schowalter, D.B., J.R. Gunson, and L.D.Harder. 1979. Life history characteristics of little brown bats (*Myotis lucifugus*) in Alberta. Canadian Field Naturalist 93:243-251.

Silliman, B.S., Jr., J.D. Dana, and W. Gibbs. 1851. On the Mammoth Cave of Kentucky. American Journal of Science and Arts (Second Series) 11:332-339.

Sparks, D.W. 2003. How does urbanization impact bats? Ph.D. Dissertation. Indiana State University, Terre Haute, IN.

Sparks, D.W., C.M. Ritzi, J.E. Duchamp, and J.O. Whitaker, Jr. 2005a. Foraging habitat of the Indiana bat, (*Myotis sodalis*) at an urban-rural interface. Journal of Mammalogy 86:713-718.

Sparks, D.W., J.O. Whitaker, Jr., and C.M. Ritzi. 2005b. Foraging ecology of the endangered Indiana bat. Pp. 15-27 *in* K.C. Vories and A. Harrington (eds.), The Proceedings of the Indiana bat and coal mining: a technical interactive forum Office of Surface Mining, U.S. Department of the Interior, Alton, IL. Available at: http://www.mcrcc.osmre.gov/PDF/Forums/Bat%20Indiana/TOC.pdf. (Accessed October 17, 2006).

Speakman, J.R. and P.A. Racey. 1989. Hibernal ecology of the pipistrelle bat: energy expenditure, water requirements and mass loss, implications for survival and the function of winter emergence flights. Journal of Animal Ecology 58:797-813.

Speakman, J.R. and D.W. Thomas. 2003. Physiological ecology and energetics of Bats. Pp. 430-490 *in* T. H. Kunz and M.B. Fenton (eds.), Bat Ecology. University of Chicago Press, Chicago, IL.

Stihler, C. 2005. Hellhole Cave, Pendleton County, West Virginia: results of the winter bat survey conducted on 26 February 2005. Unpublished report. West Virginia Division of Natural Resources, Wildlife Resources Section, Wildlife Diversity Program.

Thomas, D.W. 1995. Hibernating bats are sensitive to non-tactile human disturbance. J. of Mammalogy, 76:940-946.

Thomas, D.W. 1995. The physiological ecology of hibernation in vespertilionid bats. Symposia of the Zoological Society of London 67:233-244.

Thomas, D.W., and D. Cloutier. 1992. Evaporative water loss by hibernating little brown bats, *Myotis lucifugus*. Physiologic Zoology. 65:443-456.

Thomas, D.W. and F. Geiser. 1997. Periodic arousals in hibernating mammals: is evaporative water loss involved? Functional Ecology 11:585-591.

Thomas, D.W., M. Dorais, and J.M. Bergeron. 1990. Winter energy budgets and cost of arousals for hibernating little brown bats (*Myotis lucifugus*). Journal of Mammalogy, 71:475-479.

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

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

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

Tuttle, M.D. 1999. Former home of more than a million endangered Indiana bats protected. Bats 17(3):8-9.

Tuttle, M.D. and J. Kennedy. 2002. Thermal requirements during hibernation. Pp. 68-78 *in* A. Kurta and J. Kennedy (eds.), The Indiana bat: biology and management of an endangered species. Bat Conservation International, Austin, TX.

Tuttle, M.D. and D.E. Stevenson. 1977. An analysis of migration as a mortality factor in the gray bat based on public recoveries of banded bats. American Midland Naturalist 97:235-240.

Tuttle, M.D. and D. Stevenson. 1978. Variation in the cave environment and its biological implications. Pp. 108-121 *in* R. Zuber, J. Chester, S. Gilbert, and D. Rhodes (eds.), 1977 National Cave Management Symposium Proceedings. Adobe Press, Albuquerque, NM.

Tuttle, M.D. and D. Stevenson. 1982. Growth and survival of bats. Pp. 105-150, *in* T.H. Kunz (ed.), Ecology of bats. Plenum Press, New York, NY.

3/D International, Inc. 1996. Biological Assessment of the Master Plan and Ongoing Mission, U.S. Army Engineer Center and Fort Leonard Wood, Missouri. Submitted to the U.S. Army Corps of Engineers, Kansas City District.

U.S. Fish and Wildlife Service. 1983. Recovery Plan for the Indiana Bat. Twin Cities, MN.

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

U.S. Fish and Wildlife Service. 2004a. Biological opinion on the impacts of the Laxare East and Black Castle contour coal mining projects on the Indiana bat. USFWS Ecological Services Field Office, Elkins, WV.

U.S. Fish and Wildlife Service. 2004b. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for Five Endangered Mussels in the Tennessee and Cumberland River Basins. Federal Register 69:53136-53180.

U.S. Fish and Wildlife Service. 2005. Endangered and Threatened Wildlife and Plants; Removal of *Helianthus eggertii* (Eggert's Sunflower) From the Federal List of Endangered and Threatened Plants-Final Rule. Federal Register 70:48482-48490.

U.S. Fish and Wildlife Service. 2006. Proceedings of the Indiana Bat Workshop: An Exercise in Risk Assessment and Risk Management. U.S. Department of Interior, U.S. Fish and Wildlife Service, National Conservation Training Center, Shepherdstown, WV.

U.S. Fish and Wildlife Service and National Marine Fisheries Service. 1998. Endangered Species Consultation Handbook - Procedures for Conducting Consultation and Conference Activities under Section 7 of the Endangered Species Act. Washington, D.C.

U.S. Forest Service. 2004. Land and Resource Management Plan for the Daniel Boone National Forest. Management Bulletin R8-MB 117A. Winchester, KY.

U.S. Forest Service. 2002. Southern Forest Resource Assessment. Southern Forest Research Station, Asheville, NC.

Verboom, B. and H. Huitema. 1997. The importance of linear landscape elements for the pipistrelle *Pipistrellus pipistrellus* and the serotine bat *Eptesicus serotinus*. Landscape Ecology 12:117-125.

Viele, D.P., A. Kurta, and J. Kath. 2002. Timing of nightly emergence. Pp. 199-207 *in* A. Kurta and J. Kennedy (eds.), The Indiana bat: biology and management of an endangered species. Bat Conservation International, Austin, TX.

Whitaker, J.O., Jr. 2004. Prey selection in a temperate zone insectivorous bat community. Journal of Mammalogy 85:460-469.

Whitaker, J.O., Jr. and V. Brack, Jr. 2002. Distribution and summer ecology in Indiana. Pp. 48-54 *in* A. Kurta and J. Kennedy (eds.), The Indiana bat: biology and management of an endangered species. Bat Conservation International, Austin, TX.

Whitaker, J.O., Jr. and D.W. Sparks. 2003. 2002 Monitoring program for the Indiana myotis (*Myotis sodalis*) near the site of the future Six Points interchange in Hendricks and Marion Counties, Indiana as required under the Six Points Interchange Habitat Conservation Plan.

Whitaker, J.O., Jr., J.B. Cope, and V. Brack, Jr. 2003. Bats of Wyandotte Cave. Proceedings of the Indiana Academy of Science 112:75-84.

Whitaker, J.O., Jr., D.W. Sparks, and V. Brack, Jr. 2004. Bats of the Indianapolis International Airport Area, 1991-2001. Proceedings of the Indiana Academy of Science 113:151-161.

Whitaker, J.O., Jr., D.W. Sparks, C.M. Ritzi, and B.L. Everson. 2005a. 2004 Monitoring program for the Indiana myotis (*Myotis sodalis*) near the site of the future Six Points interchange in Hendricks and Marion Counties, Indiana as required under the Six Points Interchange Habitat Conservation Plan.

Whitaker, J.O., Jr., D. Sparks, J. Boyles, D. Judy, J. Burskey, and C. Ritzi. 2005b. 2005 Monitoring program for the Indiana myotis (*Myotis sodalis*) near the site of the future Six Points interchange in Hendricks and Marion Counties, Indiana as required under the Six Points Interchange Habitat Conservation Plan.

Wilhide, J.D., M.J. Harvey, V.R. MacDaniel, and V.E. Hoffman. 1998. Highland pond utilization by bats in the Ozark National Forest, Arkansas. Journal of the Arkansas Academy of Science 52:110-112.

Willis, C.K.R. and R.M. Brigham. 2004. Roost Switching, roost sharing and social cohesion: forest-dwelling big brown bats, *Eptesicus fuscus*, conform to the fission-fusion model. Animal Behaviour 68: 495-505.

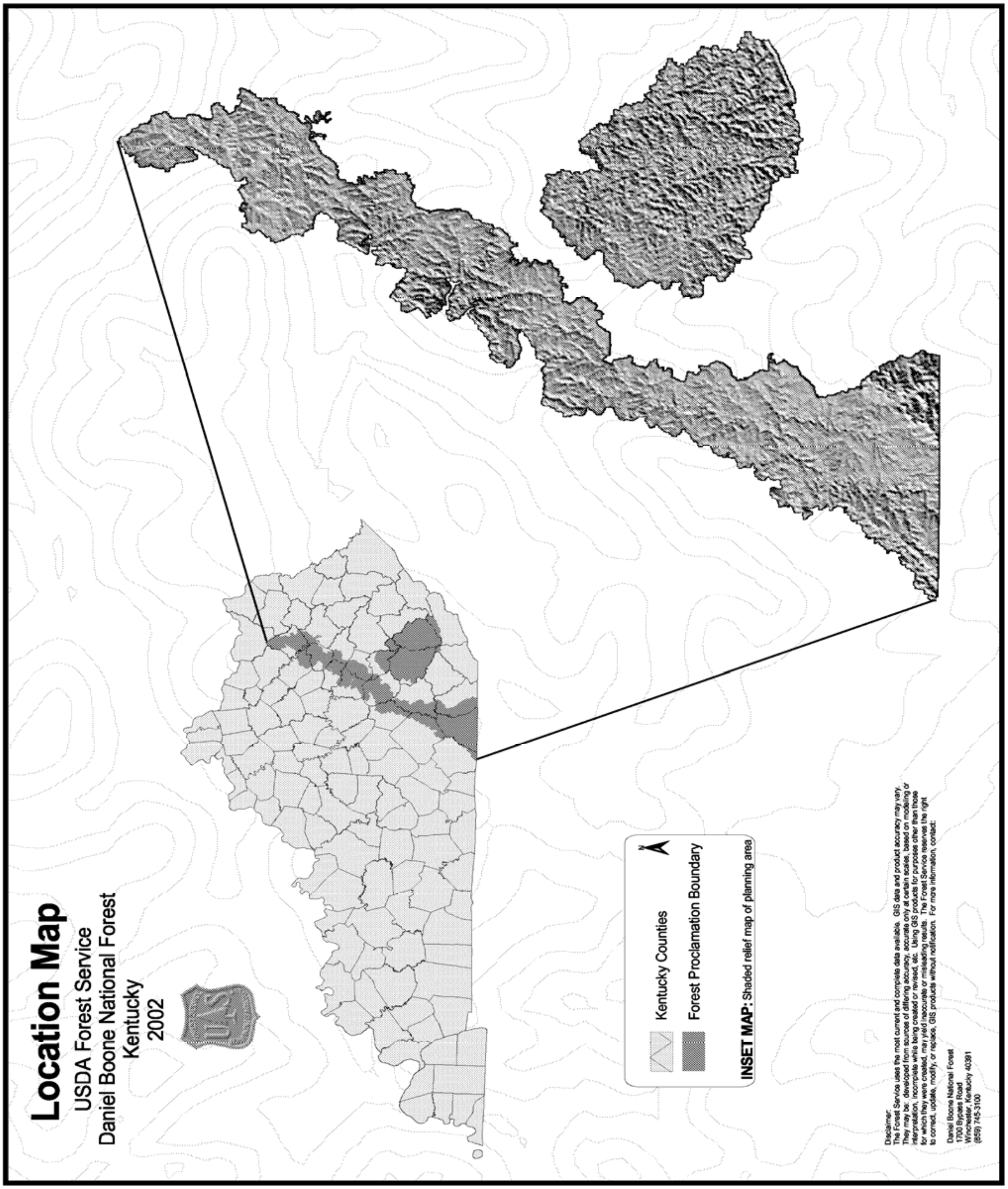
Willis, C.K.R., J.E. Lane, E.T. Likness, D.L. Swanson, and R.M. Brigham. 2005. Thermal energetics of female big brown bats (*Eptesicus fuscus*). Canadian Journal of Zoology 83:871-879.

Williams, B.K., J.D. Nichols, M.J. Conroy. 2002. Analysis and management of animal populations. Academic Press, San Diego, CA.

Winhold, L. and A. Kurta. 2006. Aspects of Migration by the Endangered Indiana Bat, *Myotis sodalis*. Bat Research News 47:1-11.

Winhold, L., E. Hough, and A. Kurta. 2005. Long-term fidelity by tree-roosting bats to a home area. Bat Research News 46:9-10.

APPENDIX A


Location Map
USDA Forest Service
Daniel Boone National Forest
Kentucky
2002
Kentucky Counties
Forest Proclamation Boundary
INSET MAP: Shaded relief map of planning area
Disclaimer:
Daniel Boone National Forest
1700 Bypass Road
Winchester, Kentucky 40391
(859) 745-3100

APPENDIX B

Standards – Daniel Boone National Forest
(From Revised Land and Resource Management Plan)

<u>Minerals</u>:

DB-MIN-2. Within 200 feet of any cave openings associated with karst systems: the surface is not to be disturbed during any federal mineral exploration or development activity; development of federally owned oil and gas is subject to the no surface occupancy stipulation.

DB-MIN-3. No drilling or mining is allowed into known cave voids (systems) where federal leasing is authorized.

<u>Roads/Engineering</u>:

DB-ENG-1. Subject to valid existing rights, no new roads, or trails will be built or maintained in protected zones around cave openings, associated sinkholes, or cave collapse areas, except for designated recreational caves.

<u>Recreation</u>:

DB-REC-1. Recreational activities inside caves will not be promoted except for designated recreational caves. Public information concerning location and access to non-recreational caves will be limited.

<u>Wildlife</u>:

DB-WLD-1. No snags equal to or greater than six inches in diameter at breast height (dbh) and equal to or greater than 10 feet in height are to be intentionally felled within timber harvest, regeneration and thinning projects, unless identified as an immediate threat to human safety. This standard does not apply to salvage or sanitation projects.

DB-WLD-2. Retain or create at least three snags per acre equal to or greater than 9 inches dbh within all timber harvest, regeneration, sanitation, salvage, or thinning project units when available.

DB-WLD-3. Retain enough live trees to provide partial shading of about one-third of all snags equal to or greater than 12 inches dbh and equal to or greater than 10 feet in height that are suitable for roosting by Indiana bats.

DB-WLD-4. In the two-aged shelterwood method, retain a minimum of 10 to 15 square feet of basal area per acre (average in stand) of live potential roost trees (Indiana bat).

DB-WLD-5. In harvest units equal to or greater than 10 acres that prescribe the two-age or even-age systems, leave some clumps or strips averaging at least 50 square feet of basal area (of trees equal to or greater than 9 inch dbh) per acre, or the density of the original stand if less. "Leave areas" such as the Cliffline Community and Riparian Corridor Prescription Areas can provide this habitat based on site-specific conditions.

DB-WLD-6.In regeneration or thinning project areas, retain all shagbark, shellbark, and red hickories that are (equal to or greater than 6 inch dbh), unless the removal of these trees is specifically designed to improve habitat for PETS or Conservation species.

DB-WLD-7. During implementation of vegetation management, retain any immediate roost trees (Indiana bat) that are equal to or greater than 6 inches dbh. These trees must be designated prior to project implementation. This standard does not apply to salvage or sanitation projects.

DB-WLD-8. Tree cutting may not be conducted within 2.5 miles of any Indiana bat maternity colony from May 1 through August 15.

DB-WLD-9. For non-vegetation management projects, currently suitable Indiana bat roost trees may be felled only from October 15 through March 31, if they are more than five miles from a significant bat caves (Indiana bat). If tree removal occurs at other times, the trees must be evaluated for current Indiana bat use, according to U.S. Fish and Wildlife Service protocol.

DB-WLD-10. For non-vegetation management projects, removal of currently suitable roost trees (Indiana bat) within five miles of a significant bat caves (Indiana bat), may occur only from November 16 through March 15. If removal occurs at other times, the trees must be evaluated for current Indiana bat use, according to U.S. Fish and Wildlife Service protocol.

DB-WLD-11. Timber harvest will not occur on the DBNF within one mile of a known significant bat caves, or PETS bat staging cave (with the exception of the wooded grassland/shrubland habitat association), if this activity would result in more than 120 acres of forest less than 10 years of age on all ownerships (public and private).

DB-WLD-12. Within five miles of a significant Indiana bat hibernaculum, tree cutting is not to be conducted from September 1 through December 1)

DB-WLD-13. Where caves exist outside Cliffline Community Prescription Area a minimum zone of 200 feet is to be maintained around openings to caves, and mines suitable for supporting cave-associated species, as well as any associated sinkholes and cave collapse areas except for designated recreational caves. Prohibited activities within this protective area include use of motorized wheeled or tracked equipment (except on existing roads and trails), mechanical site preparation, recreation site construction, tractor-constructed fire lines for prescribed fire, herbicide application, and construction of new roads, skid trails or log landings. Vegetation in this buffer zone may be managed only to improve habitat for PETS or Conservation species.

DB-WLD-14. Activities that create a toxic water source (e.g. brine pits and oil catch basins) must be filled, covered, or otherwise modified in an environmentally appropriate manner to prevent contact with wildlife.

DB-WLD-15. Create, or retain where available, at least one snag 12 inches dbh or greater per acre in any area in which overstory trees are cut as part of habitat creation or maintenance, sanitation or salvage.

Vegetation:

DB-VEG-1. Hazard trees (dead or alive) considered to be an immediate threat to human safety may be removed anytime. Supercedes all other standards.

DB-VEG-14. Do not apply triclopyr within 60 feet, of known occupied gray, Virginia big-eared, or Indiana bat hibernacula or known maternity tree.

DB-VEG-22. The maximum size of a temporary opening created by even-aged or two-aged regeneration treatments is 40 acres. These acreage limits do not apply to areas treated as a result of catastrophic conditions such as wildland fire, insect outbreak, or windstorm. Areas managed as woodland, wooded grassland/shrubland, or non-forested areas (e.g., rights-of-way and grassy openings) are not subject to these Standards and are not included in calculations of opening size, even when within or adjacent to created openings.

DB-VEG-23. Temporary openings created by even-aged or two-aged regeneration treatments will be separated from each other by a minimum of 330 feet. Such openings may be clustered closer than 330 feet as long as their combined acreage does not exceed the maximum opening size. An even-aged or two-aged regeneration area will no longer be considered an opening when the certified re-established stand has reached an age of five years.

Prescribed and Wildland Fire:

DB-FIRE-8. Prescribed burning is not to occur within Indiana bat roosting areas between May 1 and July 31.

APPENDIX C

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

PROJECTS	SERVICE OFFICE AND DATE BO ISSUED	INCIDENTAL TAKE (IT) FORM	TAKE EXEMPTED or SURROGATE MEASURE TO MONITOR
1996 Programmatic Biological Opinion for Surface Coal Mining Regulatory Programs Under the Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87)	Washington DC October 1996	IT by harm, harassment, and killing of all current and future listed species	Unquantifiable
Cherokee National Forest LRMP; Note: As a result of new information, this Forest is now operating under a "not likely to adversely affect" determination, and this BO is no longer in effect.	Tennessee FO January 1997	IT by killing harming or harassing	1,300 acres
Relocation of US Army Chemical School & US Military Police School to Fort Leonard Wood, Missouri	Missouri FO	IT by harming, harassing, or killing	56 hibernating bats from fog oil and TPA smoke pots; summer bats difficult to determine sub-lethal take
Daniel Boone National Forest LRMP; Note: This BO has been superceded by a March 2004 BO.	Tennessee FO April 1997	IT by killing, harming, or harassing	4,500 acres
Ozark-St. Francis National Forest LRMP; Note: As a result of new information, this Forest is now operating under a "not likely to adversely affect" determination, and this BO is no longer in effect.	Arkansas FO June 25, 1998	IT by killing, harming or harassing	Annually 8,000 acres of timber harvest in hardwoods, 11,000 acres harvest of pine and pine/hardwoods; 30,000 acres of prescribed burning
Construction of New Training Facilities at Fort Knox, KY	Tennessee FO October 1998	IT by killing, harming or harassing	2,000 acres
Construction of a Qualification Training Range at Fort Knox, KY	Tennessee FO October 1998	IT by killing, harming or harassing	80 acres
Construction & operation of the Multi-purpose training Range at the Camp Atterbury Army National Guard Training Site-Edinburgh Indiana	Indiana FO December 4, 1998	IT by harm through habitat loss and exposure to toxic agents	1 maternity colony (200 bats total) and 99.7 ha of forest
Disposition of Lands Acquired by the Tennessee Valley Authority for the Columbia Dam Project, Maury County, Tennessee	Tennessee FO March 1999	No take provided	No take provided
Proposed stream bank stabilization at Yano Range and upgrade of the Wilcox Tank Range at Fort Knox, KY	Tennessee FO April 1999	IT by loss of summer roosting, foraging, and maternity habitat	1800 acres; 2 maternity colonies

Agricultural Pesticide Application Practices at Newport Chemical Depot, Newport IN	Indiana FO April 13, 1999	IT by harm through exposure to pesticides	2 maternity colonies with 74 bats total
Ouachita National Forest LRMP; Note: As a result of new information, this Forest is now operating under a “not likely to adversely affect” determination, and this BO is no longer in effect.	Arkansas FO April 26, 1999	IT by killing, harming or harassing	40,000 acres commercial harvest; 3,000 acres wildlife management & road construction/reconstruction; 24,000 acres thinning; 200,000 acres prescribed burning
Mark Twain National Forest LRMP; Note: This BO has been superceded by the September 2005 BO	Missouri FO June 23, 1999	IT by killing, harming, or harassing	Timber harvest – 20,000 acres per year; Prescribed fire - 12,000 acres/yr; Wildlife habitat improvement -2000 acres/yr; Timber stand improvement – 4000 acres/yr; Soil & water improvement – 150 acres/yr; Range management – 50 acres/yr; Mineral exploration & development – 50 acres/yr; Wildfire fire lines – 50 acres/yr; Special use – 50 acres/yr; Road construction – 25 acres/yr
Impacts of Forest Management and Other Activities to the Bald Eagle, Indiana Bat, Clubshell and Northern Riffleshell on the Allegheny National Forest, Pennsylvania; Note: As a result of new information, this Forest is now operating under a “not likely to adversely affect” determination, and this BO is no longer in effect.	Pennsylvania FO June 1999	IT by killing, harming, or harassing	Within a 5-year period (1999 to 2003), the disturbance of 45,594 acres
National Forests in Alabama; Note: As a result of new information, this Forest is now operating under a “not likely to adversely affect” determination, and this BO is no longer in effect.	Alabama FO December 10, 1999	IT by killing, harming or harassing	No more than 100 trees
Supplement for Proposed Bridges & Alignments Modifications to Kentucky Lock Addition Project	Tennessee FO January 2000	IT by killing, harming or harassing	No more than 20% of available suitable habitat
Green Mountain National Forest LRMP; Note: As a result of new information, this Forest is now operating under a “not likely to adversely affect” determination, and this BO is no longer in effect.	New England FO 2000	IT by harming or harassing	300 acres
White Mountain National Forest LRMP; Note: As a result of new information, this Forest is now operating under a “not likely to adversely affect” determination, and this BO is no longer in effect.	New England FO 2000	IT by farming or harassing	1,500 acres

Nantahala and Pisgah National Forests LRMP Amendment #5	Asheville (NC) FO 2000	IT by killing, harming, or harassing	4,574 acres per year
Daniel Boone National Forest LRMP and the Proposed Special Habitat Needs and Silviculture Amendment	Tennessee FO May 2000	No take provided	No take provided
Hazard Tree Removal and Vegetation Management Program at Mammoth Cave National Park	Tennessee FO June 2000	IT by loss of roosting habitat, direct mortality or by forcing bats to abandon tree	No take provided
Salvage Harvest Necessitated by 1998 Storm Damage on the Daniel Boone National Forest	Tennessee FO July 2000	IT by killing, harming, or harassing	3,100 acres
North East research Station – Fernow Experimental Forest – Five year plan	West Virginia FO November 2000	IT by potential harm or mortality of roosting bats	210 acres timber harvest and 154 acres prescribed burn
National Forests in Alabama Re-initiation; Note: As a result of new information, this Forest is now operating under a "not likely to adversely affect" determination, and this BO is no longer in effect.	Alabama FO January 23, 2001	IT by killing, harming or harassing	Level of take changed for southern pine beetle suppression areas – upper limit of 65 suitable roost trees
Hoosier National Forest LRMP; Note: This BO has been superceded by a January 2006 BO.	Indiana FO June 13, 2001	IT by harm	Pine clear cuts – 578 acres; Pine shelterwood cuts – 391 acres; Pine thinning – 408 acres; Hardwood group selection cuts – 777 acres; HW single tree selection cuts – 100 acres; HW even aged salvage cuts – 518 acres; Prescribed fire treatment – 7000 acres; Forest openings maintenance – 3311 acres; Timber stand improvement – 2264 acres; Special use permits – 286 acres; Wildfire management – 250 acres; road construction – 16 acres; hazard tree removal – 100 trees; trail construction – 15 miles
Wayne National Forest LRMP; Note: BO has been superceded by a November 2005 BO.	Ohio FO September 20, 2001	IT by harm	Permanent loss of habitat – 2,504 acres; Habitat alteration – 8,102 acres plus 125 trees
Ozark-St. Francis National Forest Prescribed Fire Plan (an amendment to June 1998 LRMP BO); Note: As a result of new information, this Forest is now operating under a "not likely to adversely affect" determination, and this BO is no longer in effect.	Arkansas FO March 21, 2002	IT by loss of roost trees and potential roost trees	Prescribed fire - 153,000 acres/yr

1986 (as amended) Monongahela National Forest Land and Resource Management Plan (Forest Plan); Note – This BO has been superceded by a July 2006 BO.	West Virginia FO March 2002	IT by killing, harming, or harassing	A maximum of 6,125 acres annually and prescribed burning on a maximum of 300 acres annually.
Huron-Manistee National Forest LRMP; Note: This Bo has been superceded by a March 2006 BO.	Michigan FO June 13, 2003	IT by killing, harming, or harassing	0-65 bats; 3,150 ac (1,275 ha) of potential Indiana bat habitat may be harvested and 2,648 ac (1,071 ha) of habitat may be burned for fire management or wildlife habitat management activities for the duration of this proposed action
Great Smoky Mountains National Park Prescribed Burning	Tennessee FO August 12, 2003	IT by loss of suitable roosting or foraging habitat	One maternity colony
Construction, Operation, and Maintenance of Alternative 3C of Interstate 60 from Indianapolis to Evansville	Indiana FO December 3, 2003	IT by harming, killing	Summer action area: permanent direct & indirect loss of up to 1527 acres of forested habitat and 40 acres of non-forested wetlands. Winter action area: permanent loss of up to 947 acres of forest habitat around 10 known hibernacula. Death by vehicle collisions: 10 Indiana bats per year.
2003 Revised Jefferson National Forest Land and Resource Management Plan, Virginia, West Virginia, Kentucky	Virginia FO January 2004	IT by killing, harming, or harassing	16,800 acres total (15,000 fire; 1,800 other habitat manipulations)
2004 Daniel Boone National Forest Revised LRMP	Kentucky FO March 20, 2004	IT by killing, harming, or harassing	Green tree harvest – 4000 acres; Salvage/sanitation – 350 acres; Prescribed burning during summer – 50,000 acres
Upper Mississippi River – Illinois Waterway System Navigation Feasibility Study	Rock Island (IL) FO August 2004	IT by injury, death, harming or harassing	511 acres of forested habitat annually for 50 years. Less than 20 bats per year.
Department of the Army 88th Regional Readiness Command, US Army Reserve Center	Ohio FO April 14, 2005	IT by harming or harassing	18 acres of high quality roosting and foraging habitat
Construction, Operation, and Maintenance of the U.S. 33 Nelsonville Bypass	Ohio FO April 15, 2005	IT by harming, death, injury	No more than 10 Indiana bats
Big Monon Ditch Reconstruction Project	Indiana FO May 24, 2005	IT by harming and harassing	Permanent loss of 75 acres of occupied summer habitat
Mark Twain National Forest 2005 Forest Plan, Missouri; Note: Replaces June 1999 BO.	Missouri FO September 2005	IT through removal of roost trees	10 occupied roost trees over 10 years; 19,400 acres and 240 miles of fireline

BO on the Interstate 69 (I-69) preferred alternative #2 from Henderson, Kentucky to Evansville, Indiana, and its effects on the Indiana bat; Henderson County, Kentucky and Vanderburgh County, Indiana	Kentucky FO October 2005	IT through harm, harassment, and/or mortality	The level of take authorized is for those wooded areas of occupied and/or potentially occupied Indiana bat habitat within the construction limits of the proposed project that lie within the Indiana bat focus area identified in the BA, which was determined to be about 28 acres of wooded habitat and all of the potential Indiana bat roost trees contained within those 28 acres.
Wayne National Forest Land and Resource Management Plan; Note: Replaced September 20, 2001 BO.	Ohio FO November 2005	IT through removal of roost trees	No more than 4 occupied roost trees will be incidentally taken over the next ten years; Permanent Road Construction & Reconstruction -392 acres; Temporary Road Construction -146 acres; Skid Trails and Log Landings - 740 acres; Utility Development - 50 acres; Fire Lines - 74 miles
Shawnee National Forest LRMP	Illinois FO December 3, 2005	IT through harming, harassing, and killing	First 10 Years of plan: -- 11,565 acres of timber harvest/mgt. and minerals mgt. -- 5,630 acres of timber stand improvement and wetlands mgt. Second 10 Years of plan: -- 21,255 acres of timber harvest/mgt. and minerals mgt. -- 13,289 acres of timber stand improvement and wetlands mgt. Mortality of up to 2 individuals during research and monitoring.
North East Research Station – Fernow Experimental Forest – Five year plan; Note: Replaced November 2000 5-year BO.	West Virginia FO December 2005	IT by potential harm or mortality of roosting bats	124 acres timber harvest and 466 acres of prescribed burns (previous 210 acres timber harvest and 154 acres prescribed burn)
Final Biological Opinion on implementation of the 2003 Ice Storm Recovery Project and it effects on the Indiana bat, Morehead Ranger District, Daniel Boone National Forest, Rowan County, Kentucky	Kentucky FO December 2006	IT through harm, harassment, and/or mortality	The level of incidental take authorized is 4,704 acres of commercial removal of damaged trees and restoration and creation of bat habitat when accomplished during the summer roosting period of the Indiana bat (April 1 to September 15).

Hoosier National Forest LRMP; Note: This BO replaced the June 2001 BO.	Indiana FO January 2006	IT by injury or death or harassing	No more than four (4) occupied roost trees/year and between four (4) and twelve (12) individuals injured or killed each year. 2956-acres; 60 hazard trees; 100 "accident" trees per year
Huron-Manistee National Forest LRMP	Michigan FO March 2006	IT through harming, harassing, and killing	For first 10 years of revised Forest Plan: Thinning = 59,497 Clearcut = 45,144 Shelterwood = 8,261 Selection = 0
Biological Opinion – Impacts of the Laxare East and Black Castle Contour Coal Mining Projects on the Indiana bat; Note: Reinitiation of February 2005 BO.	West Virginia FO March 2006	IT in the form of harm due to habitat loss, degradation and fragmentation, Harassment during active mining, Permanent loss of foraging loss and roosting habitat, habitat fragmentation and degradation, permanent loss of streams and their associated watering and prey base for Indiana bats, long term alteration of streams	No more than 17 adult females and their pups; 912 acres of forested habitat and 5.0 miles of stream
Hoosier National Forest's Proposed Tell City Windthrow 2004 Salvage Timber Harvest	Indiana FO April 2006	Death and injury from direct felling of occupied trees; Harassment of roosting bats from noises/ vibrations/ disturbance levels causing roost-site abandonment and atypical exposure to day time predators while fleeing and seeking new shelter during the day-time; and Harm through the loss of primary and/or alternate roost trees	Project-wide Combined Total: 8,525 acres

Final Programmatic BO on Minor road Construction Projects in Kentucky and their effects on the Indiana bat	Kentucky FO June 2006	IT through harming, harassment, mortality	The level of take authorized is for those wooded areas of Indiana bat habitat within the construction limits of a proposed project covered by Tier 2 during KYTC FY 2006 through KYTC FY 2010, which was determined to be 500 acres of Indiana bat habitat as described in the HAM in KYTC FY06, 600 acres in KYTC FY07, 720 acres in KYTC FY08, 864 acres in KYTC FY09, 1,037 acres in KYTC FY10.
Programmatic Biological Opinion for the Monongahela National Forest 2006 Forest Plan Revision	West Virginia FO July 2006	IT through harming, harassment, and/or mortality	10,052 acres of suitable Indiana bat habitat annually
Proposed Construction, Operation, and Maintenance of Alt. 3C of Interstate 69 from Evansville to Indianapolis	Indiana FO August 2006	Death/kill and/or injury/wound from direct felling of occupied trees, direct collision with vehicles, and other sources.	2,148 acres of forested habitat and 20 acres of non-forested wetlands within summer action area; 1,097 acres of forested habitat within winter action area; 11 individuals per year from collision with vehicles
Review of Ongoing Operations and Maintenance Activities at Tennessee Valley Authority Dams in the Tennessee River Basin located in Alabama, Georgia, Kentucky, Mississippi, North Carolina, Tennessee, and Virginia and Their Effects on Federally Listed Endangered and Threatened Species per Section 7 of the ESA	Tennessee FO October 2006	No take provided	No take provided
BO on the Ohio DOT's Statewide Transportation Program for the Indiana bat	Ohio FO January 2007	IT through harm, harassment, and/or death	22,118 acres of suitable Indiana bat habitat