ILLINOIS NATURAL HISTORY SURVEY
PRAIRIE RESEARCH INSTITUTE

Conservation Guidance for

Indiana Bat

Myotis sodalis (Miller and Allen, 1982)

IL status:
Endangered

US status:
Endangered

Global rank:
Imperiled[1]

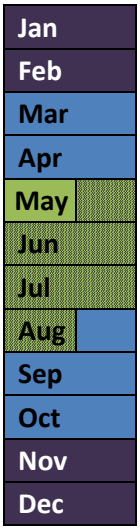
Trend:
Stable[2]

Family:
Vespertilionidae

Habitat:
Riparian-forested corridors, caves, mines

Similar species:
Little brown bat, Northern long-eared bat

Seasonal Cycle:



Hibernating
Migrating/Mating
Summer foraging/ Birthing and raising young
Survey period

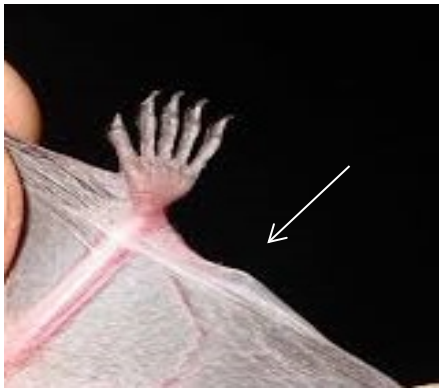
Species information

Characteristics

Indiana bats have dull grayish brown fur on their back and lighter brown fur underneath[3]. The wings of Indiana bats are also dark brown and usually **very similar in color** to their back fur. Indiana bats have a **pinkish nose** and a flap of skin near the ankle called a **keeled calcar**. Indiana bats are 2.8-3.9 inches in length, have a 9 to 11 inch wingspan, and have a **forearm length that ranges from 1.4-1.6 inches (1.5 inch average)**[3]. Hibernating Indiana bats are often recognized by the large, dense clusters they roost in and their noticeably pink noses[3].

Adult Indiana bat. Photo by Adam Mann,

The Indiana bat is commonly confused with the other Myotis species, especially little brown bat (*Myotis lucifugus*) and the northern long-eared bat (*Myotis septentrionalis*). The back fur of the little brown bat is more silky or glossy, and lighter brown creating a larger contrast between the fur and wings than in Indiana bat[3]. In addition, little brown bats have little toe hair, do not have a keeled calcar, and lack the pinkish nose of Indiana bats. Northern long-eared bats have longer ears that extend past the snout and a longer, more pointed tragus projecting from the inner ear[3].



Hind foot of an Indiana bat showing keeled calcar and long toe hairs. Photo by Adam Mann.

Little brown bat on the left and Indiana bat on the right. Photo by Adam Mann.



Roosting and foraging habitat (left), shagbark hickory tree with exfoliating bark used as a roost site (center), and Indiana bat roosting under exfoliating bark (right). First two photos by Joey Weber, Indiana State University, third photo by John MacGregor, KDFWR.

Habitat

During winter, Indiana bats hibernate in caves and abandoned mines that have specific temperature, humidity, and physical characteristics. They require cool, humid caves with stable ambient winter temperatures around 32–50º F[4–6], but laboratory research shows optimal conditions for reducing energy usage around 37–43º F[7]. Indiana bats use cave locations with high average humidity levels between 65-95%[4,5,8,9]. Large, structurally complex caves provide greater diversity of microhabitats and are generally better able to store cold air and buffer against freezing[6,10]. Indiana bats often hibernate well away from the entrances of caves or mines, where temperature and humidity are more stable[5]. There are few caves within the range of Indiana bat that have suitable conditions.

The area surrounding hibernacula also provide important foraging and mating habitat. Fragmented forest landscapes that provide forest edges and feeding corridors within 5 miles support the largest hibernacula[11].

Indiana bat summer habitat is dispersed across a highly fragmented landscape with low to moderate forest cover[12]. They have been observed to use summer habitat as far as 350 miles from their hibernaculum[4]. In the summer, Indiana bats are most frequently found in areas with forest cover and open water, especially floodplain forests[12–15]. They frequently use wooded corridors, such as riparian areas and tree lines, to travel between forest patches, but they have also been observed moving more than 0.6 miles across open landscapes, such as cropland[4,12]. They use semi-open forests and forest edges for foraging[16]. One of the most important characteristics of colony habitat is likely the density of potential roost trees[4].

Indiana bats roost under loose, shaggy tree bark on live, dead, or dying trees[4,17]. Trees used include ash (*Fraxinus*), elm (*Ulmus*), maple (*Acer*), cottonwood (*Populus*), oak (*Quercus*), and hickory (*Carya*), especially shagbark hickory (*Carya ovata)*[4]. Maternity colony roost trees are often larger than surrounding trees, with diameters averaging 16–24 inches (in)[4]. Roosts typically occur 23–33 feet (ft) above ground level and are found in forest gaps, edges, or other conditions that expose the roost tree to sunlight for most of the day[4,17]. However, roosts in shaded areas may be selected in warmer regions and may be a response to increasing temperatures[18]. Canopy cover in the forest around maternity colonies is 50% on average, but ranges from <20 to 88 percent[4]. Male Indiana bats have similar roost tree usage but are more likely to use smaller (13 in. diameter, average) and more shaded trees with an average of 63% canopy cover in the surrounding forest[4]. In addition, male Indiana bats may roost in caves, mines, and bridges during the summer.

Distribution and Status

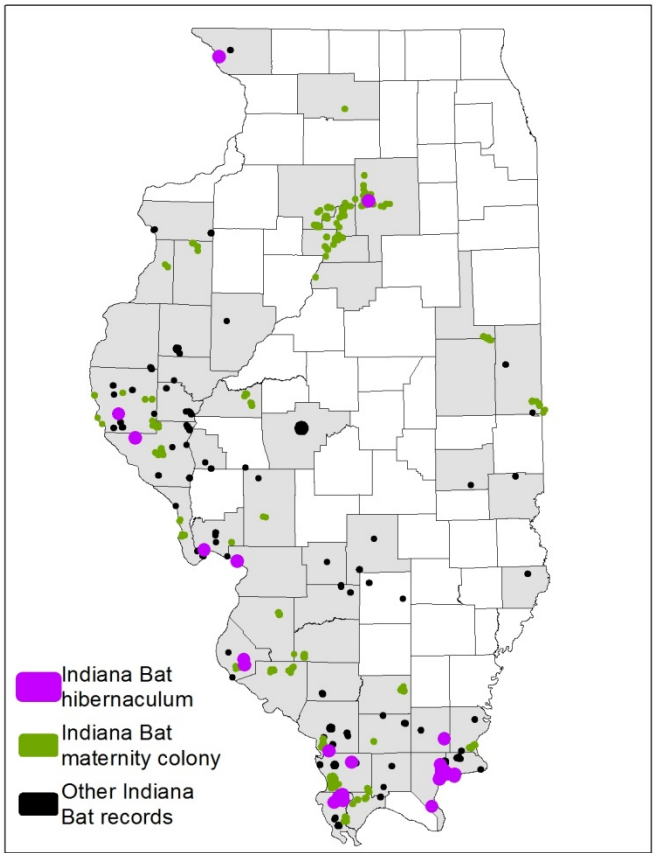
Indiana bats are found over most of the eastern half of the United States. Indiana bats range from New England in the east to Oklahoma in the west and from southern Michigan in the north to northern parts of the Gulf States in the south[1].

Range wide, there are at least 281 known Indiana bat hibernacula[4]. Indiana bat hibernacula are classified to prioritize protection[4]. There are 23 Priority 1 hibernacula, which are considered essential to recovery and have contained at least 10,000 Indiana bats and continue to have suitable

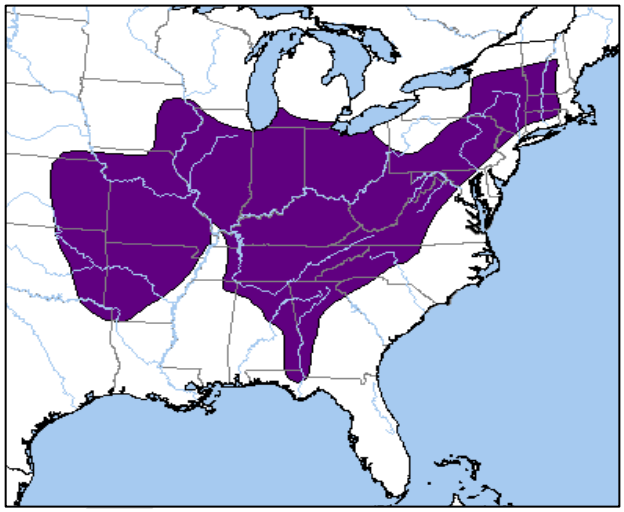
conditions[19]. There are 54 Priority 2 hibernacula, which contribute to recovery and have contained 1,000-10,000 Indiana bats[19]. Almost half of all Indiana bats (207,000 in 2005) hibernate in caves in southern Indiana[4]. The locations of maternity colonies are less well known, and the 269 known maternity colony sites probably represent less than 10 percent of colonies[4,19].

Over 10% of all Indiana bats hibernate in Illinois[20], mostly in abandoned silica mines. There are only 16 known hibernacula in Illinois, including one Priority 1 site and six Priority 2 sites[4]. Over 40,000 Indiana bats hibernate in Magazine Mine, a privately-owned abandoned silica mine in Alexander County, Illinois[19]. During the summer, Indiana Bats occur at scattered locations across southern and central Illinois including 45 known maternity colonies[21,22].

The Indiana bat has been listed as endangered by the U.S. Fish and Wildlife Service (USFWS) since March 1967; Illinois, like every state within the range, also lists them as endangered. The primary reasons for initial listing were dramatic decreases in populations and susceptibility to human threats and



Indiana Bat records in Illinois from the Illinois Natural Heritage Database[21]



Distribution of the Indiana bat in North America[1].

disturbance[4]. It is considered a species with a high degree of threat that has low recovery potential[19]. USFWS has designated critical habitat for Indiana bat, including one site in Illinois at Blackball mine[4].

In 2015, the range wide population was estimated at 523,636 bats and the Illinois population was estimated at 56,000 bats[20]. Indiana bat populations were estimated at 880,000 individuals in the 1960s[4]. It is likely that this was a significant decline from previous years, before official records were kept[4]. Declines continued into the early 2000s with the population at its lowest in 2001 with an estimated 496,000 bats[4,20]. The species started to experience modest increases until 2005, when the population started declining again after white-nose syndrome (see threats section) was first detected [20,23].

The Indiana bat range has been divided into four recovery zones and Illinois is part of the Ozark-Central recovery zone[4]. Unlike the other recovery zones, the Ozark-Central zone population was declining prior to 2005, but it has not declined as steeply as other zones since then[20].

Taxonomy

Indiana bat is one of six bat species in the *Myotis* genus in Illinois. *Myotis* are small, brown bats with mouse-like ears. Indiana bat has no sub-species. Alternative common names for the species are Indiana Myotis, social bat, pink bat, and little sooty bat[4].

Natural History

Range wide, Indiana bat hibernation may start as early as September and extend as late as May[4].

Hibernation is an adaptation to reduce metabolism during the cold winter months when no prey insects are available. Hibernating Indiana Bats sometimes roost alone or in small groups, but most often congregate in dense clusters containing more than 300bats/ft^2 [4]. This clustering may help regulate temperature and likely allows Indiana bats to hibernate at a wider range of ambient temperatures than would be possible for non-colonial species. Larger clusters of hibernating Indiana bats are typically found at colder sites, whereas smaller clusters are found at warmer sites[4]. Hibernating bats often arouse a couple of times a month, or more often if disturbed or roosted in unsuitable microclimate[4]. During arousals, they may drink water, expel waste, mate, move around, or change locations, perhaps to more suitable microclimate conditions[4,24]. Arousals account for approximately 75-85% of winter fat depletion, and excessive arousal reduces survival[4].

Indiana bats typically leave their hibernacula in March or April to migrate to their summer ranges, but may leave as late as the end of May in Illinois[21]. Their migratory routes and habits are not well known. During summer, males and non-reproductive females roost alone or in small groups, while reproductive females roost in larger groups of up to 100 bats or more[4]. Individuals roosting together do not necessarily hibernate together[4,20].

Males and non-reproductive females tend to migrate short distances or remain in the vicinity of hibernacula[4,22]. They may form summer "bachelor" colonies within the cave that they hibernate and forage in the surrounding forest each night[4]. This strategy minimizes the dangers associated with migration and maximizes the chances that they will be present when the females return in the autumn for mating and hibernation. Alternatively, they may migrate and be found in the same areas as reproductive females.

Female Indiana bats radiate across the landscape during the spring to form maternity colonies for raising their young. Female Indiana Bats may travel more than 350 miles to summer habitat, although shorter migrations of less than 100 miles appear more common[4]. In Illinois, Indiana bats

Hibernating Indiana bats sometimes roost alone or in small groups, but often congregate in dense clusters containing more than bats 300/ft^2. Photos by Andrew King (USFWS).

have been observed at maternity roosts as early as mid-April and as late as mid-September[21].

A single roost tree may contain over 300 bats[4]. Roosting in colonies provides temperature regulation, which is important for growth and development of young[4]. There is no evidence of successful rearing of young outside maternity colonies[4]. Colonies vary in size and are spread across multiple roost trees on any given night. A colony will typically use 10-20 roost trees per year[4]. Females typically return to the same roost area each summer, and a roost tree may be occupied for several years until it becomes unsuitable due to falling or shedding bark[4]. There are 1-3 primary roost sites that are regularly used by an individual, as well as secondary roost sites that see less frequent use[27]. Individual females switch roost sites frequently (once every 3-4 days)[17,27], but less often when it is colder and while they are feeding young[4]. Roost switching may reflect the maintenance of long-term social relationships between individuals within a colony that is spread among a number of different trees on a given night[27,28]. The colony become less gregarious after young have weaned[4].

Indiana Bats give birth to a single pup, typically in late May or early June in southern Illinois and from late May to early July farther north[3]. Reproduction is weather dependent and females may forgo reproduction in years with adverse weather conditions[4]. Females lactate for 3-5 weeks after birth until their young are able to fly[4].

After sunset, Indiana bats leave their roosts to forage for insects and drink water. They typically forage over streams, along forest edges, and in other flyways, at 6-100 ft above ground level in the forested habitats surrounding their roosts, but they may travel as far as 5 miles to access foraging areas[4,16]. Mean home range sizes of Indiana bats vary from 205 to 926 acres[12,15], but a maternity colony as a whole may use more than 8900 acres for foraging[27]. They typically follow tree-lined corridors, such as fence lines or streams, to move between forest patches, and will go out of their way to avoid crossing open areas[4]. However, they have been observed crossing open areas, such as croplands, to reach small, isolated, forest patches[4,12]. Individuals return to the same foraging grounds, which they may share with other individuals[27].

Indiana bats can capture and consume insects while flying[4]. Their diet consists mostly of flying insects from the orders Coleoptera (beetles), Diptera (flies), Lepidoptera (moths), and Trichoptera (caddisflies)[4]. They are considered selective opportunists because, while they target these insect groups, they also adjust their diet to what is available[4].

In Illinois, Indiana bats start to return to hibernacula in early September[21]. They generally return to the same hibernaculum as the previous year, but they also explore multiple hibernacula and readily discover newly available sites[4]. For example, in Illinois, Magazine mine and Blackball mine, two of the most populated sites, were only recently colonized by Indiana bats, despite Blackball mine being located far from other hibernacula occupied by Indiana bats[4].

Prior to hibernating, Indiana bats spend a few weeks swarming, or flying around the entrance to the cave, mating and foraging[4]. Fat reserves necessary for survival during hibernation are put on during the swarming period[4,24]. Bats may travel long distances (more than 19 miles) from hibernaculum for foraging during this time[4]. The distance may depend on competition for essential resources.

Population dynamics

In general, bats are long lived, have low reproductive rates, and slow population growth, which limits their ability to recover from declines. There is little empirical information on Indiana Bat demographics, but survival and reproductive rates have been estimated for stable populations[29]. Prior to white-nose syndrome, annual adult survival was estimated at 87% with a mean life span of 5.7 years[29]. The oldest known Indiana bat was at least 20 years old[4]. Adult female Indiana bats are expected to breed 3 out of 4 years and have a 75% success rate[29]. Adult survival during winter, summer, and fall have the greatest impact on population trends, in descending order[29].

Conservation/Management

Threats

Indiana bats are threatened by the disease white-nose syndrome, habitat loss, degradation and fragmentation, winter disturbance, climate change, environmental contaminants, and wind turbines[4,19,29]. In addition, disasters, such as hurricanes, tornadoes, wildfires, cave collapses, and cave flooding, can kill large numbers of bats and destroy habitat[4].

<u>White-nose syndrome</u>

The primary threat to Indiana bat is white-nose syndrome, a disease caused by the fungus *Pseudogymnoascus destructans* that is known to kill bats. The fungus grows on hibernating bats and rouses them prematurely using up limited fat reserves that cannot be replenished during winter months when insects have not emerged[30]. As a result, Indiana bat populations in infected caves have declined around 70%[31] and summer abundance has dropped by 60%[32]. White-nose syndrome first appeared in New York in 2006-2007 and spread from there, first appearing in Illinois in 2012-2013[33]. It is suspected that 99% of all Indiana bats are hibernating at sites with white-nose syndrome[20]. Models predict that the Indiana bat population will drop by more than 86% by 2022 but may then begin

to rebound if the species acquires immunity[29]. The model also predicts the loss of viable Indiana bat populations within 2 of the 4 recovery zones including Illinois[29].

Habitat loss, degradation, and fragmentation

Habitat degradation at hibernacula is a serious threat to Indiana bats because it can impact large numbers of bats when they are densely congregated. Alteration of hibernacula by mining, complete blocking of entrances, and tourism is thought to be the cause of initial declines of Indiana bats[4]. Changes to the structure within a cave changes the airflow, temperature, and suitability of hibernacula[4,6]. The entrances of many caves and mines have been closed for liability purposes, and in some cases, have also blocked bat access[4]. In addition, abandoned mines are prone to collapses that can alter interior habitats. Flooding of caves has also killed large numbers of Indiana bats[4].

Loss of summer habitat threatens Indiana bats during sensitive reproductive periods. Forest cover in Illinois has declined from nearly 40% in the early 1800's to around 14% today, but has been slowly increasing since 1945[34–36]. Decreased forest cover reduces the number of potential roost trees available for Indiana bats. Standing dead trees (snags) with exfoliating bark are often only suitable roosts for a few years[37]. Indiana bats have adapted to this ephemeral resource by scouting and using multiple roost trees, requiring that additional roosts are available in the area. In many areas, humans have interrupted the snag production process by reducing disturbances that create snags, such as flooding, insect infestation, and fire[17,38]. In addition, snags are often intentionally removed. Clear cutting of forested areas, even when bats are not present, likely reduces reproductive success because bats are known to return to the same sites, and delay reproduction in unfavorable conditions[4].

Although Indiana bats readily use highly fragmented forest landscapes, they need travel corridors between patches and edge habitat for foraging. However, fencerows and hedgerows have been greatly reduced across the Illinois landscape with agricultural intensification, which has been shown to reduce bat activity[39]. Roadways further fragment the landscape and endanger bats. Bats fly lower when passing through open areas, putting them in danger of vehicle collisions, and road killed Indiana bats have been observed[40]. Highest abundance of road kills occur where roads cross flyways, such as tree rows, stream corridors, or forest edges[41].

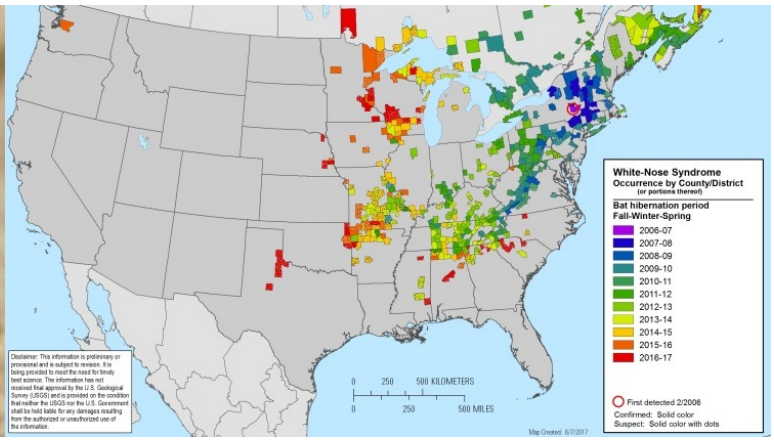
Human disturbance

Disruption of hibernation sites in winter is a serious threat because it rouses bats from hibernation and causes them to deplete limited energy stores, ultimately jeopardizing their survival[4]. Direct disturbance by tour groups, recreational cavers, and researchers is thought to have had large impacts in the past[4]. Access has been reduced and is now controlled in most Priority 1 and Priority 2 hibernacula by bat friendly gates[19]. Human activity also reduces Indiana bat use in summer habitat[42,43].

Climate change

Reproductive cycles, hibernation patterns and migration of temperate zone bats are closely linked to temperature indicating they may be sensitive to climate change[18]. The suitability of the few

Bat showing signs of white-nose syndrome infection. Photos by Ryan von Linden/New York Department of Environmental Conservation



Occurrence of white-nose syndrome, with red-tones indicating more recent detection[33].

hibernacula available will likely be altered by changes in surface temperature. Models indicate that maximum summer temperatures are the most important variable in predicting summer maternity range[18]. Once average monthly summer maximum temperatures reach 81ºF, the climatic suitability of an area declines and at 86ºF it becomes completely unsuitable[18]. Under various climate models, only 13 –37% of current summer maternity colony range is forecasted to remain suitable after 2050, with a range shift towards the northeast. Under all model scenarios, Illinois will become climatically unsuitable for Indiana bat[18].

Environmental contaminants

There is also concern about the impacts of environmental contaminants, especially pesticides, on Indiana bats[4]. Roosting bats can be directly exposed to contaminants while the chemicals are sprayed on agricultural fields or other areas. Bats may also ingest contaminant residues in water or their insect prey. Exposure may have lethal effects at high doses, but lower exposure may have sub-lethal effects that reduce survival and reproduction[44]. Exposure to environmental contaminants may suppress the immune system of bats and make them more susceptible to white-nose syndrome[45]. The indirect impact of contaminants, specifically insecticides, through the significant reduction of prey insects, is also a major concern[46], and is suspected of playing a role in the reduced population growth of Indiana bats in areas, such as Illinois, with intensive agricultural practices[23].

Use of organochlorine pesticides, such as DDT and dieldrin, was banned in the United States in the 1970s, but these chemicals and their breakdown products persist in the environment for decades. Organochlorine pesticides travel up food chains and accumulate in the bodies of predators, such as bats. Organochlorine pesticides were implicated in bat deaths during the 1970s and 1980s[4]. For example, lethal levels of dieldrin were found in the brains of dead juvenile gray bats in Missouri. Low levels of organochlorines were still found in bats collected in Indiana as recently as 2005-2007[4].

Pesticides that are now widely used include organophosphates and carbamates, such as chlorpyrifos. These chemicals are highly toxic nerve agents, but do not accumulate in the body and break down quickly in the environment. However, organophosphates recently have been detected in nearly all Indiana bats and guano tested and have the potential to interfere with thermoregulation, flight, and movement abilities[4,47,48].

More recently neonicatinoids have come under widespread use due to their effectiveness and lower toxicity to vertebrates[49]. However, sublethal impacts of neonicatinoids on bats have been detected, such as the impairment of the spatial memory of bats by Imidacloprid[50].

Although no longer produced in the United States, Polychlorinated Biphenyls (PCB) is a persistent pollutant that is often concentrated in floodplains, and may cause reproductive failures in bats[4].

Wind turbines

Wind energy potential in Illinois is attractive for wind farm development, and in 2015, Illinois had the 5th most installed wind energy generation capacity in the US[51]. Wind turbines pose a threat to all bats when they collide with spinning blades[52,53]. However, cave-roosting bats, such as Indiana bat, are killed at lower rates than tree-roosting bats[54]. Bat fatalities at turbines peak in late summer and fall, coinciding with migration periods, especially on nights with low wind speed (<13 mph)[54]. Habitat variables do not appear to have a consistent effect on the fatality rates of turbines[54]. Although the number of Indiana bats killed by wind turbines may be small relative to other species, the loss of individual bats, especially older females, may have repercussions for the rest of the colony that is maintained by their social ties[28].

Biologists monitor bat fatalities from wind turbines. Photo by Merlin Tuttle, Bat Conservation International.

Regulations
The Indiana bat is classified as an endangered species by USFWS and the Illinois Endangered Species Protection Board. In Illinois, it is illegal to "take" any threatened or endangered animal, such as the Indiana bat. "Take" of listed species, defined as "to harm, hunt, shoot, pursue, lure, wound, kill, destroy, harass, gig, spear, ensnare, trap, capture, collect, or attempt to engage in such conduct," is prohibited by the Illinois Endangered Species Protection Act. In addition, the Illinois Cave Protection Act protects caves and all cave dwelling fauna in Illinois.

The IDNR Impact Assessment Section reviews proposed actions to assess potential impacts to listed species, using their online tool EcoCAT:

- http://dnr.illinois.gov/ecopublic/

Take of a federally listed species must be coordinated, and approved by, the USFWS and IDNR. To receive Incidental Take Authorization from IDNR, one must prepare a conservation plan and notify the public of the impact. See:

- http://www.dnr.illinois.gov/conservation/NaturalHeritage/Pages/ApplyingforanIncidentalTakeAuthorization.aspx
- https://www.fws.gov/ENDANGERED/what-we-do/hcp-overview.html

Research, handling, and possession of listed species requires IDNR permits, including a Scientific Collector Permit and an Endangered and Threatened Species Possession Permit, and additional site permits if research takes place on IDNR land, a dedicated Nature Preserve or registered Land and Water Reserve. Risks and impacts of research methods on the species survival must be weighed against the benefits to justify the activity. In addition, any researcher working with Indiana bat is required to have an USFWS recovery permit. For permit information see:

- http://www.dnr.illinois.gov/conservation/NaturalHeritage/Pages/ResearchPermits.aspx.
- http://www.fws.gov/forms/3-200-55.pdf

Species conservation goals
The federal recovery goal for Indiana bat is a population of at least 457,000 individuals with positive population growth for 20 years and protection of 80% of Priority 1 hibernacula and 50% of Priority 2 hibernacula[4].


Biologists monitoring the number of hibernating bats. Photo by USFWS Andrew King

Illinois conservation efforts
Conservation efforts for the Indiana Bat in Illinois have included monitoring of population trends, research on its biology and threats, and habitat protection and enhancement.

<u>Research and monitoring</u>
Population trends are monitored through hibernacula counts and acoustic surveys. Hibernacula counts have been conducted at most Priority 1 sites biennially since 1980[19]. Many Priority 2 and 3 sites have also been monitored over this same time period. This monitoring effort has enabled USFWS to track the status of the species over time[20]. In addition, acoustic surveys at stationary points across Illinois were initiated in 2017[55]. Research on Indiana bat biology and threats, including migration, white-nose syndrome, and

habitat use, is being conducted in Illinois and throughout its range.

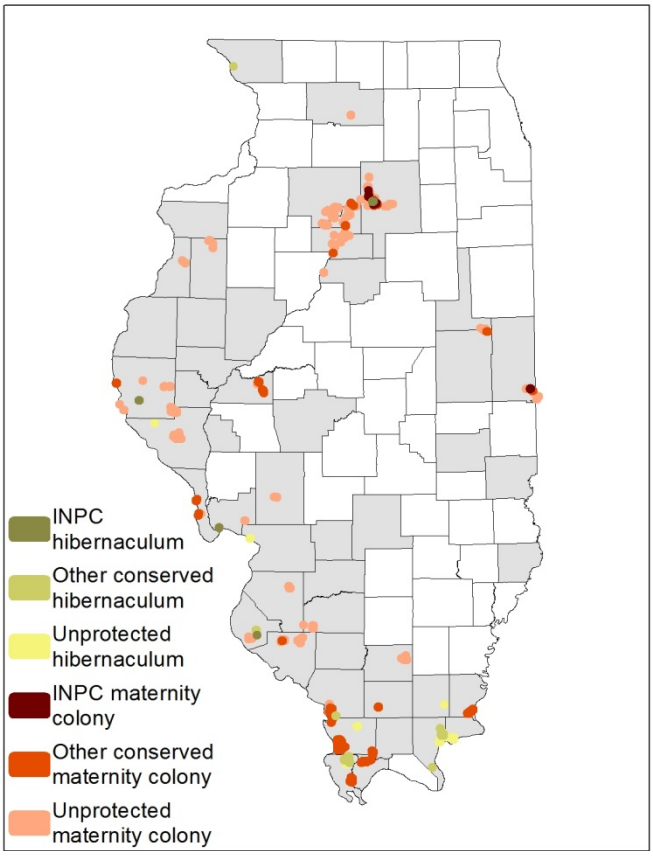
Hibernacula protection and restoration

The single Priority 1 hibernaculum in Illinois is under long term protection, has a gate to control access, and a protected buffer zone[19]. In addition, the Priority 1 hibernaculum was stabilized to prevent collapse and ensure continued availability for hibernating Indiana bats[4]. The six Priority 2 hibernacula in Illinois have inadequate or unknown protections[19]. Bat friendly gates, which allow bats to enter and exit the caves but exclude people to prevent winter disturbance, have been installed at the entrances of several caves and mines in Illinois that are important hibernacula[4]. Four of the 16 Indiana bat hibernacula in Illinois are protected by the Illinois Nature Preserves Commission (INPC), and an additional 6 are under another form of conservation ownership[21,56].

Bat friendly gate installed at cave entrance to deter disturbance of hibernating bats. Photos by Steve Widowski.

Summer habitat protection and restoration

Two of the 45 known summer maternity colonies in Illinois are protected by the INPC and an additional 16 are under another form of conservation ownership[21,56]. Summer habitat is controlled by many private landowners[57], who are targeted by United States Department of Agriculture Conservation Programs that provide incentives for conservation efforts on private land for practices that may benefit Indiana bat. Natural Resources Conservation Service practices that may to providing benefit to bats include: Forest Stand Improvement, Brush Management, Riparian corridor and tree planting, Bottomland wetland restoration. Protection and reforestation of a corridor connecting isolated patches of Indiana bat habitat is ongoing in Champaign County. In addition, there is increasing interest in artificial structures that provide roosting habitat for bats. Many people and organizations have placed bat boxes on their properties. Although use of artificial roosts by Indiana bats have been observed, it remains uncommon[58].



Indiana bat hibernacula and maternity colonies protected by Illinois Nature Preserve Commission, owned by other conservation land owners, and unprotected[21,56]

Indiana bats in a bat house. Photo by Joey Weber Indiana State University

Survey Guidelines

Monitoring for population trends

The North American Bat Monitoring Program (NABat) was initiated in 2015 to provide regular analyses and reporting on the status and trends of bat populations[59]. The program provides standardized methods including winter hibernaculum counts, maternity colony counts, mobile acoustic surveys along road transects, and acoustic surveys at stationary points. Indiana bat populations are best monitored using winter hibernaculum counts and acoustic surveys at stationary points[59].

Surveys for presence

To determine whether Indiana Bats are present or likely absent at a given site during the summer, USFWS recommends using the phased-approach. The phased approach includes of the following steps:

1. Determine proximity to known occurrences.
2. Conduct habitat assessment.
3. Assess potential for adverse impacts.
4. Conduct mist-net surveys or acoustic surveys between May 15 and August 15. Acoustic surveys are recommended to increase sensitivity of detection. Research has shown that the probability of detecting *Myotis* spp. when they are present is much higher using the acoustic survey option (~0.9 probability of detection) compared to the mist-net option (~0.15 probability of detection)[60].
    a. Mist net survey effort: Linear projects: a minimum of 4 net nights per km (0.6 miles) of suitable summer habitat. Non-linear projects: a minimum of 9 net nights per 123 acres (0.5 km^2) of suitable summer habitat.
    b. Acoustic survey effort: Linear projects: a minimum of 2 detector nights per km (0.6 miles) of suitable summer habitat. Non-linear projects: a minimum of 4 detector nights per 123 acres (0.5 km^2) of suitable summer habitat.
5. Conduct radio tracking and emergence surveys to determine roost location and colony size.

Details on the survey guidelines can be found at:

- https://www.fws.gov/midwest/endangered/mammals/inba/inbasummersurveyguidance.html

Monitoring for impacts

Surveys to monitor long term impacts of conservation or development action should assess occupancy, reproductive success, and survival. Ideally, a before-after-control-impact design would be used. Surveys should be initiated as above to locate bats, which are then marked and tracked over time. Acoustic surveys may be used to track changes in the level of bat activity in an area. Habitat and environmental variables should also be evaluated, and installation of temperature and humidity loggers may be necessary. For ongoing impacts such as wind farm operation continuous assessment of fatality rates should be used to monitor impacts.

Stewardship Recommendations

Areas known or suspected of supporting Indiana bat should be protected and managed to maintain suitable habitat. Management actions may include:

- Prevent human disturbance in caves.
- Prescribed fire within 0.25 miles of known hibernaculum should only occur from November 15 to March 31 under conditions that cause smoke to dissipate away from the hibernaculum.
- Prevent the spread of white-nose syndrome when visiting hibernaculum[61].
- Maintain 50% canopy closure through girdling, selective removal of competitive vegetation, herbicide application, and prescribed burns to promote tree vigor and forest health.
- Avoid disruptive management actions in summer habitat from April 1 to October 15.
- Preserve snags (standing dead trees) and dying

Girdling of trees to produce snags can ensure a continuous availability of potneial roost sites for Indiana bat. Photo by Gary Cziko.

trees.

- Preserve shagbark hickories and other potential roost trees.
- Girdle select trees to create more standing snags.
- Selectively remove trees near valuable roost trees to provide more solar exposure.
- Create small forest openings to serve as foraging areas.
- Reforest deforested areas with tree species used by Indiana bat for roosting.
- Created wooded corridors between habitat patches.
- Restore water sources (small ponds, vernal pools) for drinking water and increased foraging opportunities.
- Reduce use of pesticides around roost sites and hibernaculum to reduce Indiana bat exposure and increase prey abundance.
- Create artificial roosts using shingles, asphalt paper, or bat boxes.
- Inform adjacent landowners of the presence of Indiana bat and what they can do to support them.

Avoidance, Minimization, Mitigation

Avoidance measures

The simplest and preferred method to avoid take of Indiana bats is to avoid directly impacting areas known to be used by Indiana bats:

- Avoid known hibernaculum and the surrounding swarming habitat within 10 miles.
- Avoid summer maternity roosts and the surrounding foraging habitat within 2.5 miles[4].
- Avoid areas within 5 miles of a female or juvenile Indiana bat record without an identified maternity roost.
- Avoid areas within 2.5 miles of a male Indiana bat record.
- In addition, avoid impacting wooded corridors, such as riparian zones, that may be providing flight paths[4].
- Disturbances to summer habitat that do not cause physical alterations may avoid impacting Indiana bats if they take place between October 15 and April 1.

Minimization measures

If impacts to Indiana bat habitat cannot be avoided, the following measures may reduce impact.

Area impacted

- Minimize the area to be impacted and locate disturbances as far from roosts and hibernaculum as possible.
- Selectively avoid impacting potentially suitable roost trees (trees 5 inches in diameter or more with shaggy bark).
- Avoid creating large breaks in wooded corridors[40].
- Limit tree removal operations within 300 feet of a water source.

Timing

- Reduce impact by limiting removal of suitable roost trees in Indiana bat summer habitat to October 15 to March 31. Impacts to roost trees from late May to July, especially should be avoided to reduce impacts to Indiana bat pups.
- Reduce impact by limiting tree removal activities around hibernaculum to November 15 to March 31.

Compatible design

- Maintain 50% canopy cover.
- Manage for the continual production of snags such as through flooding or girdling.
- Maintain wooded corridors. Corridor breaks for roadways should not be more than 75 ft. wide and the canopy of the corridor should be at least 60 ft. high up to the edge of the break [40].
- Curtail wind turbine operation and feather blades on nights with low wind speeds (< 5 m/sec)[62], especially during fall migration (typically August 15 to November 1).
- Reduce the use of pesticides through integrated pest management.
- Minimize on-site lighting.

Construction practices

- Clearly mark areas not to be disturbed.
- Locate staging areas far from sensitive areas such as caves, sinkholes, streams, and springs in karst topography.
- Educate construction personnel of the sensitive nature of the project and the required practices.

- Implement, monitor, and maintain erosion and sediment control practices and a pollution prevention plan.

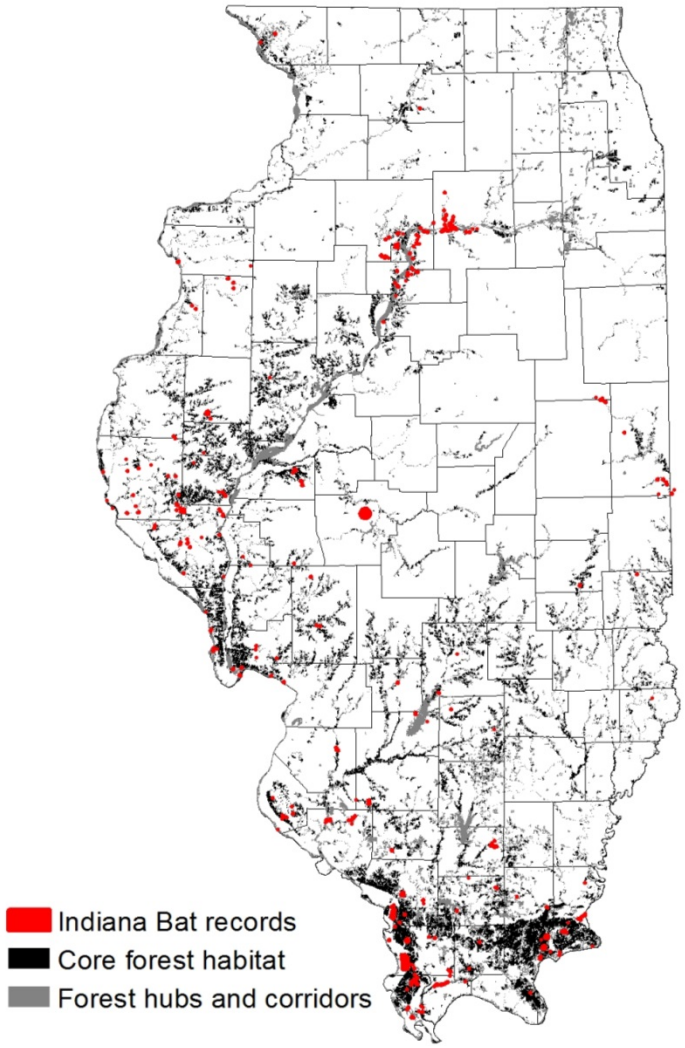
Mitigation and Conservation Opportunities
Mitigation opportunities for the Indiana bat include protection of suitable summer habitat, hibernacula, and swarming habitat[4]. In addition, stewardship or restoration of habitat can provide conservation benefit.

Protection
Summer roost sites and the surrounding 5 miles, and hibernacula and the surrounding 3.5 miles should be protected. Protection may consist of acquisition or conservation easements. Acquired land may be donated to a conservation agency or local conservation organization. Conservation easements may provide a level of protection without acquisition. The Illinois Nature Preserves Commission permanently protects high quality natural areas and habitat for listed species on both private and public lands in the Illinois Nature Preserve System. Conservation easements on agricultural land can also protect habitat through retirement of farmed and previously converted wetlands. Local conservation organizations that may be interested in partnering on conservation efforts can be located through Prairie State Coalition:

- www.prairiestateconservation.org

If hibernaculum are threatened by human disturbance, the entrances of caves and mines can be gated to protect bats. It is imperative that proper gate design is followed so that animals still have access to and from the cave and that proper air-flow, and hence internal temperature, is maintained[63]. Bat gate designs can be found at:

- http://www.batcon.org/pdfs/sws/AgencyGuideCaveMineGating2009.pdf
- https://www.fws.gov/northeast/pafo/pdf/Mine_Opening_Assessment_for_Bats_appendix%20B_091012.pdf



Map showing Indiana bat records and priority areas for forest habitat stewardship and restoration. Areas were identified by modeling the needs of Indiana bats and other focal species[64].

Stewardship and Restoration
Habitat stewardship and restoration may also provide conservation benefit to Indiana bat. Mitigation opportunities at the ecosystem level have been identified by modeling the needs of various focal species, including Indiana bat (see map)[64]. These areas should be targeted for stewardship and restoration (see stewardship recommendations section).

Research needs

- What are the survival and reproductive rates of Indiana bats through different life stages?
- What are the migratory habits and pathways of Indiana bats in Illinois?
- What is the current distribution and abundance of maternity colonies in Illinois?
- What is the minimum habitat patch size that can sustain an Indiana bat maternity colony?
- What factors are limiting in summer habitat and what is the availability of suitable summer habitat?

- Do artificial summer roosts provide benefit as a management tool?
- What are the effects of environmental contaminants on Indiana bat populations?

Additional information

USFWS
- http://www.fws.gov/midwest/endangered/mammals/inba/index.html
  http://ecos.fws.gov/docs/recovery_plan/070416.pdf

Bat Conservation International
- www.batcon.org

Center for Bat Research, Outreach, & Conservation
- www.isubatcenter.org

Midwest Bat Working Group
- www.mwbwg.org

North American Society for Bat Research
- www.nasbr.org

Bats & Wind Energy Cooperative
- www.batsandwind.org

White-Nose Syndrome Information
- www.WhiteNoseSyndrome.org

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