ELECTRIC POWER RESEARCH INSTITUTE

Individual Species Assessment

Indiana Bat (*Myotis sodalis*)

2015 TECHNICAL REPORT

Individual Species Assessment

Indiana Bat (Myotis sodalis)

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NOTE

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Abstract

Following listing under the Endangered Species Act (ESA), the United States Fish and Wildlife Service (FWS) or National Oceanic and Atmospheric Administration (NOAA) drafts a species recovery plan. This plan lists the benchmarks for recovery, generally based on population and habitat status. For a species to be considered recovered, it must meet these benchmarks and the FWS or NOAA must determine that any threats to its existence have been controlled or eliminated. The Indiana bat (*Myotis sodalis*) was listed as an endangered species in 1967, and a draft recovery plan was written in 2007 listing recovery benchmarks.

Significant research has focused on the Indiana bat and there is considerable data on current populations. In the 2009 species status update report by the FWS, the agency concluded that several of the recovery benchmarks have already been achieved. Since that time, White-Nose Syndrome (WNS), a severe fungal infection causing mortality rates as high as 95%, has been observed within the population. Thought to be transmitted by direct contact with an exposed environment or infected individual, the disease has spread quickly. The infection was first observed in a New York hibernacula in 2006, and by 2015 had been observed in over 95% of hibernacula.

This study sought to determine the best conservation practices to support recovery of the Indiana bat, and lead to its delisting from the ESA. Our research suggests, however, that without control of WNS, recovery of the species is unlikely in the short term. While significant research effort has been focused on WNS, no consensus regarding best management practices has been reached. Some researchers have noted that WNS affects all hibernating bats, and if left uncontrolled, has the potential to cause the listing of other species under the ESA. Because of the extreme threat to hibernating bats, we recommend considerable attention be paid to researching WNS treatment and control. Additional conservation actions to protect the Indiana bat should be focused on achieving the remaining recovery benchmarks listed in the 2007 Recovery Plan - focused on the conservation of hibernacula and maternity grounds. A concerted effort to address WNS and to protect all known hibernacula and maternity colonies will be necessary to delist the Indiana bat.

Executive Summary

Under the Endangered Species Act of 1973 (ESA), a species may be listed as endangered, one that is in danger of extinction throughout all or a significant portion of its range, or threatened, one that is likely to become endangered in the foreseeable future throughout all or a significant portion of its range. Once a species is listed, the ESA affords special protections to the species and its habitat, triggering the enactment of conservation actions aimed at recovery. Once a species is listed, the lead federal agency develops a recovery plan, describing the benchmarks for recovery, generally based on population and habitat status. For delisting or downlisting of a listed species, the benchmarks in the recovery plan must be achieved and any threats to the existence of the species controlled or eliminated.

The Indiana bat (*Myotis sodalis*) was listed in 1967 under the Endangered Species Preservation Act, the precursor to the Endangered Species Act. These social bats have two annual stages that are particularly sensitive: hibernation in winter, and maternal colonies in summer. During hibernation, they form dense aggregations in caves or abandoned mines and undergo torpor, subsisting only on internal fat stores. Maternal colonies roost under loose tree bark in dense, wooded areas in the summer.

In their Draft Recovery Plan (2007) and Status Report (2009) the FWS identified four primary threats to Indiana bats: (1) human disturbance; (2) improper cave maintenance; (3) summer habitat loss; and (4) pesticide and other environmental contamination. In addition to these, an additional threat has since become more apparent. White-Nose Syndrome (WNS), a disease caused by the fungus *P. destructans*, was first observed in a New York hibernacula in 2006. According to the most recent data published by the FWS, WNS has now been observed in over 95% of active hibernacula, and 99% of Indiana bats hibernate in WNS-exposed hibernacula. *P. destructans* infects the muzzle and wing membranes of hibernating bats, and causes a wide range of physiological responses, including altered arousal patterns in hibernating bats. WNS mortality rates have been estimated as high as 95% in some populations. Whether or not the species is doomed to extinction due to this disease is an unresolved issue.

An optimistic view is that a small portion of the population might become resistant and the species will recover from low abundances.

It is in this context that the plan for conservation has to be considered.

According to the most recent FWS status report, much progress has been made toward meeting the recovery benchmarks in the Draft Recovery Plan. It is critical to note, however, that this plan was drafted prior to the appearance of WNS in the population. Even though progress has been observed in meeting the recovery benchmarks, the threat of WNS to the population continues to exist, and some studies have suggested that if left uncontrolled, WNS has the potential to cause regional extinctions of the Indiana bat. While much research has focused on the management and control of WNS, little progress has been made. Despite the uncertainty regarding WNS, the FWS continues to recommend the conservation of hibernacula, maternity colonies, and foraging habitat.

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Section 1: Downlisting Under the Endangered Species Act

In their Program 55-funded research, the Electric Power Research Institute (EPRI) commented on the importance of improving endangered species listing decisions and noted that a large number of Endangered Species Act (ESA) listing decisions are likely to occur within the next three years. Additionally, the report noted the possibility of undertaking research and conservation actions in advance of listing decisions to potentially preclude listing. There is also interest in identifying actions that could allow for recovery and subsequent downlisting or delisting of endangered and threatened species. In support of this goal, the EPRI Endangered Species Listing and Conservation Planning Supplemental has identified species with broad ranges, crossing multiple electric power company service territories, to act as foci for research efforts.

The goal of this study is to determine methodology and proposed actions for:

1. improving the quality of listing decisions;
2. providing information for meeting compliance should species become listed; and
3. identifying conservation actions that could promote the delisting or downlisting of a species.

In particular, this project is a rapid assessment of the Indiana bat (*Myotis sodalis*) population status; with the goal of providing the best available science and determining the most appropriate conservation actions to aid in population recovery.

Listing Species As Threatened Or Endangered

The ESA, passed by Congress in 1973, is designed to provide a formal program for the protection of threatened and endangered species and their habitat. For a species to be afforded protections under ESA, it must first be added to the federal list of threatened and endangered species. An endangered species is defined as one that is in danger of extinction throughout all or a significant portion of its range. A threatened species is one that is likely to become endangered in the foreseeable future throughout all or a significant portion of its range. A candidate species is one the United States Fish and Wildlife Service (FWS) or National Marine Fisheries Service (NMFS) has determined may meet the definition of threatened or endangered, but has not yet been officially reviewed or listed.

The listing process is initiated either through a FWS or NMFS status review, or through a petition by US citizens or non-governmental organizations. When a petition is received, the lead agency has 90 days to determine if there is substantial evidence to support listing (Figure 1-1). If the agency determines there is substantial evidence, a 12-month status review is begun to determine if listing is warranted, warranted but precluded by higher priority listings, or not warranted. If listing is deemed warranted, a proposed rule is published in the Federal Register for comment before a final rule is decided. If listing is warranted but precluded, the candidate species is added to the candidate species list, where lead agency assesses its status annually and promotes candidate conservation measures until a listing decision is made.

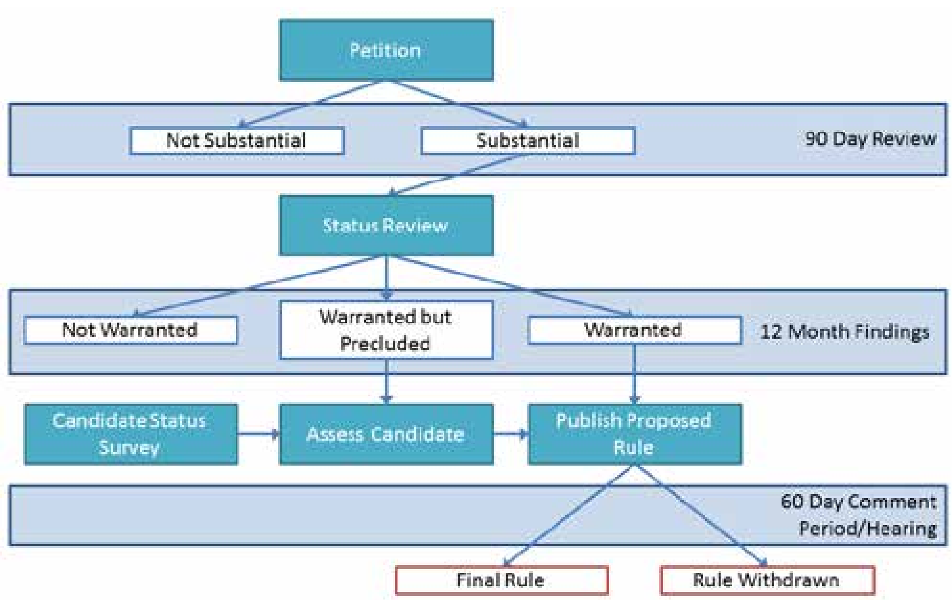

Figure 1-1
The ESA listing process. Image adapted from FWS.

Downlisting and Delisting Species

For species that are listed as either endangered or threatened, signs of successful conservation (i.e., the species is able to survive without further intervention) indicate the species is considered recovered and may be removed from the endangered species list (Figure 1-2). Federal law requires the development of species recovery plans for all endangered and threatened species within US jurisdiction. Included in these recovery plans are benchmarks for recovery, generally based on population and habitat status. For delisting to occur, however, the recovery benchmark must be achieved and it must be determined that any threats to the existence of the species have been controlled or eliminated (Figure 1-2). If there is sufficient evidence for recovery and elimination of threats, the listing agency will publish a proposed delisting ruling in the Federal

Register and seek comments and peer review before publishing a final ruling to delist. A species may also be downlisted from endangered to threatened if it is determined that some of the threats have been controlled and recovery objectives have been met. As of June 2015, a total of 29 species have been removed from the endangered species list due to recovery, and 31 species, including two separate stocks of Chinook salmon (*Oncorhynchus tshawytscha*) have been downlisted (FWS ECOS, 2015).

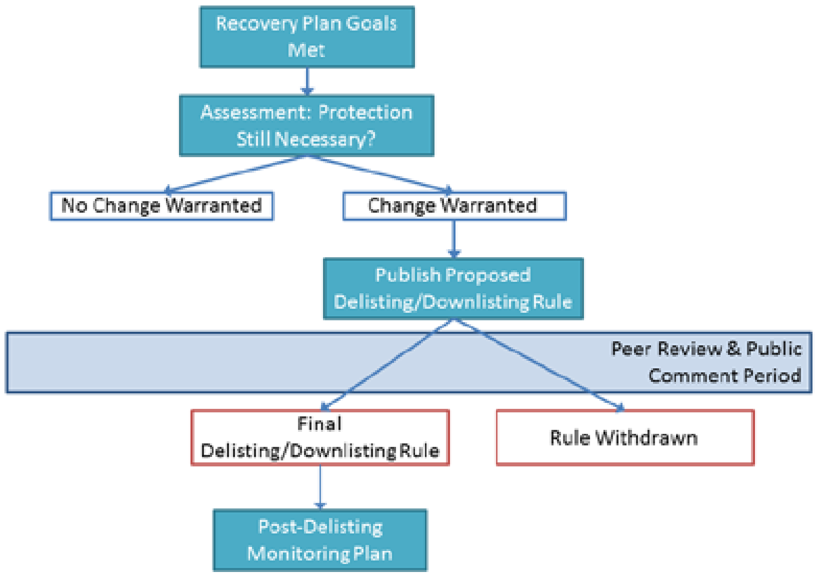

Figure 1-2
The ESA delisting and downlisting process. Image adapted from FWS.

Burden of Proof

A key difference between the decision to list a candidate species versus the decision to downlist or de-list a protected species lies in the notion of "burden of proof." If regulatory decisions are primarily driven by precaution, then listing a species should generally require less evidence than delisting, simply because the risks are strongly asymmetric from the perspective of conservation. While most of the world employs the precautionary principle in regulatory decision-making, the United States does not. Regulation in the US uses cost-benefit approach. The net difference between precaution and cost-benefit depends on the definition of costs and benefits, which may vary by application. The burden of proof during the review of candidate species is on the regulator. FWS or NOAA must defend the decision to list. In contrast, the burden of proof to downlist or delist a species is on stakeholders. The regulator is charged with taking appropriate actions to protect listed species, but is under no duress to demonstrate that those protections have achieved their goal.

The shift of the burden of proof from regulator to stakeholder following a decision directly affects the interpretation of incomplete information. For a candidate species, such as Eastern massasauga, uncertainty stemming from sparse or qualitative data makes the decision to list more difficult to support. For a listed species, such as Indiana bat, that same uncertainty makes the decision to downlist more difficult.

Section 2: Rapid Assessment of Threatened and Endangered Species

The overarching goal of effective conservation planning is to establish quantitative metrics and corresponding thresholds for action. While it is generally agreed that the gold standard by which conservation decisions are supported is population viability analysis (PVA), this type of assessment generally requires practitioners to have a thorough understanding of the biology of the species being assessed. While PVA or related approaches can sometimes help identify conservation action priorities with surprisingly incomplete information, in many cases little is known about the distribution, biology, or population status, such that an in-depth assessment of population viability is impossible.

IUCN Red List

The International Union for Conservation of Nature (IUCN) has established a rigorous and widely accepted set of criteria by which both qualitative and quantitative information can be adapted to a quantitative framework for conservation action. This type of framework allows for the incorporation of a variety of data of different qualities and resolutions to categorize the threat status of each assessed species (Fig. 2-1). Such “rapid assessment” frameworks allow policymakers and conservation planners to make decisions based on the best available science, indiscriminate of the format or quality of that information. For many species, however, even this data is unavailable; 15.2% of the 5,488 mammals assessed by the IUCN were deemed “data deficient” – there was not enough quantitative or qualitative data available about these species to use even the IUCN’s rapid assessment framework. (IUCN 2015).

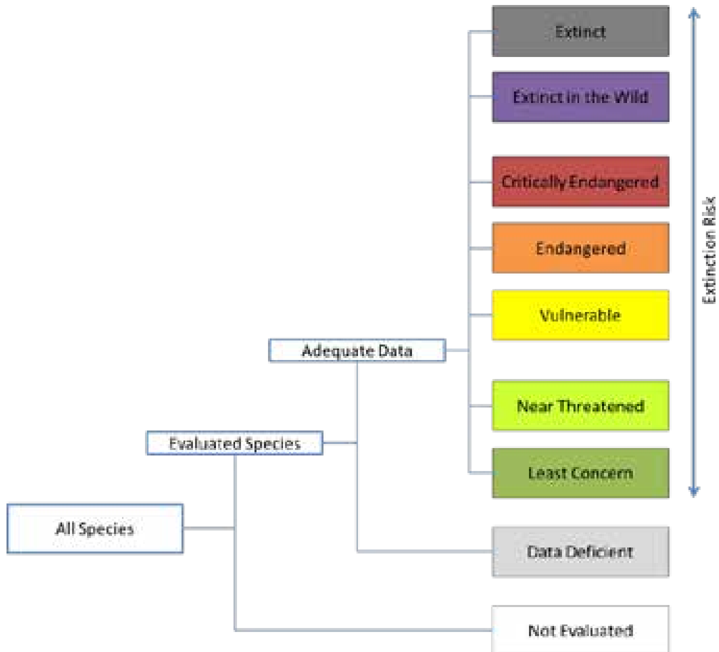

Figure 2-1
Categories of the IUCN conservation status classification system. The categorization process is standardized and can make use of a variety of types of data. Image adapted from IUCN.

Defining Rapid Assessment

Rapid assessments of endangered species are tools that allow conservation practitioners to make decisions with the data that area currently available to them.

For endangered species conservation, the IUCN Red List criteria take advantage of data indicating (or even suspicion of) trends in population size, geographic extent, or patterns of occupancy. Even without trend information, established thresholds can be used to rapidly assess status from current population size or geographic extent.

The Red List framework's usefulness lies as much in its promulgation of carefully negotiated thresholds as in its accommodation of diverse forms of evidence. Whereas the criteria for listing a species under ESA are set forth without indication of their relative importance or combinatorial significance, Red List criteria are, as much as possible, quantitative rules linking data to classifications.

Similar rapid methods have become common in other fields of ecology. Ecosystem ecologists have developed Rapid Ecological Assessments (REAs) to aid in ecosystem-level conservation planning (Sayre et al. 2000). This type of ecosystem approach has been used widely by the NOAA in their conservation planning of coral reefs (Ayotte, et al. 2011). In these coral reef ecosystem REAs, NOAA scientists collect data about species occupancy and habitat, including biotic and abiotic features.

Rapid assessment is an active field of research. A primary goal is to develop methods for conservation status classification that can draw conclusions from even less information. Bianchi (2010) noted, " there are three fundamental questions to be answered when dealing with potentially threatened species: (1) what is the species' distribution?; (2) what is the extent of the species' habitat in time and space?; and (3) how does the species use its habitat and how are populations distributed and arranged?" (Bianchi 2010). He developed a new rapid assessment framework with the motivation that it might be possible to answer these questions even for species whose IUCN status would be data deficient.

Given the role that good science can play in the conservation of species, it is useful to explore what constitutes a good framework for the assessment of species conservation needs. Ideally, such a framework will

§ make maximal use of existing information, avoiding the delay and expense of additional data collection in the field;

§ result in quantitative measurements such that the potential benefit of conservation actions can be judged against their cost; and

§ provide transparency so that assessments can be effectively communicated and reviewed by stakeholders and regulators alike.

This report presents a rapid assessment of Indiana bats. As such, it will address several of the questions Bianchi suggested. Additionally, the following sections will address emerging risks to these populations and discuss the current state of knowledge regarding these risks. Lastly, we will discuss the present and projected population status and range under uncertain environmental and disease scenarios.

Section 3: Indiana Bat

The Indiana bat (*Myotis sodalis*) is a small, social bat whose range extends from the southeastern to midwestern United States (Figure 3-1). At an average adult weight of 0.25 ounces and a wingspan of approximately 10 inches, these bats are of a similar size and appearance to many other species within the region. The Indiana bat was listed as endangered under the Endangered Species Preservation Act, the precursor to the ESA, on March 11, 1967.

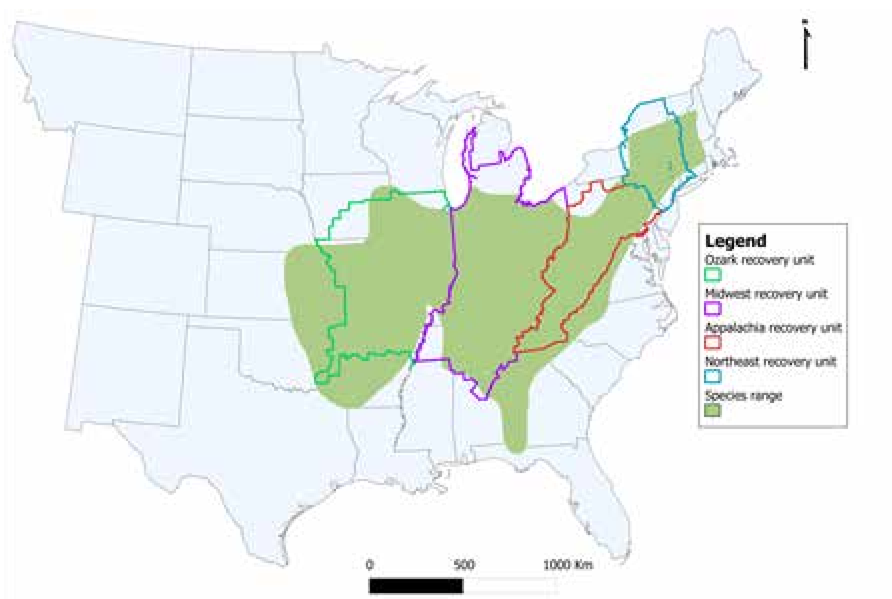

Figure 3-1
Indiana bat range and FWS management units.

Population Status

At the time of listing, the Indiana bat population was estimated to be 880,000 bats, however FWS estimates suggest that the population has declined to 523,636 bats in 2015. Bats populations generally have high adult survival, with low fecundity. These vital rates tend to result in fairly stable population growth rates and abundances (Frick et al. 2010; O'Shea et al 2010). Indiana bat populations, however, have fluctuated widely over the past twenty years (Fig. 3-1).

The FWS manages Indiana bat populations in four distinct recovery units: New England, Appalachian, Midwest, and Ozarks (Figure 3-1). While population increases were seen across all management units in the early 2000s, since 2011, population declines have been apparent in all except the Ozarks management unit (Fig. 3-3).

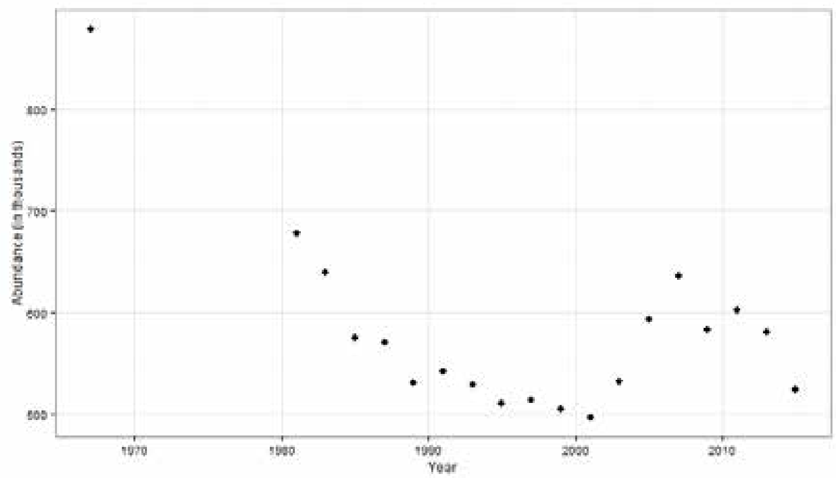

Figure 3-2
Indiana bat abundance from 1978-2013.

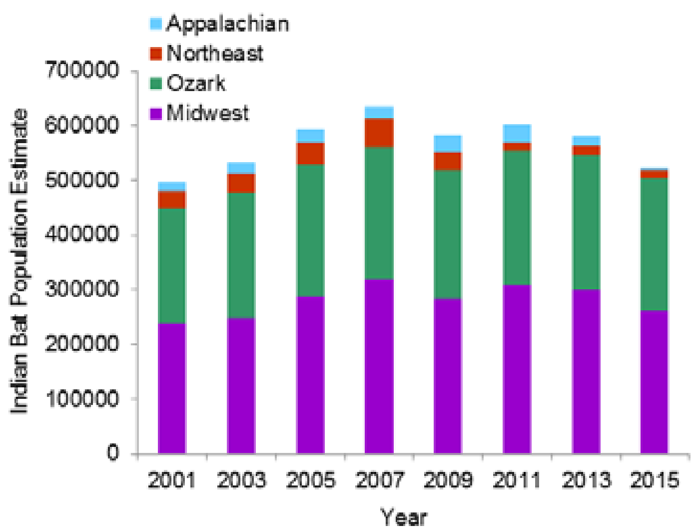

Figure 3-3
Indiana bat population size estimates by recovery unit. Data from 2015 FWS survey update.

Life History

These insectivorous bats are known to forage along rivers, lakes, and upland habitats, consuming nearly half their body weight in insects each night. During the winter, when prey availability is low, the bats hibernate in cool, humid caves with stable temperatures between 0 and 10 °C. During hibernation, bats maintain a very low metabolic rate and body temperature is within a few degrees of ambient temperature (Geiser 2004; Speakman and Thomas 2003). With fat stores providing their only source of nutrients for six months a year, changes in cave temperatures or any other disturbance to hibernating bats may increase their energy requirements, potentially leading to starvation (FWS).

Due to the particular characteristics needed in hibernacula, there are few suitable caves available to the species and individuals tend to congregate in large numbers, averaging 500 individuals per square foot. These hibernacula, each potentially housing a large proportion of the entire population, are very susceptible to environmental or anthropogenic disturbance. As of 2007, the FWS had identified 281 occupied hibernacula in the United States. The bats maintain a strict energy budget during hibernation.

In the summer, female bats aggregate to form maternity colonies, roosting under loose tree bark in dense, wooded areas. As of 2007, the FWS had identified 269 active maternity colonies. During periods of hibernation and maternity, the bats are extremely vulnerable to disturbance and as such, the FWS has highlighted these habitats as particularly important for conservation. Loss of either habitat type could be directly harmful to species persistence.

Conservation Threats

The FWS previously identified four threats to Indiana bat populations:

1. human disturbance;
2. improper cave maintenance;
3. summer habitat loss; and
4. pesticide and other environmental contamination.

Because these bats hibernate in dense aggregations, with large colonies reaching 50,000 individuals, a single hibernaculum could comprise nearly 10% of the entire population. Disturbance, including anthropogenic or physical disturbance, to these large hibernacula would be catastrophic. The FWS has noted that historical human-induced disturbance of hibernating Indiana bat colonies has led to mass mortality events. Additionally, the loss of summer habitat, including foraging grounds and maternal colonies, is also a threat to this species. In particular, deforestation of old-growth, hardwood forest habitat is of particular concern due to the loss of suitable roosting habitat. Lastly, concern has been expressed regarding environmental contamination. The use of pesticides to manage pest insect species has dramatically decreased prey availability in some localities. FWS scientists have suggested that the increased use of pesticides and other environmental contaminants may have caused the initial declines in Indiana bat abundance (FWS).

White-Nose Syndrome

In recent years another threat, White-Nose Syndrome (WNS), has become an increasing, and perhaps primary, concern to hibernating bat populations (Figure 3-5). Blehert, et al. (2009) described the detection of WNS in Howe Caverns near Albany, NY in February 2006. By July 2010, WNS has been detected in hibernating bats in New York, Vermont, Massachusetts, New Jersey, Connecticut, Pennsylvania, New Hampshire, Delaware, Virginia, West Virginia, Tennessee, Missouri, Oklahoma, Ontario, and Quebec (Foley, et al. 2010). WNS is caused by the fungus *Pseudogymnoascus destructans* (*formerly called Geomyces destructans*), which infects skin and wing membranes of hibernating bats and causing up to 95% mortality in some hibernacula (Foley, et al. 2010; Frick et al. 2010). *P. destructans* grows in areas with ≥90% humidity and temperatures between 3-15°C (Lorch, et al. 2011; Cryan et al. 2010). Transmission of the fungus occurs through direct contact and indirect vectors, such as exposure intermediate hosts or habitats (Lindner, et al. 2010; Foley, et al. 2010). Infection by *P. destructans* has been shown to initiate a wide range of physiological responses, including changes in hibernation and respiratory patterns and changes in body chemistry (Verant, et al. 2014). Mortality is believed to occur through either interrupted hibernation, increasing the metabolic rate of the bats and leading to starvation, or through mortality related to wing infection (Boyles and Willis 2010; Cryan et al. 2010; Reeder, et al. 2012). Studies of WNS in other species has suggested that WNS infection may affect not only winter activity in infected individuals, but also may affect summer activity in the entire bat population (Dzal, et al. 2011). Recovery from WNS has been observed in some individuals, but it is almost always associated with permanent wing damage (Reichard and Kunz 2009).

Figure 3-4
Indiana bats with white-nose syndrome in a hibernaculum. Source: US FWS.

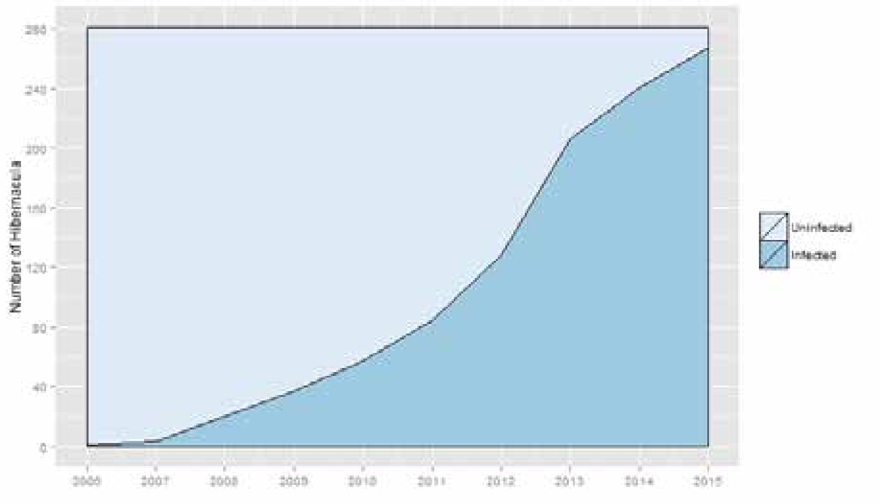

Figure 3-5
Increase in the number of Indiana bat hibernacula infected with White-Nose Syndrome. By 2015 it was estimated that WNS threatens 99% of hibernating bats. Data from FWS.

The threat WNS poses to Indiana bat survival cannot be overstated. Thogmartin, et al. (2012) modeled the population dynamics of 222 bat populations before and after the introduction of WNS to the population. Before the disease appeared in 2006, the range-wide population was stable, however a west-to-east gradient in population growth rate was evident. Westernmost populations were in decline, with easternmost populations were increasing. Since the onset of WNS, however, Thogmartin et al. (2012) reported a 10.3% annual decline in bats. Another study, estimated that over 90% of wintering populations were expected to be affected by WNS in the next 20 years (Thogmartin, et al. 2013). This trend appears to be holding; in 2015, the FWS estimated that 99% of Indiana bats hibernate in WNS-exposed hibernacula (Fig. 3-6). Even if bat populations were to develop immunity to WNS, Thogmartin, et al. (2013) predicted that there would still be a 69% decline in female abundance. Additionally, the authors predict complete regional extirpation of Indiana bats from two of the four current FWS management areas, and a population of less than 250 females in an additional management area.

Section 4: Assessing Population Status

A Brief Introduction to Population Modeling

Population models use the formal logic of mathematics to organize and leverage our understanding of each population, their spatial structure, and vital rates to project possible future states of the population and to identify the key factors that may cause or alleviate risks of decline. Many types of population models exist, spanning a range from simple, theoretical models to complex models of interacting individuals.

For this report, we employed a common approach called age-based modeling. An age-based model requires information on the annual survival and reproduction rates of individuals as they age. Hence, it is necessary to have information on the average number of offspring by a female of a given age, as well as the survival of those offspring through their first year of life. It is common, especially for poorly understood species, to include age classes for the first year up through the year at which all individuals are expected to be mature. This final age class is structured so that individuals remain in it until they die (Lande 1988). Besides the schedule of survival and reproduction, all population models require an initial abundance. Abundance may not always be known for the areas which are being modeled. However, estimates of average population density can be derived from other, better-studied populations.

A powerful way to use an age-based population model is for the projection of future population trajectories. In particular, this method allows for the introduction of random variation around the expected vital rates. This variability enters in two forms. The first is called demographic stochasticity and is the random errors in survival and reproduction rates that would occur in a small population (much as a coin flipped 10 times is will not always yield 5 heads). The second, called environmental stochasticity, is the potentially larger influence of variation in environmental conditions. As is familiar in any discussion of the weather, no year is average and the factors affecting survival and reproduction may vary widely from one year to the next. Projections of population growth over time that consider stochasticity can be used to characterize the probability that a population will decline or go extinct within a given time horizon.

Dispersal and Spatial Context

With dispersal distances up to 500 km and bats from the same summer roosting sites occupying separate distant hibernacula (and vice versa; Kurta and Murray

2002) it is apparent that distinct populations of Indiana bats are likely to cover a large geographic area. For this report, we considered the Recovery Units designated by USFWS in their 2007 Recovery Plan as distinct, panmictic population units (Figure 3-1). Because information was very sparse regarding regional variation in vital rates, we made the important simplifying assumption that vital rates were identical across Recovery Units.

Vital Rates

Annual variability in vital rates is poorly understood for Indiana bats and similar species. From the published literature, adult survival rates of Indiana bats and similar species range from approximately 60% to 80% annually. Published estimates of juvenile survival rate for Indiana bats and similar species range from approximately 35% to 50%. However, most banding studies from which these estimates are derived cannot distinguish between mortality events and emigration events. Therefore, we selected an annual adult survival rate of 80%, an upper value for these species chosen to counter the inherent bias in survival measurements. We chose to use a juvenile survival value of 50% in our baseline population model, also representing among the highest published estimates for this parameter. Fecundity terms in the model reflect the expected number of new female yearling bats produced per female yearling individual in the population in the previous year. We computed a juvenile fecundity of 0.095 juvenile females per female per year and adult fecundity of 0.38 juvenile females per female per year (Shoemaker, et al. 2012).

Population growth rates in wild populations are often dependent upon the abundance or density of individuals in the population. Little is known about density dependence in vital rates for the Indiana bat or for any other bat species, closely related or otherwise. Therefore, we made the conservative assumption that Indiana bat survival and fecundity are density-independent. Therefore, our models did not include a compensatory mechanism wherein vital rates increase at low abundance.

A Population Model for Indiana Bats

To determine the population trajectory, a series of population viability analyses were conducted using the software tool, RAMAS Metapop (Akçakaya and Root 2005). For each analysis, risk metrics were summarized from 1000 simulation replicates at 60 time steps with the first 10 time steps discarded as burn-in. Parameterization of the population model was based on information from the literature, synthesized from studies on Indiana bats and the closely-related little brown bat (*Myotis lucifugus*), as reported in Shoemaker, et al. (2012).

Population Status Without WNS

First, a model of Indiana bat in the absence of WNS was used to explore the innate capacity of the species to persist. Simulations suggested that the population would be stable over a 50-year period without the stress of disease.

Figure 4-1 depicts the mean and standard deviation of projected abundance in the Midwest recovery unit.

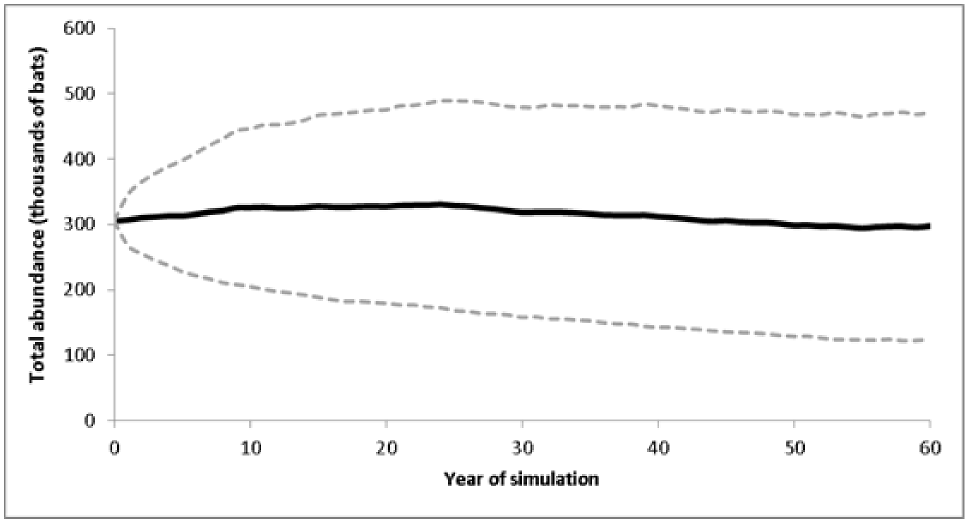

Figure 4-1
Results of a population viability analysis (PVA) for the Indiana bat in the absence of WNS for the Midwest Recovery Unit. The solid black line illustrates the mean abundance each year and the grey dashed lines depict the region ± 1 standard deviation from the mean.

The Impact of WNS on Population Viability

To model the effects of WNS, Shoemaker et al., (2012) added an additional mortality factor to the PVA models. Fatality rates under WNS were modeled based on the analysis of Frick et al. (2010b), resulting in a very high extirpation rate. Because the most severe estimates of fatality rates used in the analysis of Frick et al. (2010b) resulted in certain population collapse, we elected to use the lowest-impact WNS fatality scenario investigated by these authors, in which the fatality rate from WNS ameliorated quickly over time. Under this scenario, the probability of surviving WNS was set at 20% in the first year, followed by survival rates of 50%, 65%, 80%, 90%, 95%, and 99% in subsequent years, respectively. After that, survival rates returned to the rates expected prior to the onset of WNS.

Even with this most optimistic of disease impact scenarios, WNS greatly increased the risk of decline (Figure 4-2). In the Midwest recovery unit, infection of hibernacula reduced the projected median minimum population size from roughly 300,000 to less than 25,000.

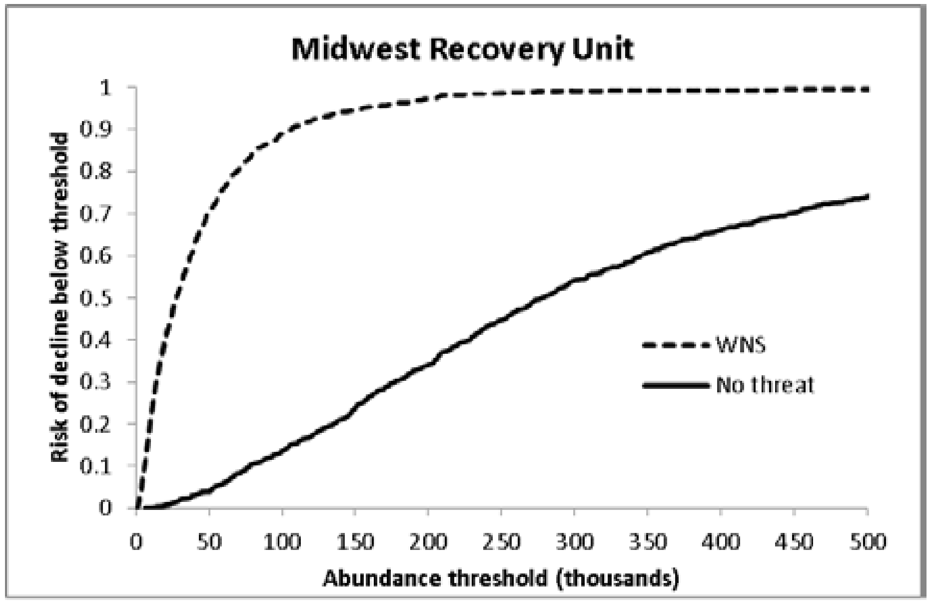

Figure 4-2
Results of population viability analyses for the Indiana bat with and without WNS for the Midwest Recovery Unit. The solid black line illustrates the risk of decline in the absence of WNS and the dashed lines indicates the risk of decline when accounting for WNS.

Section 5: Conservation Actions

Delisting or downlisting of the Indiana bat requires the achievement of the goals set forth in the species' recovery plan. Although there is no recent recovery plan in place for the Indiana bat, a 2007 draft outlines the following criteria for downlisting:

§ Permanent protection of a minimum of 80% of Priority 1 hibernacula in each Recovery Unit, with a minimum of one Priority 1 hibernaculum protected in each unit.

§ A minimum overall population equal to the 2005 population estimate of 457,000.

§ Documentation that shows important hibernacula within each Recovery Unit have a positive annual population growth rate over the next 10-year period.

For delisting to occur:

§ Permanent protection of a minimum of 50% of Priority 2 hibernacula in each Recovery Unit

§ A minimum overall population estimate equal to the 2005 population estimate of 457,000.

§ Documentation that shows a positive population growth rate within each Recovery Unit over a ten-year period.

Progress Toward Improved Conservation Status

To determine the conservation actions necessary to downlist or delist this species, it is necessary to determine the progress that has been made toward achieving the goals set forth in the recovery plan. The last published 5-year review on the species status provides a starting point for this analysis, as the authors have outlined the progress toward these conservation goals as of 2009 (Table 5-1). Additionally, there are other threats to the Indiana bat that were not specifically mentioned in the recovery plan. In the 2009 five-year review, the FWS acknowledged the additional threat of White-Nose Syndrome to the Indiana bat, which was not incorporated into the aforementioned draft recovery plan. This additional recovery criterion is expected to be included in the final recovery plan (FWS 2009). Thogmartin, et al. (2012) noted that WNS is "having an appreciable influence on the status and trends of the Indiana bat populations, stalling and in some cases reversing population gains made in recent years". Foraging habitat fragmentation, environmental contamination, wind farm development, and climate change have been suggested as other threats that should be addressed to ensure the continuity of the species (O'Shea and Clark 2002; Sparks, et al. 2005; FWS 2009; Johnson, et al. 2012).The influence of these emerging threats is particularly important to note because even if Indiana bat populations meet the recovery criteria listed in recovery plans, prior to delisting, the species must undergo an independent scientific review to determine if recovery has been achieved (Figure 1-2).

Table 5-1
Criteria for delisting and downlisting according to the 2007 Draft Recovery Plan and the status as of the 2009 species status assessment.

	Criteria	2009 Status
Downlisting	Permanent protection of a minimum of 80% of Priority 1 hibernacula in each Recovery Unit, with a minimum of one Priority 1 hibernaculum protected in each unit.	48% of hibernacula protected across range: · 57% of Ozark-Central Recovery Unit · 50% of Midwest Recovery Unit · 50% of Appalachia Recovery Unit · 0% of Northeast Recovery Unit
	A minimum overall population equal to the 2005 population estimate of 457,000.	Achieved
	Documentation that shows important hibernacula within each Recovery Unit have a positive annual population growth rate over the next 10-year period.	71% of hibernacula across the range meet this criteria: · 67% of Ozark-Central Recovery Unit · 75% of Midwest Recovery Unit · 50% of Appalachia Recovery Unit · 100% of Northeast Recovery Unit
Delisting	Permanent protection of a minimum of 50% of Priority 2 hibernacula in each Recovery Unit	31% of Priority 2 hibernacula protected across range: · 25% of Ozark-Central Recovery Unit · 42% of Midwest Recovery Unit · 25% of Appalachia Recovery Unit · 0% of Northeast Recovery Unit
	A minimum overall population estimate equal to the 2005 population estimate of 457,000.	Achieved
	Documentation that shows a positive population growth rate within each Recovery Unit over a ten-year period.	Achieved

To evaluate the potential conservation actions which may affect the recovery criteria outlined in the Recovery Plan, a review of management plans and mitigation reports was conducted to determine the broadly accepted conservation actions and estimated costs associated with these actions (Table 4-2, 4-3, 4-4). Additionally, we evaluated federal spending on conservation actions. In FY 2013, the federal government reported spending $13,879,775 on Indiana bat conservation with an additional $9,970,896 spent on land acquisition associated with Indiana bat conservation. Additionally, state agencies reported spending an additional $302,331 on Indiana bat conservation measures (FWS 2014). The conservation actions associated with these expenditures, however, is not reported in the annual ESA expenditure reports, so it is difficult to identify the specific action and associated expenditure.

Currently, the conservation actions broadly supported by the FWS are focused in two areas: (1) supporting research; and (2) habitat management and conservation. It should be noted that the FWS' recovery criteria are primarily focused on habitat preservation and population status. However, many of the unprotected hibernacula currently exist on private lands. As such, many conservation plans have included an educational component, as well.

Managing for White-Nose Syndrome

As described in Section 2, WNS has been a strong contributor to recent declines in Indiana bat populations and is expected to be a major challenge in the restoration of their population. Thogmartin, et al. (2012) reported an annual population decline of 10.3% in the Indiana bat since the emergence of WNS in 2006. Follow-up studies have confirmed this, predicting complete extirpation of the bats from at least two of the FWS' management areas (Thogmartin, et al. 2013). In light of this important threat, much research has been focused on potential management of WNS in hibernating bat populations. An analysis by Thogmartin, et al. (2013) suggested that, considering the predicted effects of WNS, management actions should be focused on increasing winter survival of adult females. Foley, et al. (2011) identified several potential management options, including (1) treatment of infected individuals; (2) population resistance; (3) hibernacula modification; (4) culling; and (5) transmission reduction (including through human vectors). Each of these management options has been, at a minimum, cursorily addressed in the literature:

1. Meteyer, et al. (2011) reported limited success with rehabilitation of 30 little brown bats (*Myotis lucifugus*) infected with WNS by providing supportive care, however their methods were effort-intensive and required the relocation of individuals to a sterile habitat, which is likely impossible on a larger scale.
2. While Foley, et al. (2011) suggested the potential use of vaccines, and cited a precedent for vaccination against fungal diseases, to our knowledge there is currently no vaccine against WNS. Indeed, Johnson, et al. (2015) found that in little brown bats vaccines producing antibodies to *P. destructans* were insufficient to prevent WNS infection. In contrast, Frank, et al. (2014) provided evidence that some bat species may be naturally resistant to WNS.

This potentially significant finding is likely to initiate new research directions in the resistance of WNS.

3. There is some evidence to suggest that the modification of hibernacula may reduce the transmission and mortality rates associated with WNS. Several studies have demonstrated a lower mortality rate in WNS-infected bats in colder hibernacula (Verant, et al. 2012; Greineisen, et al. 2015).
4. Hallam and McCracken (2011) evaluated the efficacy of culling individuals in infected hibernacula. Their results suggest that culling of bats will have little effect in social bat species.
5. Shelley, et al. (2013) reported on a decontamination protocol to reduce the human-induced spread of the *P. destructans* pathogen, however, it remains unclear if this is eliminates the human transmission vector.

To date, however, there is no consensus regarding best management practices for WNS and additional research is necessary.

Research

In addition to researching the effects and management of WNS infections, it is also essential to maintain an accurate estimate of population trends (Table 5-2). While the FWS tracks range-wide surveys biannually, local and continuous monitoring efforts are crucial, especially in populations at-risk of WNS infection. The specific costs of establishing these types of research programs are highly variable, however, Table 5-2 provides examples of specific conservation actions and associated costs drawn from recent management plans.

Table 5-2
Conservation actions and estimated costs addressing research needs for the Indiana bat. Estimated costs are inflation adjusted (2015 USD) costs incurred by recent FWS-approved conservation programs.

Action	Estimated Costs
Support scientific research on WNS through grants and other funding opportunities	$160,000-$500,000 (per grant) Variable, dependent upon discipline and project
Monitoring, which may include: · Occupancy surveys · Annual population monitoring · Installation of bat detectors · Installation of forest stands for surveys · Aerial photo survey of maternal colonies	Variable dependent upon methodology, personnel and spatial extent $150-2,000 per bat detector $6,000 per stand Variable dependent upon methodology, personnel and geographic area, and plane specifications.

Habitat Protection and Management

Many of the recovery criteria in the Indiana bat Recovery Plan specifically cites the need to conserve hibernacula and maternity colonies. While many of these sites are already protected (Table 4-3), several hibernacula and maternity colonies remain unprotected. The majority of these exist on private lands. While scientists have a broad understanding of general habitat preferences across the range, there is little discussion or research regarding the fine-scale habitat preferences of this species. Using our current understanding, it is possible to identify potential regions of suitable habitat at a very coarse spatial resolution. It should be noted that to complete this analysis for the entire range of the massasauga, the spatial resolution is quite low. To identify particular regions for conservation actions to occur, a higher resolution analysis at a smaller spatial scale would be necessary.

Shoemaker, et al. (2012) developed a habitat suitability model based upon the following assumptions and guided by expert opinion:

1. Roost site is selected based upon the physical attributes of the roost tree and the vicinity to resources.
2. Hardwood trees offer the most suitable roosting habitat, therefore any forested site composed of hardwood trees is suitable roosting habitat
3. Older forests will contain more large trees with sloughing bark, suitable for roosting.
4. Forest edges provide optimal foraging habitat, particularly the transition zones between forested areas and open grasslands, croplands, or open water.
5. Access to water and associated flying insects also offer denser insect forage for bats.
6. Access to a diversity of land cover types from the roost location is an important component of the suitability of summer habitat (Gardner & Cook 2002; Yates & Muzika 2006).
7. Suitable summer habitat must be within migration distance from at least one hibernaculum

Using these assumptions, Shoemaker, et al. developed the habitat suitability model described in Table 5-3 using data from the National Land Cover Database 2006, a forest stand age map layer from the Oak Ridge National Laboratory, US Geological Survey National Atlas Water Feature Areas (Fry, et al. 2006; Pan et al. 2012; US Geological Survey 2003).

Table 5-3
Habitat suitability model rules.

Habitat Suitability Component	Habitat Suitability Rule
Hardwood forest	Deciduous forest must comprise ≥ 15% of the area within a 2 km search radius.
Stream density and wetland density	Wetlands must represent 5% of available area OR streams must occur with an average density of 5 km per km2 within a 2 km search radius.
Foraging habitat diversity	Three or more distinct foraging habitat types must occur within a 2 km search radius.
Distance to hibernacula	Decay function based on estimated migration distances
Forest age	Forest stand age must be ≥ 30 years.
Forest edge density	Forest/field edges must occur with an average density of 2 km per km2 within a 2 km search radius.

In total, the algorithm for predicting likely summer maternal roost sites identified over 2,600 suitable sites, comprising a total of 1.6% of the total range extent. Figure 5-1 displays the locations of suitable habitat patches identified using the methods outlined above.

Within these regions of suspected occupancy and suitable habitat, several habitat management actions have been suggested. The specific costs of conducting this type of habitat conservation are variable. However, Table 5-4 provides examples of cost estimates from Indiana bat management plans expressed in 2015 US dollars.

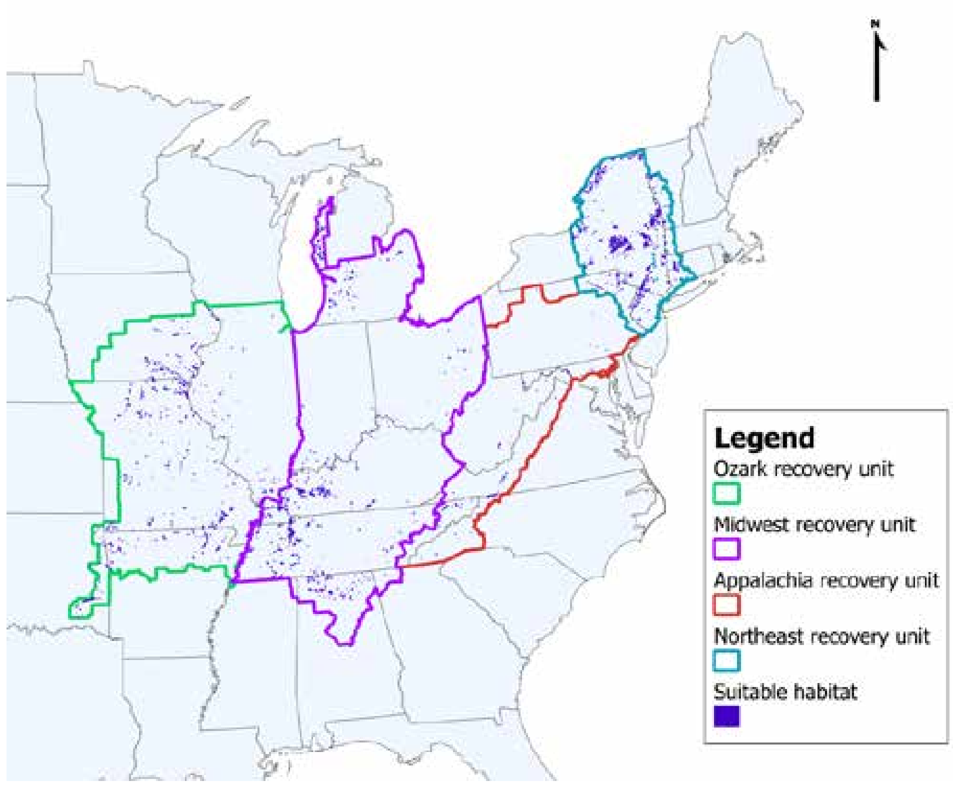

Figure 5-1
Suitable maternal roosting habitat identified by an Indiana bat habitat suitability model (Shoemaker, et al. 2012).

Table 5-4
Conservation actions and estimated costs addressing habitat conservation and management for the Indiana bat. Estimated costs are inflation adjusted (2015 USD) costs incurred by recent FWS-approved conservation programs.

Action	Estimated Cost
Land acquisition (primarily of forested areas) through purchase or permanent easements	$4,000-$6,000/acre
Hibernacula protections, including cave gating	$50,000/cave
Maternal colony habitat development, potentially through: · Bat boxes · Tree installation · Artificial roosting habitat	$250-2,500 each $3,000/acre

Public Outreach and Education

Lastly, we have identified education as an important focus for conservation actions. Scientists have identified the use of pesticides and other anthropogenic sources of contamination as the likely cause of the initial decline of the Indiana bat. Additionally, human involvement has been implicated as a potential vector for WNS transmission. Because of the potential for humans to negatively impact the foraging ability and health of this species, public education and outreach programs are suggested to increase awareness. Similar programs have been developed for other at-risk species and the associated costs are listed in Table 5-5.

Table 5-5
Conservation actions and estimated costs addressing public education and outreach needs for the Indiana bat. Estimated costs are inflation adjusted (2015 USD) costs incurred by recent FWS-approved conservation programs.

Action	Estimates Cost
Development of public outreach program, possibly including: · Workshops · DVD · Website development · Brochure publication	$5,000-15,000

Section 6: Conclusions & Recommendations

Since the listing of the Indiana bat under the ESA in 1967, significant effort has been placed on protecting both the winter and summer habitats of this species. While this comprises a very large portion of the recovery criteria described in the 2007 Draft Indiana Bat Recovery Plan, recent additional threats have become apparent. The appearance of White-Nose Syndrome (WNS) in Indiana bats, a disease caused by the fungus *P. destructans*, was first noted in a New York hibernacula in 2006. Since that time, WNS has spread rapidly though the population. A 2015 estimate by the FWS suggests that 99% of all Indiana bats winter in WNS-infected hibernacula. Recent studies have suggested that WNS infection in Indiana bats causes an annual population decline of 10.3% and will lead to regional extirpation within the next 50 years (Thogmartin, et al. 2012; Thogmartin, et al. 2013). Models incorporating declining transmission of or increased resistance to WNS over time still project severe population bottlenecks and elevated risks of extinction (Shoemaker, et al. 2012; Thogmartin, et al. 2013; Maslo and Fefferman 2015).

Currently, there are no accepted or widely-adopted management techniques to address WNS in bats. As such, research funding to support WNS management options is critical. While it clear that no conservation action short of WNS eradication could generate any likelihood of downlisting or delisting the Indiana bat, focused research on the disease and its interaction with bat ecology still has significant value. WNS affects most social, hibernating bat species. Already, it is prompting the review of little brown bats for ESA protection. Many researchers have suggested that if no management solution is obtained more bat species will become endangered or threatened.

Finally, the focus on WNS should not distract from basic conservation actions. In particular, the protection or improvement of maternal roosting habitat not only alleviates the direct impact of habitat loss on current population vital rates, it may lay the groundwork for a recovery of Indiana bats should their ability to adapt to WNS manage to outpace their approach to extinction.

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Appendix A: Responses to Questions on Draft Report

Draft Recovery Plan

Q: Could you comment on the fact that the draft recovery plan does not talk about white-nose syndrome?

A: The draft recovery plan was created in 2007, prior to knowledge of white-nose syndrome.

Bat Boxes

Q: Could you comment on any research you found on bat boxes?

A: It appears that both bat boxes and an artificial tree bark are viable options for creating Indiana bat habitat, though it is not clear how these options compare with natural habitat. Whitaker, et al. (2006) observed two Indiana bats using bat boxes installed near the Indianapolis International Airport. The structures had been in place for 10 years prior to the study and had been used almost exclusively by other bat species for that time. Artificial bark, marketed under the brand name BrandenBark, showed immediate use by bats in an unreviewed pilot study (Adams, et al. 2014). Unlike bat boxes, the majority of bats using the artificial bark installations were Indiana bats engaging in summer maternal roosting.

Temporary Construction

Q: Could you comment on whether you think temporary work (like temporary construction) in a right of way could cause problems in a population?

A: While we cannot make specific comments without details of the work being performed, we offer some guidance based on what is known about the species. This guidance is our professional judgement and does not reflect the judgement of any regulatory agency.

Work performed during the winter months, away from hibernacula, should not have any direct impact on individuals. Changes to forest structure and the availability of maternal roosting habitat caused by construction activities could impact local survival and reproduction in the following summer. Work during the spring and summer could have the potential to disturb individuals through noise and vibration or to destroy individuals if roost trees are damaged or removed. Activity in right of ways during spring and fall migrations may pose a risk of collision or disturbance. Nighttime work during migrations may disturb roosting migrants. For Indiana bats, which have a large total abundance, the loss of small numbers of individuals does not necessarily increase the long term risk of decline (even in the absence of WNS), though it may affect the number of bats using the local habitat in subsequent years. Given the large geographic range of the Indiana bat and the dispersion of summer populations from their shared hibernacula, it is possible that seemingly minor local infractions upon habitat or survival could lead to a significant cumulative effect.

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