Session 5

Program Development

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THE COLORADO BATS/INACTIVE MINES PROJECT

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Introduction

The Colorado Bats/Inactive Mine Project is a cooperative effort between two sister agencies; the Colorado Division of Minerals and Geology and the Colorado Division of Wildlife. The Colorado Division of Minerals and Geology, Inactive Mine Reclamation Program (IMP) has the responsibility for safeguarding hazardous mine openings in the State. The Colorado Division of Wildlife (DOW) manages and protects the State's wildlife.

Colorado's history is mining. Mining attracted people to the State in 1859 and it was the most important economic activity in Colorado for many years. Mining is still important to Colorado's economy today although it is now oriented more towards coal and aggregate. There are over 23,000 hazardous abandoned mines and 1,300 miles of stream impacted by mining in the State of Colorado. To date, seventeen people have died in abandoned mines and twenty-four people have been injured.

While these abandoned mine openings represent a hazard to the public; they can be important habitat for bat species. Colorado is home to 18 different bat species, 13 of which are known to use caves and mines to some extent. Bat populations have been decreasing in Colorado and elsewhere in North America due to pesticide use and destruction of habitat. As bats lose their traditional roost sites, man-made structures, such as abandoned mines, have become increasingly important to bats.

History of the Colorado Bats/Inactive Mine Reclamation Program

The Inactive Mine Reclamation Program (IMP) in Colorado began in 1980 and the first mine closures were installed in 1982. Presently the IMP has installed over 5,000 mine closures in the State. The first three years of the program were spent exclusively on coal sites. The IMP has safeguarded about 900 coal openings since 1982. Initially most of the openings were safeguarded by backfilling or installing concrete caps. In 1985 the IMP began work on hardrock mines and in 1987 the first bat gate was installed on an uranium mine adit just west of Denver. In 1988, the IMP installed safeguards at the Orient Mine in southern Colorado. The Orient mine contains a bachelor colony of over 250,000 bats. Over 320 bat gates have been installed or are scheduled to be installed by DMG on abandoned mine openings. Over 300 of these gates are protecting Corynorhinus Townsendii roosts.

In 1990, the Division of Wildlife (DOW) began actively pursuing a bat conservation program. Neither the DOW nor the IMP had adequate funding to provide bat gates for all mine closures. Consequently, after a series of meetings, the two agencies outlined major goals to guide the Bats/Inactive Mines Project.

Goals

The goals of this cooperative venture are:

1. Develop a cost effective inter-agency project to evaluate and identify mines with significant populations of bats, particularly Corynorhinus Townsendii populations. The system that was developed requires close cooperation between IMP project managers and DOW coordinators.

2. Protect mines that are important bat habitat with bat gates. Bat gates allow bats to continue to use mines while providing for public safety. Gates also lessen the amount of human disturbance to bats. Several factors influence the decision concerning the installation of bat gates, particularly available funding. Other factors include: (1) species use, (2) opening characteristics, (2) degree of visitation to the site, and (4) susceptibility to vandalism.

3. Increase awareness about bat conservation and the hazards associated with abandoned mines.

Funding

The Federal Office of Surface Mining funds most of the IMP activity in Colorado. The money for this work comes from fees paid by current coal mine operations. The fees are placed into a trust fund by the Federal Office of Surface Mining. Fifty percent of these funds can be returned to the State for reclamation purposes. The program budget is approximately $2.5 million per year with the majority of the funds allocated to construction. The IMP safeguard mines by cost sharing with the National Park Service, the Bureau of Land Management, the United States Forest Service, and private landowners. The priorities of the program fall into four categories: (1) emergencies (coal only), (2) extreme hazards, (3) dangerous hazards, and (4) environmental degradation). Preference continues to be given to coal problems since the funding is derived from active coal mines. The IMP can safeguard extreme hazards at non-coal/hard rock mines with a letter from Governor and approval from the Secretary of Interior. Collection of fees is currently set to expire in 2004 and consequently it is imperative that the mines be safeguarded as soon as possible. The IMP continues to pay for the majority of the costs associated with special bat closures. Currently, only one third of one percent of construction dollars comes from DOW. DOW usually pays the incremental costs between the standard closure and the bat gate on lands where there is no other funding source other than the Office of Surface Mining.

Process

The following is the process used to initiate an Inactive Mine Project:

1. The IMP, with a citizen's advisory council, selects general candidate areas (geography, watersheds, part of a mine district, etc.) in order to target a reclamation project. A 1980 inventory of sites is used to locate mine openings as well as citizen requests.

2. IMP project managers visit sites and complete a mine site field form for each opening. Project managers may note the presence of bats on the field form. However, in most cases, no formal bat assessment is made.

3. The IMP gives copies of mine site field forms to DOW and begins a realty search to determine ownership.

4. The IMP identifies the owner and begins attempts to obtain consent for safeguarding work. Ownership information is given to DOW. DOW procures consent for bat surveys directly from the landowners of the mine sites.

5. DOW reviews IMP mine site field forms and, along with site inspections, determines which sites warrant further investigation.

6. DOW conducts site surveys where trapping and internal surveys are involved at some sites.

7. DOW makes recommendations to IMP on the desirability of installing bat gates. IMP reviews DOW recommendation as to:

    A. Feasibility (competency of surrounding material, "constructability," access for necessary equipment)

    B. Cost (size, accessibility for equipment, specific/special design needed)

    C. Landowner requirements.

    D. Effectiveness of the proposed closure with respect to eliminating the hazard.

    E. Future maintenance requirements/susceptibility to vandalism.

    F. Compatibility with possible competing interests such as historical preservation requirements.

Conclusion

The Bats/Inactive Mines Project is a great example of how two sister agencies can cooperate to accomplish related, though sometimes divergent, goals. The success of the project is due to the efforts of the coordinators of the DOW Bats/Inactive Mines Project, hundreds of volunteers, DMG project managers and the contractors who install the gates.

THE MCLAUGHLIN MINE BAT PROGRAM: NEW IDEAS IN AN OLD MINING DISTRICT

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Introduction

Homestake Mining Company's McLaughlin gold mine (located in northern California about 70 miles north of San Francisco) has distinguished itself by its adaptive approach to wildlife management. Homestake's strategy at McLaughlin has been one of open review and adaptation as new information becomes available. This approach is clearly exemplified in the management of bat populations at the site. Of sixteen species predicted to occur at the site, ten have been confirmed thus far.

Bat Colony Relocation

A pioneering effort to understand and provide for the needs of a sensitive bat population at the McLaughlin mine was initiated by Homestake in 1987. Under the guidance of Drs. Elizabeth "Dixie" Pierson and William Rainey, mine staff undertook the relocation of a colony of Townsend's big-eared bat (*Corynorhinus* (=*Plecotus*) *townsendii*). The colony resided in legacy mine workings from historic mercury mining in the district. Seventy females were identified as using nearby tunnels as a summer roost. Winter monitoring revealed that other workings in the vicinity were used as hibernacula. Excavation in the vicinity of these roosts was postponed until alternative roosting habitat could be found, and until additional behavioral/ecological data could be gathered to understand the needs of the colony.

In May 1988, once sufficient information had been gathered to proceed, the colony was relocated to safe alternative habitat sites. The new sites are protected within the boundaries of Homestake's lands, are stable, and have been gated to prevent human intrusion. Since relocation, the maternity colony has more than doubled in size, recently numbering in excess of 200 individuals. The methodology and habitat considerations used during the course of this effort were novel and unprecedented at the time. Little was known of the roosting requirements for this species. The success of this program is attributable to careful observation of the roosting patterns in the district to determine the preferences of the species. Once these needs had been identified, suitable alternative sites were selected for stabilization and occupation.

Creation of Artificial Habitat

Ongoing habitat innovation at the McLaughlin mine led to the installation of an artificial tunnel habitat for bats in 1996. This experimental structure was constructed of used heavy equipment tires, placed side-wall to side-wall, extending outwards in an X shape from a central concrete hub. The structure was built in an area where mine overburden "waste rock" was being placed.

Once filled over with clay and soil, the habitat consisted of 445 feet of tunnel, two gated entrances, and two ventilation risers. Although no bat occupation of the structure has been documented, its interior conditions are favorable for roosting. It is thought that occupancy may occur when suitable woody cover has been established across the exterior landscape, which now consists of recently reclaimed expansive grasslands.

Summary

In summary, the McLaughlin mine bat protection program is a highly successful model. Using the decision-making processes described above, an effective habitat management program (with minimal budgetary consequences) is established and is self-sufficient. Ongoing monitoring continues to confirm the effectiveness of this approach.

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IMPLEMENTATION OF A RECOVERY PLAN FOR THE ENDANGERED INDIANA BAT

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Abstract

The Indiana bat (*Myotis sodalis*) has been listed officially as endangered since 1967. The species was listed because it was and remains exceptionally vulnerable to disturbance and destruction during the winter hibernation season. This is because a high proportion of its population congregates during winter in a small number of caves and mines. Despite protection of many of these hibernacula, the overall population has continued to decline. Declines are not universal, however, throughout the species' range. The population in the southern portion of the Indiana bat's range has suffered disproportionately and lost numbers while that in the northern Midwest and northeast it has maintained or increased numbers during the same time period. At this time, the *Indiana Bat Recovery Plan* is being revised. The foremost need identified in the plan is research into the cause or causes of the observed declines and the reasons for the disparity in population trends in the different parts of the species' range. It still is important, however, for Indiana bat colonies in caves and mines to be protected during hibernation, and for management authorities to attempt to restore colonies that have declined in or been excluded from historic hibernacula. It also is possible to manage for summer colonies of Indiana bats by enhancing or restoring surface habitat to conditions favorable for the species. Mining concerns and regulatory agencies can participate in the recovery of the endangered Indiana bat in both winter and summer by: (1) identifying mines that are occupied by the species and protecting them, and (2) restoring surface mine landscapes to forested conditions.

Introduction

Land managers, including managers of mine lands, may be concerned about a number of bat species and their habitat needs. One bat species that has attracted attention in the eastern U.S. is the endangered Indiana bat (*Myotis sodalis*). The *Indiana Bat Recovery Plan* contains information and recommendations that may be used to manage underground and surface habitat for this species. Management for the Indiana bat not only would provide habitat for an endangered species, but also would provide habitat for a variety of other cave-dwelling and forest bats.

Current Status and Population Trends

Indiana bat populations first were surveyed in the late 1950s (Hall, 1962). In the decades since then, additional colonies of hibernating Indiana bats were discovered and our knowledge of the distribution and status of the species has expanded. Regular surveys have been conducted since the 1970s. Based on censuses taken at hibernacula, the total, known Indiana bat population in 1999 was estimated to number about 350,000 bats. More than half of the current population of

the Indiana bat hibernates in the nine Priority One hibernacula. Eight of the nine have been surveyed every two years from 1983 to the present (one is unsafe to enter). The populations in these caves are presented in Table 1. During the period 1983 through 1999, the populations in these caves have declined by 39 percent.

Table 1. Populations of Indiana bats in the eight surveyed Priority One hibernacula, 1983-1999.

Year	1983	1985	1987	1989	1991	1993	1995	1997	1999
Population	288225	246600	239200	213050	228675	208875	189000	178525	176125
Survey to survey % change		-14.4	-3.0	-10.9	+7.3	-8.7	-9.5	-5.5	-1.3
% change since 1983		-14.4	-17.0	-26.1	-20.7	-27.5	-34.4	-38.1	-38.9

The three States with the highest numbers of Indiana bats in winter are, in descending order, Indiana, Kentucky, and Missouri. The known population in Indiana appeared to drop from the earliest surveys through 1980, but has been growing almost steadily in recent years. Indiana now contains about 183,000 of its namesake bats, which is half of all the Indiana bats in existence.

Between 1960 and 1975, Kentucky had the greatest Indiana bat population decline among the States, an estimated 145,000 bats. Losses were attributable to exclusion and changes in microclimate at two of the three most important hibernation sites. Most of these were caused by poorly designed cave gates (Humphrey 1978) and by construction of a building over the upper entrance to one of the hibernacula (J. MacGregor, personal communication.). Although not as dramatic as earlier losses, many of the most important remaining hibernating populations have declined steadily during the past 15 years. During this period, populations in west-central, northeastern, and extreme southeastern Kentucky have declined, while the populations in east-central Kentucky and those in western Kentucky have increased.

Populations of hibernating Indiana bats in Missouri have declined steadily and drastically since 1980, despite efforts such as the construction of bat friendly gates at cave entrances. The colonies of Indiana bats in both of the Priority One caves that can be surveyed and 12 of the 13 Priority Two hibernacula in the State have declined during this period. Since 1983, the overall Missouri population has shown a cumulative estimated decline of over 130,000 bats, a loss of more than 85 percent of the population.

Among the other States with regularly occurring hibernating populations of Indiana bats, recent trends are mixed. For five States, trends either are not known or are not well documented. One southern State (Arkansas) has seen its population decline while two northeastern States (New York and Pennsylvania) and one eastern State (West Virginia) have seen population increases.

Reasons for Decline

Not all of the causes of Indiana bat population declines have been determined; nor do we know why the species is declining at its current rate. Although several known human-related factors have caused declines in the past, they do not appear to account for the declines we are now witnessing.

A serious cause of Indiana bat decline was human disturbance of hibernating bats during the decades of the 1960s through the 1980s. Bats enter hibernation with only enough fat reserves to last until spring. When a bat is aroused, it uses a portion of these reserves, as much as 68 days of fat supply in a single disturbance (Thomas *et al.*, 1990). Humans, including recreational use of caves and researchers, passing near hibernating Indiana bats cause arousal (Humphrey, 1978; Thomas, 1995). If this happens too often, the bats' fat reserves may be exhausted before spring and insect prey again are available. Direct mortality due to human vandalism has also been documented.

Some hibernacula have been rendered unavailable to Indiana bats by the erection of solid gates in the entrances (Humphrey, 1978). Other cave gates have so modified the climate of hibernacula that Indiana bats were unable to survive the winter on their fat reserves (Richter *et al.*, 1993).

Indiana bats are subject to a number of natural hazards. River flooding, internal cave flooding, and flash flooding have drowned Indiana bats during hibernation in several caves throughout the range of the species (Hall, 1962: DeBlase *et al*., 1965, J. MacGregor, and T. Wethington, personal communications.).

Bats hibernating in mines are vulnerable to ceiling collapse (Hall, 1962; R. Myers, pers. communication.). To a lesser extent, ceiling collapse in caves also is possible.

Another hazard exists because Indiana bats hibernate in cool portions of caves that tend to be near hibernacula entrances, or where cold air is trapped. Some bats may freeze to death during severe winters (Humphrey, 1978; Richter *et al.*, 1993).

Possible Causes of Decline

Caves and mines change far more than is generally recognized. Entrances and internal passages essential to air flow may become larger or smaller, or close altogether, resulting in increases or decreases in air flow. Blockage of entry points, even ones too small to be recognized, can be extremely important in hibernacula that require chimney-effect air flow to function.

Hibernacula in the southern portions of the Indiana bat's range may be either near the warm edge of the bat's hibernating tolerance or have relatively less stable temperatures, while hibernacula in the North may have passages that become too cold. In the South, bats may be forced to roost near entrances or floors to find low enough temperatures, thus increasing their vulnerability to freezing or predation. In the North, bats must be able to escape particularly cold temperatures.

In Missouri's hibernacula, average mid-winter temperatures appear to have risen from the mid 1980s through the present, compared to temperatures in the 1970s and early 1980s. During this period, major population losses have occurred. Preliminary analysis of fall and winter temperature data suggests that a similar trend has occurred in ambient temperature outside the cave, and thus appears to have played a role in these population losses (R. Clawson, pers. observation.). A much more detailed analysis is underway, with detailed temperature profiles of important hibernacula throughout the range of the species, to better understand the relationship(s)

between climate, air flow, and hibernation microclimates within hibernacula.

During summer, when Indiana bats are roosting under exfoliating bark, they are vulnerable to the effects of severe weather such as thunderstorms stripping the bark from their roost (J. Gardner, personal communication).

The Indiana bats' maternity range has been changed dramatically from pre-settlement conditions. The forests has been fragmented in the upper Midwest, fire has been suppressed, and prairie has been supplanted with agricultural systems. Native plants, especially grasses, have been replaced with exotics in large portions of the maternity range, and diverse plant communities have been replaced with simple ones or monocultures. Simplification of the habitat could have profound effects through factors such as availability and abundance of insects on which the bats prey. Conversely, regions surrounding hibernacula in the Missouri Ozarks and elsewhere may be more densely forested than they were historically. In the eastern U. S., the area of land covered by forest has been increasing in recent years. Whether this is beneficial, neutral, or negative for the Indiana bat is an open question, however. The age, composition, and size class distribution of the woodlands will have a bearing on their suitability as habitat for the species.

Pesticides have been implicated in the declines of a number of insectivorous bats in North America (Mohr, 1972; Reidinger, 1972, 1976; Clark and Prouty, 1976; Clark *et al*., 1978; Geluso *et al*., 1976; Clark, 1981). The effects of pesticides on Indiana bats have yet to be studied, but a study of closely-related species in Missouri suggests that Indiana bats may be exposed to organophosphate pesticides as well as persistent residues of organochlorine pesticides (McFarland, 1998).

Habitat Requirements

Winter Habitat

For hibernation, Indiana bats require specific roost sites in caves or mines that attain appropriate temperatures. Specific cave configurations determine temperature and humidity microclimates, and thus suitability for Indiana bats (Tuttle and Stevenson, 1978; LaVal and LaVal, 1980). In southern parts of the bat's range, hibernacula trap large volumes of cold air and the bats hibernate where resulting rock temperatures drop. In the northern parts of the range, however, the bats avoid the coldest sites. In both cases, the bats choose roosts with a low risk of freezing. Ideal sites are 50^{o}F (10^{o}C) or lower when the bats arrive in October and November, and a mid-winter temperature range of 37-43^{o}F (3-6^{o}C) appears to be best for the species. Only a small percentage of available caves provide for this specialized requirement. Stable low temperatures allow the bats to maintain a low rate of metabolism and conserve fat reserves through the winter until spring arrives (Humphrey, 1978; Richter *et al*., 1993).

Relative humidity at roost sites during hibernation usually is above 74 percent but below saturation (Hall, 1962; Humphrey, 1978; LaVal *et al*., 1976), although relative humidity as low as 54 percent has been observed (Myers, 1964). Humidity may be an important factor in successful hibernation (Thomas and Cloutier, 1992).

Summer Habitat

A full understanding of the summer needs of the Indiana bat is yet to be attained, but progress is being made. Flood-plain and riparian forest were considered by early researchers to be the primary roosting and foraging habitats used in the summer by the Indiana bat (Humphrey *et al*., 1977) and these forest types unquestionably are important. More recently, upland forest has been shown to be used by Indiana bats for roosting (Clark *et al*., 1987; Gardner *et al*., 1991*b*; Callahan *et al*., 1997; MacGregor, personal communication). Upland forest, old fields, and other upland habitats have been shown to provide foraging habitat (Gardner *et al*., 1991*b*; J. MacGregor, personal communication).

Indiana bats live in highly altered landscapes and use an ephemeral resource (dead and dying trees) as roost sites. There is evidence, in fact, that suggests that the Indiana bat may, in fact, respond positively to habitat disturbance.

Within the range of the species, the existence of Indiana bats in a particular area may be governed by the availability of natural roost structures, primarily standing dead trees with loose bark. The suitability of any tree as a roost site is determined by: (1) its condition (dead or alive), (2) the quantity of loose bark, (3) the tree's solar exposure and location in relation to other trees, and (4) the tree's spatial relationship to water sources and foraging areas. The most important characteristics of trees that provide roosts are not species but structure, specifically, exfoliating bark with space for bats to roost between the bark and the bole of the tree. To a very limited extent, tree cavities and splintered, broken tree tops also have been used as roosts (Gardner *et al*., 1991*a*; Kurta *et al*., 1993; J. MacGregor, personal communication).

Indiana bat maternity colonies use multiple roosts in both dead and living trees. Exposure of roost trees to sunlight and location relative to other trees are important factors in suitability and use (Humphrey *et al*., 1977). Miller (1996) found that sites in north Missouri at which Indiana bat maternity colonies had been located had significantly more large (> 30 cm [12 in] diameter) trees than sites at which Indiana bats were not captured.

Most of the roost trees used by a maternity colony are close together. The spatial extent and configuration of a colony's regular use area is probably determined by the availability of suitable roosts. The distances between roosts occupied by bats within a single maternity colony have ranged from just a few meters to as much as several kilometers (A. Kurta, personal communication; Callahan *et al*., 1997).

Maternity colonies have at least one primary roost that is used by the majority of the bats throughout the summer. Colonies also use multiple alternate roosts that are used by small numbers of bats intermittently throughout the summer. Primary roosts are located in openings or at the edge of forest stands, while alternate roosts can be in the open or the interior of forest stands. Primary roosts are not surrounded by a closed canopy and can be warmed by solar radiation, thus providing a favorable microclimate for growth and development of young during normal weather. Alternate roosts tend to be more shaded, frequently are within forest stands, and are selected when temperatures are above normal or during periods of precipitation. Shagbark hickories seem to be particularly good alternate roosts because they provide cooler roost

conditions during periods of high heat and their tight bark shields bats from water during rain events (Callahan *et al*., 1997; Kurta *et al.*, 1996).

Trees that provide Indiana bat roosts are ephemeral. It is not possible to generalize or estimate roost longevity due to the many factors that could affect it. Bark may slough off completely or the tree may fall over. Roosts in oaks (*Quercus spp.*), hickories (*Carya spp.*), and ashes (*Fraxinus spp.*) may be habitable for six to eight years, but roosts in some tree species such as elm (*Ulmus spp.*) and cottonwood (*Populus deltoides*) may be available for a much shorter time - only one to two years (Humphrey *et al*., 1977; Gardner *et al*., 1991*a*; Callahan *et al*., 1997; A. Kurta, personal communication).

Indiana bats have strong site fidelity to summer colony areas, roosts, and foraging habitat. Females have been documented returning to the same roosts from one year to the next and males have been recaptured when foraging in habitat occupied during prior summers (Humphrey *et al*., 1977; Gardner *et al*., 1991*a*,*b*; Callahan *et al*., 1997).

During the fall, when Indiana bats swarm and mate at their hibernacula, male bats roost in trees nearby during the day and fly to the cave during the night. These roosts are similar to roost sites selected during the summer, are primarily on upper slopes and ridge tops not far from hibernacula, and often tend to be exposed to sunshine rather than being shaded (Kiser and Elliott, 1996; J. MacGregor, pers. communication.;C. Stihler, pers. communication.)

Indiana bats forage in and around tree canopy of flood-plain, riparian, and upland forest. In riparian areas, Indiana bats primarily forage around and near riparian and flood-plain trees, as well as solitary trees and forest edge on the flood-plain (Belwood, 1979; Cope *et al*., 1974; Humphrey *et al*., 1977; Clark *et al*., 1987; Gardner *et al*., 1991*b*). Indiana bats, however, also forage within the canopy of upland forests, over clearings with early successional vegetation (e.g., old fields), along the borders of crop lands, along wooded fence rows, and over farm ponds in pastures (Clark *et al*., 1987; Gardner *et al*., 1991*b*).

The extent of foraging area used by an Indiana bat maternity colony has been reported to range from a linear strip of creek vegetation 0.5 mile (0.8 km) in length (Belwood, 1979; Cope *et al*., 1974; Humphrey *et al*., 1977), to a foraging area 0.75 miles (1.2 km) in length, within which bats flew over the wooded river or around the riverside trees (Cope *et al*., 1978). Indiana bats return nightly to their foraging areas (Gardner *et al*., 1991*b*).

During summer, male Indiana bats that remain near their hibernacula forage at the edges of small flood-plain pastures, within dense forest, and on hillsides and ridge tops (LaVal *et al*., 1976; LaVal *et al.* 1977; LaVal and LaVal, 1980). In the fall, male Indiana bats tend to roost and forage in upland and ridge top forests, but also may forage in valley and riparian forest (Kiser and Elliott, 1996; 3D/International, 1996). Upon emergence from hibernation in the spring, some males remain within the vicinity of their hibernacula, where they roost and forage in mature forest, however, other males leave the area entirely upon emergence in the spring (Hobson and Holland, 1995; 3D/International, 1996).

The Recovery Plan

History

A *Recovery Plan for the Indiana Bat* was first drafted in 1976. At that time, only limited data on populations and the distribution of the species were available. In addition, a lack of knowledge of life history made it difficult to write an extensive or comprehensive plan. The *Recovery Plan* was redrafted in the early 1980s and was approved on 14 October 1983. A *Technical Draft* of the *Indiana Bat Revised Recovery Plan* was completed in October 1996. An *Agency Draft* of the *Recovery Plan* was prepared and comments were received in 1999, but these comments have yet to be incorporated into the *Plan*.

Emphasis of the Plan

Given the concern about the cause or causes of the continued population decline, it should be no surprise that the highest priority identified in the *Recovery Plan* is research to answer this question. The *Plan* also, however emphasizes the need to continue to monitor the population status and trends, as well as the distribution of the species; and the need to protect Indiana bats during the hibernation period. Management of summer habitat is addressed, but the *Plan* at present does not spell out specific standards or guidelines. Instead, the Recovery Team recommends that land managers apply guidelines similar to those developed by the Daniel Boone National Forest or the Missouri Department of Conservation.

Management Strategies

The Hibernation Period

Current hibernacula should be protected and abandoned hibernacula should be restored, if it is feasible to do so. Preventing unwarranted entry by humans is the best way to curtail disturbance at these sites. Entry to hibernacula should be prohibited during the period of September 1 - April 30 in most of the species' range, and September 1 - May 31 in the northern portion of the range.

Signs may be used at caves to discourage entry, and should be used in conjunction with gates to inform the public. Signs should be placed inside cave entrances so as not to attract potential violators to the cave, but not block bat movement or air flow.

A structure, such as an angle-iron gate or fence, may be placed at the roost cave entrance to prevent unauthorized human access. The structure must permit Indiana bats to pass without danger and must not alter air flow. Plans and descriptions of proper gate designs are available from the American Cave Conservation Association and were reported by Tuttle and Taylor (1994). Caves that receive flash flooding should be carefully evaluated before barriers are constructed, especially if the bats roost where water may be impounded by a gate. Special care must be taken where detritus can accumulate against a gate over time, causing high water levels with flooding events, or blocking air flow.

Because of the vulnerability of Indiana bats to disturbance during hibernation, monitoring should be conducted every other year. This frequency should be sufficient to determine population trends, but not put additional pressure on the species.

Hibernacula are vulnerable to changes made to the surface areas above them. Some have other entrances, well away from the main entrance, that are crucial to chimney-effect air flow. Activities such as road construction, urban development, the conversion of forest to pasture or crop land, surface mining, or logging should be planned carefully or excluded within a $^1/_4$ mi (0.4 km) buffer zone around a hibernaculum. Forested buffer zones should be designed to conform to the surrounding topography on a case by case basis.

The maintenance of forest cover in the vicinity of hibernacula is important because male Indiana bats forage nearby and use snags and loose-barked trees as daytime roosts prior to entering hibernation (Kiser and Elliott, 1996). Forest management activities should incorporate standards and guidelines that protect and enhance Indiana bat roosting and foraging habitat.

The Summer Maternity Period

Forest management practices should incorporate standards that protect and enhance roost trees for Indiana bats. Silvicultural practices should favor the creation and retention of suitable roost trees, including the development of multiple age classes so that a sustainable supply of large diameter, mature and over-mature trees is assured through the foreseeable future. Uneven-aged management or even-aged management that includes provisions for snag retention may be used. Large diameter, standing dead trees, especially those at forest edges or in the open, should be retained. Snag retention guidelines developed by the USFS Daniel Boone National Forest and Missouri Department of Conservation are considered to be adequate and should be consulted by land managers. Managers are encouraged to use information on the life history and ecology of the Indiana bat in concert with their own experience to tailor management strategies to their own particular circumstances and situations.

For a real-world example, the following is a synopsis of the recommendations designed to provide Indiana bat roosting and foraging habitat on State-managed forest lands throughout Missouri: Within a management compartment, management should preserve or create a diversity of age and size classes, with mature and over-mature trees well represented. These trees, as they die and become snags, will provide a continuing supply of potential roost sites for Indiana bats. The goal should be to develop patchiness, vertical height diversity, and dead and dying trees to provide potential roosts and foraging habitat for bats.

In bottomland forest, management should perpetuate hardwoods with a diversity of tree species and age classes. Uneven-aged management should be used to create a mixture of mature and over-mature trees in groups within stands and small openings in the canopy.

In riparian corridors, management should perpetuate a diversity of tree species and age classes, and maintain a minimum forested buffer strip of 100 feet on each side of streams. This corridor should be wider if it is possible. Reforestation should occur on lands lacking minimum forest corridors.

Forested acres should be managed for optimum numbers of snags using the following recommendations:

	Number of Snags per Acre		
	>19" dbh	10-19" dbh	<10" dbh
Heavily Forested	0.5	4	2
Open/Semi Open	1	4	2
Riparian Corridor	1	7	4
Bottom land Hardwood	1	4	2

Where choices are possible, oaks, hickories, and ashes should be favored for retention or snag creation. During harvest, snags should be left wherever they are found except where they pose a safety hazard or are part of a salvage harvest. Some snags should be retained in groups with live trees to prevent wind-throw.

In regions with large areas of contiguous, mature canopy, forest management practices that open the canopy and reduce understory may enhance Indiana bat roosting and foraging habitat. Reducing the canopy from a solid, 100 percent coverage into the range of <80 percent but >30 percent would create openings and edges where snags would receive sunlight, thus improving them for roosting. Reduced canopy also would create foraging areas because Indiana bats preferentially forage around and adjacent to tree crowns. Reducing the understory would make snags more accessible by removing obstacles to flight, allow sunlight to strike the trunks of the snags, and allow the bats to forage beneath the tree canopy. Savanna management may supply some or all of these conditions and should be applied on appropriate sites within the landscape. Providing water sources such as ponds, ephemeral pools, seasonal depressions, and road ruts may enhance Indiana bat habitat. These should be sited along ridge tops, approximately ½ mile apart. Snag retention and development should be targeted at upper slopes and ridge tops.

Old growth forest should be designated around Indiana bat hibernation caves. Twenty acres is recommended, but topography, watershed, and other considerations should be factored into the old growth design, size, and configuration to protect the integrity of the cave system. In addition, the site should be managed to provide corridors of tree canopy from the cave to foraging areas.

- Within 5 miles of known Priority 1 and Priority 2 hibernation caves:
- A minimum of 10 percent of total forest should be designated as old growth.
- Forest conditions, including numbers of snags and cavities, should be inventoried regularly - at least every 15 years. Managers should attempt to inventory and manage at near uniform intervals around a given cave (e. g., if there were 5 forested compartments around a cave, one compartment should be inventoried and treated every three years rather than all being done during a single year).
- A balanced age and size class distribution should be maintained through forest management methods.
- The recommended number of snags should be retained or created in any stand that is treated, whether it be by clear cut, timber stand improvement, or intermediate cut. Leave stands or old growth should not be treated, because these will provide snags in the future.

Challenges and Opportunities

By law, managers have to deal with an endangered species, the Indiana bat. It is an animal whose life history and habitat needs were not well known until recent times and about which there still is much to learn. Even so, managers should make a good faith effort to apply what is known. Mining concerns and regulatory agencies can participate in the recovery of the Indiana bat in both winter and summer. During the winter, mines that are occupied by the species can be identified, assessed for needed protective measures, and made off-limits to humans during the hibernation season. Summer habitat can be provided for the Indiana bat by managing surface mine landscapes to restore or create forested conditions and managing the forest as outlined above. Forums such as this can bring together Federal and State agencies, private landowners, and professional organizations to work together rather than at cross purposes to one another.

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