Session 3

Methods for Protecting Bat Habitat Associated with Underground Mines

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METHODS FOR DETERMINING LOCAL MINE CHARACTERISTICS OF IMPORTANCE TO BATS

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Abstract

When attempting to address questions regarding specific characteristics of mines that can be used to predict occupancy by bats, investigators need to identify several important criteria. We propose that the key questions that need to be articulated are: 1) what species is being addressed -- no two species have the same physiological/natural history requirements, 2) what type of use is being investigated (maternity, hibernation, etc.)-- this can greatly impact the conditions that are being sought, 3) what is the spatial scale of interest -- a tremendous amount of variability can be exhibited both within and among populations, 4) what temporal scale is being investigated -- a mine may appear unused for years and even decades, but that does not necessarily indicate that it is not actual habitat, 5) how will occupancy be interpreted -- what does occupancy indicate about roost "quality", and 6) how will habitat be defined -- where the bat roosts in a mine, the mine itself, a mine complex, etc. A decade of research has revealed that bat occupancy of mines is a highly complex issue. While simple explanations of complex phenomena may be attractive for management purposes, there is no accurate list of mine characteristics that can be used to gauge quality of habitat. When individual bats or colonies select roosts, they are most likely selecting for a set of conditions that a roost provides, not selecting for specific roost attributes. These conditions include (but are not limited to) temperature, humidity, protection from predators, density of local roosts, and protection from ambient conditions. Suitable conditions can be realized in mines of all type, structure and configuration. Conversely, local surface effects (such as climate, elevation, aspect, number of openings), may constrain subsurface conditions, making specific characteristics of a given mine irrelevant. Likewise, these same surface conditions may make seemingly unsuitable mines (small, simple workings) excellent habitat. As stated, no template is available against which mines can be compared to infer actual or potential use. Therefore, techniques for identifying constraints and important characteristics of roosts, on a local scale, will be discussed.

Key Words: Bats, abandoned mines, habitat, roosts, habitat selection, variability

Introduction

The use of abandoned mines by bats has become an important issue to the mining industry, management agencies, conservation groups and wildlife biologists. While documentation of bats using abandoned mines as roosts has long been known (Pearson, 1962), it has only been in the

past two decades that the management and protection of abandoned mines has become a serious, industry-wide issue. The challenge of locating, identifying, and protecting critical roost locations, while concurrently providing for human safety and ongoing mineral exploration and extraction, is daunting. Techniques associated with locating (i.e., survey techniques) and protecting (education, signing, gating, etc) roosts are being addressed elsewhere in these proceedings (Altenbach *et al.*, this issue; Brown,*et al*., this issue). Here we discuss how to identify specific characteristics of abandoned mines that are important to bats.

There is no list of variables that can be used to absolutely gauge the quality of a particular abandoned mine to local bats. In reality, the use of abandoned mines by bats is far too complex to suppose that a "cookbook" approach that lists attributes of all mines, that all bats select for can be effective. At best, sweeping inference about large scale biological processes is inaccurate, at worst, it can cause the implementation of inappropriate management and result in the destruction of the very resources needing protection. Examples of misappropriate extrapolation of data across spatial scales, are the following statements: "bats don't use coal mines," "bats won't use shafts," "mines less than 50' long won't be used by bats." Unfortunately, these statements were used to excuse conducting biological surveys of mines prior to site destruction (through reclamation, renewed mining activity, etc).

When attempting to identify habitat associations of a given species or group of species, it is imperative that the proximate and ultimate constraints of the system be understood (Krebs, 1989). As a general rule, the smaller the geographic range and more simple the natural history of a given organism, the more narrow will be the constraints imposed on the system (Krebs, 1989). The more narrow the constraints, the lower the potential variability, and the more easily definable the habitat associations. For example, habitat associations of the Rocky Mountain Bighorn Sheep (*Ovis canadensis*) are much more easily identified than those of the Great-horned owl (*Bubo virginianus* – Krebs, 1989).

Habitat associations of bats are difficult to define for several reasons. First, the proximate and ultimate constraints on the system are not clearly understood. Second, the natural history of most bats is complex, and in most species is still not well understood. Bats spend a significant amount of time roosting, and the first step in determining habitat affinities is to understand the types of roosts used. Approximately 25 species in the US are known to roost in abandoned mines and 22 of these are considered to be dependent upon abandoned mine workings during at least part of the year (ex. for hibernating – see Bogan, this issue; Harvey, this issue--). The association of these bat species with abandoned mines, coupled with the loss of abandoned mines to reclamation and renewed mining activity make it critical that we understand specific attributes of individual mines that make them suitable or unsuitable to bats.

The Problem

Unfortunately, no data set currently exists from which a model can be generated that can be used to identify specific variables of all abandoned mines that make them suitable to all bats as roosting habitat. It is important to remember that when individual bats or colonies select roosts, they are likely selecting for a set of conditions within a roost and are not selecting for specific

roost attributes. Conditions of importance can be realized in mines of all size and configuration. In addition, local surface effects (climate, elevation, aspect, etc), often constrain subsurface conditions, making specific attributes of a given mine irrelevant (See Kurta, this volume).

For example, models of use by Townsend's big-eared bat (*Corynorhinus townsendii*) in northern Utah indicate that this species is distributed independent of internal characteristics of mines. Additionally, they are randomly distributed among available roosts in lower elevations associated with juniper woodlands (Sherwin, *et al.*, 2000b). However, this model does not work beyond the sub-regional level (scale dependent); in addition, this same model may not be applicable across temporal scales (Sherwin, *et al.*, 2000a). Models of roost affinities are both spatially and temporally scale-dependent, and will likely be extremely effective at local scales. However, applying these models to other locations and/or other systems is inappropriate at best (Sherwin, *et al.*, 2000a).

Investigating the Problem

The sensitivity of local models to variation in spatial and temporal scales make it critical that resource managers and researchers collect appropriate data in their system of interest and consider important variables driving selection of roosts at the local level. Due to the inherent complexity of this system, investigators need to clearly define specific problems and objectives of interest. Therefore, we propose that the a *priori* answering of six questions will aid managers and researchers in identifying local mines of importance to bats.

What species is being addressed?

No two species of bats have the same physiological or natural history requirements (Hill and Smith, 1984), therefore, it is essential that researchers clearly identify which species is/are being studied. Merely stating an investigation of roost selection by "bats" supposes that the entire system is static, with all populations of all species driven by the same constraints. In fact, enough variability exists among populations, and across ranges, that even species-level generalizations are rarely accurate (Sherwin, et al., 2000a).

What type of "use" is being investigated?

When discussing selection of abandoned mine roosts by bats, it is imperative that the type of use being discussed is clearly articulated. Types of use include maternity (pre-birthing, birthing, pre-weaning, weaning, post-weaning), bachelor, mating (lek sites), night roosts, migratory, hibernation, etc. Variables driving selection of roosts differ dramatically depending on the specific type of use being investigated.

What is the spatial scale of interest?

Effects of spatial scale are often ignored when attempting to identify variables of significance to selection of roosts by bats. Spatial scale should be clearly articulated *a priori*, as level of inference is limited to the level of spatial scale of collected data (i.e. data can never be applied at smaller spatial scales). For example, a landscape level study provides no data from which micro-climate inference should be made (see Channel and Lomolino, 2000; Sherwin, et al, 2000b; Sherwin, et al., 2000a; Strayer, 1999).

What temporal scale is being investigated?
Temporal scales range from within and among seasons to use of roosts within and among years. Some species exhibit tremendous variability in relative fidelity to specific roosts (Lewis, 1995; Sherwin, et al., 2000a; Sherwin, et al., 2000b). While all scales of temporal investigation are valuable, care must be made when attempting to impose short-term patterns on larger temporal scales. Systems can only be interpreted as simple (black and white—presence/absence) by a single visit. Only through the implementation of multiple surveys, across temporal scales, can accurate resolution of biological processes be achieved. This is particularly important when attempting to investigate more subtle patterns of roost fidelity and complex use of roosts reflecting complex behaviors (e.g., mating, intra/interspecific behaviors).

Temperature is probably the most important feature affecting use of roosts by bats and can be extremely temporally sensitive. The high surface-to-volume ratio of bats increases thermal stress, making activity metabolically costly. To offset these physiological costs, many temperate bat species respond to environmental stressors (decreased ambient temperatures, lowered concentrations of prey, etc.) by entering torpor and/or hibernation. There is an optimal temperature range that individuals seek, at which they minimize energy output, while maintaining some theoretical minimum of physiological activity. Temperatures below this range may induce permanent cellular damage while higher temperatures may result in costly output of energy. Similarly, other seasonal use requires equally complex thermal requirements (ex. maternity). When attempting to create a thermal profile of internal mine conditions, researchers must be aware of the difference between mean internal temperatures and the variance of internal temperatures. Some species appear to select for stable mean temperatures while others appear to prefer areas with low temperature variance. In addition, resolution of internal temperature profiles can only be achieved through the use of continuous recording devices (data loggers), as temperatures can vary dramatically within a site and can fluctuate tremendously (Figure 1). Point measurements at time of survey are not accurate estimates of internal temperature profile (Sherwin, *et al*., 2000b – Figure 2). Other potentially significant variables that are temporally sensitive include human disturbance and predation.

What level of biological significance will be attributed to occupancy, and what will occupancy infer about roost quality?
This will vary due to specific natural history requirements and current management status of individual species. For example, maternity sites are often viewed as more significant than bachelor sites. This assumes that constraints on reproductive females (with regards to roost selection) are more pronounced than those imposed on males. In addition, this may vary across a species' range. For example, in Utah, groups of hibernating Townsend's big-eared bats are generally small (1-2 individuals), with groups exceeding 5 individuals considered rare. So in Utah, a gate might be recommended for a mine used by a single individual, whereas this same standard may not be valid in New Mexico where wintering groups tend to be much larger.

How will habitat be defined?
The spatial scale of habitat is critical to the management of abandoned mines. It is vital that habitat be clearly and concisely defined. For example, will a roost be defined as the point of

actual interface between the organism and the substrate (i.e. the contact point), the feature of use (i.e. the crack, crevice, rock), the working providing the feature (the drift, stope, etc.), the entire mine (all drifts, stopes, etc), the opening(s) providing access to subterranean workings (many mines include dozens of openings), all mines in a complex (complexes often include hundreds of workings), all complexes in a landscape, etc. The definition of habitat dictates what kind of data will be collected. For example, if habitat is defined as the actual interface of the bat and the mine (point of roosting), only intensive, non-invasive techniques are appropriate to provide data necessary to elucidate selection of micro-climates (i.e. data loggers, continuous video, etc). If habitat is defined as "the mine" – including all openings, less intensive monitoring is necessary, but less resolution is provided. In addition, habitat should not be limited to specific roost attributes (however defined), but should include adjacent vegetative communities and other landscape data, because mines do not exist in a vacuum and selection of roosts can be completely independent of subsurface conditions.

Summary

While the use of abandoned mines by bats is a complex system we do not propose that it is unmanageable. However, it is only through understanding and appreciating the potential variability and reflected complexity of this system that biologically valid data regarding roost affinities of bats can be obtained. If the inherent complexity of this system is ignored and simplistic measures applied, mismanagement will result. By appreciating the potential variability in this system, researchers and managers will collect data applicable to the specific problems being investigated. We propose that by addressing the above questions before initiation of data collection, the likelihood of suitable techniques being applied increases.

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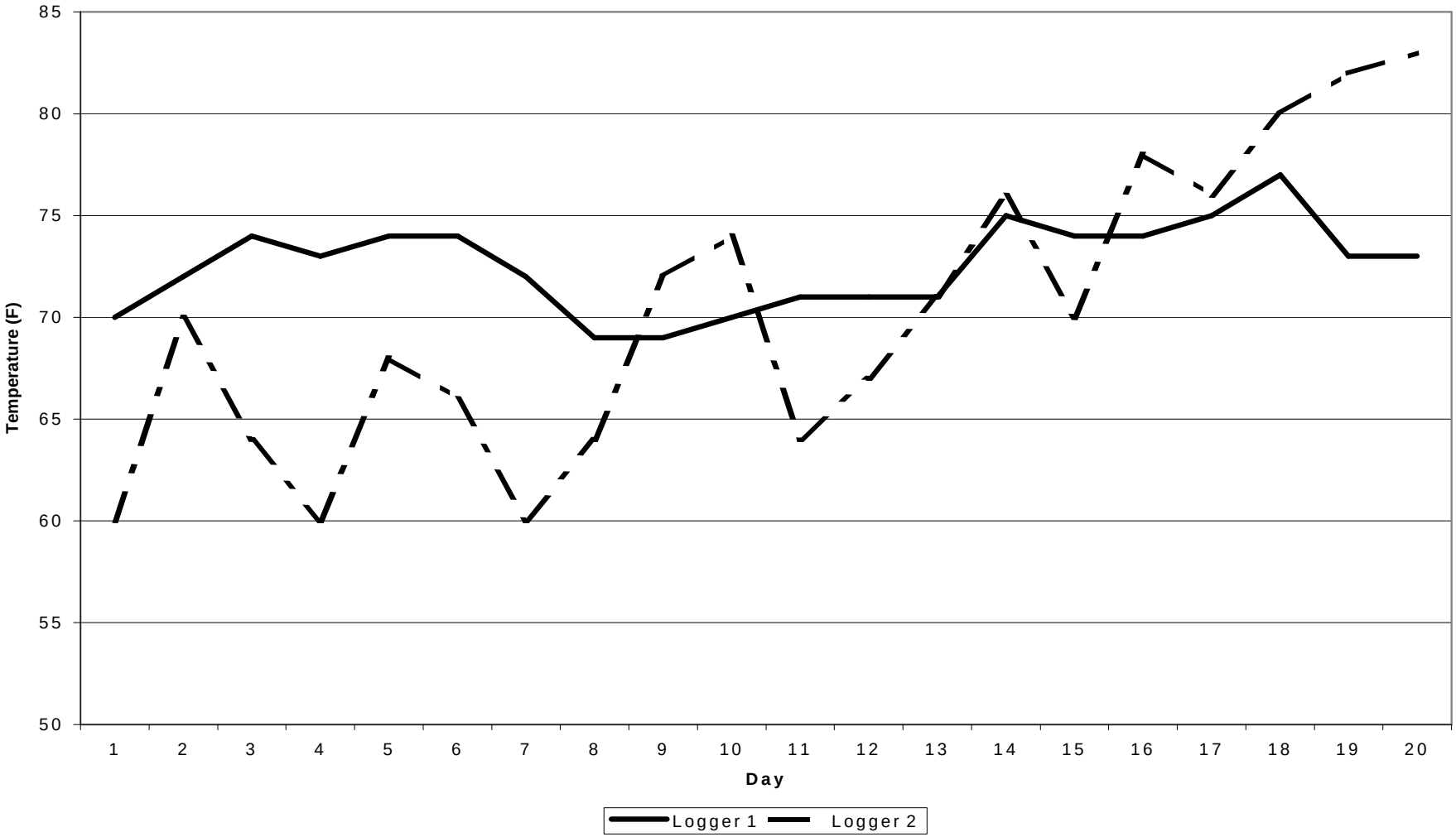

Figure 1. Two data loggers placed two feet apart in the same mine. These data suggest that caution be taken when attempting to create a thermal profile of mine with limited data.

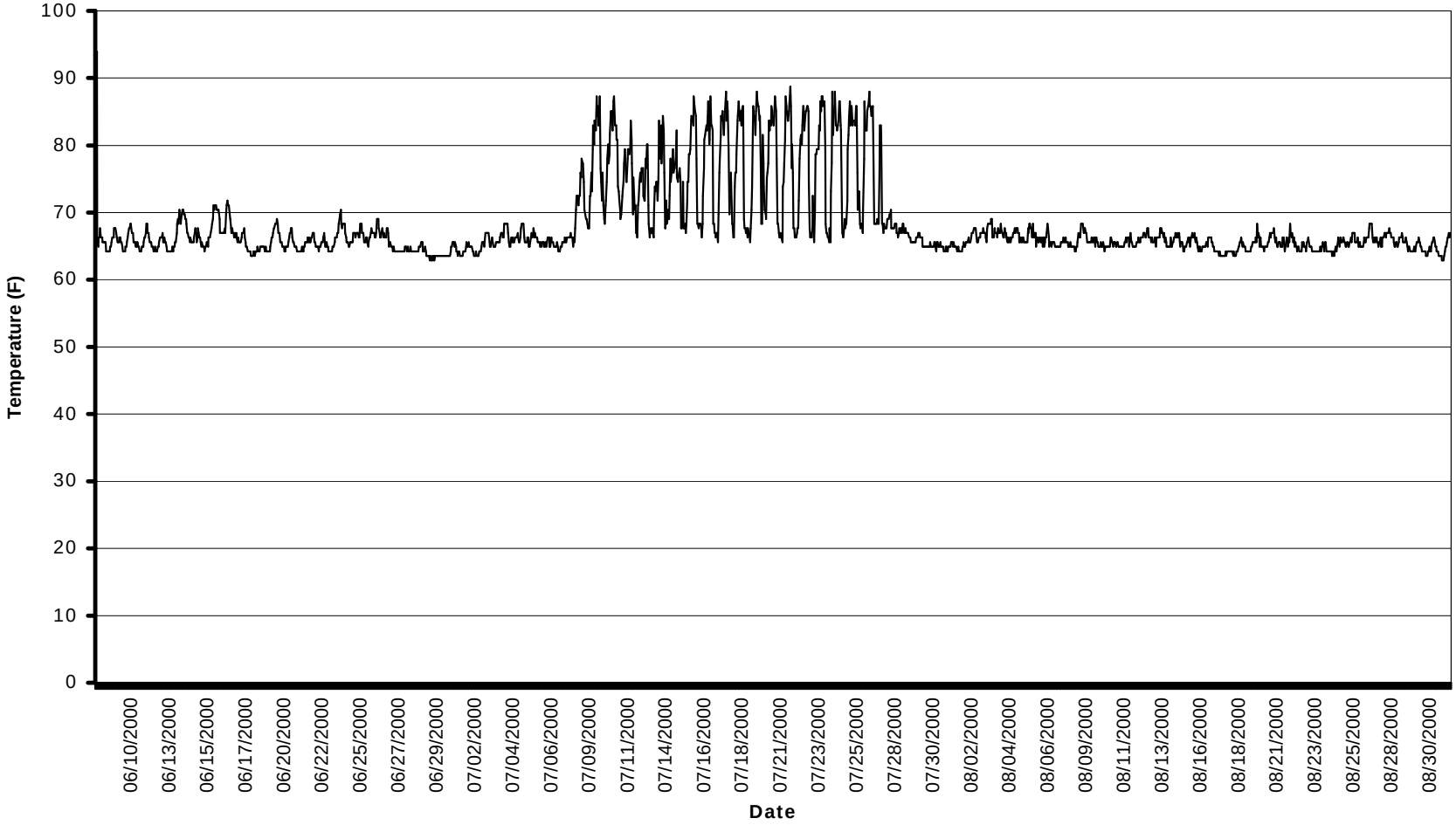

Figure 2. Temperature data collected at the interface of substrate and a maternity colony of Townsend's big-eared bat (*Corynorhinus townsendii*). Maternity colony present between 07-07-2000 and 07-29-2000. Internal micro-climate is regulated by the roosting colony and would appear to be "unsuitable" for a maternity colony based on simplistic sampling of temperatures.

PRE-MINE CLOSURE BAT SURVEY AND INVENTORY TECHNIQUES

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Abstract

Programs to safeguard abandoned mines have stimulated active programs to evaluate them for wildlife use, particularly use by bats. Experience gained over more than a decade of surveying abandoned mines has demonstrated that we still do not understand enough of the biology of the bat species commonly using abandoned mines, particularly in the West, to accurately predict patterns of use. Surveys are required and experience again has demonstrated that external surveys require specialized equipment and vastly more time than internal surveys. They are virtually incapable of detecting several types of bat use common in the West and those relying on them must be willing to err on the side of excessive caution to keep from making disastrous decisions about destructive closure based on negative survey results. Although internal surveys require proper equipment, experience and training, they are the most reliable and least labor intensive type of survey for evaluating roost quality. Internal surveys provide data from which more informed decisions about appropriate types of closures of mines, particularly those which are complex and have multiple entrances. They can provide critical information for the design of both protective and destructive closures. A small, steadily-growing pool of qualified surveyors makes internal evaluation more feasible and an enlightened attitude on the part of several agencies now permits formal training and experience in abandoned mine entry. In recent times, shaft evaluation has become feasible and can make a considerable contribution to informed closure decisions where shafts comprise a high proportion of abandoned workings. Orders of magnitude more complicated than entry of horizontal workings, specialized equipment and experience is required. Although marginally effective for bat surveys in shafts, relatively new down-hole camera technology has proven itself to be useful in identifying blind shafts and thus eliminating time intensive internal evaluation of working with virtually no bat potential. In districts with large numbers of shafts, this technology has saved hundreds of hours of survey time.

Introduction

As illustrated by Sherwin *et. al*. (this volume), the use of abandoned mines by bats is complex, as is the environment provided by the mines they use. The use of abandoned mines by bats is sensitive to both spatial and temporal scale, making any short term evaluation of abandoned mines difficult. As more time has been devoted to understanding this system across these scales, the more we have learned, and the better we are able to evaluate and predict the use of mines by bats. Experience over the last decade demonstrates we had only limited understanding of the capabilities, habits and requirements of many species of bats using mines and we still have a great deal to learn. Sherwin *et. al*. (this volume) emphasize that extrapolation from one temporal or spatial scale to another is risky. For example, use of correlative data of internal temperature and specific bat use at one site to judge another abandoned working as suitable or unsuitable, without appropriate survey, courts disastrous decisions. These problems are magnified when this same data is applied across larger spatial or temporal scales.

The following should not be taken as a comprehensive manual on mine evaluation, rather it points out stumbling blocks and factors that can be easily overlooked. It should be used as a starting point and a guide for refinement of a local program. The process of evaluation of abandoned mine use by bats is complicated and must be adjusted to accommodate regional differences, time schedules and availability of expertise. The material presented in this document is only applicable within the framework of the question which is being asked. For example, a biologist wishing to understand local population dynamics would apply these techniques over several years and gradually accumulate a more complete picture. Several years of surveys would be required to resolve patterns exhibited over a multi-year period. In contrast, a local manager who is limited to a single year of survey time, or worse, a single survey, is unlikely to resolve complex spatial and temporal patterns of use. Therefore planning of surveys must consider the least labor intensive and most productive approach and the limitations of the data must be understood prior to its interpretation. Sherwin, et al. (2000a) present effort curves which show average times required to resolve patterns of use in abandoned mines by *Corynorhinus townsendii*. This work emphasizes the need to understand what could be learned from single compared to multiple visits to the same mine workings.

Inventory and Initial Survey

Even though persons doing external surveys (either initial surveys or external bat surveys) are not required to go underground, they should realize that hazards exist on the surface around abandoned mine openings and they should have proper training on these hazards and how to avoid or minimize them. Shafts are very dangerous and surveyors should be specifically trained to approach them. Navo (1995) discusses possible levels of training for personnel as does Perkins and Schommer (1993).

An inventory is simply the location and generation of a map of all mine features in a project (an inactive mine or group of inactive mines scheduled for closure). An initial survey involves description of the mine openings (features) and recording of all information that can be gathered without underground entry including: dimensions, elevation relative to other openings, airflow direction and airflow temperature, obstacles in opening (rocks, vegetation, limbs, trash, portal or headframe timbers), potential hazards, depth of the mine feature (vertical or horizontal) as can be observed from outside, presence of internal complexity (drifts, crosscuts, raises, winzes or stopes) which can be observed from outside, and observations of any wildlife or wildlife sign (excrement, carcasses, staining, discarded parts of insect prey etc.). In some cases mine maps are available that can provide insight regarding the size, internal configuration and possible interconnection of multiple openings. However, for many older mines, no maps exist, or workings may have been modified subsequent to the creation of maps. The size of the mine dump is not a reliable indicator of internal volume. Typically a large dump indicates a proportionally high volume of internal workings but the inverse may not be true.

Airflow can indicate at least moderate size, multiple openings at different elevation, and complexity, but lack of airflow does not indicate their absence. Airflow in mines with single openings may be caused by barometric pressure changes. In mines with multiple openings at different elevation, airflow will typically change direction with season, and will cease for varying periods at seasonal turnover points. As the outside temperature drops below the mean annual temperature, air will generally exhaust from higher openings. It will exhaust from lower openings as the outside temperature rises above the mean annual temperature. However, there are numerous examples where this does not occur and no explanation of airflow patterns exists.

In an initial survey, a mine can sometimes be eliminated as a possibility for bat habitat. If the rib (side), back (ceiling) and floor of shallow adits and the rib (side) of shallow shafts can be observed to determine that no lateral workings are present (blind) and no sign of wildlife is seen,

the mine probably has low potential as bat habitat. If a shaft is flooded above any lateral workings or if an adit is flooded to the back, even periodically, it can be considered to have low potential. However, even in some very shallow mine features, it is sometimes impossible to distinguish depressions from lateral workings. Adits as shallow as 10 ft have been found to have maternity colonies and guano accumulations from them are easily obscured by rock or debris on the floor. Significant colonies of bats have been found in lateral workings, impossible to see from the shaft collar, off of shafts as shallow as 10 ft. Reliable determination from the surface that a shaft is blind can be difficult in shafts as deep as 10 ft, highly unreliable in most down to 30 ft and virtually impossible in those deeper than 30 ft. The presence of shaft timbers makes reliable evaluation even more difficult. The use of a current generation of small, light video cameras offers a technological solution to the difficulties of finding lateral workings in shafts without the necessity of shaft entry. This is discussed below in the section on Shaft Evaluation.

Internal or External Surveys

If a mine feature cannot be eliminated as wildlife habitat by an initial survey, an external or internal survey is warranted. A decade of experience by many surveyors has demonstrated that external surveys are generally much more time consuming and can be less reliable for determining some kinds of use than internal surveys. Although this discussion treats external surveys as a fall-back option to be used when restrictions or underground hazards prevent a thorough internal survey, external surveys can provide data that internal surveys cannot. Some of the situations which favor internal surveys include: 1) large, complex underground mines with the possibility of multiple openings, 2) an area has a high number of scattered openings and underground connections are unknown, 3) time to conduct surveys is limited, 4) an understanding of interconnections required to maintain airflow to support significant bat use is needed. Some of the situations which favor external surveys include: 1) accurate counts are required for subsequent establishment of population trends, 2) data is required to establish which of several entrances are used by bats, 3) situations described below in A. In many situations, detailed knowledge of bat use requires a combination of both internal and external surveys.

Bat Survey Decision Key

The following decision making processes are presented in the form of a dichotomous key where each couplet references additional options. These are presented below and subsequently discussed in greater detail.

A Complete Internal Survey Possible.....B (below)

An internal survey should be conducted until at least a high proportion of the mine is evaluated before declaring that no bats or sign have been encountered. Generally, if bat use in a mine is significant, bats, sign, or both are encountered before the entire mine has been evaluated. It is seldom possible to see all of large and complex mines but it is also seldom necessary. If no evidence of bats has been encountered and the mine has inaccessible levels, large stopes which cannot be accessed, or levels in shafts which cannot be accessed, either the search must be expanded or an external evaluation is required.

A' Complete Internal Survey Not Possible.....G (below)

Reasons in A, hazards prevent or force termination of internal survey, authorities will not permit.

When it is determined that an internal survey is possible the following approach is one that has been used by one of the authors (JSA). Although continuously updated as understanding has changed, it was originally proposed by Altenbach and Milford (1991) and modified by Altenbach

(1995, 1999). It has been used, sometimes with modification necessitated by local conditions, for mines in much of the United States.

B Cold Season Survey

No Guano, Sign or Residents.....**F**
Guano or Other Sign.....**C**
Residents.....**E**
Internal Conditions (Water) May
Obscure Sign.....**C**
All, or enough, of the mine cannot be seen.....**G**

C Warm Season Survey

No Residents - Night Roost, Migratory Use,
Specialized Reproductive Behavior,
Undocumented Use.....**D**
Residents.....**E**

D Fall or Spring Survey, Dropping Boards

No Residents, No Additional Sign
(Roost Abandoned, Used Periodically).....**E, F**
Residents, Additional Sign.....**E**

E Decision to Bat Gate Involving Following Questions

Is a threatened or endangered species involved?
Is use significant (determined regionally)?
Are alternative features, used in the same way, nearby?
How feasible is bat-compatible gating?
Will preservation of an abandoned roost provide habitat or mitigate habitat destruction elsewhere?
Is it likely survey missed periodic use?

F Closure By Any Means

Could survey have missed periodic use? Realization of assumptions which must be made if an external survey was applied. If any concern, final internal inspection, mist netting and tarping, or smoke bombing before closure.

G External Survey

By similar accumulation of data, involving observation of activity at openings, then decisions to E, F or G but with realization of the severe limits of external survey. With external survey techniques, significant kinds of use, eg. hibernation, reproductive behavior, migratory stopover, have a high probability of being missed.

Discussion of Internal Surveys (A)

An internal survey, conducted by an experienced bat biologist (experienced with the bat species which are likely involved based on geographic region, and experienced with bats and bat sign in underground workings), also trained and experienced in abandoned mine entry, has proved to be more reliable and less labor intensive than any other survey option. A team approach combining an experienced bat biologist, familiar with the hazards of abandoned mines, with a safety monitor, with a higher level of abandoned mine training and experience is equally appropriate. The safety monitor must make a decision that an internal survey is possible within the limits of safety or must make a decision to abort an internal survey if warranted. It is difficult for a safety

monitor to watch every move of someone unfamiliar with basic mine hazards. Their lack of awareness of common and obvious underground hazards (eg. open winzes) invites catastrophic injury or death. A bat biologist, inexperienced in abandoned mine evaluation is often unaware of common hiding places and bat sign in underground workings.

Training and Safety Considerations for Abandoned Underground Mine Entry
As little as ten years ago, agencies and many private entities generally prohibited employees from entry of abandoned underground mines and were hesitant to hire even qualified consultants. Over the last ten years, a gradual and cautious change in attitude about entry of abandoned mine workings has taken place on the part of some Federal, State and private entities. Formal training on Abandoned Mine Entry by the Bureau of Land Management (Course No.3000-83), Forest Service (National Minerals Training Office, Mine Safety), combined with MSHA New Miner and Annual Underground Refresher training, has provided a small, but growing pool of persons qualified for entry.

Appendix 1 lists some required safety equipment. Internal surveyors should realize it is useless without comprehensive training in its use and limitations. Both are useless without thorough training in, and understanding of, the hazards associated with underground mines.

The subsequent discussion of internal surveys of abandoned or inactive mine workings is provided to illustrate the extent to which such mines are used by bats and the difficulties inherent in assessing that use. This is not a recommendation for others to conduct such surveys nor is it intended as a "how to" description. Abandoned or inactive underground mines are not "safe" to enter and there is no way they can be "made safe". (By the same reasoning cars and airplanes are not safe to ride in and mountains and lakes are not safe to hike or swim in). Persons entering them must understand and accept the associated risks. Anyone entering abandoned underground workings must have appropriate training and experience with the associated hazards and with the ways to minimize them. Caving experience does not qualify someone to enter an underground mine.

Cold Season (Internal) Survey (B)

Hibernating bats typically leave no trace of their presence and mine entry during this period is required to survey for them. Exceptions would include situations where pre-hibernation swarming of large numbers of certain species would be detected by external surveyors. During the initial cold season survey note is made of the layout of the mine and the possibility that parts of the mine cannot be explored. If it is determined that significant parts of a mine cannot be explored and no bats or bat sign is observed, external, warm season evaluation of the mine is required. Careful checking of even tiny cracks or holes in the back and rib is necessary since several species of bats hibernate in such openings. The evaluation of sign (guano, staining, discarded invertebrate parts, remains of dead bats) unless present in very large quantities, requires an experienced eye. An experienced surveyor should be able to identify the guano of many of the species, or at least most of the genera, likely encountered.

If bats are encountered in a cold season survey they must be identified with minimum disturbance. An experienced surveyor should be able to correctly identify any species using an abandoned mine. Mine lamp beams should not be aimed directly at hibernating bats and any attempt at identification should be limited to the minimum time possible. Getting exact counts of clustered or scattered bats does not warrant the disturbance involved. A quick estimate of numbers or of the size of a cluster is adequate and disturbance is kept at a minimum.

The above descriptions emphasize the necessity for experience on the part of an underground surveyor. Only an experienced surveyor is likely to find the sign indicative of use by all but very large numbers of bats, and bats which may use mine workings in an unobvious way may be

overlooked. Highly experienced underground explorers with no bat experience (eg. miners, geologists) are notorious for completely missing obvious sign and conspicuous bats.

Warm Season (Internal) Survey (C)

Warm season generally means at a time when bats are active and flying in and out on a regular basis. The exact timing of these surveys will vary geographically and with yearly variations of local climactic conditions. For example, an unusually cold or prolonged Spring may cause a delay of a month in maternity activity. Consultation with local bat biologists is necessary to time warm season surveys. Maternity colonies may occupy one roost before delivery of pups, another for delivery, and a third after the pups are volant. This complexity must be considered in the timing of warm season evaluation.

Internal surveys during warm season are conducted with extreme care. Many species of bats are intolerant of disturbance at a roost site, especially during the time they are having and caring for pups. Disturbance can easily cause relocation of a colony and worse, mortality of pups (Mohr 1972, Humphrey and Kunz 1976). A mine is approached, entered and explored quietly during a warm season survey. Serious disturbance of alert bats in order to make identifications or counts is not warranted. If bats cannot be identified, or if an approximate count is not possible, without disturbing them, external evaluation involving capture or bat detectors and experienced interpretation is in order.

If no bats are found in residence, guano may contain discarded invertebrate appendages and wings that indicate night roosting. If night roosting is suspected, the mine is again entered at night to observe the species and numbers involved. The portal can be monitored with a bat detector or individuals can be captured with mist nets or harp traps. Bats are seldom encountered during an internal survey in mines used as migratory stopover roosts and identification of the species typically involves a careful search for carcasses which can then be identified. Repeated visits to the mine in the time period when migration is thought to occur makes encountering and identification of the residents more likely. Material placed on the floor where guano accumulation occurs (dropping boards) can resolve the time and amount of guano deposition. Recent discovery of mines used entirely for complex reproductive behavior (Brown, 1999) demonstrate highly significant, periodic use that can be difficult to resolve. Repeated external and internal observation was required to clarify this highly significant use after evidence was noted on an internal survey.

Shaft Evaluation

In many mining districts, shafts are common and may constitute a high proportion of the abandoned workings. In localities in many Western States, a high proportion are not flooded and many provide bat habitat. Because of the greater difficulties involved, many private interests and government reclamation programs have not been evaluating shafts as potential habitat prior to closure. Although sometimes sealed with non-destructive closures (ex., rebar grates), typically because of historic preservation requirements, most have been close destructively without evaluation or consideration of habitat potential. A notable exception is the Abandoned Mine Lands program in New Mexico where shafts have been evaluated and bat compatible closures have constructed if appropriate. Ten years of extensive experience evaluating shafts (over 2000) in New Mexico, California, Nevada, Utah, Minnesota, and Texas by the authors, has demonstrated that bats readily use them in all of the ways that horizontal workings are used, and the incidence of bat use of shafts is actually higher than in horizontal workings (Altenbach, et al., In Prep).

Lateral workings are notoriously difficult to detect in shafts and this is compounded by shaft timbering. A second issue is that even though internal shaft evaluation can be done safely, it is

an order of magnitude more difficult and time consuming than horizontal mine evaluation because of the highly specialized equipment required to compensate for the higher risks. It requires more experience and is generally not recommended unless a specialist is available. The use of vertical climbing techniques is extremely dangerous for shaft evaluation because of the probability of material falling from the collar or rib. Surveyors using climbing techniques to access vertical workings are reckless, and jeopardize a cautious acceptance of internal mine evaluation procedures!

Use of down-the-hole video cameras, hard-wired to a surface viewing screen, has proved an effective tool to determine if a shaft is shallow and blind and thus does not require time consuming additional evaluation. This technique can also identify shafts that have one or more levels where bat use is possible and internal evaluation or conservative assumptions about use warranted. Without internal evaluation, this information would make a bat compatible closure a more reasonable alternative than if the internal complexity remained a mystery.

This technique is not a substitute for internal evaluation of shafts with lateral workings, deep shafts, or timbered shafts where a bat, or bat sign is probably not visible to the video camera. If internal evaluation is not possible in these shafts, it must be assumed that at least appropriate habitat for a variety of bat use exists and the mine feature should be surveyed externally. Highly significant hibernation sites for several species have been found to depths of nearly 3000 ft and maternity and bachelor colonies have been discovered at depths of over 400 ft. In addition, even blind shafts (without lateral workings) can trap cold air providing ideal hibernation sites for bats. Other shafts are warmed at depth, perhaps by geothermal heating, and provide warm temperatures ideal for other kinds of use.

Discussion of External Surveys (G)

External surveys require experienced personnel and a larger number of person-hours than internal surveys. Specialized equipment which is vital for effective external surveys can be costly, eg. night vision and sophisticated acoustic monitoring equipment, and can require extensive experience to use properly, eg. acoustic monitoring equipment. If an external survey is the only option, techniques are discussed by Navo (1995), Navo et. al.(1995) and Tuttle and Taylor (1994). Rainey (1995) provides an excellent overview of equipment, and references, to assist external surveying.

Applications

External survey techniques are suited for resolving warm season use (maternity or bachelor colonies) where exit or entry flights occur nightly over an extended period. Pre-hibernation swarming typified by large colonies of *Corynorhinus townsendii* and *Myotis lucifugus* may be readily detected if the timing of these events is predictable in a given locality. If these types of use are expected, external surveys may be appropriately timed and implemented to detect them. External surveys can only provide positive data, so absence of evidence should not be interpreted as evidence of absence. Uses such as migratory stopover, short-term responses to climatic changes, use in cold season by small numbers of bats or by bats which do not swarm are difficult to detect. In addition, external techniques are not reliable for resolving events which happen inside a mine, such as reproductive behavior. Data from an external survey cannot be applied across temporal scales and inference cannot be made about past or potential future use.

External surveys are particularly useful when combined with internal surveys at large, complex mines. Some bats (eg. *Antrozous* and some species of *Myotis* and *Pipistrellus*) are very secretive and are easily missed by experienced internal surveyors. If no bat use is detected in a large mine and it is clear that many parts of the mine are not accessible for close evaluation, an external survey of entrances in warm season may be appropriate.

Timing and Implementation

The timing of surveys is critical and depends upon the seasonal changes in bat activity typical of the region in question. Publications on the biology of species that might be in a particular area, as well as consultation with local bat biologists, provide a good starting point for planning the timing of external surveys.

Surveys should be conducted on nights without rain or strong wind, by observers stationed at least 15 ft off to the sides of the mine opening. Setup must be kept quiet be completed at least 30 minutes before sunset. Although red lights have been recommended for external surveys, recent evidence suggests bats may be more sensitive to red light than previously thought. After bats can no longer be seen silhouetted against an evening sky, night vision or InfraRed (IR) video camera equipment can be used to observe a mine opening. Observations must be maintained for at least 2 hours after sunset.

Bats often prefer specific entrances of multi-entrance mine complexes and disturbance by surveyors at this entrance is likely to cause use of an alternate. Even when surveyors attempt to be quiet, a large body of evidence suggests that bats are likely to be aware of their presence. Therefore, all entrances in a particular complex should be surveyed on the same night.

Equipment

The technology for remote, data logging, acoustic or proximity detector monitoring of mine openings has grown over the last decade. Rainey (1995) gives an overview of some examples but the availability of relatively inexpensive video cameras has revolutionized the field. These small cameras with highly sensitive IR detection can record bat activity at mine openings at distances of well over 50 ft. Unattended cameras, set to actuate at predetermined times, can collect data at as many mine openings as a surveyor has cameras. At one sixth the cost of high resolution night vision devices, the external survey capabilities of a single surveyor is increased enormously. An added benefit is that a carefully positioned, unmanned camera will be less likely to cause disturbance and use of alternate mine opening by bats. An IR video camera, coupled with a sophisticated acoustic monitoring system, provides the capability of accurate timing and resolution of activity with improved species identification.

External Capture Survey

If active bats cannot be identified during an internal or external survey, or if determination of sex or reproductive status is required, capture of some individuals for close examination may be warranted. Persons conducting capture surveys must be capable of field identification, rabies immunized and have necessary state and/or federal collecting permits. The help of local bat biologists, experienced in the use of capture devices to minimize injury to bats, and familiar with handling of local species is appropriate. Setup of mist nets or harp traps is completed at least 30 minutes before sunset and is done as quietly as possible. Nets or traps (with someone in attendance at all times) are left up at least two hours after sunset or later if there is a possibility that the mine is used as a night roost. After enough bats have been caught for identification and released, the capture devices are taken down to minimize disturbance.

Decision to Install Bat Compatible Closure (E)

Significance

If a threatened or endangered species is using a mine the decision to use some type of bat compatible closure is clear but must involve consultation with appropriate State and or Federal authorities. Presence of a Species of Concern, formerly a USFWS Category II, might be more significant than species not so listed.

The question of significant use is difficult as it is dependant on location and community structure. For example a single, hibernating individual of one species might not be significant in one part of its range but would be in another. Variability in the use of roosts within a species' range makes it impossible to create range wide rules about significance. In some regions single hibernating individuals in small, scattered mines are typical, in others, small to large groups are typical. Input from local bat biologists is necessary to evaluate numbers and conditions of use in the light of comparison with other local populations or trends in population size. Significance must also be weighted against the presence or absence of a comparable mine feature or protected natural roost site, used in the same way, being nearby. All scenarios must be weighed against the complexity, feasibility, cost and reliability of such closures.

A maternity or bachelor colony of any species is significant and cause for installation of bat-compatible closure. The use of a mine by bats in any way not documented or not understood should be considered highly significant unless it can be demonstrated otherwise. All closures but must be weighed against involved costs, feasibility and availability of comparable, more easily gated features nearby.

Another complicating factor is the movement between roost sites over seasons or even years. Maternity colonies of some species such as *Corynorhinus townsendii* routinely move among available abandoned mines over the course of gestation, birth, growth and maturation of the pups (Sherwin, et al., 2000b). Before a site is declared abandoned, additional evaluation over at least a year to check for fresh sign, or bats, is prudent.

Timing of Mine Closure (E, F)

The selection of appropriate "time windows" for non-bat-compatible closure must minimize the chance that unknown residents will be trapped inside. Installation of bat-compatible closures must likewise be timed to minimize disturbance of residents. These time windows will vary with the type of use, the species present and the region of the country. Closure activities need to be coordinated with the help of local bat biologists.

Conclusions

When the systematic evaluation of bat use in abandoned mines was undertaken on a near national scale a decade ago, it was hoped that correlations between external characteristics of an abandoned mine and its use by bats could be established. This would at best eliminate the need for internal evaluation and at least simplify the survey process. Tuttle and Stevenson (1978) and Tuttle and Taylor (1994) have suggested that if the internal configuration, configuration of openings and mean annual surface temperature is known, internal temperature conditions, and thus suitability for bat occupancy, can be predicted. They infer, perhaps correctly, that mines with multiple openings and complex internal configuration are likely to have variations of internal conditions that maximize the chances parts will be suitable to bat use. However, as Sherwin *et. al* (this volume) have shown, correlations of use and temperature, especially microenvironmental temperature, have been difficult to establish. Small, uncomplicated mine workings can have large and significant use by bats. Even if we could make broad spatial and temporal scale predictions about temperature and use, we are still unable to predict internal temperature itself.

The size, internal configuration and number and configuration of openings of most mines is nearly impossible to determine by external evaluation. In some instances, mine maps may be available but our experience shows that these are seldom complete. The quantity of waste rock at a portal is not necessarily an indicator of internal volume. Ventilation openings, common in many mines (Hardesty, 1988), sometimes have no waste rock around them, are often small and

many times inconspicuous. Where there are several mines in a restricted area, the configuration of surface openings gives virtually no indication of how, or if, the internal workings connect. Airflow measurements must be made at all openings to even guess at internal configuration and a variety of conditions can influence airflow. Strong airflow at a mine portal suggests that there are other openings but lack of airflow does not indicate their absence. In addition, the airflow patterns of some mines as yet cannot be explained. Similar mines, close to each other, can have very different internal temperatures because of geothermal heating or for unknown reasons.

For the majority of abandoned mine sites no mean annual temperature data exists. Often a town for which temperature data is available is at a different altitude than a mine site only a few miles away and has different surface temperature conditions.

Bat biologists have a great deal to learn about even basic bat biology. This data has been accumulating for many years and a great deal is known about many species but even for very common species, large gaps exist. For example, *Myotis yumanensis* is an extremely common warm season resident of the Rio Grande and Pecos drainage in New Mexico but until a migratory stopover roost of this species was discovered in a deep shaft in the mountains of central New Mexico, **nothing** was known of the non-warm season activity of this species in New Mexico. In June the internal temperature of this mine is several degrees cooler than any known maternity roost site of any bat found in New Mexico. However, in June female *Myotis thysanodes* with near term foetuses were found in torpor in these workings. A possible hypothesis is that the animals may be driving embryonic diapause with this behavior. Both of these examples of bat use were considered highly significant and justified bat-compatible closure. We are continually surprised by finding bats at great depth in shafts in both warm season and cold season.

Until comprehensive research provides a measure of predictability, we believe the systematic evaluation of all mine features scheduled for closure provides the only possibility for combination of the goals of securing abandoned mines for human safety and protecting bats that may rely on them. We have to consider that almost any mine can be potential habitat for bats and the only way to know is to look.

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Appendix 1: Safety Equipment for Abandoned Mine Entry

The **MINIMUM** safety equipment required for underground work includes: Approved hard hat with chin strap, steel-toed boots, three sources of MSHA-approved light, multi-gas detector with at least O_2, CO, Combustible Gas capability, O_2 detector with remote sensor head. Additional equipment such as a respirator with filters is useful in some situations where particulates, radioactive particles or pathogens may be a factor. If any vertical climbing is required, the appropriate, specialized equipment and training (as well as practice) in its use is obviously vital. Vertical climbing in abandoned mines, especially in shafts, is an order of magnitude more dangerous than typical vertical mountaineering practice and is warranted under only rare circumstances. Training and supervised experience with this safety equipment, as well as thorough understanding of the circumstances and conditions which necessitate its use, is vital.

AN EVALUATION OF ALTERNATIVE METHODS FOR CONSTRUCTING BAT GATES AT MINE CLOSURES

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Introduction

Construction of bat compatible closures at abandoned mine entrances requires a careful balance between the needs of the species occupying the site and the hazard reduction required to protect the public. Leaving an entrance completely open may be satisfactory for bat conservation but ignores the responsibility to protect the public. Backfilling may eliminate most hazards but will not meet the need to protect the declining and vulnerable species that depend on abandoned mines. Bat compatible closures have evolved as we have gained a better understanding of both the needs of the species, and of the effectiveness of different techniques and materials in producing vandal resistant structures. This process of evolution will continue. Various construction materials and techniques have been used to provide bat compatible closures. The merits and disadvantages of several alternative gate designs and alternative construction materials are discussed. Each project requires development of a site specific plan that addresses safety, bat use, air flow, vandal resistance, maintenance and monitoring. No single design is applicable in all situations. Shafts and open stopes require special considerations during project design and construction. Post construction monitoring is an important component of a successful program and will provide the data needed to continue to improve the effectiveness of bat compatible closures.

Purpose of Closures

The primary purpose of installing a gate or fence at a mine entrance is to control human access. The motivation for this can be to protect vulnerable natural resources or historically significant artifacts within the mine but more often it is to protect the public from the hazards inherent in abandoned underground workings. Many of the cave dependent bats found in the US have come to depend upon abandoned mines for their maternity and hibernation roosts. These bats include several that are Federally endangered or have declined to the point that they may need to be added to the Federal list in the near future (Altenbach, J. S. and E. Pierson 1995, Belwood, J. 1991,Currie 2001a).

What Makes an Abandoned Mine Important to Bats?

All bats have a series of microclimate requirements that determine if an abandoned mine will provide suitable conditions for hibernation and maternity roosts. Each species inhabits sites with specific temperature and humidity ranges. Generally hibernation sites are cold, ranging from near freezing for species like the big brown bat (*Eptesicus fuscus*) to relative warm (12-14 degrees C) for species like the eastern pipistrelle (*Pipistellus subflavus*). Most of the endangered

and Federal concern species prefer temperatures between 3 and 10 degrees C for hibernation. Maternity sites for species such as the gray bat (*Myotis grisescens*) or the endangered and non-endangered subspecies of Townsend's big-eared bat (*Corynorhinus townsendii*) require warm sites to raise their young. Abandoned mines that provide optimum conditions for bat use are configured in a manner that facilitates trapping cold air for hibernation or warm air for maternity use (Tuttle and Stevenson 1978). The physical mechanisms that result in these pockets of cold or warm air are the same in both caves and mines (Tuttle and Taylor 1998).

Bad Gates, Good Gates, and The Ideal Gate

Early gates were often designed to protect significant, non-biological cave resources or to restrict access to commercial caves. The first gates and gate construction guidelines (Hunt and Stitt 1981) often concentrated upon controlling cave access alone, rather than controlling access while maintaining the internal microclimate. Early attempts to control mine access with gates often had this same priority. While sometimes successful in restricting unauthorized access to a cave or mine, these structures often had disastrous impacts upon bats.

Wyandotte Cave, in Southern Indiana, is a significant hibernation site for the endangered Indiana bat (*Myotis sodalis*) that originally supported at least 10,000 bats. Human disturbance and an early, restrictive rock wall caused the population to decline to less than 1,000 bats by the time another gate and wall were built in 1970 (Figure 1). The 1970 gate and wall was successful in controlling access to the cave but compounded the problem caused by the earlier rock wall. Temperatures behind the wall were generally too warm for successful Indiana bat hibernation (Richter, et al. 1993). In 1978 the stone wall and restrictive doors were removed and a new gate (Figure 2) was installed. Although not an optimal solution, this gate was less restrictive to airflow and bat movement and temperatures started to return to normal. Although the hibernating Indiana bat population responded positively to the 1978 gate, the gate still caused problems for the Indiana bats since the flat steel bars still restricted airflow and the small openings in the gate still restricted bat movement. An additional problem, noted by Dr. Virgil Brack, (Environmental Solutions and Innovations, personal communication, 2000), was significant predation by feral house cats at the gate. In 1991, an angle iron gate was installed at Wyandotte Cave (Figure 3) (Johnson 1992). The angle-iron gate eliminated the airflow restriction and bat movement problems at the gate and seems to have significantly reduce the predation that occurred at the 1978 gate. Between 1991 and 1999, the Indiana bat population increased from about 13,000 bats to almost 27,000 bats. (Virgil Brack, personal communication, 2000).

"Bad" gates can significantly alter air flow or act as a physical barrier to bats or other species using the cave or mine. They can also be so poorly constructed that they are easily vandalized and bypassed. A "good" gate is effective in controlling human access and is vandal resistant while maintaining unrestricted airflow and bat movement. The design of an ideal gate is constantly evolving. At this time the bat friendly, minimal airflow restriction, angle-iron gate is the recommended standard for protecting colonies of bats in mines and caves (Figures 4 and 5). This gate design was developed by Roy Powers (Mountain Empire Community College, Big Stone Gap, Virginia) working with others in the caving community to meet the need for a strong,

effective bat gate that has minimal air flow resistance and provides maximum space for bat movement. This is the design recommended by the U.S. Fish and Wildlife Service for use at caves or mines that support bats that accept full gates. The angle-iron gate is used by the: National Park Service's abandoned mine reclamation program (Burghardt 1997); U.S. Forest Service in the Pacific Northwest and other parts of the country (Jim Nieland, U.S.F.S., personal communication, 2000); New Mexico abandoned mine program (John Kretzmann, New Mexico Energy, Minerals and Natural Resources Department, personal communication, 2000); and many others. Prior to using this design, the American Cave Conservation Association, Horse Cave, Kentucky, should be contacted to obtain the most recent general drawings of this gate. Gate designs in general and the angle-iron gate in particular are constantly being improved (Tuttle and Taylor 1998, Powers 1993).

Other Gate Designs

The first gates installed to protect bats were constructed of 1" or 3/4" round steel bars. Round bar gates have minimal affect on airflow and if proper spacing is maintained between the vertical and horizontal bars they have minimal affect on bat movements. Their greatest disadvantage is that the small size of the bars allows vandals to easily cut through them. This was particularly true at many early round bar gates that were constructed of mild steel or even rebar. Round bar gates constructed of alloyed steels, such as the gates constructed of Manganol by the Utah Division of Oil, Gas and Mining, are much more resistant to vandalism (see Figure 3 in Currie 2001b). Detailed information about the Manganol steel gates can be obtained from Mark Mesch, at the Utah Division of Oil, Gas and Mining (see list of attendees at this forum for contact information).

The Colorado Division of Minerals and Geology (Mining, Mine Safety and Mine Reclamation) has developed an approach to mine closures that incorporates a prefabricated bat window/door into a gate constructed of non-bat compatible grating (Figure 6). This design has been used successfully in some situations and is probably suitable at mines that have small populations of bats. Because of the reduced flight space available through this gate, caution should be exercised in using this design at mines supporting a large number of bats. Kirk Navo (Colorado Division of Wildlife, personal communication, 2000) reported that Townsend's big-eared bat (*Corynorhinus townsendii*) maternity colonies supporting up to100 females have accepted this gate, for summer colonies supporting over 200 bats he recommends that a full bat gate be used.. This design also may restrict air movement through the gate and therefore may have an adverse effect on mine microclimate, especially at hibernation roosts. For more information on the Colorado approach to bat gates at abandoned mines contact Jim McArtle, Colorado Division of Minerals and Geology, contact Kirk Navo for information on Colorado's gate monitoring efforts (see list of attendees at this forum for contact information).

Open Stopes, Shafts, and Large Adits

The standard angle-iron gate is best suited for use on small to medium sized horizontal mine entrances or on inclines or declines of less than 45 degrees. Large entrances, open stopes and shafts often require a different type closure. Often a mine closure plan will address a

combination of entrances that include shafts, adits, inclines, declines, and open stopes. The structure designed to close each type of entrance should be developed to meet the biological and hazard abatement needs of each site.

Shafts often have an integral function in the maintenance of the temperature and humidity regimes that make an abandoned mine complex important to bats. Shafts may or may not be used by bats but are often essential for optimum airflow. If a shaft is only important for airflow the closure design only needs to maintain airflow and provide for public safety (Figures 7 and 8). If bats also fly through the entrance then the closure should not only provide for unrestricted air flow but should also minimize restriction of bat movement (Figure 9).

Open stopes are often difficult problems to deal with from the standpoint of hazard reduction with bat protection. Cable netting is one useful tool to use in securing this type of area (Figure 10). If bats must fly through the open stope, then unrestricted bat movement may be accomplished by combining cable netting with a more substantial structure that incorporates a cupola (cage gate), or other bat friendly design. Alternative closures for very large adits, shafts, declines, inclines, and open stopes include some type of fencing such as chainlink (Figure 11) or the more secure (and expensive) iron fence (Figure 12).

General Gate Considerations

The type of structure constructed to control access to an abandoned mine must be designed to meet the physical conditions at the site and nature of bat use of the mine. Some species, such as Brazilian free-tailed bats (Tadarida brasiliensis) and gray bats at their maternity colonies, will not accept full gates at the entrances to their roosts. Fences, iron gates and half-gates are the only acceptable structures at mines supporting these types of bat colonies [see Table 1 in Currie (2001b) for a list of species that will accept full gates at their roost sites].

The strength, integrity and vandal resistance of the angle-iron gate make it an excellent choice for most closures. If alterative designs are used, the designer should insure that the alternative gate will produce an acceptable closure. The basic criteria for an acceptable gate is one that protects the public, maintains current airflow patterns and is accepted by the species using the mine. At a minimum, a gate should have structural strength, correct bar spacing (5 3/4"x24" minimum, or 5 3/4"x 4' for angle-iron gate), a secure foundation, adequate horizontal and vertical bar anchors, and a protected lock.

Gate foundations must be secure or vandals can easily tunnel under the gate. The first choice is to anchor the base of the gate directly into bedrock. A second choice is to build a steel barrier extending along the ground in front of the gate and cover the barrier with concrete or rocks. A third choice is to use expanded metal sheeting or fabricated steel grid under the foundation. In some situations another alternative is to drive 1" diameter steel bars into the ground every 6-8 inches along the base of the gate and weld these to the back of the gate. In constructing the foundation and in installing structures to prevent tunneling under the gate the designer should be careful to avoid restricting airflow at the entrance.

Anchors for the horizontal and vertical bars are an important part of any gate. These anchors should firmly attach the gate to the mine in order to prevent someone from pulling the gate out of the entrance with a wench, or pulling the side of the gate away from the wall. Anchors pins generally should be at least 1" in diameter and inserted into holes drilled 6" to 10" deep, depending upon the strength of the rock. The pins should be protected from easy hacksaw access (Figures 13 and 14).

Gate access door locks are often the most vulnerable portion of the gate and they should be protected from hacksaws, torches, and hammers as much as possible. There are several types of lock guards available and the angle-iron gate drawings in Tuttle and Taylor (1998) show a very effective one for a gate with a removable access bar. McGard security bolts are an effective alternative to locks (Figure 15).

Regardless of which gate design is used, avoid incorporating plate steel or concrete or stone walls into the gate. These can adversely affect bat movement and airflow at the entrance. Use adequate sized openings and be sure to maintain at least the minimum 5 3/4"x24" bar spacing (four foot minimum between vertical bars with angle-iron design). An exception to this spacing may be necessary in some situations. If the gate will be accessible to small, unsupervised children and a smaller spacing between the horizontal bars is needed, it may be appropriate to decrease the spacing to 3 ½ or 4 inches between the horizontal bars in the bottom half or bottom third of the gate. Bats usually fly through the upper portion of a gate and using smaller dimensions in a portion of the gate that is not in their flight path is appropriate.

Evaluating Success–Post Construction Monitoring

In simplest terms a gate can be considered successful if it keeps people out, does not adversely modify mine microclimate and the bat population remains stable or increases. To insure that gates continue to serve their purpose a regular monitoring program should be incorporated into mine closure plans. Closures should be regularly checked for vandalism and repaired as soon as vandalism is detected. Biological monitoring is needed to determine if the bats using the mine accept the closures (Figure 16). The information gained through security and biological monitoring will expand the data base on the use of gates to protect bats and can be used to make positive modifications to future closure plans. Monitoring and incorporation of the information gained through monitoring into mine reclamation programs will benefit the public by developing more successful and effective closure plans and will benefit endangered and declining bats by providing the secure roosts that are essential for their survival.

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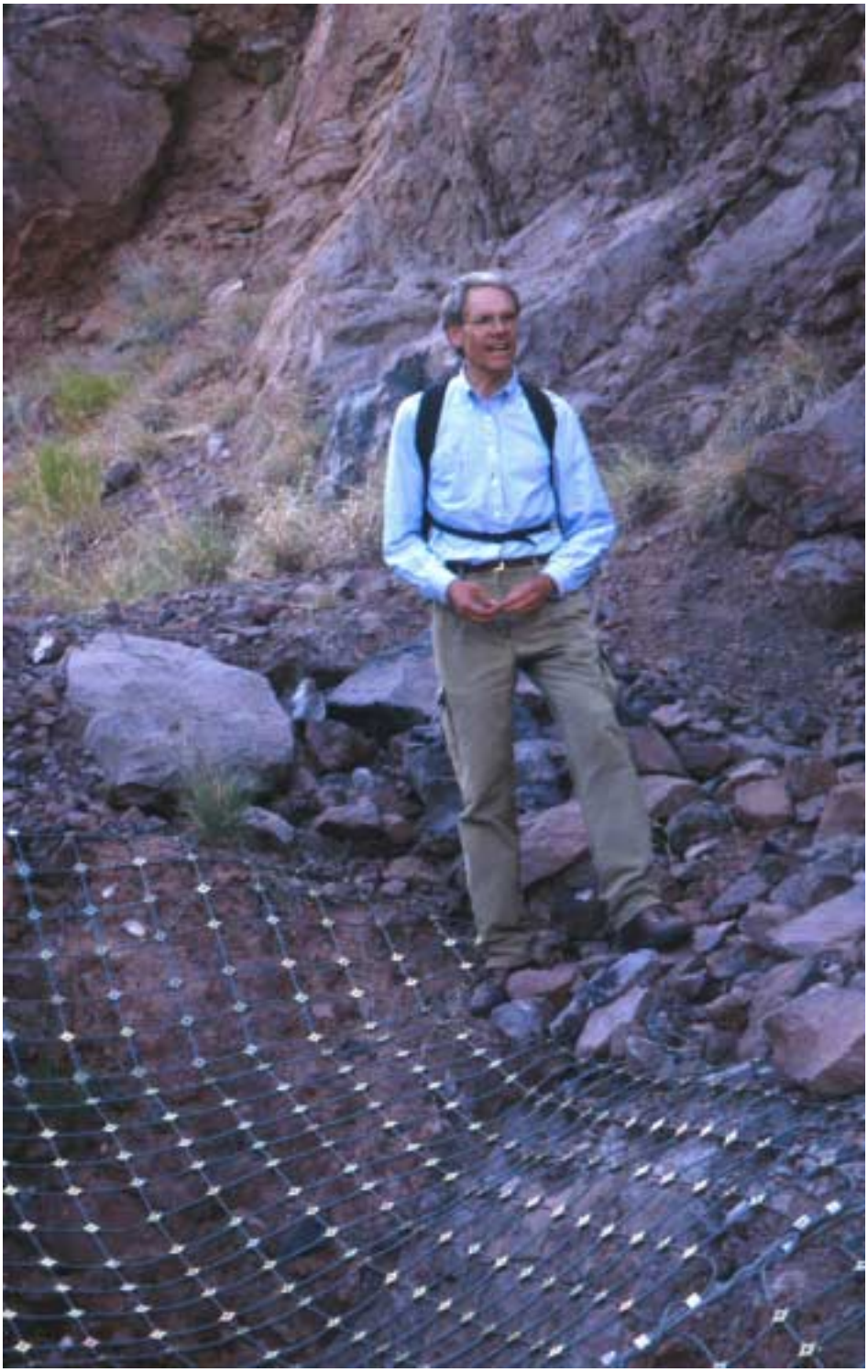

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Figure 16

NEW MEXICO EXPERIENCE WITH BAT GRATES AT ABANDONED MINES

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Abstract

Following external and internal surveys of abandoned mine workings, the New Mexico Abandoned Mine Land Bureau designs and installs bat-compatible and bat airflow closures for mines with significant bat habitat. The Bureau has developed various designs for shaft, adit and stope openings and for a variety of rock conditions at these openings. These closures seem compatible with most bat species in New Mexico that use abandoned mines and keep most people out. However, vandalism has been a problem and several grates have been breached. Solutions to reduce vandalism include refinements in design and use of materials, camouflage of the mine openings where bat grates are installed, and closure of roads and trails that lead to grated mine openings.

Introduction

The New Mexico Abandoned Mine Land Bureau (NM AML) closes and safeguards up to a couple hundred mine openings in the state each year. Before design of the closure method, the Bureau's biologists enter most abandoned mines to check for internal bat habitat, including use for winter hibernation, summer maternity roosting and night roosting. Where significant bat usage is found and a reasonable bat closure can be built, NM AML designs steel bat grates at or inside the mine openings. In the last ten years, the NM AML program has designed and constructed over sixty bat closures at shaft, adit and stope openings.

Any discussion of bat grate design inevitably ends up focusing on the problem of vandalism. People seek to enter and explore abandoned mines for a variety of reasons: to collect rock and mineral specimens, to search for old mining artifacts, or simply for the adventure of exploring dark and dangerous places. The fact of vandalism drives many of the decisions we make in bat grate design and raises issues regarding long-term inspection and maintenance.

General Design Criteria

To the extent that we understand the needs of bats, consideration of the following criteria[1,2] are important in designing bat grates:

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[1]Tuttle, M. D., and D. A. R. Taylor. 1998. Bats and Mines. Bat Conservation International, Inc. Resource Publication No. 3, Revised Edition. Austin, TX. 50 pp.

- avoidance of adverse impact to airflow and surface water drainage patterns to maintain mine temperature and moisture conditions;

- reduction of the number and sizes of vertical columns and other vertical obstructions and maximization of the number and sizes of horizontal bat fly-through areas;

- use of designs that are as simple and safe as possible to construct and that do not present a danger to the public; and

- use of durable, vandal-resistant designs that prohibit unauthorized entry, safeguard the general public from the hazards of unprotected abandoned mines, require minimum maintenance, and are easily repaired if breached or damaged.

Minimizing the impacts to airflow patterns is achieved by giving attention to several factors. The efficient use of construction materials decreases the reduction in cross-sectional area at the grate. Streamlining of the grate installation, particularly in adit grates where there is significant movement of air, can be important. It is also important to maintain air passage at mine openings that significantly contribute to ventilation of the mine workings, even where bats seldom or never use these openings.

Surface drainage into underground mines may be important for maintaining proper humidity conditions for bat habitat, particularly if groundwater is not present in the mine workings. Surface drainage patterns can be maintained by placing pipes through the concrete footing for the grate or by other means appropriate for the site. NM AML safeguarded one stope opening unused by bats in the mine, but which captured the surface runoff from a half-acre of rocky hillside, by partially filling the opening with riprap. This allows runoff from summer thunderstorms to continue to enter the mine.

Reducing the vertical obstructions and maximizing the number of bat fly-through spaces serve to eliminate the predation that occurs if bats need to alight, slow, or circle at the structure. Generally fly-through spaces are 5 3/4 inches high and a minimum of 24 inches wide. In openings that directly access areas used as nurseries, where the mother bats will make frequent trips through the grate, the uppermost two or three crossbar spaces are often increased to six inches.

Designers need to listen to their bat biologists for the particular needs of the bat species being protected and of the type of bat use in the mine workings. Grate requirements can vary according to the species and type of bat habitation in the mine, e.g., hibernaculum, maternity, or day or

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[2]Hawthorn, J., and J. Thornton. No date. The Common Sense Guide to Cave Gates. American Cave Conservation Association/CMS. 20 pp.

night roost. Some species do not accept bat grates, except at hibernation sites, and information on grate acceptance for some species is inconclusive.

It is important that bat grates be constructed when construction activities will cause the least disruption to the bats using the mine. This depends on the type of bat use of the mine. In New Mexico, we often build grates in the spring and fall, between the winter hibernating season and the summer nursery season.

All bat structures should be designed to ensure long-term public safety and constructibility. Professional engineers design all NM AML bat grates and ancillary structures.

Finally, I believe that bat grates should be not only durable but also beautiful. I see each one of them as a small monument to humankind's reawakening sense of responsibility for the fate of other species. They remind us of our responsibility to care for the world and those with whom we share it.

Current Design Approach in the New Mexico AML Program

Many bat grate designers have adopted the approach of using stout steel members to construct bat grates. These members are anchored to concrete or to the rock at or inside the mine opening to resist prying, jacking, and pulling of the grate components. We fill the vertical columns with reinforced concrete or grout and a continuous length of reinforcing steel. This prevents cutting by torch and stiffens the entire assembly against prying and pulling. Where rock conditions are competent at the adit portal, we anchor the columns and at least half the horizontal crossbars to the back and ribs using ¾-inch diameter steel rods tightly fitted into drilled holes. Grates are generally installed close to the mine entrance, to protect the public from as many hazards as possible.

For all of our bat grates, we use weathering steel (meeting ASTM A588 or ASTM A242) which has two to four times the corrosion resistance of mild steel. This steel weathers to a dark rust color and does not require field painting. The dark color helps to camouflage the grate inside or at the mine opening. A concrete sill is cast on the adit floor for column anchorage, to keep the steel above the dirt floor, and to discourage digging underneath the structure. An adhesive vinyl explanatory/warning sign is often placed on one horizontal member. Standardization of materials and design simplifies initial construction and repair of vandalized grates.

As shown in Figure 1, crossbars are usually built from four-inch angle iron rotated 45 degrees for improved airflow, with two small angle internal stiffeners. We place these stiffeners primarily to discourage vandalism; they add little to structural strength. My calculations show that an internally stiffened, weathering steel crossbar (L4x4x3/8), with supports four feet apart, can conservatively withstand a vertical force of at least 3800 pounds and a horizontal force of more than 6900 pounds. When supported eight feet apart, allowable forces are one-half those values.

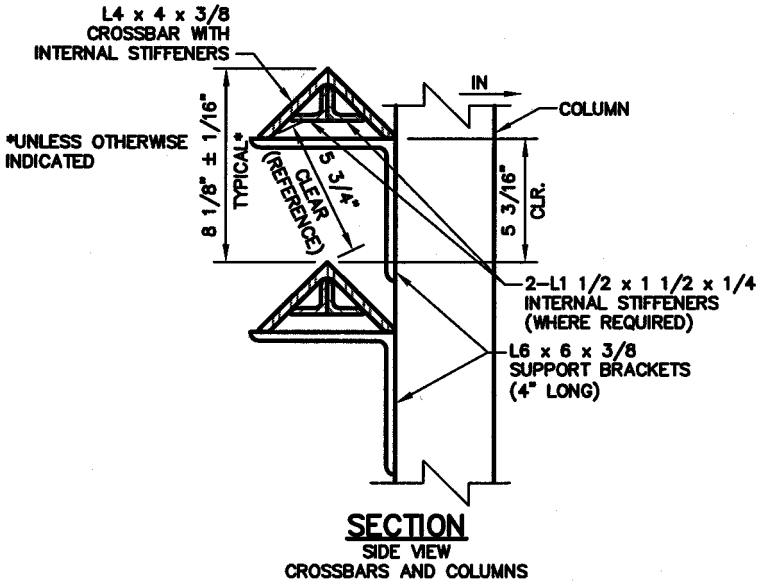

Figure 1

We are beginning to design gazebo-type structures over shafts using two-inch by four-inch structural tubing crossbars with quarter-inch wall thickness. This tubing has similar structural characteristics as the stiffened angle iron crossbars but with significantly less welding required. In areas of high vandalism potential, to address the reduced area of steel to cut through, we can place a continuous high-manganese "Manganal" steel rod inside each tube and fill the tube with concrete or grout. A hacksaw is unable to cut Manganal steel (and consequently is widely used in prison construction) and the concrete or grout discourages cutting with a torch or cutting wheel.

NM AML uses removable locking crossbars, rather than hinged doors, at bat grates where biologists or mineral claimants require authorized access. We specify two security bolts to lock each removable crossbar, which require a special matching pattern in the socket wrench keys. These bolts considerably simplify construction and are highly resistant to unauthorized attempts at removal. The bolts are now placed under the bar, rather than on the outside face of the crossbar, to make it difficult to shear the bolt with a sledgehammer.

Generally NM AML places one or two removable crossbars per grate, as shown in Figures 2 and 3. Short removable crossbars are more difficult to vandalize than long removable crossbars. After a cut near one end, a long removable crossbar may be able to be levered back and forth enough to loosen the opposite locking bolt. Consequently, we make removable crossbars as short as two feet. For removable crossbars this short, two cuts would be needed to breach the grate.

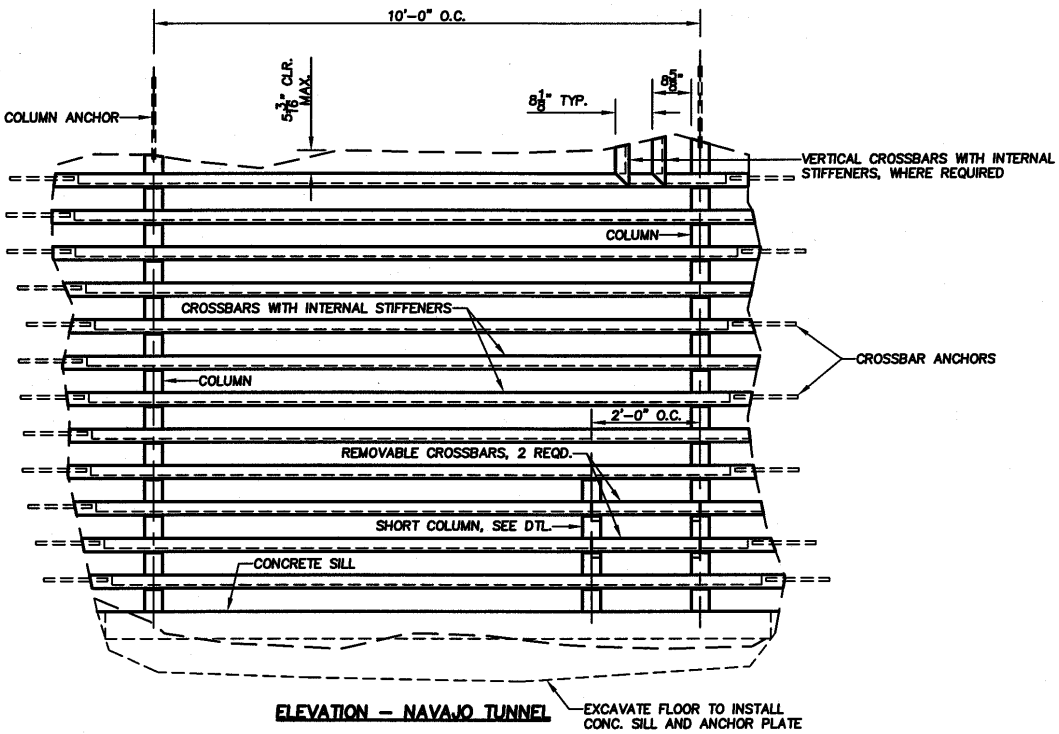

Figure 2

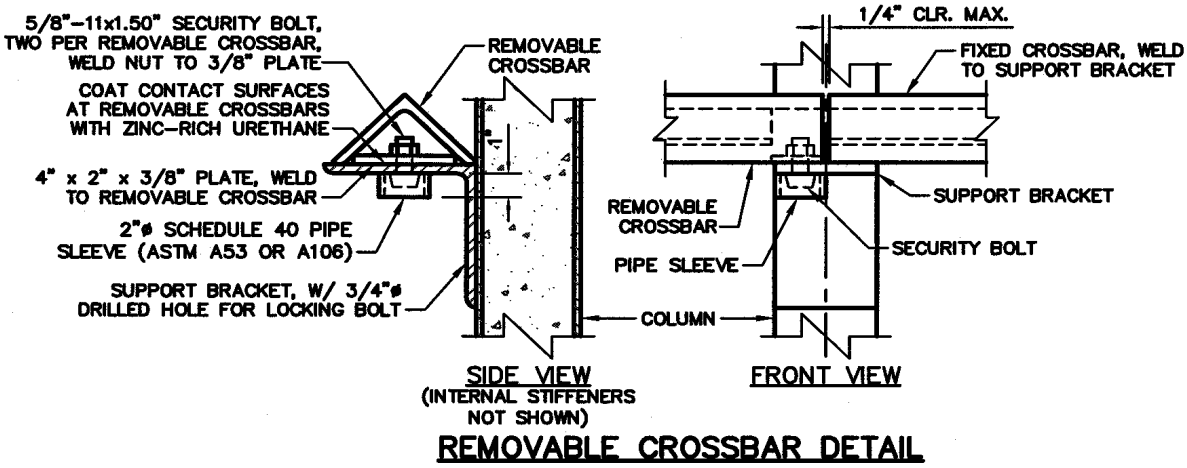

Figure 3

Where rock is soft, collapsing, or extensively fractured at an adit entrance, we have placed the bat grate inside a corrugated steel culvert. The grate is welded inside an octagonal steel frame bolted to the culvert. Melvin Tuttle of Bat Conservation International has recommended that, to reduce predation, the bat grate be placed toward the inside end of a minimum three-foot diameter pipe.

To insure that young children and small persons cannot crawl through the grate, some AML programs are spacing the lower crossbars more closely. This should have minimal impact on bat passage, since most bat flights through grates seem to take place near the top. NM AML is considering adopting this design refinement.

Design requirements for vertical mine openings (shafts and stope openings) are less well defined than for grates at horizontal openings, but we have used the following design solutions:

- fences (often chain link fencing with black PVC-coating to reduce visibility), with or without barbed wire, around the shaft or stope collar, sometimes combined with other bat closure methods such as horizontal steel grates;

- cable netting to maintain ventilation in the mine workings, sometimes with bat windows to provide ingress and egress for small bat populations and at mine openings infrequently used by bats;

- horizontal steel grates inside shaft collars where rock conditions, opening size and shape are favorable; generally for small bat populations that tolerate this design (predation of larger colonies could be a problem since space for exit is restricted) and at openings where bat passage is not significant and maintenance of air flow conditions is the primary consideration; and

- steel bat gazebos that can accommodate larger bat populations, either founded on a competent bedrock collar or using corrugated steel pipe risers held in place by concrete or polyurethane foam plugs cast against bedrock.

In complex mines with multiple openings, NM AML has on occasion used permeable closures that do not allow for bat passage, but simply help to maintain ventilation conditions for the internal workings. We use these at openings with little or no bat usage or where nearby openings offer better locations for bat passage and construction of bat-compatible closures. These airflow closures have included cable netting and grated shaft covers of various designs.

Success in Protecting Bat Habitat

At the Socorro West Mine Safeguard Project, we have the strongest verification of the success of our approach in protecting bat habitat. One of the two mines in this project once held the largest recorded hibernating colony of Townsend's big-eared bats, *Corynorhinus townsendii*, and a significant maternity colony until vandals set mine timbers on fire in the winter of 1992-93.

Carbon monoxide, carbon dioxide, and fire killed many of those bats. In 1996 NM AML safeguarded 12 of the 24 mine openings either with bat compatible closures or with closures that provide ventilation of the mine openings.

Scott Altenbach, bat biologist from the University of New Mexico, has visited the features several times since construction. Hibernating populations of bats have increased steadily since the mine features were protected and the guano piles beneath maternity roosts have markedly increased in size.

New Mexico AML Experience with Vandalism and Partial Solutions

Experience has shown that bat grates require inspection for vandalism and repair of damage. Longer experience may show the need to repair or replace corroded steel members and spalled concrete, to clear rock fall, and to take care of other problems at bat grates.

Of the approximately forty bat grates built in adits by NM AML, we know of seven grates that have been breached. One location was where the rock in the adit was highly fractured and soft. The vandals excavated the rock on one side of the grate to allow a crawl space around the closure. At the other locations, vandals breached the grates by cutting a removable crossbar. At one location the vandals accomplished this with a rotary cutting wheel, at another with a cutting torch, and in the other four by hacksaws.

The breached grates have had several things in common. All breach locations have been in adits at sites with significant visitation either before or after safeguarding. We discovered four of the breached grates at adits within a quarter mile of each other shortly following the publication of the discovery of a rare microcrystal at that site. Only one of the seven breached grates had internal stiffeners in the crossbars, and that one was opened using a cutting torch. To discourage future vandalism, we have fortified the breached grates, now place internal stiffeners in all new adit bat grate crossbars, and place grates inside of culverts where rock conditions near the adit entry are soft, weathered or highly fractured. Since making all of these changes within the last two years, we have not yet experienced further adit grate breaching at those sites.

We have not had significant bat grate vandalism problems at deep shaft and stope closures, and no breaching, presumably because once they were breached vandals would need climbing equipment to enter the mine workings. Bat grates at horizontal mine openings are the easier targets for vandals.

To reduce the necessity and expense of returning to a site to repair and harden breached bat grates, the Utah Abandoned Mine Reclamation Program has built grates made entirely of one-inch diameter Manganal steel bars. We have not adopted this approach because these grates do not have the structural strength and resistance to prying and pulling that our designs have. Manganal grates also remain as vulnerable as our designs to cutting with cutting wheels and torches. However, to increase resistance to hacksaw cutting, NM AML has built a few gates with loose high-manganese steel bars placed inside the internal stiffeners at horizontal crossbars. An

option we have not tried is laying down a hardening weld bead along those points where a saw can be used. Since these beads can be removed with a hammer and chisel, they need to be placed in relatively inaccessible locations on the grate members.

On the hypothesis that grates less frequently visited by the public are less likely to be vandalized (unless in well-patrolled areas), NM AML has restricted access to some sites and planted vegetation in front of some mine openings in an effort to eventually camouflage them. Vegetation is placed far enough from the opening so that when full grown it will not obstruct bat passage. We have limited access by closing jeep trails to mine openings with locking gates and earthen and rock berms and by building fences and bramble barriers in adit entry trenches and across jeep trails in steep terrain. Bramble barriers are dense plantings of cactus and thorny bushes. Barriers to access also make it difficult to get heavy tools, such as winches and oxygen-acetylene or oxygen-propane tanks, to the grate site. The disadvantage to trail closure is, of course, that access is more difficult if repairs are needed.

Prompt repair of breached grates is important to reduce the length of time that mine hazards are exposed. Prompt repair may also frustrate the vandals and, over time, lead to less vandalism. This implies that regular site inspections are necessary. For many Western abandoned mine programs, covering large areas with limited personnel, such a commitment is impossible to maintain with in-house staff. NM AML is just beginning to establish working relationships with public and private landowners to establish inspection schedules for bat grates and other structural closures on their lands.

Conclusions

The primary mandate of AML programs is to provide for the long-term public safety at abandoned mines. In deciding whether or not to protect bat habitat in a mine, the size and importance of that habitat need to be weighed against initial construction costs, the degree of public hazard, and the feasibility of long-term inspection and maintenance. Not all mines with bats should be or need to be grated.

Ultimately no perfect mine safeguard method exists. Backfilled adits can be dug through. Deep shaft fills sometimes settle or collapse. With sufficient time, tools, and desire, vandals can breach any type of structural closure. Nature will continue her work to corrode and weather construction materials. What AML designers can do, however, is to fashion durable closures with high levels of public safety and vandal resistance, acceptable construction and maintenance costs, and good aesthetics. AML programs need to work to provide for sensible inspection schedules and prompt repair not only of bat grates but also of all closures.

All AML safeguarding methods will benefit from continued improvements in design, implementation and maintenance. In this regard, bat grates are no different.

John Kretzmann works in abandoned mine reclamation for the New Mexico Energy, Minerals and Natural Resources Department. This work has involved not only design for bat preservation, but also design of other structural and nonstructural closures of abandoned mine openings as well as reclamation and revegetation of abandoned coal mine waste piles. He holds a B.S. in Civil Engineering from Valparaiso University

A COLORADO CASE STUDY
TO SECURE UNDERGROUND MINES FOR BAT HABITAT

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Abstract

The Colorado Division of Wildlife initiated the Bats/Inactive Mines Project in 1991 to evaluate the use of abandoned mines by bats before closure. The goals of the project are: (1) to identify important roosts for bats; (2) protect these roosts with bat gates; (3) obtain more information on the status and distribution of bats; and (4) educate the public and resource managers about bat conservation in the State. This project represents a cooperative effort between several State and Federal agencies, the National Fish and Wildlife Foundation, and volunteers from the general public. Trained volunteers conduct surveys outside designated mine entrances using bat detectors, and document bat activity at mine sites. Mines with bat activity are then surveyed by trained biologists to determine species and roost types. During the last nine years, over 1800 surveys have been conducted with volunteers contributing more than 26,000 hours. The project has evaluated 2,242 mines to date. Results show that 34 percent of the mines surveyed have bats associated with the site. Of these, 15 percent are determined to provide significant roosts for bats based on follow-up surveys. During the last nine years 1,903 bats representing 11 species have been documented roosting in mines. Four species make up 85 percent of the total bats captured at mines, *Corynorhinus townsendii, Myotis volans, Myotis evotis,* and *Myotis ciliolabrum*. The surveyed mines ranged in elevation from 4,960 to 12,842 feet, and averaged 8,404 feet. Bats were documented using mines as roosts at elevations ranging from 5,800 to 12,160 feet. The average elevation of mines used as roosts was 7,411 feet. Maternity roosts were documented at elevations up to 9,100 feet for *myotis volans,* and use by reproductively active females was documented at up to 10,580 feet. Bat gates have been installed at 142 mines, and an additional 188 mines are scheduled for gate installation. Gate monitoring indicates that all species documented using abandoned mines before gating continue to use the gated mines.

Introduction

Colorado, like many western States, has a rich mining history. Mining communities were found across most of the western two thirds of the state. This history has resulted in the occurrence of many abandoned or inactive mines, scattered across the State. During the early 80's, a push to safeguard these potentially hazardous features was initiated, and the Colorado Abandoned Mines Land Program was created to implement this program. While many of these mines present a hazard to the public safety, they also potentially provide roosting habitat for many species of bats (Altenbach and Pierson 1995; Tuttle and Taylor 1994).

There are currently six species of bats Federally listed as threatened or endangered in North America. Although no longer a formal category, in 1994 thirteen species and sub-species, eight of which occur in Colorado, were petitioned for Federal candidate status (FC-2). While there are many factors that could be responsible for declining populations of bats, the loss of habitat is an essential issue. Roost sites for bats may be the important conservation factor for most Nearctic bat faunas, especially for colonial species. The distribution and abundance of colonial bats is linked to the availability of suitable roosts. Although many species of bats use a variety of roosts, including mines, the natural history of most species in Colorado is poorly known, making it difficult to assess their status and potential impacts to populations from the loss of habitat. Abandoned mines provide roosting habitat used by many species of bats. Most cave/mine obligate species in North America have experienced declines, and many are current, or proposed, threatened or endangered species (Gates et. al. 1984; Perkins 1985). Townsend's big-eared bat (*Corynorhinus townsendii*) is considered a cave/mine obligate species, and, in Colorado, is a species of concern and listed as imperiled with the Natural Heritage Program. While mines are man-made habitats, they have been part of the natural landscape for over 100 years and some species of bats may have become dependent on them for survival.

Because of the concern for the status of many bat species in the State, the Colorado Division of Wildlife (CDOW) initiated the Bats/Inactive Mines Project in 1991 to evaluate the use of abandoned mines by bats before their closure. The goals of the project are: (1) to identify important roosts for bats, (2) preserve these roosts by the use of bat gates, (3) obtain more information on the status and distribution of bats, and (4) educate the public and resource managers about bat conservation in the State. The project is a cooperative effort between the Colorado Division of Wildlife, Colorado Division of Minerals and Geology, US Forest Service, Bureau of Land Management, the National Fish and Wildlife Foundation, and volunteers from the public. Because of the large volume of abandoned mines scheduled for closure each year, other options were needed to supply the manpower necessary to evaluate the mines for bat use. We recruited and trained volunteers to conduct most of the initial surveys, and narrow down the number of mines that required more in depth evaluations. In 1994, the Bureau of Land Management and US Forest Service entered the partnership and we hired additional seasonal biologists for the project.

Methods

Mines included in the project are located throughout the western two-thirds of the State. They are comprised of privately owned mines, and un-patented mines on public lands. The Colorado Division of Minerals and Geology, Bureau of Land Management, or the US Forest Service first inventories all mines included in the project. At that point, closure projects are developed and maps are provided to the Colorado Division of Wildlife to initiate bat evaluations. Bat evaluations start with a pre-survey of each mine, designed to collect information at the entrance of a mine to aid in prioritization of survey efforts.

We enter each mine into a project database and give it a project ID number. This number is utilized to track each individual mine site. Mines that are not eliminated during the pre-survey are then scheduled for initial detector surveys by volunteers, or capture surveys by biologists. Division personnel survey those sites that are determined to be too hazardous for volunteer work only. Methods for data collection and evaluation are those found in *Guidelines for the Survey of Caves and Abandoned Mines for Bats in Colorado* (Navo 1994). Also see Riddle (1995), for guidelines to the

evaluation of mines for bats.

Volunteers on the project are required to attend a training session before participation. The training consists of a three-hour classroom course. Topics include mine safety, survey techniques, and learning about the natural history of bats. The first 3 years of the project made extensive use of volunteer surveys. We established numerous safety rules. At no time do we allow volunteers to enter any of the mines.

The volunteer survey team monitors the mine entrance at sunset with bat detectors, instruments that detect the ultrasonic vocalizations of the bat. When bat activity is documented, teams of CDOW biologists, often supplemented by volunteers, perform capture surveys at indicated sites. A capture survey will determine what species are using the mine and what type of roost use is occurring. Bats are captured and identified as to species, sex, age and reproductive condition. The data are used to evaluate the roosting habitat provided by the mine and, thereby, the importance of the site to local bat populations. This information is the basis for recommendations to land management agencies and DMG for closure or protection of the mine. Survey work continues for each mine until all seasons are covered, or enough information is obtained to base a recommendation for the site. Recommendations will include final disposition of the mine as bat habitat and any bat gate recommendations.

Bats can use a mine as: a hibernacula, maternity roost, day roost during the warm season, night roost, transition roost during migration, or interim periods between the winter and summer seasons. Therefore, the season of use of a mine by bats can vary. This makes it critical that surveys take place at different times of the year in order to adequately evaluate the potential of a mine as roosting habitat for various species of bats. Winter roost habitat can only be inferred by the documentation of fall use by bats when using external survey techniques. Fall swarming behavior by bats is well documented in eastern populations (Davis 1964; Fenton 1969) and, in Colorado, has shown that it can serve as an indication of hibernacula.

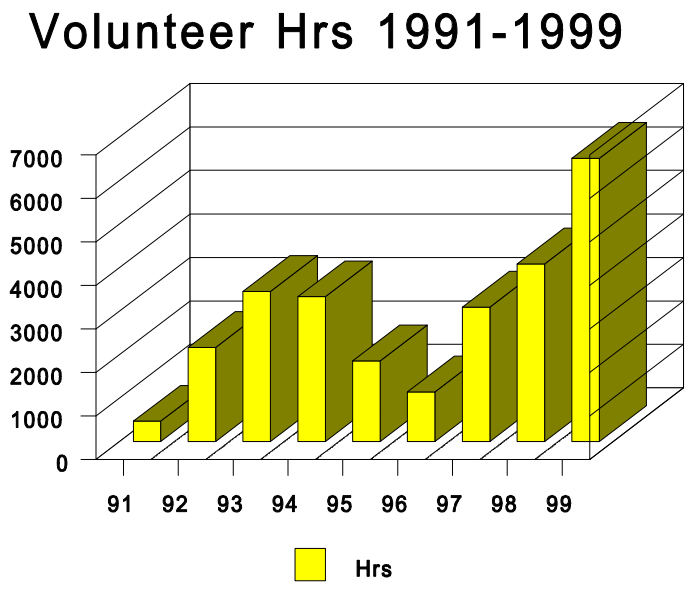
Little is currently known about gate designs and acceptance by various species of bats. Therefore, it is important that gate installation projects include some degree of monitoring and documentation in order to evaluate acceptance of gate designs by bats and their effect on populations. Some designs, such as the modified “window” gate used in Colorado, have preliminary results that are favorable. Tuttle (1977) stated that it might take several years to see the impact of an improper gate design on a bat colony.

Results

Over the 9 years from 1991-1999, we conducted more than 1800 external surveys during the evaluation of 2,242 mines. Additional internal surveys conducted by project biologists resulted in 453 more surveys. Survey results indicate that 34 percent of the mines surveyed have bats associated with the site. This means that bats were detected at or near the portal of the mine by visual or acoustic documentation, or captured at the mine. Of these, 15 percent were determined to provide significant roosts for bats. Significant roosts were considered those that provided: (1) maternity roosts, hibernacula, or transition roosts for Townsend’s big-eared bats, or (2) maternity roosts, or large hibernacula for other species of bats.

Volunteers have compiled more than 26,000 hours over the first 9 years of the project. This volunteer effort has saved the State of Colorado thousands of dollars and allowed for a large number of mines to be evaluated. In addition, the initial surveys conducted by the volunteers have allowed the project biologists to focus on those mines with bat activity. While the number of volunteers participating in the project has fluctuated over the years, a core group of volunteers has provided the bulk of the donated hours each year. In 1999, volunteers conducted and assisted with detector and capture surveys. This resulted in 5629 survey related volunteer hours in 1999. Volunteers donated a total of 6510 hours (including 445 training hours and 436 administrative hours) to the project. This volunteer effort has resulted in an estimated saving to CDOW of $61,409 in 1999 alone.

Over nine years, 1903 bats representing 11 species have been documented roosting in mines. These numbers do not represent the total numbers of bats using these mines because capture survey techniques are designed to catch just enough bats to base a decision on gating. Attempting to capture all bats using a mine would potentially be too disturbing to a colony of bats. Four species make up 85 percent of the total bats captured at mines, *C. townsendii*, *Myotis volans* (long-legged myotis), *Myotis evotis* (long eared myotis), and *Myotis ciliolabrum* (small footed myotis). These species were all considered as candidates under the 1994 Federal register species listing. In addition, the largest known colony of bats in the State resides in an abandoned mine. This colony of Brazilian free-tailed bats is estimated to be around 100,000-250,000 bats. However, unlike eastern mines that sometimes contain large colonies of hibernating bats, the largest colony documented in Colorado to date has been 200-300 bats. This may be a factor of the higher range of elevations that comprise the landscape of Colorado.



Mines surveyed over the 10 years of the project have ranged in elevation from 4,960 to 12,842 ft, and averaged 8,404 feet. Bats were documented using mines as roosts at elevations ranging from 5,800 to 12,160 feet. Night roosting by bats is very common at mines, and most mines are likely to be used by night roosting bats at some time or another. The average elevation of mines used as roosts was 7,411 feet. Maternity roosts were documented at elevations up to 9100 ft for *myotis volans.* Use by reproductively active females was documented at up to 10,580 feet.

The majority of roosts documented in Colorado have been fall transition and winter hibernacula. While the number of summer maternity roosts has been limited, there has been a significant number of roosts identified in the State. Complex mines systems can provide the range of microclimate conditions that provide all types of bat roosting habitat, even at the higher elevations that predominate in our State. Conversely, even simpler, single entrance mines can provide ideal roosting habitat for bats, but typically not at higher elevations.

Bat gates have been installed at 142 mines. An additional 188 mines are scheduled for gate

installation. Most gate designs were window (or ladder) style or slot gates. Window bat gates are typically installed at summer roosts or large hibernation sites. Slot gates are used at smaller hibernacula. Some special culvert gate designs have been used at mines with large trenches at the portals. Evaluation of their success is still underway. We initiated monitoring a subset of gated mines during the first year of the project and continue this effort every year. Monitoring indicates that all species documented using abandoned mines before gating continue to use the gated mines. At this point, the success rate of gated mines is over 90 percent. All styles of bat gates have had documentation of continued bat use.

Conclusion

Overall, the approach used in Colorado was been successful in identifying and protecting many bat roosts in abandoned mines. A combination of trained bat biologists and trained volunteers, working in concert with good mine inventories and closure planning, has provided the a sound approach to identifying and protecting mines important to bats. The use of volunteers has proved to be a viable approach to facilitating wildlife management activities. Volunteers can help prioritize survey work when large numbers of mines are scheduled for closure over short time frames. However, the effective use of volunteers requires a commitment of personnel to recruit, train, schedule, and coordinate their activities. External survey approaches have been the dominant technique used on the project. During the last 5 years, we have started using more internal surveys. Internal surveys allow for winter evaluations, if mines are accessible, and allow more mines to be surveyed in one day than external techniques. While volunteers have been helpful in our evaluations of abandoned mines, the limitations of their work in such hazardous situations, combined with the need for trained and experienced biologists to conduct the capture and handling of bats, requires use of adequately trained biologists, proper safety equipment, and a multi-technique approach to properly evaluate bat use of abandoned mines.

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PENNSYLVANIA CASE STUDIES TO SECURE UNDERGROUND MINE WORKINGS FOR BAT HABITAT

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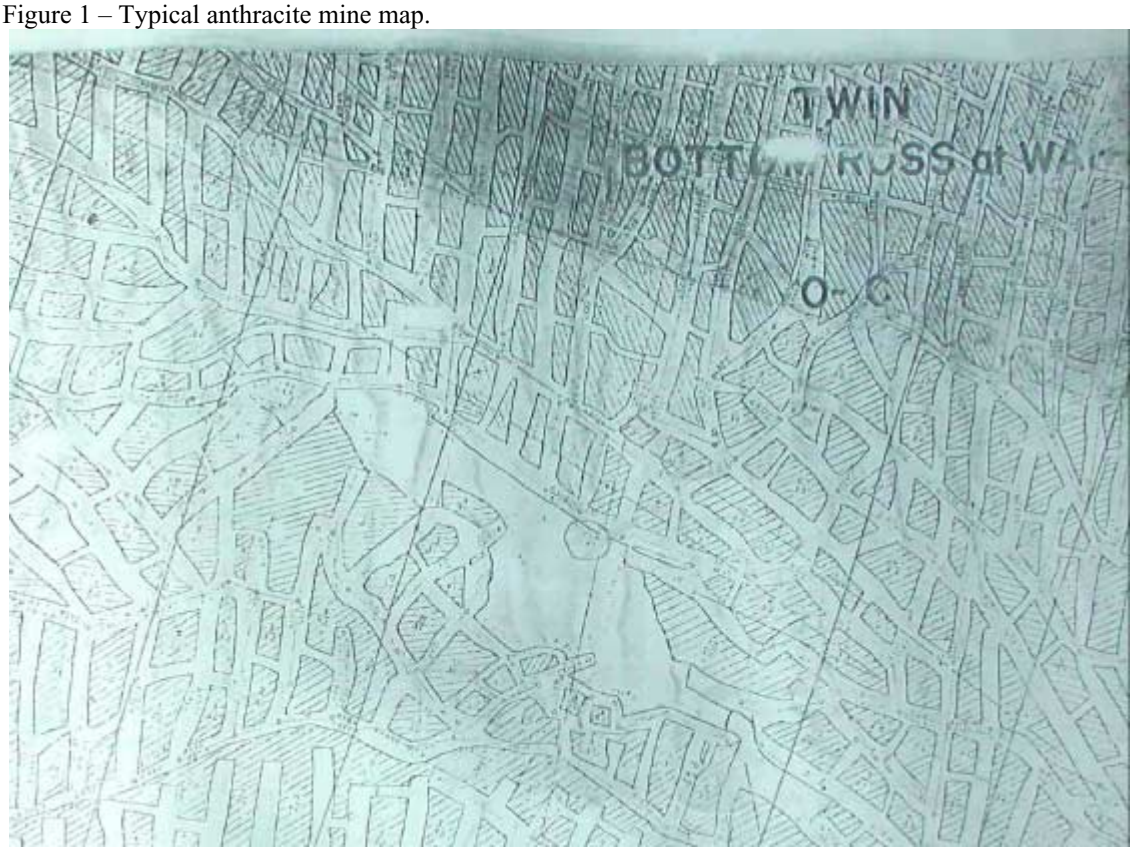
Abstract

Our objective is to protect the general public from hazardous abandoned mine entries, and to identify and protect bat populations that roost in the abandoned underground mine workings. In Pennsylvania the largest known bat concentrations are dependent on man-made habitat. Annual surveys to locate and monitor large winter roosts were begun in 1980. The Indiana bat (*Myotis sodalis*), northern long-eared bat (*Myotis septentrionalis*), eastern small-footed bat (*Myotis leibii*), little brown bat (*Myotis lucifugus*), big brown bat (*Eptesicus fuscus*) and eastern pipistrelle (*Pipistrellus subflavus*), use mine entries to access areas for winter roosts. Conservation management included but was not limited to construction of bat-friendly steel gates to protect hibernacula. Approximately 10 percent of the studied abandoned mine entries were occupied by bats and were preserved by gating. The vulnerability of such habitat and large concentrations of bats requires both proactive and reactive management.

Study Area

This study area is in the eastern part of Pennsylvania, where large deposits of anthracite coal were formed in the Appalachian Mountains section of the Valley and Ridge Physiographic Province. These deposits are within an area of 1,254 km² and are not continuous. The deposits are divided into four fields: Northern, Southern, Western Middle and Eastern Middle. Over five billion metric tons of anthracite were mined between 1807 and 1967 by underground room and pillar type mining. Much of this area is today considered abandoned mine land. Numerous entries to abandoned workings still exist. These entries probably contribute to a complicated and, for the most part, unknown airflow throughout thousands of kilometers of abandoned mine tunnels that can be used by bats. An example of an old map of a portion of the workings is shown in Figure 1.

Figure 1 – Typical anthracite mine map.



Entries are classified as:

1. Shafts - vertical openings constructed for ventilation, haulage, or personnel.

Photo #1 – An abandoned mine shaft used for ventilation of the mine workings Schuykill Co. PA)

2. Slopes - diagonal entries to the workings mostly for haulage or personnel.

Photo#2 – An abandoned mine slope used for personnel and coal haulage (Schuylkill Co., PA)

3. Drifts - horizontal entries to the coal mostly for haulage or personnel.

Photo # 3 – An abandoned mine drift used for personnel
And Coal haulage (Lackawanna Co., PA)

4. Cropfalls - caused by subsidence or mine collapse.

Photo # 4 – A cropfall within a surface mine (Schuylkill Co., PA)

The dangers to humans that exist from entries are: roof falls, uncharted abandoned underground mine workings, mine pools, and mine gases. Limiting factors for bats are: mine gases, temperature requirements, and collapses. Many of the entries are located in uninhabited. However most entries are accessible via abandoned haul roads or existing dirt roads. Many times, human visitation to these sites is apparent from discarded beverage containers, food wrappers, and other telltale signs.

Endangered Species Act

It is the policy of the Endangered Species Act that all Federal departments and agencies shall seek to conserve endangered species and threatened species and shall utilize their authorities in furtherance of the purposes of the act. It is further declares that Federal agencies shall cooperate with State and local agencies to resolve water resource issues in concert with conservation of endangered species. In order to close a mine entry potentially occupied by bats, we are required by law to consult with the US Fish and Wildlife Service and State wildlife agencies. This is done with consultation letters.

Site Evaluation

The first step in determining the possibility of bat use is a site evaluation. Criteria include:

1. **Flooding** - Is the interior of the site flooded to the ceiling, excluding bat use?

2. **Adequate Ventilation** - Does the site seem to have a significant amount of airflow? Some of the best bat sites have a large volume of air exchange with temperatures in the 4.5ºC to 10ºC range. The problem is airflow can vary by day or by time of year. Depending on time of year, three airflow conditions will prevail: intake, exhaust, and stagnant.
3. **Open Entry** -Can bats enter the opening? Some entries may be already gated with fine mesh that excludes bats or covered with a solid door.
4. **Guano** - Are bat droppings visible around the openings or on rocks within? This is a good indication of bat use, but absence of droppings is not reliable for excluding the possibility of use.

If the possibility of bat habitat exists, the site may be surveyed to detect their presence by live-trapping using harp traps and/or by mist netting, or through the use of bat detectors. These surveys are usually conducted in September and early October when bats are entering hibernation and some time in April and May when bats are exiting. Occasionally an entry is gated without surveying due to time and safety concerns or when gating is less costly than the survey.

Winter hibernacula surveys were begun in 1980. Surveyors enter caves and mines to count visible hibernating bats. In Pennsylvania, the largest concentrations of hibernating bats are found in mines rather than caves. Site totals have ranged from 0 to 17,695 bats. Species found during these surveys include the little brown bat (*Myotis lucifugus*), northern long-eared bat (*Myotis septentrionalis*), eastern small-footed bat (*Myotis leibii*), Indiana bat (*Myotis sodalis*), big brown bat *(Eptesicus fuscus*), eastern pipestrelle (*Pipistrellus subflavus*) and, on one occasion, the silver-haired bat (*Lasionycteris notivagans*). The six largest sites, each containing over 3,500 visible bats, are in abandoned limestone, clay, or iron ore mines. Four of these sites have been gated to restrict human activity and allow bat access without altering airflow. Other, smaller sites with significant populations and good interior habitat have also been gated. The response of the hibernating bat population to gating has been an increase in numbers where human disturbance was formerly a problem, as shown in the Canoe Creek Limestone Mine (Figure 2).

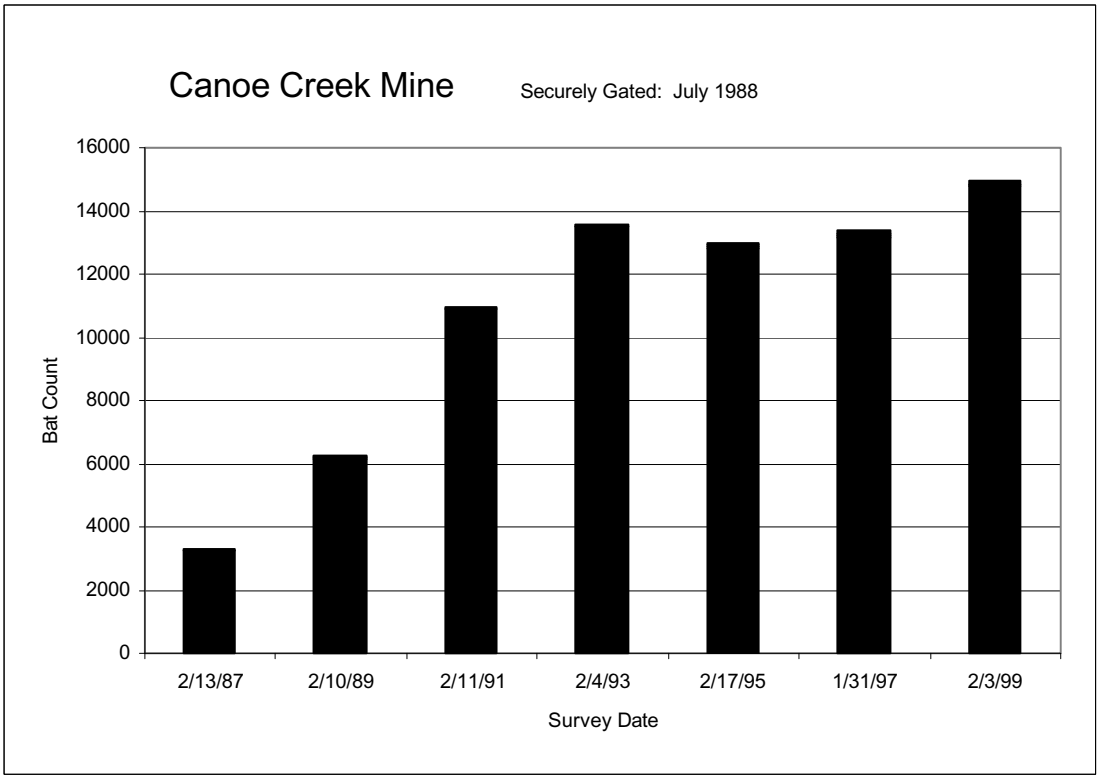
Installation of Bat Gates

Following gating, numbers have grown from 3,500 to over 15,000 visible bats counted during interior hibernacula surveys.

Gating must satisfy 3 objectives:

1. Keep people out, minimizing both human safety concerns and disturbance to bats.
2. Provide for airflow to maintain the interior environmental conditions.
3. Allow for bat access.

Figure 2 – Bat count during hibernation.



The abandoned openings in the anthracite coal fields of Pennsylvania pose a different gating dilemma. Gating prevents entrance of humans to the mine workings – thereby abating the threat to humans – and also allows access to the mines by bats. Further, the gates can be cheaper than backfilling the opening with material, which is the usual method of reclaiming these sites. Most of these site contain hibernation chambers. Several of these sites have been found to contain significant bat populations. These are surveyed by exterior live-trapping due to hazardous conditions that preclude interior surveys. The most significant mine site found thus far is a subsidence opening where over 1,000 bats were live-trapped in an evening, including the endangered (Federally listed) Indiana bat. Indiana bats have been found at two other anthracite sites. One of these is so large it is difficult to gate. At this site we are proposing to restrict road access to prevent dumping that may contribute to a mine fire. The other will be gated in the future. Because of the configuration of both entrances, human entry is unlikely.

Approximately 50 percent of all anthracite mines live-trapped or netted have bat activity. A number of these show considerable use by bats. Collectively, anthracite openings may provide significant habitat by allowing bats access and, just as important, contribute to the natural airflow of the miles of tunnel beyond. If entrances contributing to airflow are backfilled, the entire tunnel system used by bats could be altered. This is especially important where noticeable airflow is detected through rubble and passages. The question then arises as to how important are the marginal or unused openings to bats. For the most, part this is unknown. In all cases, the openings must be modified to protect the public, either through gating or backfilling.

Gating involves the use of: welding equipment, acetylene torches, steel, and manpower. Typically the cost ranges from $500 to $2,000 for a small opening. To date, larger openings with more elaborate preservation techniques have not exceeded $20,000.

Where used, the gating alternative:

1. Preserves bat habitat, including bat entrances and airflow to the underground environment, and

2. The hole remains without being hidden with backfill material. Dangerous building zones are then identifiable for future .

Since 1994, the Office of Surface Mining in Wilkes-Barre has gated approximately 10 percent of mine entries that were reported as emergency projects. Those entries gated were either assumed to have bats or the Pennsylvania Game Commission determined their presence with live-trapping at the entry or the use of sonar devices.

There are four types of entries for gate design. The horizontal entry requires placement of a louver type iron wall anchored to the exposed bedrock by drilling and pinning. This type of gating is relatively easy to install because there are no special considerations other than securing the gate to the sidewalls and floor of the bedrock.

Photo # 5 – Typical louver style bat gate panel.

Photo #6 shows a surface collapse around a slope, which required reconstruction of the site.

Photo # 6 – Surface collapse of an abandoned mine slope (Schuylkill Co., PA)

Excavation to the bedrock was followed by the placement of beams and installation of a cap.

Photo # 7 – Footer and "W" beam installation to support the surface (Schuylkill Co., PA)

Photo # 8 – Capping on top of "W" beam and footer with steel decking and rebar prior to concrete (Schuylkill Co., ,PA)

The cost of this gate was $18,810. Gating cost for this project are listed in Table #1.

Table #1 – Listing of lump sum items for a slope in Schuylkill Co., PA

Items Description	Cost
1. Mobilization	$1,000.00
2. Demobilization	$1,000.00
3. Bat Gate	$2,000.00
4. Reinforced Concrete Cap	$10,800.00
5. Reclamation	$400.00
6. Mod #1 Bulkhead	$3,250.00
7. Mod #2 Backhoe rental	$360.00

Vertical entries e.g., shafts or cropfalls, are typically more complex than horizontal entries. A horizontally-oriented gate requires a stable. Fitting and stabilizing a pipe into the opening is also problematic. Entries are not uniform in configuration and have irregularly shaped perimeters.

A typical design is illustrated by Bat Conservation International in Photo #9.

Photo # 9 – Typical vertical mine entry taken from CI Resources Publication #3

This design was used on two OSM projects in Schuylkill County. One of the projects was a modified version of BCI's design, in which the pipe fit snugly into the bedrock opening with grouting around the pipe. The cost of this project was $8,300. Costs are itemized as shown in Table #2.

Table #2 – Listing of lump sum items for a small vertical entry in Schuylkill Co., PA

Item Description	Cost
1. Mobilization	$500.00
2. Demobilization	$500.00
3. Footing	$1,800.00
4. Shaft Housing	$2,800.00
5. Bat Gate	$2,200.00
6. Restoration	$500.00

Photo # 10 – Shaft preserved with corrugated PVC pipe and protected by cement block structure (Schuylkill Co., PA)

The more remote and difficult the access, the more costly gating becomes, but it is still less costly than backfilling. The cost for a site with a remote access of about 400 meters, requiring hand carrying of equipment and materials, was $4,400. Typical costs are listed in Table #3.

Table # 3 – Listing of lump sum items for a remote site in Lackawanna Co. PA

Line Item Description	Cost
1. Mobilization	$400.00
2. Demobilization	$200.00
3. Gate Construction	$3,600.00
4. Restoration	$200.00

Conclusion

Abandoned mine workings in the anthracite fields of Pennsylvania provide suitable habitat for bat colonies. The absence of flooded workings and the presence of ventilation, open entry, and guano are criteria for evaluating suitability of mine openings as bat habitat. Gating must satisfy three objectives: (1) to keep people out, maximizing human safety and minimizing disturbance to bats, (2) to provide for airflow to maintain the interior environmental conditions, and (3) to allow for bat access. The four types of mine entries (shafts, slopes, drifts, and cropfalls) require gating designs specific to each. Gating is desirable because it minimizes disturbance to bats and preserves habitat and is generally less costly than backfilling.

A MIDWESTERN CASE STUDY TO SECURE AN UNDERGROUND MINE FOR BAT HABITAT: THE UNIMIN "MAGAZINE MINE" IN ALEXANDER COUNTY, ILLINOIS

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Abstract

Bats continue to rank among the world's most endangered wildlife despite extensive conservation efforts. Preserving these mammals and the ecosystems that rely on then for their existence is a prodigious task. Effective education, research, and conservation initiatives at the local, community, and corporate levels are essential to the long-term understanding and survival of these often neglected animals. Promoting bat conservation by changing attitudes, not by confrontation, has enabled professional resource managers throughout Illinois and the Midwest to work directly with local citizen groups, schools, and businesses. Extracting solutions to complex environmental problems through the power of community and industry partnerships has proven to be quite successful throughout rural Illinois. Recent public and private sector efforts at southern Illinois' "Magazine Mine" to directly protect resources critical to bat reproduction and hibernation have both strengthened and promoted a conservation ethic benefiting not only bats, but the fragile Shawnee National Forest ecosystem as a whole. "Magazine Mine" currently supports >9,000 wintering Indiana bats and is the largest winter hibernacula of Indiana bats ever documented within the State of Illinois. Because this mine has been abandoned for several years (>15 years), it requires immediate and permanent stabilization at the main entrance in order to prevent catastrophic collapse and eventual closure. Such a collapse at this Federal Priority II hibernacula would not only exterminate the large numbers of Indiana bats hibernating within this mine, but also permanently prohibit use of this mine by successive generations of *Myotis sodalis.* Stabilization of the 230 foot long "Magazine Mine" entrance using steel arches and lagging plates will take approximately 14 full work days and cost nearly $80,000.

Bat Monitoring

Summer mist-netting efforts and winter inventories of the abandoned Unimin Specialty Minerals Corporation "Magazine Mine" (silica-sand mine) conducted within the past three years have revealed the presence of significant Indiana bat maternity colonies and large hibernating groups (>9,000 *Myotis sodalis*). In order to better protect and inventory both maternity colonies and hibernating individuals, detailed surveys of this mine should continue to be performed every other year. Winter surveys of this mine were first conducted in February 1998. Most important, because this mine has been abandoned for several years (>15 years), it requires immediate and permanent stabilization at the main entrance in order to prevent catastrophic collapse and eventual closure. Such a collapse at this Priority II hibernacula would not only exterminate the large numbers of Indiana bats hibernating within this mine, but also permanently prohibit use of

this mine by successive generations of *Myotis sodalis.* Completion of this stabilization effort will directly improve and preserve on-the-ground conditions for this imperiled species.

Evaluation of Indiana Bat Habitat

Indiana bats require specific roost sites in caves or mines that attain appropriate temperatures to hibernate. Ideal sites are 50 degrees F (10 C) or below when the bats arrive in October and November. Early studies identified a preferred mid-winter temperature range of 39 to 46 degrees F (4 - 8 C), but a recent examination of long-term data suggests that a slightly lower and narrower range of 37 to 43 degrees F (3 - 6 C) may be ideal for this species (USFWS, 1999). Only a small percentage of caves and mines provide for this specialized requirement. Stable, low temperatures allow these animals to maintain a reduced rate of metabolism and conserve fat reserves through the winter, until spring. Data gathered by the Illinois DNR and Bat Conservation International, Inc. show that the Magazine Mine currently offers this narrow and specialized temperature regime (BCI, 1999).

Abandoned mines and caves change far more often than is generally recognized. Entrances and internal passages essential to air flow may become larger, smaller, or close entirely, with corresponding increases or decreases in air flow, temperature, and humidity. Blockage or collapse of entry points, even those too small to be recognized, can be extremely important in hibernacula that require chimney-effect air flow to function (i.e. Magazine Mine). Recent data shows that changes in airflow can elevate temperatures which can cause an increase in metabolic rate and a premature exhaustion of fat reserves. Such air flow changes may also force bats to roost near unsuitable entrances or floors to find low enough temperatures, thus increasing their vulnerability to freezing or predation. Overall, the fact that Indiana bats congregate in only a small percentage of known caves and mines suggest that very few caves/mines meet their requirements (USFWS, 1999). Exclusion of Indiana bats from such crucial hibernacula has been a major documented cause of Indiana bat declines.

Stabilization of Mine Entrance

Permanent/heavy-duty stabilization of the Magazine Mine entrance will allow Indiana bats to continue to use this mine for hibernation purposes. A licensed underground mining/civil engineering construction firm will conduct stabilization activities. Stabilization of the 230' long Magazine Mine entrance will take approximately 10 to15 full workdays. Construction will be scheduled sometime between May 1 and September 1, thereby eliminating any threat to hibernating *M. sodalis*. The long-term stabilization of the Magazine Mine entrance directly meets the management and recovery objectives addressed in the Federal Indiana bat Recovery Plan. The Illinois Department of Natural Resources strongly believes that completion of this abandoned mine stabilization effort will directly improve and preserve on-the-ground conditions for this imperiled species.

Itemized Project Budget
UNIMIN Specialty Minerals Corp. "Magazine Mine"

I. **SUPPLIES**

A. Steel Stabilization Arches:

*Needed for a total distance of 230 feet. Must maintain an opening that is 8' high by 14' wide.
*Total of 45 arches required.
*Cost per arch: $400.22
*Total arch cost: 45 x $400.22 = $18,010.00

B. Treated Timber Decking Plates to cover Arches:

*Needed for a total distance of 230 feet. Must maintain an opening that is 8' high by 14' wide.
*Total of 800 treated (.040 cca - copper/chromium/arsenic) 6x6x12 foot decking plates required.
*Cost per plate: $22.15
*Total decking plate cost: 800 x $22.15 = $17,720.00
*Total of 30 treated (.040 cca) 6x6x8 foot decking plates required.
*Cost per plate: $16.91
*Total decking plate cost: 30 x $16.91 = $507.30

ARCH CONSTRUCTION SUPPLIES COST: A+B = $36,237.30

II. **MANUAL LABOR/CONSTRUCTION COST**

Total manual labor cost for this mine stabilization project = $40,000 (all construction work to be completed by licensed and qualified steel fabrication and erection firm)

TOTAL MAGAZINE MINE ENTRANCE STABILIZATION COST: I + II = $76,237.30

Conclusion

Clearly, long-term stabilization of Magazine Mine will continue to foster a unique, cooperative partnership between: Private Industry, the Illinois Department of Natural Resources, the United States Forest Service, the United States Fish and Wildlife Service, as well as numerous environmental organizations and community groups. As evidenced by past newspaper, television, and radio segments explaining the significance of the UNIMIN Magazine Mine to hibernating bats, this stabilization project has tremendous potential for promotion and education. This project remains an integral component for the recovery of the Indiana bat.

Acknowledgements

The Illinois Department of Natural Resources-Division of Natural Heritage would like to sincerely thank Mr. Rick Fox of the UNIMIN Corporation for his continued support and cooperation. We also wish to thank the United States Forest Service-Shawnee National Forest and the United States Fish and Wildlife Service-Region 3/Illinois Offices. This project has received financial support from the United States Fish and Wildlife Service Region 3 Field Office located in Rock Island, Illinois; the Illinois DNR's Wildlife Preservation Fund; the

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AN OVERVIEW OF
THE RESPONSE OF BATS TO PROTECTION EFFORTS

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Abstract

Disturbance during the hibernation and maternity seasons is a significant factor in the widespread decline of cave and mine dependent bats. Early bat protection efforts concentrated on eliminating or reducing this disturbance through the installation of informative signs and the construction of gates and fences at cave entrances. The purpose of these structures was to control human access to important roost sites. These efforts sometimes failed or were counterproductive because of our limited understanding of bat behavior and our limited appreciation of the potential effect entrance modifications can have on cave microclimates. Each species responds differently to artificial barriers at their roost sites and we have had to modify and refine, primarily through trial and error, our protection efforts. There have been spectacular successes and equally spectacular failures in these efforts - one of the first structures erected to protect a gray bat colony resulted in the extirpation of the species from the site. Later protection efforts, tailored to the species needs, resulted in the restoration of colonies that had been extirpated from their roosts by human disturbance. A summary of our knowledge of the response of cave and mine dependent bats to protection efforts is provided. There is little information available on how many of these species respond to gates. A formal, voluntary survey of all agencies, organizations and individuals about the success or failure of their bat cave and mine protection efforts is needed. A method of conducting this survey and how to summarize and widely distribute the results is suggested. Failure to address this problem will limit our ability to protect bats from disturbance in caves and mines and make our efforts to protect the public from the hazards of abandoned underground mines more difficult.

Gates and Bats

A primary threat to cave dependent bats is disturbance at their hibernation and maternity roosts (Mohr 1976, U.S. Fish and Wildlife Service 1982, 1984, 1995, 1999). Disturbance at cave roosts is probably one of the factors that contributes to the increasing important role mines play in bat conservation efforts. As disturbance at natural roosts has increased, bats have abandoned their hibernation and maternity caves and moved into mines. Protection of natural and manmade roosts is one of the highest priorities in all of the recovery plans for listed bats. All of our early experience in trying to reduce this disturbance and protect bats was gained at their natural cave roosts. Like many human endeavors it was initially a process of trial and error, and we made many errors before we realized that just throwing up a gate at the cave entrance was not enough. A review of these early efforts and failures is provided by Tuttle (1977).

Problems with Past Gating Efforts

Early gate builders often did not recognize that during gate design and installation it is essential to consider the potential adverse effects that poorly or inadequately designed structures can have on cave or mine microclimate. As a result, the first bat gates often did not maintain pre-gate air flow, or did not provide adequate spaces for bats to fly through the gate, or, in some cases did not leave the open flight space over the gate that is needed by some species.

Maintenance of existing microclimate depends, primarily, upon maintenance of existing airflow patterns through the gated entrance. Other features such as internal cave or mine complexity and configuration, and the size, shape, number, and location of entrances are also important factors (Tuttle and Stevenson 1978). Although most underground microclimate research has focused on caves, the same airflow and microclimate principles apply to abandoned mines. Careful consideration of the data presented in this paper will provide a better understanding of how and why certain mines or caves are suitable for bat use while others are not. It reinforces the conclusion that all structures constructed at cave or mine entrance must be designed in a way that does not significantly alter air flow.

Ensuring that a gate design provides adequate flight space for bats requires a compromise between two extremes. One extreme provides maximum security for the public and the other provides maximum freedom for bat movement - a rock wall or back filling the entrance would provide maximum security from a safety standpoint while no physical barrier at an entrance would eliminate the possibility of restricting air and bat movement. Neither extreme is acceptable if we are to protect bats from disturbance and protect the public from the hazards of abandoned mines. The early standard for minimum spacing of gate components was 6 inches between the horizontal gate members and 2 feet between the vertical gate components (Figure 1). This was considered to be a good compromise between the two extremes. Most people can not or will not force there bodies through a six inch space. The recommended 2 feet between the vertical bars was believed to provide adequate space for bat movement while maintaining sufficient strength to keep vandals from easily bending the bars apart. Early bat gates were often constructed of mild round steel bars 3/4 inch to 1 1/4 inch in diameter. Although these gates provided a barrier that bats could fly through and had minimal effect on airflow, their greatest disadvantage was their vulnerability to vandalism. The current design standard for cave and mine bat gates is constructed of 4 inch angle iron with a minimum of 5 3/4 inches between the horizontal bars and a minimum of 4 feet between the vertical columns (Figure 2), however, the round bar gate is still successfully used in some parts of the U.S. The Utah Division of Oil, Gas and Mining has developed a modification of the round bar gate that they install at most of their abandoned mines that support significant colonies of bats(Figure 3). Their design incorporates a high strength steel that resists cutting by hacksaws and other low-technology vandalism attempts (Mark Mesch, Utah Division of Oil, Gas and Mining, personal communication, 2000).

How Bats Respond to Gates

Full gates at cave or mine entrances are not accepted by some species. The endangered gray bat (*Myotis grisescens*) will generally not accept full gates at their maternity roosts but will accept

them at their hibernation sites. Brazilian free-tailed bats (*Tadarida brasiliensis*) will not accept full gates at their roosts at any time of year. Alternative barriers, such as fences or half-gates (Figures 4 and 5) must be used when dealing with species that will not accept a full gate. Species such as the endangered Indiana bat (*Myotis sodalis*) and the four subspecies of the Western big-eared bat (*Corynorhinus townsendii*) that occur in the U.S. readily accept properly designed full gates at all of their roost sites. There may also be regional differences in how bats respond to gates. Although the gray bat will not accept a full gate at its maternity roosts throughout most of its range, it has accepted full gates at maternity sites in Oklahoma at the western edge of its range (Steve Hensley, U.S. Fish and Wildlife Service, Tulsa, Oklahoma, personal communication, 2000). The successful gray bat full gates in Oklahoma are all constructed in the dark zone well back from the entrance. This approach to gray bat protection may only work with the Oklahoma population. A full gate was constructed in the dark zone in an Alabama gray bat cave to test this approach with another population of the species. This test was not successful and after three years the gate was removed. After the gate was removed the gray bats returned to the cave (Keith Hudson, Alabama Department of Conservation and Natural Resources, Florence, Alabama, personal communication, 2000). The acceptability of full gates by cave and mine dependent bats is variable and not known for many species (Table 1).

Proposed Bat Gate Survey

We should be very cautious when considering the construction of a full gate at mines supporting any of the species with an unknown response to gates. Table 1 presents a limited, incomplete summary of our knowledge of the response of bats to gates. A complete survey of all the agencies and organizations that have built bat gates needs to be conducted. The information gained through this survey should be compiled, reviewed, summarized and made readily available to public and private land managers. The U.S. Fish and Wildlife Service (Service), Bat Conservation International (BCI), and Arizona Game and Fish Commission have developed a bat gate survey form (Form 1) to obtain this information. This form is designed to gather information on gate construction material and design specifications, on how different species respond to gates and, how resistant the various designs are to vandalism. This survey form will be distributed to as many of the organizations and individuals that have been involved in constructing bat gates as possible. Survey results will be widely distributed by BCI, the Service and the Office of Surface Mining. To increase the availability of this information the Utah Division of Oil, Gas and Mining may make the survey results available on the internet. During compilation of this information we recognized that we must insure that site specific locations of important roosts must be protected from unrestricted access. Misuse of location information could easily lead to increased vandalism and other threats to vulnerable roost sites.

Summary

Knowledge of the response of cave and mine dependent bats to gates has increased over the past 25 years resulting in the evolution of gate design from simple round bar gates to the current angle-iron standard gate. This evolution has resulted in substantial improvements in the security and effectiveness of closures for bats. This process will continue, the current design standard will be modified in the future as we learn more effective methods of protecting bats while we

protect the public from the hazards of abandoned mines. We must ensure that the information gained through gating efforts throughout the U.S. is made available to everyone involved in abandoned mine reclamation. Improvements in gate design and construction techniques will result in increased effectiveness in maintaining the roost sites that are essential for the protection and recovery of endangered and other declining cave and mine dependent bats.

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Table 1[1]

Acceptance of Full Gates By Cave and Mine Dependent Bats[2]

Species[3]	**Summer Roosts**	**Winter Roosts**
Ghost-faced bat (*Mormoops megalophylla*)	Unknown	Unknown
Mexican long-tongued bat (*Choeronycteris mexicana*)	Yes	Yes
Lesser long-nosed bat (*Leptonycteris curasoae*)	Yes	Yes
Mexican long-nosed bat (*Leptonycteris nivalis*)	Unknown (probably will)	Yes
California leaf-nosed bat (*Macrotus californicus*)	Yes	Yes
Pallid bat (*Antrozous pallidus*)	Yes	Unknown (Probably will)
Rafinesque's big-eared bat (*Corynorhinus rafinesquii*)	Yes	Yes
Townsend's big-eared bat[4] (*Corynorhinus townsendii*)	Yes	Yes
Big brown bat (*Eptesicus fuscus*)	Unknown (probably will)	Yes
Allen's big-eared bat (*Idionycteris phyllotis*)	Yes	Unknown (Probably will)
Silver-haired bat (*Lasionycteris noctivagans*)	N/A	Unknown (Probably will)
Mexican long-eared bat (*Myotis auriculus*)	Unknown	Unknown
Southeastern myotis (*Myotis austroriparius*)	Unknown	Unknown
California myotis (*Myotis californicus*)	Yes	Yes

Table 1 (Continued)

Small-footed myotis (*Myotis ciliolabrum*)	Yes	Yes
Long-eared myotis (*Myotis evotis*)	Unknown	Unknown
Gray bat (*Myotis grisescens*)	No	Yes
Leib's bat (*Myotis leibii*)	N/A[5]	Yes
Little brown bat (*Myotis lucifugus*)	Unknown (probably will)	Yes
Eastern long-eared bat (*Myotis septentrionalis*)	N/A[5]	Yes
Indiana bat (*Myotis sodalis*)	N/A[5]	Yes
Fringed myotis (*Myotis thysanodes*)	Yes	Unknown (probably will)
Cave myotis (*Myotis velifer*)	Yes	Unknown (probably will)
Long-legged myotis (*Myotis volans*)	Unknown (probably will)	Unknown (probably will)
Yuma myotis (*Myotis yumanensis*)	Yes	Unknown
Western pipistrelle (*Pipistrellus hesperus*)	Yes	Yes
Eastern pipistrelle (*Pipistrellus subflavus*)	N/A[5]	Yes
Mexican free-tailed bat (*Tadarida brasiliensis*)	No	No

Notes:

1. The information presented in this table is based upon personal observations and personal communications over a period of years from Mike Bilbo (Bureau of Land Management (BLM), Roswell New Mexico), Pat Brown (Brown-Berry Biological Consulting, Bishop, California), Elizabeth Pierson (Consultant, Berkeley, California), Matt Safford (BLM, St. George, Utah), Tim Snow (Arizona Game and Fish Department, Tucson, Arizona), and

others.

2. A full gate is a structure that fully encloses the entrance to a cave or mine. (A half-gate is a structure that is constructed in a manner that leaves an unobstructed flight path over the top of the gate, or, alternatively a large open section within the gate.
3. This list of mine dependent bats is from Altenbach and Pierson (1995.)
4. Including the subspecies *P. t. virginianus*, *P. t. ingens*, *P. t. pallescens*, and *P. t. townsendii*, no information is available on how the Mexican subspecies (*P. t. australis*) will respond to gates.
5. Species not believed to use caves or mines as maternity roosts to a great extent, although males and non-reproductive females may use these sites during the summer.

Figure 1. Round bar gate installed at the entrance to a West Virginia cave supporting a maternity colony of endangered Virginia big-eared bats (*Corynorhinus townsendii virginianus*). This gate has been replaced by an angle-iron gate. (Photograph credit Robert R. Currie, U.S. Fish and Wildlife Service, Asheville, North Carolina)

Figure 2. Angle iron gate constructed at one of the entrances to an abandoned limestone mine in Ohio. This mine supports a hibernation colony of over 10,000 endangered Indiana bats (*Myotis sodalis*) and a large hibernation colony of little brown bats (*(Myotis lucifugus*) (Photograph credit Robert R. Currie, U.S. Fish and Wildlife Service, Asheville, North Carolina)

Figure 3. Recent round bar gate installed by the Utah Division of Oil, Gas and Mining. This gate is constructed of Manganol steel. This material is much stronger and more resistant to cutting than the mild steel that was often used in early round bar gates. (Photo credit Robert R. Currie, U.S. Fish and Wildlife Service, Asheville, North Carolina)

Figure 4. Fence constructed at the entrance to an endangered gray bat (*Myotis grisescens*) maternity cave in Tennessee. (Photograph credit Robert R. Currie, U.S. Fish and Wildlife Service, Asheville, North Carolina)

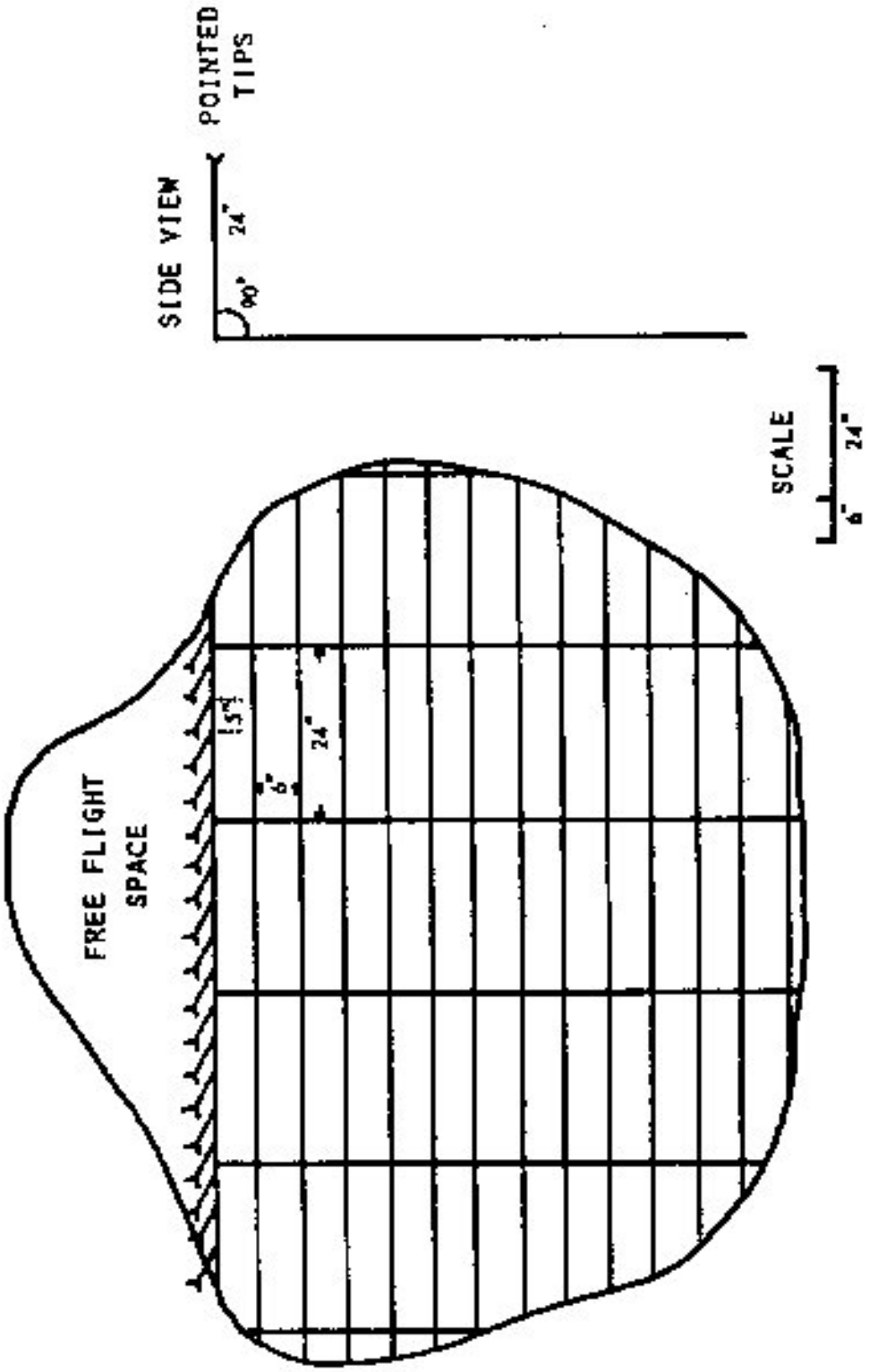

Figure 5. A ½ gate similar to this was constructed by the U.S. Fish and Wildlife Service at Sauta Cave in Northern Alabama. Caves and mines supporting species such as the gray bat (summer roosts) or the Brazilian free-tailed bat (*Tadarida brasiliensis*) usually must be protected with a ½ gate that provides an open flight space over the gate or with a fence installed far enough from the entrance to permit free bat flight over the fence. [From U.S. Fish and Wildlife Service (1982)]

BAT GATE MONITORING FORM

GATE/SITE LOCATION		
State:	County:	Name of Site:
Property Owner/Manager: (e.g., USFS, Tonto NF, etc.)		Administrating Agency:
Contact: (please include name, address, phone, fax, E-mail as appropriate)		

SITE DETAILS	
Describe opening(s): (e.g. mine shaft/adit, cave opening on hillside, etc.)	
Opening size: (adit or cave height x width, shaft collar length x width or diameter)	Number of openings (including vertical shafts and other entrances too small for human entrance):
Number of openings gated at sites with multiple openings: (if multiple openings to the same roost area were gated, describe each on a separate sheet but indicate their linkage)	Distance to driveable road:

PRE-GATING MONITORING

Are all openings monitored? Yes / No If no, how many are monitored? not monitored?

Date:	Method/Duration	Bat Species	# of Bats, by species	Reproductive Condition

GATING INFORMATION				
Date gate(s) installed:	Gate Details: (please attach copies of drawings, photos, etc. as available)	Height:	Width:	Depth: (if cage or other 3D structure)
Horizontal bar material and dimension, spacing (on center):		Vertical bar material and dimension, spacing (on center):		
Door or other access built in? If yes, please describe, include locking mechanism		Sill/foundation constructed? If yes, what type of materials used, dimensions.		
Additional supports? (e.g. perpendicular to the predominant bars) If yes, include number, material, dimensions, spacing, orientation .		Any signing erected? (warning or interpretive)		
Any breach attempts? (success of attempts, repair details, etc.)		Other information you think is relative:		

POST-GATE MONITORING				
All openings monitored? Yes / No				
Date*	Method/Duration	Bat Species	# of Bats, by species	Reproductive Condition
Assessment of the gating effort, suggestions for others considering similar gating:				

EVICTING BATS WHEN GATES WON'T WORK: UNSTABLE MINES AND RENEWED MINING

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Abstract

At most abandoned mine sites, the installation of bat gates can protect both humans and bats. However, sometimes the openings are too large or the mine too unstable to be considered for bat gates. The mine may be in danger of collapse, thereby entombing bats. Acid mine drainage may be polluting water supplies. Radioactivity could be a threat to people and bats. The only option may be to evict the bats and to seal the mine permanently.

While historic mining created new roosting habitat for many bat species, contemporary mining practices can adversely impact bats. Renewed mining in historic districts usually destroys old workings in the creation of open pits. Occasionally underground techniques are employed, but this method usually enlarges or destroys the original drifts. Even during exploratory drilling, historic mine openings can be covered as drill roads are bulldozed, or drills can penetrate and collapse underground workings. Nearby blasting associated with mine construction and operation can disrupt roosting bats. Finally, at the completion of mining, any historic mines still open on the property may be sealed as part of closure and reclamation activities. The net result can be a loss of bats, and bat roosting and foraging habitat. Sometimes in contemporary underground or surface mining operations, future roosting habitat for bats is created or can be fabricated. An experimental approach to the creation of new roosting habitat is to gate new underground workings or to bury culverts beneath waste rock. Different bat species with varying seasonal roost requirements will require customized designs. Temperature profiles of the bat mines that will be closed are useful in the identification of alternate habitat. Mining companies and agencies can mitigate for impacts to bats by: (1) identifying roosting habitat in non-impacted mines that can be protected with gates and fences, and (2) basic research to identify and protect critical foraging habitat.

Whether the concern is public safety or renewed mining, bats (and other animal tenants) may need to be evicted. The challenge is to accomplish this in a manner that removes the most bats with the least impact. Previous surveys for bats should provide knowledge of the seasonal occupancy and type of roost (maternity colony, migratory stopover, hibernaculum, breeding site, etc.) in order to plan the method and time of exclusion. If surveys conducted in another year or season did not disclose the presence of bats, it is important that a survey be conducted immediately prior to exclusion, since bats are mobile and can change roosts between seasons and years. For example, the closure of other mines in the vicinity may cause bats to relocate to a

previously unoccupied mine.

Introduction

Historic mining operations created new roosting habitat for many bat species. Some bat populations colonized mines when traditional roosts in caves or trees were disturbed or destroyed. In areas where natural caves never existed, bats may have congregated in abandoned mines because they offered protected roosting areas with stable temperatures that can shelter large colonies (Brown and Berry, 1991). Whatever the reason for colonization, mines have now become an important roosting habitat that concentrate large numbers of bats. This concentration of bats in relatively few roosts makes then vulnerable to disturbance and eradication (Tuttle and Taylor 1994). Determining why, how and when bats use mines presents many challenges (Sherwin *et al*. and Altenbach *et al.*, this volume). For some species in the western United States, such as the California leaf-nosed bat (*Macrotus californicus*) and Townsend's big-eared bat (*Corynorhinus townsendii*), the largest colonies now occur in man-made mine habitat (Bogan, this volume).

Now the same industry that was responsible for creating bat habitat has the potential to adversely impact bats (Meier, this volume; Brown, 1995a,b; Brown and Berry, 1997). Contemporary mining operations usually occur in historic mining districts where bats are commonly found. New methods of sampling ore bodies, such as drilling, often detect reserves that are now economical to extract. New mining activity typically produces an open pit and destroys historic adits and shafts. Occasionally underground techniques are employed, but only if high quality ore is located deep beneath the surface. This method usually enlarges or destroys the original drifts. Even if a mine working is not directly impacted, nearby blasting associated with mine construction and operation can disrupt roosting bats. Besides the physical disturbance of mining, other aspects of contemporary operations can have adverse impacts to bats and other wildlife, such as the introduction of cyanide and other contaminants (O'Shea, this volume) or the removal of foraging habitat (Kurta, this volume). At the completion of renewed mining, any historic mines still open may be sealed as part of closure and reclamation activities. The motivation for closing potentially hazardous mines is to reduce liability while at the same time possibly removing the unsightly scars of old dumps. Agencies might require this closure as part of the reclamation plan, without knowledge of the potential impacts to the bats and other wildlife inhabiting the mines. Safety is an issue since new or improved road access into the region can bring increased human visitation to an area after the cessation of active mining. The goal of protecting bat habitat in mines and excluding people by the installation of bat-accessible gates is the preferred option, although it may not be feasible if the mine entrance is too large or the substrate unstable. Acid mine drainage or radioactivity can pose threats that are only solved by permanently sealing the mine.

Ideally, when a mine needs to be closed either for renewed mining or public safety, all information on the use of that mine by bats and other wildlife has been determined in advance: what species, what season, for what purpose and how frequent the use (Sherwin *et al.*, this volume). In addition, alternate roost sites in the region (close to good foraging habitat) have been identified and protected with gates. The targeted mine can then be closed when bats are not in

residence, or at a time when eviction has the least impact. Unfortunately this is not an ideal world, and usually mining companies and land management agencies to not have the time, expertise and/or money to get the necessary data to make the best management decision. This paper aspires to provide some guidelines for mitigating impacts to bats when mine gates are not feasible.

Exclusion Considerations

The methods and timing of bat exclusion will need to be modified in specific situations. A bat biologist with the necessary equipment and experience should be involved in the preliminary surveys (Altenbach *et al.*, this volume). Surveying mine openings during the day is not an adequate method to determine bat use. More detailed surveys are required to determine when and how the mine is being used by bats (i.e. maternity colony, males, hibernation, mating, migratory stopover, etc.). This usually requires entering the mine to search for bats or guano (Altenbach, 1995). The size, shape, odor and deposition pattern of guano as well as culled insect remains can aid in bat identification and seasonal use even if bats are not present in the roost. If entry into the mine is not feasible due to safety considerations or the mine is so complex that it cannot be thoroughly surveyed even if entered, then an external survey using night vision equipment and/or infrared video is necessary to document bat habitation. All entrances of a mine should be monitored, although without an underground survey, connections between surface features may not be understood. During the winter, most bats hibernate and do not exit to forage; therefore an external survey will not determine presence or absence of bats. "Winter" will vary with altitude, latitude and between years, and signifies that time of year when bats remain torpid and survive on stored energy reserves.

Timing of Exclusion

Schedule the time of bat exclusion during that period when bats are absent or the fewest bats are using the mine. If there is any possibility of a maternity colony, then no closure should be made during that season, usually between April and August. The exact months of the maternity season may vary between years as well as with geographic location and species of bat. A local bat biologist should be consulted to determine when maternity colonies begin to form and when they will disperse. A maternity colony as a group may move between mines several times during the reproductive season. For example, in a survey of over 200 mine workings in Battle Mountain Nevada, the maternity colony of Townsend's big-eared bats used at least three mines: preparturition, post-parturition and after the young begin to fly. Additional mines were used for courtship and breeding activities in the fall (Brown and Berry, 2001). If only a single survey of a mine site is conducted during the warm season, the significance of some mines would be missed (Sherwin, *et al*., In Press), and exclusion might be scheduled for a time that bats are using the mine. Mine closures should avoid winter, especially if a mine cannot be safely entered to survey for hibernating bats. Even in mines that can be entered, torpid bats are often hidden in very small crevices. Attempting to arouse and move hibernating bats may lead to their demise.

In order to avoid hibernation and maternity periods, exclusion is usually scheduled for early spring or late summer/early fall (i.e. April or September-October). This is always subject to the local conditions in the year closure occurs. Eviction should not be attempted if the weather

during any month becomes cold and windy, since the bats may not exit to forage during these conditions. Always monitor the mine for bat activity using night vision equipment or infrared prior to any closure. We have been surprised to see large numbers of *Macrotus* entering a mine after dark in the fall for courtship activities (Berry and Brown, 1995). This could be the case with other species. A site may be used for a specific function for only a few weeks a year and may have been missed during an initial survey. Bats may have moved into a mine since an initial survey due to closure or disturbance at other mine sites. Be prepared to be flexible and return later if conditions are not favorable for exclusion.

Exclusion protocol

A "cookbook" approach should be used cautiously as no one method will work for all species in all locations. Our methods have evolved for mines in the arid southwest, and may not be applicable for bats in other regions. A sample protocol would require that a mine be watched with night vision equipment for at least an hour after dark or until most bats appear to exit the mine (the number of bats having been determined by a prior night exit count). The mine opening can be covered with one-inch chicken wire. After years of experimentation, this material has been selected for the following reasons: (1) Most bat species, if inadvertently trapped in the mine, can squeeze through the wire and escape, yet they do not appear to want to squeeze into the mine on subsequent nights; (2) Chicken wire can be molded to provide an awning effect so that bats inside the mine detect a window, yet bats approaching from outside the mine perceive a barrier; and (3) Woodrats and other rodents cannot incorporate chicken wire into their nests, while they will readily gather tarps, fish seine and other soft netting.

If the mine contains a large number of bats (i.e. >10), then the chicken wire should be partially removed prior to dusk on the next night to allow trapped bats to exit. Not all bats exit every night, especially if some detect the presence of a large predator (i.e. human) near the mine. Usually these bats will exit the following night. Two-way bat traffic is encountered in most mines. Little brown bats (*Myotis* sp.) and pallid bats (*Antrozous pallidus*) may be entering a mine to night roost before the Townsend's big-eared bats have exited. The use of two finger tallies (or tape-recorded voice notes) with the night vision equipment will help to keep track of bats entering and exiting the mine. In the case of two-way bat traffic, the creation of awnings and one-way valves may be necessary, so that bats can exit a mine through a "window", but the opening will not be apparent when bats approach it from the outside. If the mine can be safely entered, any bats remaining in the mine might be captured in hand nets and removed. This would be impossible in shafts and complex mines.

All entrances to a mine complex must be closed. Some of the best bat roosts are in mines with multiple entrances that provide a variety of temperatures at different seasons. Without conducting a thorough internal survey, multiple openings of a mine may not be known. Old mine maps (if they exist) may be outdated, since new openings may have been created or old connections destroyed. If only one access into a mine is sealed, the bats may continue to use a "back door". The conservative approach is to systematically close any opening that might possibly connect. Some of these might be on the other side of the hill or on the next ridge.

The chicken wire should be left in place a few days to allow bats to escape before being permanently closed or covered with a more opaque material. Whereas large colonies of bats may be deterred by the chicken wire, individual bats may enter the mine again. Especially prior to winter hibernation, bats have been known to squeeze through small openings (even chicken wire) to enter a favorable site. Additionally, if the covered mine is not destroyed or permanently sealed within a few weeks of covering, it will be necessary to periodically check it to be sure that openings do not erode open and bat access is restored. If this happens, then exclusion will need to be repeated at a favorable time.

Mitigation

Habitat Replacement

When bats are roosting in a mine slated for closure, then mines in a radius of about 5 miles from the closure site should be surveyed for potential replacement habitat. The exact distance that a bat will travel between roosts is a function of the species, geographic location and the season. The replacement mines should be evaluated with respect to prior or current bat use, complexity, temperatures (if entered), direction the entrance faces, etc. in order to select micro-environments similar to those in the mine(s) to be closed. Where critical roost temperature and/or configuration requirements of a particular species are known, alternate roosts are easier to identify (Sherwin *et al*., 2000). For example, *Macrotus* selects mines warmer then 80 F (Brown, 1999; Brown and Berry, 1996). If a mine has all the right qualities and no bat sign (but human disturbance is evident) then gating or fencing might result in an acceptable habitat for the evicted bats. If the mine to be closed is used by bats, it may be the "best" habitat in the area. The bats will not use another mine until they are disturbed or evicted from the original. When closure is inevitable and the mine slated for closure is safe to enter, the bats can be captured during the day and banded (but not during the maternity season or hibernation). Most of the bats will usually move to an alternate roost after this disturbance. The ability of bats to accept bands varies with species, and this method should not be used without prior research on any adverse effects.

Protection or Creation of Replacement Habitat

Mines selected as mitigation sites should be gated or fenced to provide protection from human disturbance prior to eviction of the bats from their current roosts (Currie, this volume). In situations where the bats cannot be captured, banded and allowed to relocate, the mines with the best bat potential as deducted from habitat requirements of the species should be selected for gating. In contemporary underground operations, future roosting habitat for bats can be created. For example, the American Girl Mining Joint Venture left some of the underground areas open when they finished mining, and gated the entrances (Brown *et al.*, 1995). An experimental approach to the building of new roosting habitat is to bury culverts with multiple openings beneath new waste rock, or old mining truck tires as Homestake Mining Company has done at the McLaughlin Mine (Enderlin, this volume). Bat Conservation International is encouraging innovative approaches to bat habitat creation (Ducummon, 1997). Different bat species with varying seasonal roost requirements will require customized designs.

Monitoring
Ongoing monitoring of the gated mines or replacement habitat over several years at different seasons is necessary to evaluate the effectiveness of the relocation. In a successful bat relocation project at Homestake's McLaughlin Mine in Northern California, remote monitoring of bat movements was automated (Pierson *et al.*, 1991). If after several seasons, the numbers of bats in the replacement habitat do not increase, additional surveys should be conducted to discover the roosting location of the excluded bats. Modifications may need to be made in the gate design.

Research
In addition to roosting habitat, critical bat foraging areas or water sites near mining districts need to be identified. In southeastern California, radio-telemetry studies sponsored by American Girl Mining Joint Venture have shown that *Macrotus* forages among desert wash vegetation (Brown *et al.*, 1993; Brown *et al*., 1995). When mining operations removed this vegetation near mine roosts, California leaf-nosed bat populations declined. Good foraging habitat within a mile of the roost is especially important in the winter, when bats spend most of the night in warm mines and relatively little time out in the cold. As new mines in the range of *Macrotus* plan for the future placement of waste dumps and facilities, they can avoid impacting the critical wash vegetation. More research is needed to determine foraging habitat for other bat species.

Reclamation
As mining projects enter their reclamation phase, historic mines still open on the property that could provide bat-roosting habitat should be fitted with bat-compatible gates or fenced. Educational signs (Currie, this volume) can be displayed to inform the public of the purpose of the barriers. Uncontaminated water sources on site will also attract bats. If specific vegetative communities are known to provide foraging habitat for bats (i.e. desert wash vegetation for *Macrotus*), these can be planted during the reclamation phase.

Summary

Historic mines provide roosting habitat for many bat species. Whenever possible, abandoned mines should be closed with bat-accessible gates to protect the bats and people. This may not be feasible or desirable for large or unstable mine openings, mines with radioactivity or acid drainage, or in areas of active mining. Renewed mining in historic districts impacts bats during the exploration, active mining and reclamation phases by death or disturbance of the bats and the removal of roosting and foraging habitat. Impacts to bats by mine closure for all reasons can be mitigated by initial surveys at appropriate seasons to identify bat roosting habitat, exclusion of bats prior to mine closure, identification and protection of alternate roost sites with gates and fences, creation of replacement habitat, and monitoring the success of relocation. Research to identify habitat requirements could be used in the development of mitigation plans.

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MONITORING AND EVALUATING RESULTS OF BAT PROTECTION EFFORTS

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Abstract

Title IV of the Surface Mining Control and Reclamation Act (SMCRA) authorizes State Programs to close abandoned mines to protect the public from potential hazards. As part of this process, abandoned mines are surveyed prior to closure to evaluate their potential as bat habitat. Those mines providing suitable habitat are sealed with bat-compatible gates that allow bats continued ingress and egress. However, a few studies suggest that for some population sizes and certain species of bats, bat gates may actually decrease bat use of mine openings; post-gate monitoring studies to document long-term effects of this technique for conserving bat populations are lacking. In Southwestern Utah, the Utah Division of Oil, Gas and Mining Abandoned Mine Reclamation Program closed 141 abandoned mine openings with bat compatible gates in the Silver Reef mining district. Additional mine openings in the nearby East Reef and the Tushar mountain areas are scheduled for closure in 2001. We are currently using these study areas to monitor and evaluate the effectiveness of gated mines on existing known bat populations. Objectives of the study include: (1) evaluating and ranking the effectiveness of techniques [e.g., night vision devices, infrared event counters (Trailmaster ™ 1500M), infrared video, ultrasonic detection equipment (Anabat™) and mist nets or harp traps] to monitor bat use; (2) using this information to develop a protocol for using the most reliable of these techniques; and (3) establish long-term monitoring sites. Evaluation criteria include: (1) purchase and operating costs; (2) security concerns; (3) equipment reliability and ease of operation; (4) number of personnel necessary to gather and evaluate the data; (5) the ease of analyzing the data; and (6) type of information needed. The results indicate that a combination of monitoring techniques are necessary to meet long-term study objectives. Infrared event counters are well suited to record relative bat activity inside mines over long periods of time with minimum observer disturbance and cost, but cannot be used to reliably gather information on bat behavior through gated entrances, or absolute numbers and species identification of bats. Ultrasonic detection equipment and mist net/harp traps are necessary techniques to reliably determine bat species composition. Infrared video cameras provide an accurate, permanent monitoring record of bat numbers and behavior. Protocols specific to each mine may be necessary to minimize observer and equipment effect on bat behavior. Efficient low cost monitoring can be accomplished using minimal equipment and personnel. Preliminary analysis suggests that bat behaviors do differ in gated and un-gated mine openings. Interpretation of these results and evaluation of their effects on protection of bat populations will require long term monitoring.

Dr. Kate Grandison is an associate biology professor at Southern Utah University. Her research interests are in behavioral ecology and conservation biology where she has been monitoring bats in southwestern Utah since 1996.