

MANAGING ABANDONED MINES FOR BATS

Authors:

Richard E. Sherwin, Christopher Newport University

J. Scott Altenbach, University of New Mexico

David L. Waldien, Bat Conservation International



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Dedication:

This handbook is dedicated to those who have done the pioneering work on understanding the importance of abandoned mines to the conservation and management of bats. The people in the trenches made a difference for the authors' views of and approaches to the challenges and issues. Their work and dedication have paved the way for a new generation that will collaboratively work with others across regional landscapes to conserve critical mine habitats for bats.

Disclaimer:

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INTRODUCTION

Well-funded and organized reclamation programs for abandoned mines began to emerge during the mid-1980s with the sole objective of locating and closing hazardous mine openings. As these programs became more effective, concerns were raised regarding the impacts of mine closures on resident colonies of bats. This led to the establishment of pre-closure bat surveys to identify and protect critical bat roosts. By the late 1990s, hundreds of bat gates had been installed throughout the United States to protect bats roosting in mines. Typically, however, pre-closure biological evaluations were of limited scope and intensity and offered little time to study subtle aspects of roost use and to truly assess the impacts of reclamation efforts. As a result, survey protocols, levels of recommended survey intensity, timing of surveys and general evaluation techniques for identifying significant bat roosts were relatively ad hoc and subjective.

As these efforts continued, agency personnel, nonprofit organizations, private consultants, academics and industry representatives began to recognize the need for more formal and science-driven models to improve their effectiveness. Collaborations and partnerships eventually produced a suite of management guidelines that have helped shift management strategies towards more objective conservation models.

The Coeur Rochester Model (Text Box 1) is one example from which site-specific reclamation strategies can be developed. The basic approach was to 1) determine biological significance of the site(s) in question; 2) understand the contextual roosting landscape; and 3) limit direct mortality of bats through careful exclusion prior to reclamation. This stepwise approach articulated and tested through the Coeur Rochester Model serves as the basic organizational template for this manual.

TEXT BOX 1:

THE COEUR ROCHESTER MODEL: MINING SILVER AND CONSERVING BATS

In 2000, Coeur Rochester Mining, Inc., (now Coeur d'Alene Mines Corp.) submitted to the U.S. Bureau of Land Management (BLM) an amendment to their Plan of Operations to expand its mining activities in Pershing County, Nevada, by developing a new satellite mining pit and access road. Coeur determined that the Nevada Packard Mine Expansion Project (NPMEP) might impact roosting habitat of bats with special status in Nevada. Mine personnel used this opportunity to collaborate with academicians to develop a scientifically robust conservation model that could serve as a management and conservation tool throughout temperate North America. The step-wise approach synthesized and formalized diverse ad hoc biological strategies commonly used throughout the western United States for abandoned-mine reclamation programs.

Internal surveys of underground workings in the NPMEP revealed two historical production mines and several individual prospects. The Rochester Mine was located on the north side of the hill and was accessible through one adit and four upper shaft openings. The mine consisted of three haulage levels that undercut a series of large, overhand stopes. The Nevada Packard Mine dominated the rest of the NPMEP and included dozens of vertical openings scattered across the hillside and at least eight different levels and dozens of large stopes.

Surveys during the winter and summer of 2000 located a maternity colony and a relatively large hibernating colony of Townsend's big-eared bats (*Corynorhinus townsendii*). Winter and summer surveys attempted to identify mitigation sites to "replace" both the maternity and hibernation roosts that might be lost in the event of future mining activities. Based on the assumption that Townsend's big-eared bats do not undertake long-distance migrations between winter and summer roosts, the biologists concluded that mitigation sites should be located within 10 miles of the NPMEP.

United States Geological Survey 7.5-minute quad maps and historic claim maps from local mining districts were used to locate and survey approximately 150 abandoned mines within 10 miles of the NPMEP. Suitability of mitigation roosts was judged on a hierarchical measure of variables recorded during surveys. Important variables included: 1) presence and number of hibernating bats; 2) similarity of internal conditions to actual roosts in NPMEP area (internal dimensions, aspect of portal, internal temperature); and 3) linear distance to NPMEP area.

In the summer, Townsend's big-eared bats were locally abundant and relatively common throughout the project area, where they occupied 22.0% of surveyed mines. Signs of use by Townsend's big-eared bats (e.g., guano, dead bats, moth wings) were detected in 64.6% of surveyed mines. Notably, five maternity colonies were found to be using 12 roosts. In most cases, roosts were located in upper-level stopes with openings facing south or west. Maternity roosts were similar in size and structure to workings used by the maternity colony in the NPMEP, and many unused mines with these same internal features were located in the immediate area.

Winter surveys revealed that hibernating Townsend's big-eared bats were relatively common throughout the area, with 59.5% of the 111 surveyed mines occupied by hibernating groups or individuals. Virtually all occupied mines were accessed through north-facing or vertical openings (including inclined openings) and had internal temperatures ranging from 40-50° F (average = 44.2° F).

Suitable mines located in closest proximity to the NPMEP area were identified as mitigation sites for the roosts that would be lost. Selected mitigation sites were gated to ensure the long-term maintenance of hibernation and maternity colonies of Townsend's big-eared bats in the landscape.

Because neither maternity nor hibernating Townsend's big-eared bats were limited to the NPMEP area, it was predicted that the loss of roosts in the NPMEP area would cause only a localized disruption and would not result in loss of the species from the landscape.

Townsend's big-eared bats were excluded from the NPMEP mines prior to portal closures. External exclusion materials (HDPE netting, one-inch mesh) were installed between September 26 and October 2, 2002. External and internal surveys were conducted between October 1 and 5, 2002. Mine openings were backfilled upon confirmation that bats had vacated individual workings. All underground workings within the NPMEP area were determined to be inaccessible to bats upon completion of the project.

Follow-up surveys at the mitigation roosts documented that bats displaced from the NPMEP mines were hibernating in the mitigation mines. The maternity colony disbanded and individuals had been absorbed into preexisting maternity colonies in the landscape. These additions were detected as sudden, unexpected increases in the sizes of other maternity colonies in the area and through the appearance of displaced individuals who had been marked (freeze branded) prior to eviction from the NPMEP area. As of the writing of this book (seven years after closure), displaced individuals remain in the landscape and continue to use the mitigation roosts.

Key Lessons Learned¹

- Mining, abandoned-mine reclamation and bat conservation are not mutually exclusive. Careful exclusion of bats from targeted mines, along with protection of replacement habitat, can be an effective means of conserving bats in the landscape.
- Knowledge of roosting needs of Townsend's big-eared bats was critical in evaluating and selecting effective replacement and mitigation habitat.
- Individual abandoned mines are part of a larger roosting landscape. Modifications or disruptions at a subset of abandoned mines may influence use at other mines throughout the region. Managers must realize that portal closure may have larger-than-anticipated spatial and temporal impacts.

¹Sherwin, R. E., W. L. Gannon, and J. S. Altenbach. 2003. Managing complex systems simply: understanding inherent spatial and temporal variation in the use of roosts by Townsend's big-eared bat. *Wildlife Society Bulletin*, 31:62-72.

- Individual bats appear to maintain long-term recollections of portal locations, a behavior that may facilitate rapid re-occupancy at previously closed mines.

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Significant maternity and hibernation roosts of Townsend's big-eared bat (*Corynorhinus townsendii*) were discovered at the NPMEP through internal assessments.

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Closure of abandoned mine shaft at the NPMEP following intensive exclusions.

HOW TO USE THIS MANUAL

This document is written for anyone involved in making decisions that will affect management of underground mines, including individual landowners, mining companies, state and federal land managers, biologists and Abandoned Mine Lands (AML) program managers. It is intended to help guide the planning and implementation of mine-closure and management projects ranging in scale from reclaiming a single feature to region-wide AML closure programs. We use real-world and hypothetical examples to illustrate concepts that are primarily applicable to mine-management issues in temperate North America: the continental United States and Canada. While many of the concepts in this publication are more broadly applicable, their use elsewhere should be tempered by the biology, ecology and life histories of the regional bat communities that may use subterranean mine habitats.

Users of this manual will benefit by working through the five-step process outlined below. Those with a broader understanding of certain topics (e.g., safety, use of roosts by bats, etc.) may choose to skip portions of some steps and simply refer to them as needed.

Step 1: Planning for Success Comprehensive planning is the foundation for successfully completing mine-closure projects at all spatial scales.

Step 2: Resource Assessments Background material that is important for selecting and implementing mine-closure activities.

Step 3: In the Field Options for use in the field and a conceptual framework will help the user select appropriate techniques for specific objectives as identified in Step 1.

Step 4: Making the Hard Choices A decision framework helps select the appropriate management decision, based on information acquired in Step 3 and evaluated with criteria established in Step 1.

Step 5: Managing for the Future Mine-closure projects are investments and should be managed to ensure the goals of the project are accomplished.



STEP I:

PLANNING
FOR SUCCESS

STEP I: PLANNING FOR SUCCESS

Comprehensive planning facilitates the successful implementation of both individual projects and broad Abandoned Mine Lands Programs. Experience with mine-closure projects will largely determine the extent to which users will refer to this Step. Even if one chooses to bypass much of the planning covered in Step 1, a critical piece that must be fully addressed with absolute clarity is *Step 1.9: Establishing Significance*. This is where partners agree upon the objectives of closure projects and determine what biological threshold(s) will trigger protection rather than the destructive closure of the mine.

Concept Planning Check Box

Step 1.1: Bats Without Borders: Collaborating Beyond Your Jurisdiction

Step 1.2: The Management Framework

Step 1.3: The Regulatory Environment

Step 1.4: Planning For Safety

Text Box 2: Spotlight on Safety

Step 1.5: Collaborating to Succeed

Step 1.6: Whose Hole Is It?

Step 1.7: Managing Mountains of Information

Step 1.8: The Rationale for Protecting Mines

Step 1.8.1: Historical, Cultural & Archeological Resources

Step 1.8.2: Geological & Mineralogical Resources

Step 1.8.3: Wildlife Resources

Step 1.9: Establishing Significance

Step 1.9.1: Absolute Versus Relative Significance

Text Box 3: The Question of Significance

STEP 1.1: BATS WITHOUT BORDERS: COLLABORATING BEYOND YOUR JURISDICTION

Abandoned mines are targeted for closure for various reasons. They may be located within the footprint of new mining activities, they may fall within a landscape-scale abandoned-mines reclamation project or a specific site may require emergency closure because of a human injury or fatality. The reason for closure often dictates the time available for biological evaluations of targeted sites, and that timetable can influence the timing and intensity of survey efforts that are deemed acceptable by managers.

Regardless of the reasons for abandoned-mine reclamation, it is best to approach the issue from a regional or landscape perspective. As discussed throughout this handbook, the relationship between bats and subterranean habitats is complex, with many species utilizing multiple abandoned mines through the year. With few exceptions, individual bats are dependent upon a variety of subterranean features to satisfy their roosting needs.

Recognizing that the scale of habitat use is often larger than the scale of an individual project, managers should always try to manage roosting landscapes rather than individual features (such as single mines or mine openings). Understanding roosting landscapes often requires sharing information among varied agencies involved in abandoned-mine reclamation and requires effective communication among diverse partners. Even in areas where no past closures have taken place or where no pre-closure biological data are available, managers can often gain insight into landscape context by examining local mining history and production records and by understanding the local density of mines.

As a general rule, we strongly discourage the whack-a-mole management style in which individual mines are managed as crises develop. This is often more expensive than a landscape-level approach and rarely results in meaningful conservation. Regardless of the purpose of closure or scale of management, however, specific types of data will always be needed for abandoned-mine reclamation projects and must be acquired before actual closure activities begin. Comprehensive project planning should be made during the pre-survey, planning phase. Timelines should be established so that all location, survey and construction activities are appropriately timed and realistically attainable.

Manage mine closures for the roost/landscape and not the single mine feature to maximize safety and conservation value.



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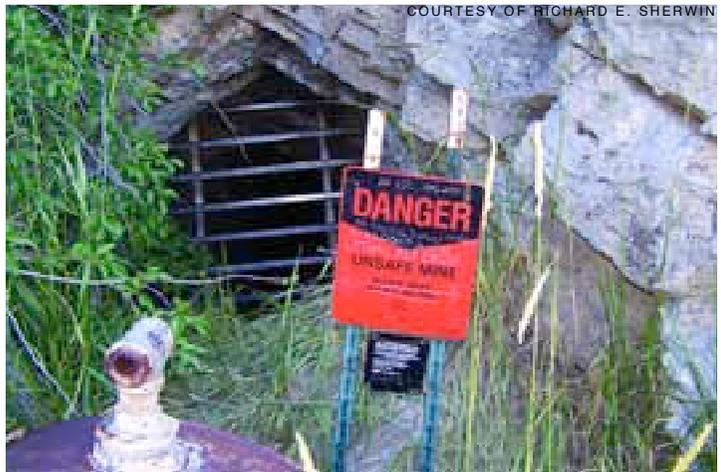
Managing abandoned mines at larger spatial scales can result in greater bat conservation, improved efficiency and maximum use of limited resources.

STEP 1.2: THE MANAGEMENT FRAMEWORK

Abandoned mine reclamation projects on state or federal lands typically require management plans. Management plans can be a powerful tool because they require *a priori* establishment of priorities, tasks, targets and desired outcomes. Time spent on the careful development and implementation of a management plan can make the difference between an efficient, successful program and a less effective *ad hoc* approach. Management plans should include project goals, desired outcomes and timelines. Decisions about the timing of each project phase (pre-surveys, biological assessments, closures and monitoring) should be included, along with such mundane and often-overlooked details as the number and location of keys to bat gates. A critical component of these management plans must include clear identification of project partners, responsibilities and protocols. Funding for pre-closure surveys, construction and post-construction biological and construction monitoring may rest with different agencies, making it absolutely critical that financial responsibilities are also clearly identified within management plans.

STEP 1.3: THE REGULATORY ENVIRONMENT²

Legal issues surrounding abandoned mines are extremely complex and vary among states, federal agencies and even mining districts. Anyone who owns or manages lands on which abandoned mines are found is responsible for understanding applicable local, state and federal laws and associated liability. As a general rule, however, those who own or manage abandoned mines are responsible for safeguarding them. An organized effort to warn the public of the dangers of abandoned mines (i.e., through installation of signs) on unclaimed, claimed or patented lands may be sufficient to achieve legal compliance. In many areas, however, abandoned-mine openings must be safeguarded before liability is actually reduced. Once safety issues are addressed through signage and/or portal closures, managers or landowners typically are required to maintain such structures or signs in perpetuity.



Signs warning of safety hazards may provide legal protection for landowners .

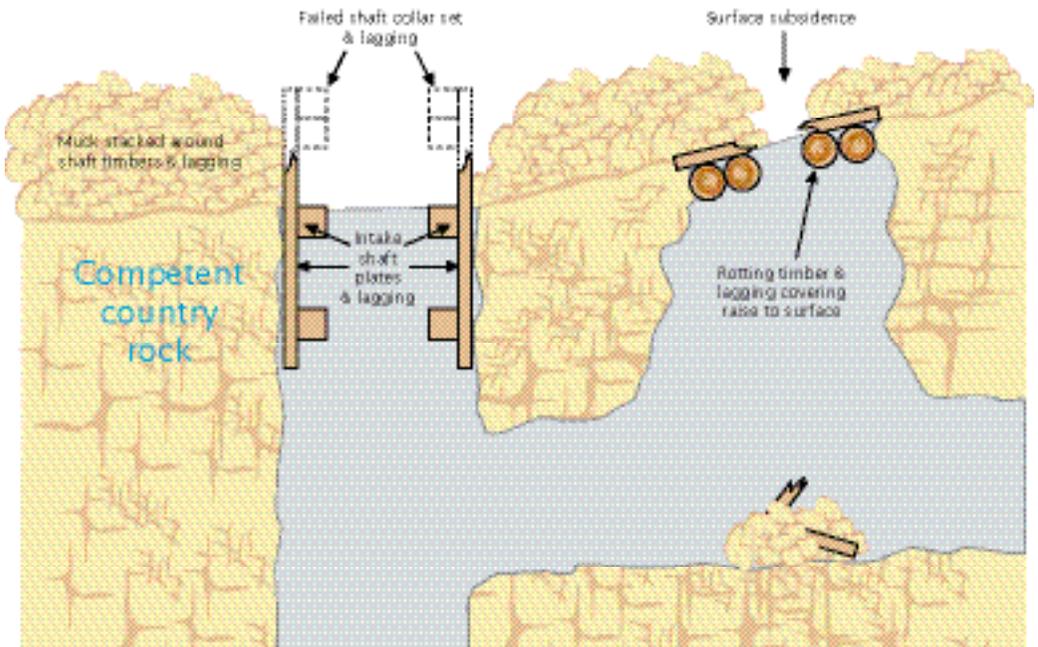
²National Environmental Policy Act: www.NEPA.gov; www.osmre.gov/osmreg.htm

STEP 1.4: PLANNING FOR SAFETY³

The areas in and around mines are extremely dangerous (Text Box 2). Accordingly, careful consideration should be given to the development of a comprehensive safety plan that will facilitate the work while best ensuring human safety during all project phases. Every management plan should have a comprehensive safety plan that adequately addresses the requirements of all collaborating partners (e.g., industry, state, and federal) on the project. Safety standards and protocols should be established during the planning phase. Among other things, safety plans should include:

- safety guidelines for work in and around abandoned mines;
- training requirements for personnel;
- required safety equipment;
- minimum number of personnel required for onsite work;
- communication protocols;
- emergency procedures and contingencies.

Surface hazards associated with shaft features



³Mine Safety Health Administration: www.msha.gov

TEXT BOX 2:

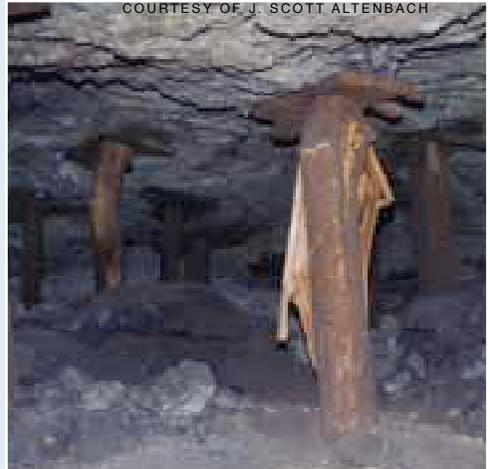
SPOTLIGHT ON SAFETY

Abandoned or inactive underground mines are hazardous environments to enter or work around. There is no way to make them completely safe. People working in or around mines must understand the risks and minimize them through training, the use of appropriate safety equipment and experience. Project managers should consider not only the biological qualifications of those who will conduct bat surveys, but should also require proof of safety training and demand adherence to established safety policies prior to allowing onsite work. Caving experience is not a substitute for appropriate mine-safety training and experience.

Physical Hazards at Mines⁴

Abandoned mines present a host of physical dangers: old explosives, abandoned equipment, structural instability, overhead hazards such as rocks, and vertical hazards that include raises, shafts and winzes. Combinations of faulty ground, violent ore extraction processes and lack or failure of internal supports leaves abandoned mines exhibiting varying degrees of internal instability. In many cases, insufficient time has passed for internal workings to stabilize. A single mine may include areas that are extremely stable (e.g., haulage tunnels through country rock) and others that are dangerously unstable. Pressure on the wrong stull at the wrong time, minor earthquakes or internal excavation can trigger the release of large amounts of energy with catastrophic results. Internal supports (timbers or pillars) are indicative of faulty ground and should be avoided and respected.

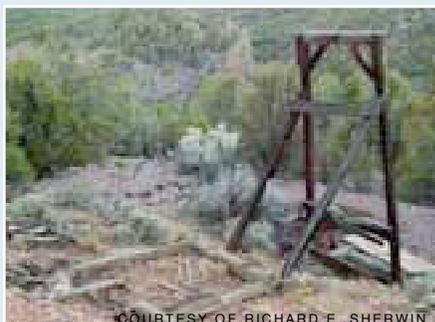
Different types of mining produce very different internal configurations that directly reflect the distribution of the mined material. These configurations and the geology associated with different minerals produce diverse hazards and risks. For example, coal and other sedimentary deposits are often distributed in broad horizontal beds; their removal typically results in large rooms with flat roofs. Although these rooms are often supported by pillars of ore material, they are still unstable and prone to failure until a more stable arch configuration is achieved.



Stull buckling under increasing pressure of the ceiling settling over time.

⁴Mine Hazard Rating: www.leg.state.nv.us/NAC/NAC-513.html#NAC513Sec320

Mines pose below- and aboveground hazards for the unwary, as well as those interested in abandoned-mine exploration, artifact hunting and similar recreational activities. Vertical openings are among the most dangerous hazards. Miners pursued ore in any and all directions, so surveyors should be vigilant and expect vertical workings to be present in any mine. Standing water and uniformly placed timbers on the floor can



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Surface conditions at a mine (left) may yield little evidence of the dangers that lie underfoot (right).

mask winzes and should be treated with suspicion. Furthermore, as timbers rot, structural integrity is lost and additional weight from a vehicle or human crossing what appears to be solid ground may cause catastrophic failure.

Invisible Hazards in Mines

In addition to physical hazards, abandoned mines may contain dangerous and even deadly atmospheres caused by toxic or oxygen-displacing gasses (“bad air”) and/or dangerously high levels of radiation. Bad air in abandoned or active mines is a serious and potentially deadly possibility. Lethal subterranean atmospheres can be produced through many processes and can involve a variety of toxic gasses, some colorless and odorless (carbon monoxide) and others with distinctive odors (hydrogen sulfide, some oxides of nitrogen). While toxic gasses such as hydrogen sulfide and some nitrogen oxides can be smelled, the former will paralyze olfactory epithelia and neutralize the ability to detect its odor within seconds, depending on the concentration. A toxic gas such as carbon monoxide is colorless, odorless and so quickly incapacitating that death can occur without warning. Although hydrocarbons, such as methane, are often associated with coal mines, they can also occur in other types of mines and are highly explosive at 5-15% by weight in the atmosphere.

Heavier-than-air gasses such as carbon dioxide can pool in the lower levels of a mine, depressions and behind air dams (ground-level structures that prevent air and gasses from freely moving within a mine). If a surveyor is climbing downward, a gas meter carried at knee or low-waist level will have a better chance of alerting the person to oxygen depletion through displacement by a heavier-than-air gas. Walking through pools of heavier-than-air gasses will cause the gas to rise, exposing surveyors to its effects. Conversely, lighter-than-air gasses such as nitrogen can pool in blind, overhead voids and exclude oxygen. If a surveyor is climbing upward, a gas meter carried near head level will minimize the chance of climbing into a low oxygen atmosphere. It is important to

remember that dynamic and sometimes dangerous atmospheric conditions can occur in any area of a mine due to changing weather patterns.

Although those with appropriate training, equipment and experience can avoid most hazards, abandoned mines present a serious threat to the general public, even to those skilled in cave and mine exploration. Everyone directly involved in mine-closure programs should work with appropriate regulatory authorities to ensure adequate training is obtained. The following are general recommendations for training and safety equipment:

Training

- Abandoned Mine Entry training (U.S. Department of Interior, Bureau of Land Management);
- National Minerals Training Office, mine safety training (U.S. Department of Agriculture, Forest Service);
- New Miner and Annual Underground Refresher training (U.S. Department of Labor, Mine Safety and Health Administration; MSHA);
- In-the-field training with those experienced in abandoned-mine surveys.

Equipment

- MSHA-approved safety equipment, including cap lamps (with adequate redundancy), helmets, safety glasses and appropriate footwear;
- A calibrated and fully functional gas meter (with at least oxygen[O₂], carbon monoxide [CO], and combustible-gas capability) must be worn at all times by those trained and qualified in their use;
- Respirator with condition-appropriate (High-Efficiency Particulate Air; HEPA) filters for dust, ammonia, radon daughters and viral, fungal or bacterial pathogens as appropriate.

Attitude is the Difference

Anybody who works around or enters abandoned mines must have a profound respect for the dangers involved. Surveyors with a thoughtful and safe attitude understand the risks associated with abandoned mines, the safety equipment necessary to minimize them and the limitations of their own knowledge and experience. A safe contractor or employee must be willing to terminate a survey if conditions exceed their knowledge, training, experience or equipment, if equipment fails, or if anything "seems wrong." Managers considering employees or contractors for abandoned-mine evaluations should be as conscious of the surveyor's attitude as of their possession and knowledge of safety gear.

There is no replacement for common sense!

Gases that may be encountered in abandoned mines

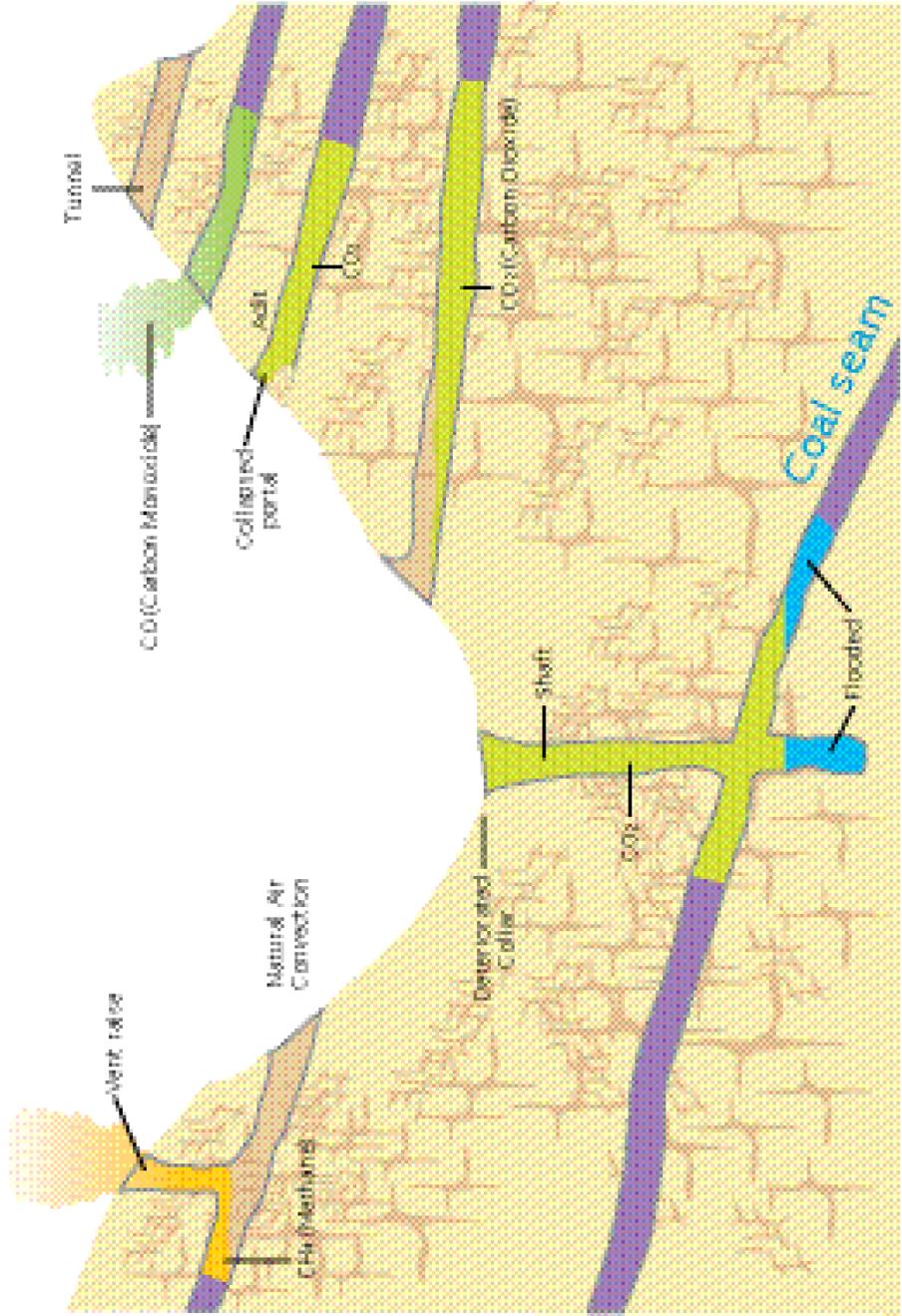
TLV: Threshold Limit Value, standard alarm level on gas monitoring equipment.

| GAS | SYMBOL | SPECIFIC GRAVITY | EXPLOSIVE RANGE | HEALTH HAZARD | HEALTH HAZARD | SOLUBLE | COLOR | ODOR | TASTE | TLV |
|-------------------------------------|------------------|------------------|-----------------|---------------------|---------------|---------|--|----------------|----------------|--|
| HYDROGEN | | | | | | | | | | |
| SULPHIDE | H ₂ S | 0.0695 | 4.0-74.2% | asphyxiant | asphyxiant | | | | | |
| METHANE | | | | | | | | | | |
| CH ₄ | | 0.5545 | 5-15% | asphyxiant | asphyxiant | slight | | "gassy" | | 20% LEL (=1% by volume) |
| CARBON | | | | | | | | | | |
| MONOXIDE | CO | 0.9672 | 12.5-74.2% | highly toxic | highly toxic | slight | | | | 50 ppm |
| NITROGEN | | | | | | | | | | |
| N ₂ | | 0.9674 | | asphyxiant | asphyxiant | slight | | | | |
| AIR | | | | | | | | | | |
| | | 1.0000 | | | | | | | | |
| 21% - normal | | | | | | | | | | |
| 17% - panting | | | | | | | | | | |
| combustible, 15% - dizziness | | | | | | | | | | |
| but not | | | | | | | | | | |
| 5% - coma | | | | | | | | | | |
| 6% death | | | | | | | | | | |
| OXYGEN | O ₂ | 1.1054 | explosive | | | | | | | |
| HYDROGEN | | | | | | | | | | |
| SULPHIDE | H ₂ S | 1.1906 | 4.3-45.5% | highly toxic | highly toxic | soluble | | rotten eggs | sweet | 10 ppm |
| CARBON | | | | | | | | | | |
| DIOXIDE | CO ₂ | 1.5291 | | increases breathing | breathing | soluble | | acidic | | 5,000 ppm (=0.5%) |
| NITROGEN | | | | | | | | | | |
| DIOXIDE | NO ₂ | 1.5894 | | highly toxic | highly toxic | slight | reddish brown at extremely high concentrations | blasting smoke | blasting smoke | 5 ppm |
| SULFUR | | | | | | | | | | |
| DIOXIDE | SO ₂ | 2.2638 | | highly toxic | highly toxic | high | | sulfur | bitler | 5 ppm |
| RADON | | | | | | | | | | |
| Rn | | 7.5260 | | radiation | radiation | high | | | | 1 WL - respirator 10 WL - supplied air |

Lighter Than Air

Heavier Than Air

Underground Gas Hazards



STEP 1.5: COLLABORATING TO SUCCEED

Diverse ownership, although a complicating factor in many ways, can also be a building block for successfully planning and implementing mine reclamation projects. It can result in collaborative relationships built upon mutual respect where partners share limited resources and more effectively manage abandoned mines over broader areas. Recognizing your neighbor's abandoned-mines management challenges and developing a collaborative partnership can achieve broader bat conservation and help ensure adequate mitigation.

Local, regional, national and international conservation groups and other organizations are often good partners for different aspects of a mine-closure project. For example, Bat Conservation International could help protect a colony of bats in a mine, while other organizations might consider collaborating to purchase the mine to protect it from destructive closure. The take-home message is that just because a landowner or manager may be directly responsible for abandoned mines, they are not necessarily alone in trying to do the "right thing" for bats or other natural resources.

STEP 1.6: WHOSE HOLE IS IT?⁵

Determining ownership ("doing the real estate") of mines can be an extremely complex process involving searches of county courthouse records of ownership or claim holdings (mineral rights) for each mine feature in a project area. In some cases, a single large mine may underlay the surface rights of several individuals, as well as encompass the mineral rights of multiple organizations. A comprehensive understanding of ownership and mineral rights is fundamental to implementing any management, protection or closure activity. A critical step is to contact the owner or claim holder with a request for a signed right of entry. Regardless of difficulties in determining ownership, managers must ensure that all claim holders and landowners are contacted before reclamation activities begin.

The BLM is the official record keeper of all mining claims in the United States, regardless of who manages the land. The BLM is also the repository for all land-ownership records if a federal entity is involved. These records are available to the public electronically via the BLM's LR2000 system on the internet.

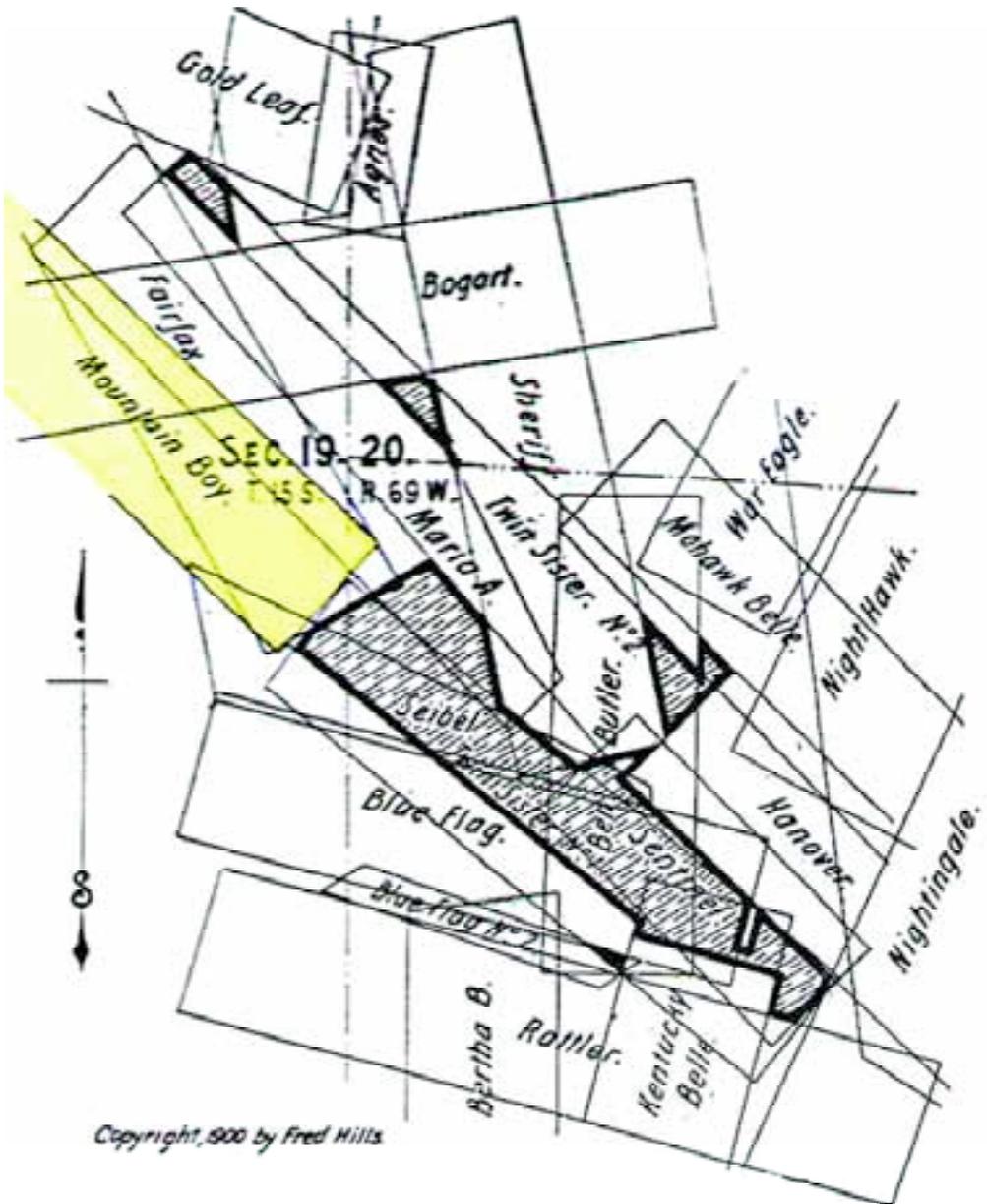
In areas where mining was relatively casual, identifying ownership of a few scattered openings may be a simple matter of referencing claim markers or local ownership maps. In areas of historical ore production, however, unpatented claims on federal and state lands often lie scattered among openings on patented lands, often within a few dozen feet of one another.

Clear identification of the goals of a mine closure or management program is important in effective planning and implementation. Less detailed information will be required if the goal is simply to locate mines in a general area than if the objective is to locate and manage specific mines or portals.

Abandoned mines are located throughout North America, with local densities ranging from a few scattered prospects to hundreds of openings per square mile. As local concentrations of mine openings increase, it naturally becomes more difficult to locate a specific opening among hundreds of openings in a small geographic area.

⁵Bureau of Land Management LR2000 system: www.blm.gov/lr2000

STEP I: PLANNING FOR SUCCESS



Ownership of specific mines or mine openings can be difficult to identify in some areas.

USGS 7.5" topographic maps often provide important information for locating mines. Maps of this scale may differentiate shafts from adits, prospect pits and open-pit mines and will often provide mine names. It is critical to remember, however, that a single symbol on a map may actually represent several mine features on the ground. Smaller scale maps (e.g., 1:100,000) will typically indicate only large production mines or areas of intense mining activities; the lack of indication of mines on maps at these scales should never be interpreted as evidence of their absence.

Historical maps of areas of intense mining are often an invaluable resource for locating abandoned-mine openings. Additionally, a literature search of historical archives at state mine bureaus (e.g., New Mexico Bureau of Geology and Mineral Resources) for maps or descriptions of mining activity may indicate many mine openings and sometimes even the extent of underground workings. Maps dating to periods of peak mining activities typically provide locations of many openings that are not indicated on newer maps. They may also show old roadways and railway beds (which can be invaluable in accessing abandoned mines), structures and even caves that may have been absorbed into a mine. Despite their absence from newer maps, many of these mines and associated features remain open and accessible and can be easily located on these historical maps. Aerial photos can provide additional information on dump sizes, persistence of old mule trails, roadways, railway beds and surface structures. Historical documents such as production records, mining publications, mine literature, mining district records, and U.S. Bureau of Mines records can be effective tools for locating abandoned mines. An Internet search using appropriate keywords (e.g., Historic Mining Record Archives, Virginia) may also prove useful.

STEP 1.7: MANAGING MOUNTAINS OF INFORMATION

Any project involving the management of abandoned mines should from the very beginning include the development and maintenance of a database. Too many abandoned-mine openings have been closed by managers who have since moved on to new positions, taking with them the locations of any reclaimed or gated sites. And too many biological evaluations have been conducted without any record of survey methods, precise timing of visits or survey results. Building and maintaining a database can reduce redundancy and facilitate follow-up surveys after reclamation work is completed (Step 5).

Project databases should include, at minimum, opening names, locations, access information and dates of site visits and of site closure and/or maintenance. Databases should also include all information collected for pre-closure assessments. Once completed, a robust database will serve as a template for creating specific assessment data sheets.

STEP 1.8: THE RATIONALE FOR PROTECTING MINES

Despite their general instability and associated hazards, many abandoned mines are worth protecting and managing, which can result in the conservation of important habitat for bats and other wildlife. Protecting abandoned mines can also preserve archaeological, cultural or historical artifacts associated with the mining, and maintain access to internal geological information. The presence of these other, non-biological resources may justify protection of a particular feature, regardless of use by bats. Preserving a site

STEP I: PLANNING FOR SUCCESS

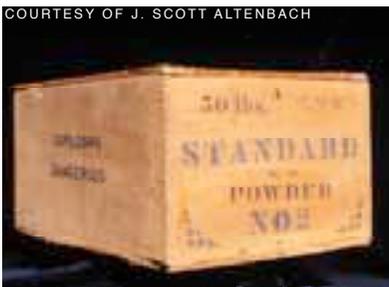
for these other resources may ultimately provide habitat for bats. Typically, a variety of assessments must be carried out before closures can be initiated.

Step 1.8.1: Historical, Cultural & Archeological Resources⁶

The preservation of archaeological, cultural or historical artifacts associated with mining communities is an important factor that can and should result in the protection of some mines. Cultural surveys are required at any mines on federal and state properties that are more than 50 years old or are associated with materials that are at least 50 years old (even if the mines are younger). Abandoned mines are often assessed from the standpoint of surface features, but underground evaluation for artifacts is typically minimal or nonexistent on state or federal lands. This is unfortunate, since underground archaeological resources can be perfectly preserved in dry workings and surprisingly well preserved even in damp or wet conditions. Mines can provide a detailed view of the chronology of the mining operation, details of the techniques and technology of historical mining and significant historical artifacts. While some mines are not old enough to warrant concern from archaeologists, most are old enough for protections mandated under the National Historic Preservation Act. Destructive closures (sealing all entrances to a mine) do not ensure the long-term preservation of artifacts, since humidity often increases once a mine is sealed, accelerating degradation of artifacts. Further, closing external entrances has resulted in the flooding of large mines in the Great Lakes region, where the mines may extend hundreds of feet below the water table.



COURTESY OF J. SCOTT ALTENBACH



COURTESY OF J. SCOTT ALTENBACH



COURTESY OF J. SCOTT ALTENBACH

Mining artifacts, such as drill steel (*top*), dynamite boxes (*bottom left*) and blasting cap tins (*bottom right*), are sometimes found in abandoned mines and provide insight into the mining history of that site.

⁶National Historic Preservation Act : www.achp.gov/nhpp.html

Step 1.8.2: Geological and Mineralogical Resources

Access to geological and mineralogical information is another reason to protect some abandoned mines rather than sealing them. Many geologists view abandoned mines as “windows into the world” that offer detailed looks at the geological history of an area. The view of underground geologic resources afforded within abandoned mines usually is not available by any other means. Surface evaluation of geologic resources is often limited by alterations caused by exposure to surface conditions, while core drilling takes a narrow and nearly linear sample of the underground and can easily miss major localized features. In addition, some types of drilling destroy much of the macro-morphology of investigated formations and cause dramatic surface disturbance. In areas where abandoned mines are present, they are often the first resource investigated during prospecting and evaluation phases of mining operations.

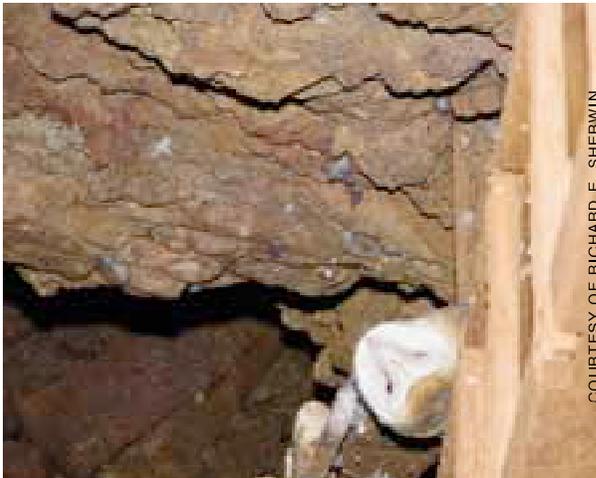


COURTESY OF RICHARD E. SHERWIN

Evidence of copper

Step 1.8.3: Wildlife Resources

Mines provide important habitat for many species of bats and may house millions of individuals (e.g., Huber Mine, Texas). Published accounts of the proportion of abandoned mines used by bats and degrees of dependence upon them vary regionally, but can run as high as 70 percent in some regions. Mines have been protected to maintain important habitat for state Species of Concern and/or federally designated Threatened and Endangered species, as well as other species without any state or federal designation.



COURTESY OF RICHARD E. SHERWIN

Barn Owl (*Tyto alba*)

In some regions, mines also may be used extensively by black rosy-finches (*Leucosticte atrata*), barn owls (*Tyto alba*) and desert tortoises (*Gopherus agassizii*). Even cave-associated fauna can be present in mines with appropriate habitat elements (e.g., water). Further, bighorn sheep (*Ovis canadensis*), bobcats (*Felis rufus*) and other wildlife may occasion-

ally use mines and complicate management of specific sites. Indiscriminant, destructive closures of key mines may inadvertently eliminate or severely impact regional populations of some species. In Mineral County, Nevada, for example, thousands of black rosy-finches from the Sand Spring Mountain Range winter in mine shafts and would be lost if exclusion techniques did not properly address their presence. Typically, however, bats are the single biological component that programmatically influences mine closure and mitigation efforts.

STEP 1.9: ESTABLISHING SIGNIFICANCE

With limited time and tight budgets for safeguarding programs of abandoned mines, determining the significance of bat use is a challenge (Text Box 3). Decision makers often are faced with such questions as:

1. Does the detected use warrant safeguarding an opening with a bat-compatible, air-flow-compatible or other wildlife-compatible closure?
2. Is such a protective closure, typically more costly than a destructive closure, worth the extra money?

These questions can best be addressed by understanding the bat species involved, its relationship with abandoned mines (See Species Guilds, Step 2), the impact of mining on the species (See Distribution Hypotheses, Step 2) and the type of use at the affected mine (e.g., hibernation, maternity, bachelor, etc., Step 2). These considerations should be formulated within a regional perspective (e.g., is it a locally unique resource) and with sensitivity towards the limitations of the survey techniques used (See Step 3). Managers must always remember that much inevitably remains unknown, and management should err on the side of caution. It is better to preserve a non-roost than to permanently close an important roost site.

Step 1.9.1: Absolute Versus Relative Significance

Absolute significance involves some *a priori* designation of roost types that will always be deemed worthy of protection, regardless of the abundance of that resource in the environment. For example, a management team may decide that all hibernation roosts of Rafinesque's big-eared bats (*Corynorhinus rafinesquii*) warrant protection regardless of the abundance of hibernacula in the landscape. Similarly, the simple presence of any federally Threatened or Endangered bat in a roost may require its protection.

Relative significance is often subjective and typically includes comparisons of a site's resource use or quality against what is available in the region. In this approach, abandoned mines are managed as part of a roosting landscape where managers attempt to ensure that various types of subterranean habitat (and associated roost types) are maintained. For example, a survey team may evaluate the internal landscape associated with

Biological significance is best established by all partners prior to fieldwork.

10 mines in a management area. They discover that nine of the mines are simple mine workings that provide similar roosting opportunities. The tenth mine is a large production mine that includes all habitat types available in the other nine mines, so its relative importance becomes elevated while the others become diminished.

Obviously, each site must be considered as part of a contextual roosting landscape when attempting to prioritize mines based on relative significance. Typically then, establishing this type of significance requires that surveyors evaluate a number of abandoned mines during a reclamation project and make direct comparisons among sites. By definition, relative significance of any site may change as additional field surveys are conducted.

The time to establish thresholds of significance and determine the unit of assessment (bats or habitat) is before a project begins and should include input from all project partners. To minimize confusion and maximize efficiency in the field, managers should clearly identify thresholds that must be reached to warrant site protection before initiating actual site assessments. Those conducting mine-closure projects in landscapes where past work has been done may be more prepared to establish specific requirements than those in less studied areas, who may need to be more liberal in determining significance.

TEXT BOX 3:

THE QUESTION OF SIGNIFICANCE

Any decision regarding the fate of an abandoned mine has potentially profound implications, because at issue is the permanent elimination of a nonrenewable resource. Due to inherent complexities in how bats utilize mines within a landscape, investigators should clearly define goals and objectives of interest for any closure project. Answering the following a priori questions will help determine what is or is not significant habitat or use.

What species is being addressed?

No two species of bats have the same physiological or natural history requirements, so it is essential that researchers clearly identify which species are potential occupants of mines within the project area. Enough variability exists among populations and across ranges that even species-level generalizations can be problematic.

What type of “use” is being investigated?

Types of use include maternity (pre-birthing, birthing, pre-weaning, weaning, post-weaning), bachelor, mating (lek sites), night roosts, migratory and hibernation. Variables driving roost selection differ dramatically based on the specific type of use being investigated.

What is the spatial scale of interest?

Spatial scale should be clearly articulated because the level of inference is limited to the spatial scale of collected data (i.e. data should never be applied at smaller spatial scales). Landscape-level studies provide no data from which microclimate inference should be made.

What temporal scale is being investigated?

Temporal scales range from within and among seasons to the use of roosts within and among years. Some species exhibit tremendous variability in relative loyalty to specific roosts. While all scales of temporal investigation are important, care must be made when attempting to impose short-term patterns on larger temporal scales. Only by conducting multiple surveys through time can accurate resolution of biological processes be achieved.

What level of biological significance will be attributed to occupancy and what will occupancy suggest about roost quality?

Biological significance and management priorities must be defined locally, since use by bats varies by species and throughout the species' range. Maternity and hibernation sites are often viewed as more significant than summer bachelor roosts because of constraints on reproductive females and on hibernating bats (with regards to roost selection).

Furthermore, use of colony size as an absolute gauge of roost significance is problematic because degrees

of association often vary across a species' range. In Utah, for example, groups of hibernating Townsend's big-eared bats are generally small (one or two individuals), with groups rarely exceeding five individuals. Therefore, a gate might be recommended in Utah for a mine used by a single individual, while this same standard is much less applicable in New Mexico, where wintering groups tend to be much larger.



Big brown bats (*Eptesicus fuscus*)

How will habitat be defined?

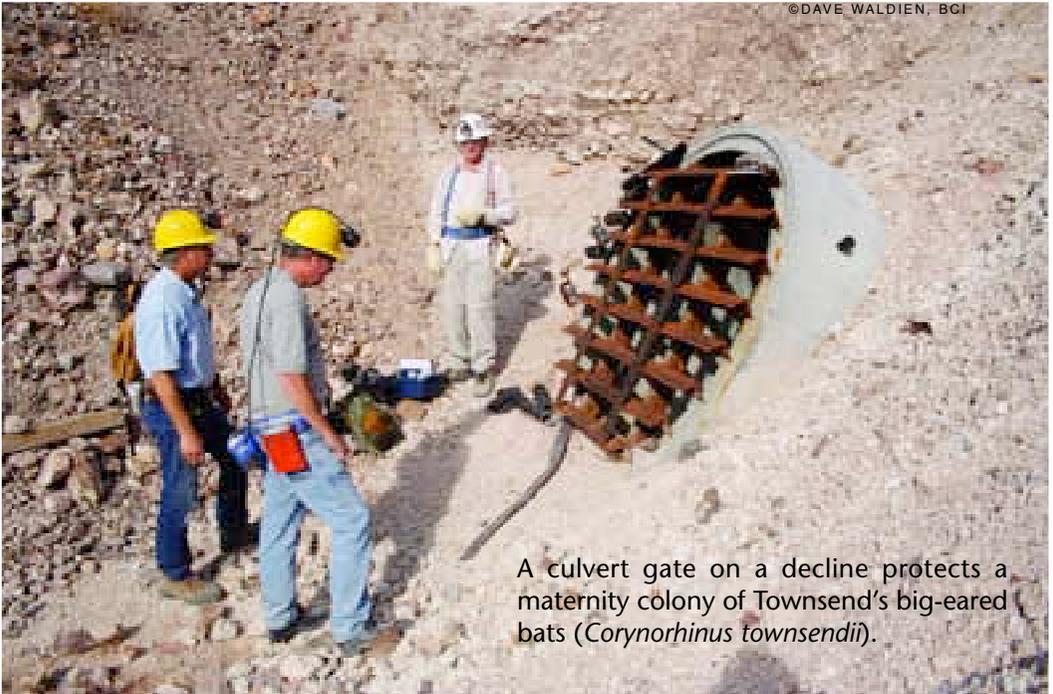
The definition of habitat dictates the data that will be collected. If habitat is defined as the interface of the bat and the mine (point of roosting), then only intensive, non-invasive techniques are appropriate to collect data necessary to explain the selection of microclimates (e.g., data loggers, continuous video). If habitat is defined as the complete mine, less intensive surveys are needed, but less resolution is provided. Habitat should not be limited to specific roost attributes or a specific mine (however defined), but should also be evaluated based on the availability and distribution of food, water and other resources in the broader landscape.

Establishing management significance of an abandoned mine, which may not be the same as biological significance, is difficult. There are two basic approaches to determining significance of a site (Fig. 1). The first is to assess the habitat itself, independent of bat occupancy at the time of survey, then base management recommendations on habitat quantity and quality (Fig. 2). The second approach is to use the presence of bats or associated sign as the primary gauge of significance (Fig. 3).

Fig. 1. This decision tree provides a framework for determining whether to base your management decisions on BATS or on HABITAT.

Fig. 2. In this example, we are using “HABITAT” as our measure for defining significance. An internal assessment of the mine is the best way to gather data upon which to make management decisions. In this example, we are interested in protecting unique roost resources in the management area, and then basing decisions upon our *a priori* guidelines for significance of other habitats. This is only one example of a decision tree that could be developed for a landscape level reclamation project. Deviations may be required to address unusual situations with modifications and adjustments based on conscious decisions.

Fig. 3. In this example, we are using “BATS” as our measure for defining significance. The local partners would have set the first level of significance as the presence of any Threatened or Endangered species and their second level as significant use (as defined locally) of any other species of bat. Deviations from this process may be required to address unusual situations but should be based on conscious decisions. This is only one example of a decision tree that could be developed for a landscape-level reclamation program.



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A culvert gate on a decline protects a maternity colony of Townsend’s big-eared bats (*Corynorhinus townsendii*).

Figure 1

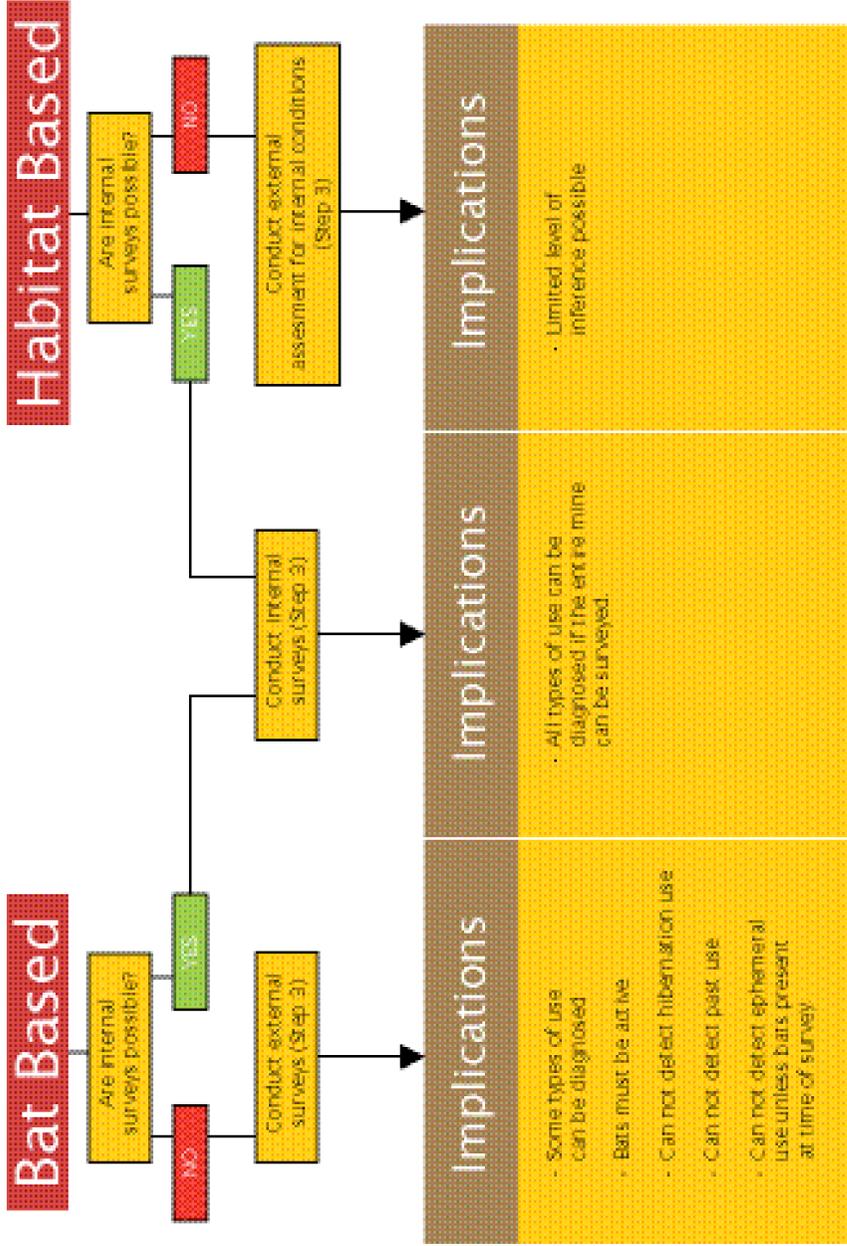
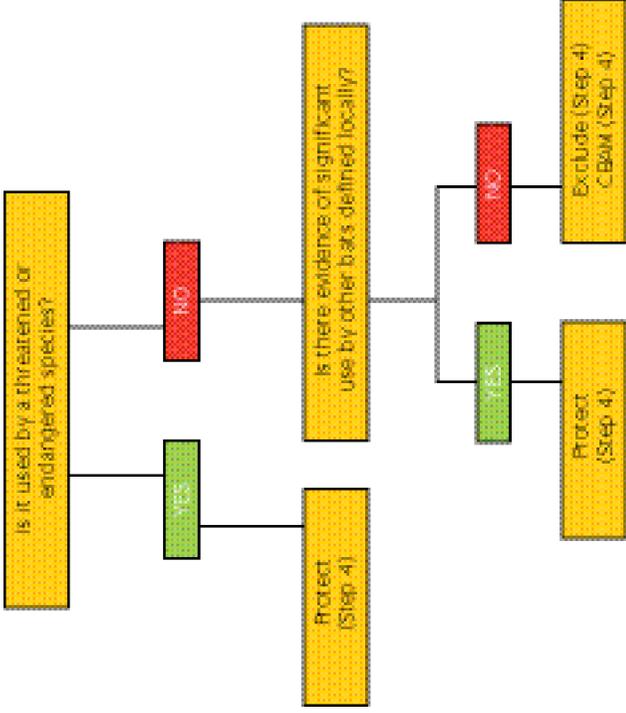


Figure 3: Bat-based model for threatened and endangered species and significant use by all other bats



STEP I: PLANNING FOR SUCCESS

Note: CBAM = Close by any means



STEP 2:

RESOURCE
ASSESSMENTS

A comprehensive understanding of mines, bats and how the two are interconnected is paramount to maximizing bat conservation and the efficiency of mine reclamation efforts. Without this basic understanding mistakes can be made that have grave consequences for bat conservation.

Concept Planning Check Box

- Step 2.1: Understanding the Mine Resource
 - Text Box 4: Understanding Underground Mines
 - Step 2.2: Understanding the Bat Resource
 - Step 2.2.1: The Importance of Temperature & Humidity
 - Step 2.2.2: Different Types of Roosts
 - Step 2.3: Understanding Bats & Mines Relationships
 - Step 2.3.1: Species Guilds
 - Step 2.3.2: Distribution Hypotheses
 - Step 2.3.3: Mine Configuration & Mine Environments
 - Text Box 5: Spotlight on Mine Temperature & Airflow
 - Step 2.3.4: Episodic versus Continuous Use
 - Step 2.3.5: Hide and Seek: Where the Bats Roost
 - Step 2.4: Single Large or Several Small
-

STEP 2.1: UNDERSTANDING THE MINE RESOURCE

Mines are important resources in many landscapes, yet are being lost through reclamation programs and erosion processes. By 2000, an estimated 48,000 abandoned mines had been closed through formal reclamation programs alone, and an unknown number had been lost to renewed mining or closure by private landowners to avoid liability issues. Such dramatic loss of mines necessitates proactive management and protection of key mines whenever feasible.

Many people consider caves and mines as synonymous. However, the lack of stability in mines is one fundamental difference that profoundly affects management decisions. Underground mines are created over relatively short periods using violent processes (such as drilling or blasting) in highly faulted ground, which often results in relatively unstable subterranean features. Internal mine workings were created to access and remove ore-bearing rock, coal or other materials and were not intended to persist for prolonged periods of time. Caves, on the other hand, develop through natural processes, generally over geological time scales, and tend to be much more stable. The Federal Cave Protection Act of 1988 dictates that protection is the default management option for a cave, while for a mine the default is destructive closure.

Over the decade and a half that formal bats and abandoned mines programs have been in place, one of the greatest and most persistent challenges for everyone involved has been how to communicate effectively. Recommendations or decisions about management, protection or permanent elimination of nonrenewable mine resources must be accomplished through the use of mining terminology (Text Box 4). Failure to correctly use the language associated with abandoned mines can result in the loss of credibility with crucial partners. Furthermore, incorrect, vague or purely descriptive language to describe a site can complicate dialog and result in incorrect responses.

TEXT BOX 4:

UNDERSTANDING UNDERGROUND MINES⁸

Glossary of Terms

These are terms often used to facilitate effective communication between biologists and people responsible for planning and implementing mine survey and closure projects. More comprehensive glossaries should be consulted as needed.

Adit – A horizontal mine passage driven in from the surface

Back (“roof” in coal-mine terminology) – The ceiling of an underground working

Bald – Untimbered workings, typically vertical or off vertical

Blind – Without lateral workings

Cap – A horizontal, (usually) wooden support holding the back or hanging wall and supported by a stull or posts

Collar – The surface opening to a shaft

Collar set – The timber, rock, steel or cement stabilizer of a shaft collar

Country rock – The ground material around an orebody; the ground material into which an orebody was deposited

Crosscut – A horizontal underground mine passage driven perpendicular to the strike of an orebody, often to intersect an orebody from a drift in country rock

Decline (“slope” in coal-mine terminology) – A mine passage driven from the surface at an upward or downward angle from horizontal; often called an incline when driven at an upward angle; in hardrock usage a decline or incline can be driven from an underground level

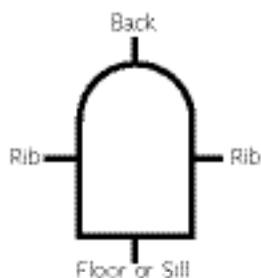
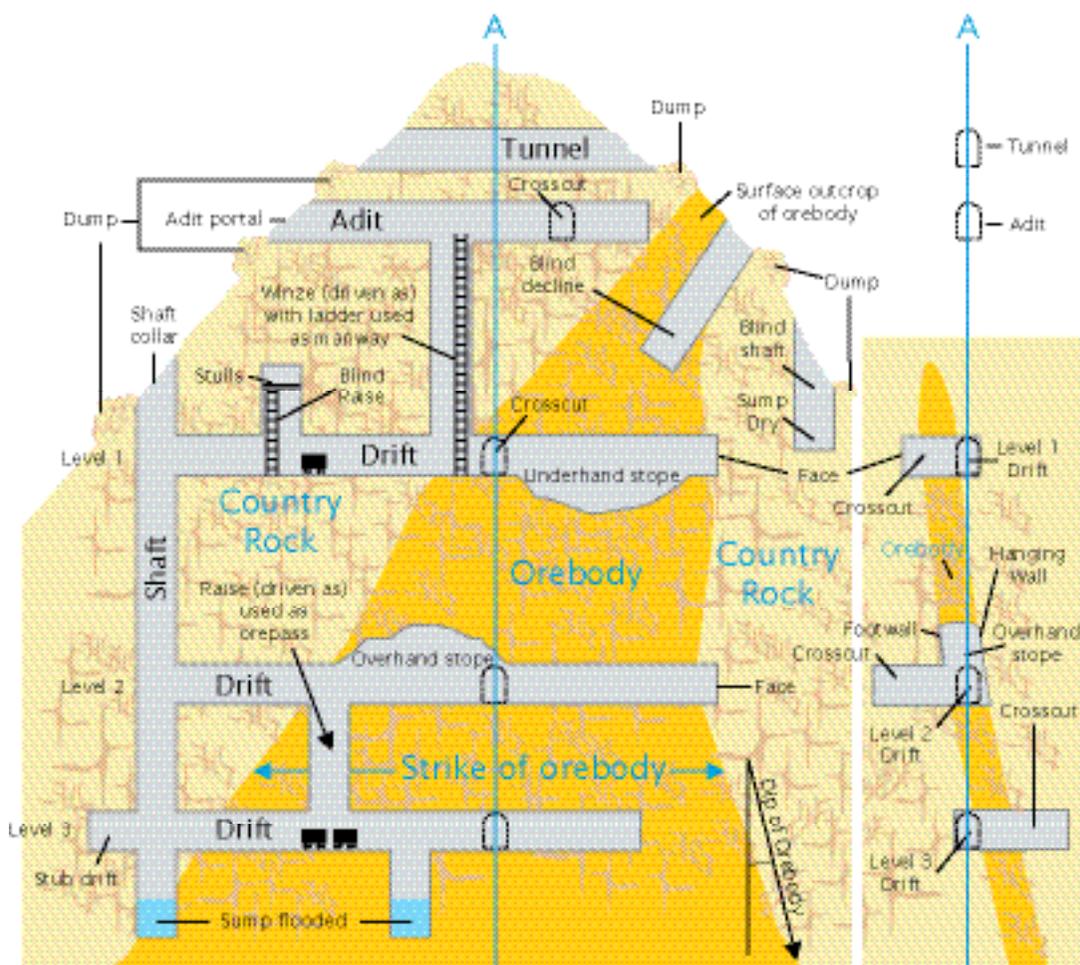
⁸American Geological Institute. 1997. Dictionary of Mining, Mineral, and Related Terms, *2nd Edition*. American Geological Institute, Alexandria, VA.

- Dip** – The angular displacement from horizontal perpendicular to the strike of an orebody, or underground mine passage (e.g. the dip of a decline)
- Drift** – Usually a horizontal underground mine passage driven parallel to the strike of an orebody
- Dump** – Waste rock (poor rock or muck) removed by mining and deposited on the surface
- Face** – The terminus of an adit drift or crosscut; usually the horizontal surface that is being advanced by mining (the working face)
- Foot wall** – The country rock below an orebody
- Hanging wall** – The rock above an orebody
- Hitch** – A shallow depression chipped in the rib for insertion of timber (e.g. plate timbers in shafts or winzes)
- Level** – Horizontal workings at different elevations (typically numbered 1, 2, 3, etc.)
- Manway** – A vertical underground passage with ladder for upward or downward movement of miners; can be in winze, raise, or shaft
- Muck** – Waste rock broken in mining and hauled to the surface dump; sometimes stacked internally or used to fill stopes
- Orebody** – A mineral deposit removed for its mineral content
- Pillar** – Usually a column of ore or coal left to support the back (or roof) in a stope (or room) or to support the hanging-wall
- Portal** – The surface opening to an adit or tunnel
- Post** – A vertical support member (often timber) used to support a cap (often timber) that in turn supports the back (or roof)
- Powder** – Explosives used in blasting (typically dynamite). The term can be applied to black blasting powder or (colloquial) ammonium nitrate-based blasting agents
- Raise** – An underground mine opening driven upward from below to access an overlying orebody or provide access to an upper level
- Rake** – The angular displacement from the horizontal along the strike

- Rib** – The side of an underground opening (i.e., drift, crosscut, adit, stope, non-footwall sides of a shaft)
- Set (timber set)** – Posts and caps supporting a horizontal underground passage or plate timbers set horizontally in a shaft (from hanging wall to footwall and from rib to rib)
- Shaft** – A vertical mine passage opening to the surface for removal of waste rock, ore or entry of miners
- Shot hole (culo)** – The hole drilled to receive explosives used in blasting or the unblasted terminus of such a hole
- Slope creep** – The sliding of loose surface material (broken rock, dirt) down to fill an adit portal, shaft collar or open stope
- Stope** – An underground cavity left by removal of ore above (overhand) or below (underhand) a working level
- Strike** – The linear orientation of an orebody, parallel to the surface (e.g. a north-south strike)
- Stull** – A brace (often timber) placed for support between hanging and foot wall
- Sump** – The bottom of a shaft, often where water will collect
- Tailings** – The finely crushed material left after a milling operation, not the same as a dump, dump rock or waste rock
- Tunnel** – A horizontal underground mine passage open to the surface at both ends
- Vein** – A definable linear zone of deposited mineral
- Waste** – Poor rock or muck
- Winze** – An underground mine opening driven downward from inside to access an orebody below or a lower level

Longitudinal Section

Cross Section



Section of Underground Opening

STEP 2.2: UNDERSTANDING THE BAT RESOURCE

Step 2.2.1: The Importance of Temperature & Humidity

Roost temperature and humidity are important variables that influence if and how bats select roosts. Because internal microclimates profoundly influence growth rates, energy conservation and survival, they are a key component in predicting site suitability and use by bats and could account for the presence or absence of bats within a roost.

Temperature: Temperature is probably the single most important factor affecting roost use by bats. The high surface-to-volume ratio of bats' bodies increases thermal stress, making activity metabolically costly. This causes bats to seek specific microclimates to optimize metabolic processes for hibernation or rearing young.

In winter roosts, many species respond to environmental stressors (e.g., decreased ambient temperatures, lowered concentrations of prey) by entering torpor or hibernation to offset physiological costs. Individual bats seek an optimal temperature range, at which they minimize energy output while maintaining some minimum of physiological activity. Stable temperatures within species-specific optimal ranges minimize energy demands and facilitate hibernation. Prolonged exposure to temperatures below this range may cause death or permanent cellular damage by freezing, whereas higher temperatures may unnecessarily result in the costly expenditure of limited energy reserves.

Researchers and managers must be aware of the difference between “mean internal temperatures” and the “variance of internal temperatures” when creating thermal profiles of internal roost conditions. While some species appear to select for stable mean temperatures (e.g., Indiana myotis [*Myotis sodalis*]; Fig. 4), others seem to be associated with areas of high temperature variance (e.g., Townsend's big-eared bats; Fig. 5). Reliable internal temperature profiles can only be achieved through the use of continuous recording devices (e.g., data loggers), as temperatures can vary dramatically within a site and fluctuate tremendously over a season. Point measurements of temperature at the time of survey do not accurately reflect internal mine temperatures through time and should not be used in isolation to justify mine closure recommendations.

Temperature also has a direct and profound impact on the reproductive success of many bat species because metabolic energy output is directly associated with thermal conditions in the roost. Generally, both juveniles and adults within a maternity colony benefit from higher temperatures because they use less energy to maintain the high body temperatures associated with metabolic activities, such as fetal development, milk production and growth. Maternity colonies of some species are strongly associated with warm locations within mines. In addition, some species (e.g., Townsend's big-eared bats, Yuma myotis [*Myotis yumanensis*]) have been documented to actively modify roosting temperatures through metabolic heat (Fig. 6). This ability to modify thermal conditions allows maternity colonies to utilize mines that would otherwise be cooler than expected for maternity use.

Humidity: Humidity likely influences roost selection, although it remains poorly understood. For example, a maternity colony of Yuma myotis selected a more humid location within a mine, possibly to minimize evaporative water loss due to increased roost tem-

Fig. 4: Idealized hibernation roost temperatures for Indiana myotis.

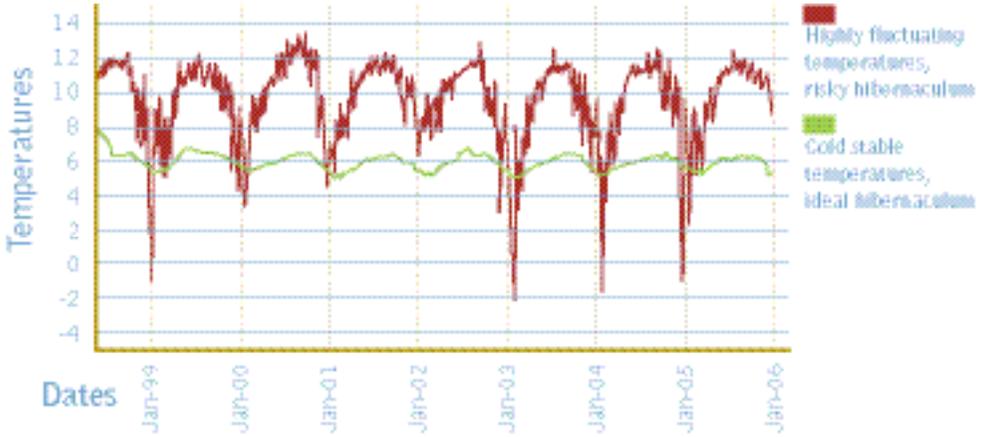


Fig. 5: Temperatures fluctuate in Townsend's big-eared bat roost in Cherry Creek Mine.

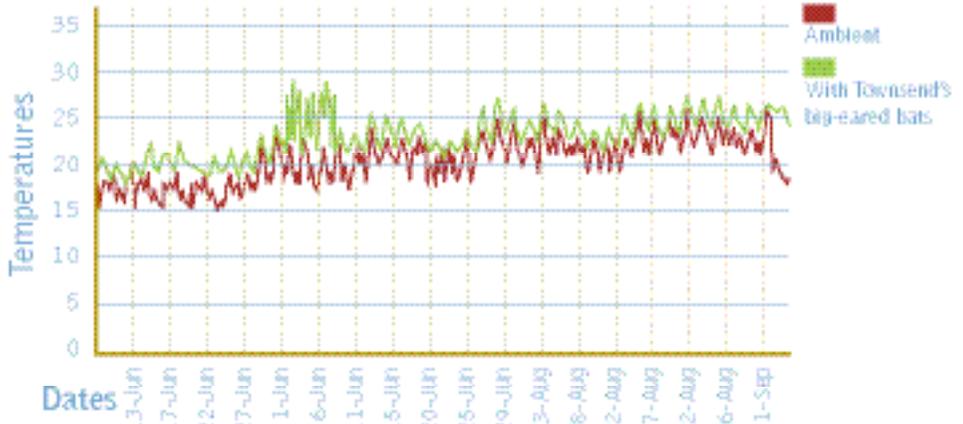


Fig. 6: A maternity Colony of Townsend's big-eared bats increase temperatures in the roost.



peratures associated with the colony's clustering behavior. Furthermore, lower humidity may drive roost selection in areas where subterranean conditions consistently remain excessively wet and very humid. Low humidity may also influence site selection by some species of hibernating bats (e.g., big brown bats [*Eptesicus fuscus*]).

Step 2.2.2: Different Types of Roosts

Understanding how bats use subterranean habitat to meet basic biological needs is critical for effective management of abandoned mines.

Maternity Sites: A maternity site is where at least one reproductive female bat roosts during the day. The size of maternity colonies varies regionally, as well as within and among species. In Texas, for instance, single maternity colonies may include millions of Mexican free-tailed bats (*Tadarida brasiliensis*). Maternity and hibernation sites are the two types of roosts most often deemed of management significance since they are thought to be more biologically significant than other types of roosts.

Among most bat species in the North American temperate zone, reproductive females segregate from males during the warm season because the physiological needs of reproductive females are greater than those of males during this period of time. The length of segregation and the timing of the establishment of maternity colonies varies across altitudinal and latitudinal gradients.

Reproductive females travel to maternity roosts at various stages of fetal development.

They seek sites with a suite of physical and microclimatic characteristics that translate directly into physiological advantages. The physiological costs of even local migrations to maternity roosts, while carrying a fetus weighing up to 40% of normal body weight and after the stresses of hibernation, are likely profound. It is no surprise, then, that females typically show much higher fidelity to subterranean maternity roosts than do males.

While maternity-roost requirements vary by species and throughout specific ranges, a few general features of abandoned mines seem to predispose them toward use by maternity colonies. Within mines, maternity colonies of many species tend to roost in higher areas that function as heat traps (e.g., Text Box 5, Example 1, Area E) and provide protection from predators. Maternity colonies may be located in areas that are exposed and



Scott Altenbach examines a large guano pile from a fringed myotis (*Myotis thysanodes*) maternity roost.

easily observed, or deep in cracks and crevices where detection is difficult. Reproductive females often select the warmest locations they can find, as higher temperatures facilitate the growth of young and reduce thermoregulatory costs for active females.

Maternity use of abandoned mines is largely limited to species that form cohesive groups (often referred to as clusters). This may be a reflection of the need of individual bats to share and conserve metabolic heat, or it might reflect a more ubiquitous pattern in which subterranean bats require a certain critical mass in order to fine-tune the microclimate of subterranean roosts.

Abandoned mines serving as maternity sites are often readily identified by the aggregations of female bats. Potential evidence of active maternity roosts includes larger concentrations of guano, carcasses of dead young bats (pups) and pronounced activity at mine portals within the regional maternity season. As always, the larger the colony, the greater the probability of detecting bats during exit surveys or by locating the actual maternity roost during internal surveys.

Hibernation Sites: Hibernation roosts, also known as hibernacula, are where individual bats spend the cold season. Stable, cool internal temperatures, the potential for relatively high levels of humidity and internal dimensions of sufficient size to provide protection from most predators often translate into winter use of abandoned mines by temperate-zone bats. For many species, associations with abandoned mines are most pronounced during the winter months. Hibernating colonies in abandoned mines can range in size from a single individual (e.g., big brown bats) to hundreds of thousands of individuals (e.g., gray myotis [*Myotis grisescens*]). Hibernation colonies typically include both males and females, although each gender may seek different microclimates within the same site. Hibernacula are often used by multiple species, although a single species often dominates numerically.

Timing of hibernation varies among species and across distributional ranges, as does the level of winter activity. For example, individual little brown myotis (*Myotis lucifugus*) and big brown bats hibernating in the Millie Hill Mine in Michigan, and little brown myotis hibernating deep in the Tower Sudan Mine in Minnesota and the Neda Mine in Wisconsin, remain in deep hibernation most of the winter. Yet individuals of both species, when hibernating in the southwestern United States, routinely



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Rafinesque's big-eared bats (*Corynorhinus rafinesquii*)

rouse from hibernation and forage when nightly temperatures rise above freezing and spend less of the winter at hibernation roosts.

Bats use abandoned mines that are cold enough to facilitate physiological hibernation and that include sufficiently stable internal conditions to minimize the movements of bats due to fluctuating temperatures. These conditions are often found in the lower workings of mines, which can function as cold-air traps (e.g., Text Box 5, Example 1, Area C). In general, large, complex mines that include cold-air traps tend to be the more important hibernacula, since they are likely to provide more stable temperatures and a

greater buffer to external environmental fluctuations. However, mines of all sizes and configurations have been documented to shelter hibernating colonies of bats. Management decisions regarding the closure or protection of mines as hibernation roosts should be based on the mine's significance for the region and species (see Step 1) – and not on general models that assume simplistic relationships.

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Indiana myotis (*Myotis sodalis*)

Bachelor Sites: Typically, any non-hibernation roost that does not include reproductive females is referred to as a bachelor roost. Bachelor roosts can be used by a single individual (e.g., Townsend's big-eared bats), a few dozen bats (e.g., pallid bats [*Antrozous pallidus*]) or by thousands of individuals as commonly observed in Mexican free-tailed bats and southeastern myotis (*Myotis austroriparius*).

There is tremendous variability in the cohesiveness and sociality of bats within bachelor colonies. Many species exhibit no group cohesion, with bachelor males scattered throughout a roost and no apparent interaction among individuals (e.g., Townsend's big-eared bats, western small-footed myotis [*Myotis ciliolabrum*]). In other species, bachelor males form tight clusters and function more as a cohesive group (e.g., cave myotis [*Myotis velifer*], Mexican free-tailed bats). It is not uncommon for a single site to be used as a bachelor roost by several species of bats, but the species usually roost independently of one another.

Roost use by bachelor males ranges from predictable and relatively easy to identify (e.g., Mexican free-tailed bats) to dynamic and difficult to recognize (e.g., Townsend's big-eared bats, western small-footed myotis). Typically, there is a strong positive correlation between the size of bachelor colonies and their loyalty to an individual roost.

Bachelor colonies with large numbers of bats and high roost fidelity are relatively easy to identify in abandoned mines. Unfortunately, bachelor colonies of many species are difficult to identify because the colonies are small and bats' use of individual roosts can change

STEP 2: RESOURCE ASSESSMENTS

frequently. Regardless of group size and cohesion, however, bachelor males tend to be found in abandoned mines that are cooler than those used by reproductive females.

Rest Sites: Several types of roosting behaviors are included in this category, including night roosts, transient roosts and migratory stopovers. As bats move within and across landscapes, they often spend time resting. This may take place during the night, in which case the site is referred to as a night roost. At transient roosts, bats use a site periodically and remain for a few days at a time. Migratory stopovers are used during species migration.

The amount of selectivity for rest sites typically reflects the degree of physiological stress realized by the individual bat. During the summer months, when resources are more abundant and physiological stress is relatively low, individuals of most temperate-zone bat species spend only a relatively short time each night foraging. And in the summer, there appears to be relatively little discretion in the choice and use of resting sites, although reproductive females are a notable exception and may choose warmer night-roosts to facilitate fetal development and food digestion. Conversely, bats are more selective and often concentrate at specific sites that provide metabolic and physiological advantages as summer ends and food resources diminish; in areas such as elevation extremes and arid landscapes where constraints remain pronounced during the summer; or where suitable roosting resources are rare.

As bats undertake regional and even continental migrations, they incur such tremendous physiological costs that they often must rest and recover at migratory stopovers. These individuals often seek locations where they can achieve torpor, thereby conserving energy and even regaining mass by foraging near the roost.

Short-distance movements at sub-landscape scales are common among many temperate-zone bats. These movements, which often involve local shifts in elevation, occur throughout the spring and fall and typically include unpredictable use of abandoned mines in a given area.

Swarming & Mating Sites: Many species of bats undergo a late-summer and early-fall ritual that is referred to as swarming. Swarming has most often been documented near abandoned-mine entrances and generally involves large congregations of males and females that continuously circle in and around a mine opening. In some cases, swarm sites also function as hibernation sites, and swarming behavior may be a precursor to entering hibernation. Conversely, bats may use one site for swarming and travel to another site to hibernate.

Although the function of swarming activity is not fully understood, it is believed to be a component of courtship and mating. It is generally believed that bats mate while individuals roost on the substrate or even land on the floor of the mine. Some species, such as the California leaf-nosed bat (*Macrotus californicus*), appear to establish specific lekking roosts where males have competitive courting displays that are not used for any other purpose, whereas the degree of association of other bat species with specific mating sites in abandoned mines remains largely unknown. Evidence of swarming includes abundant, but randomly distributed guano immediately inside mine portals, but it is best documented through external night surveys (see Step 3), where swarming behavior is often readily apparent.

Foraging & Drinking Sites: Use of abandoned mines for foraging and drinking has only recently been documented, and some researchers have found that certain species seek out abandoned mines for foraging. Potential prey found inside mines include many invertebrates, such as cave crickets (Order: Orthoptera), moths (Order: Lepidoptera) and beetles (Order: Coleoptera). Bats have been observed leaving their day roost and flying directly to abandoned mines for the first meal of the night. In some areas, specific abandoned mines support microclimates that are so rich in food and water resources that bats can meet all of their foraging and roosting needs within the mine, becoming functional troglodytes (individuals that survive exclusively in subterranean habitats) that rarely venture to the surface.

Many abandoned mines also include standing water that can be utilized by bats and other wildlife. Because the interiors of many mines do not freeze during winter months, water in these

mines remains accessible during even the coldest times, when nearby surface water may be frozen. Access to drinking water during the winter may be critical to many of the smaller hibernating species, such as canyon bats (*Parastrellus hesperus*), tri-colored bats (*Perimyotis subflavus*) and eastern small-footed myotis (*Myotis leibii*) to avoid desiccation.

Additionally, many mine workings intersect groundwater that historically flowed to the surface through a spring or seep. During active mining operations, miners pumped



Insect wings and guano are evidence that bats use the mine as a feeding roost and may even forage within the mine for insect prey.



Water in a mine can provide a critical resource for bats in arid landscapes.

water accumulating in the mine to the surface or provided drainage to keep the mine relatively dry. The cessation of water control when a mine is abandoned often results in the pooling of water inside the mine or even complete flooding. In some cases, particularly in large, deep mines, captured water drains through the mine's depths more quickly than it flows in, lowering the local water table and dewatering local surface landscapes, which

makes access to standing water in the mine critical. This impact is most profound in arid regions, where the legacy of underground mining sometimes includes diversion of all surface water into subterranean environments. When this occurs, underground mines that offer the only accessible water in a landscape become a vital resource, for which bats and other wildlife may travel many miles.

Refugia: Abandoned mines may function as significant refugia that shelter isolated colonies and even populations that survive environmental perturbations. Surface environments and their dynamic roosting structures (e.g., trees, buildings and bridges) can be relatively ephemeral components of a landscape. Dramatic and sudden changes in weather, wildfires and other phenomena can quickly and dramatically alter the surface environment, making it less capable of supporting the bat community.

Conversely, subterranean environments are relatively predictable and stable and often provide an ecological anchor that can maintain a local bat community during periods of stress. For example, use of abandoned mines in the high deserts of central Utah increased by over 300% following large-scale wildfires in 1997. This dramatic increase in use of subterranean habitat by bats included several Guild I and II species (see Table, page 45) that had not been observed roosting underground during three years of pre-fire surveys. Similarly, reproductive female fringed myotis (*Myotis thysanodes*) roost in cold, abandoned mines in New Mexico, presumably to delay birthing due to unfavorable surface conditions. Availability of predictably cool mines in these areas may translate directly into increased fitness for these females as they can delay fetal development and birthing until surface conditions become more favorable for delivering and rearing offspring.

STEP 2.3: UNDERSTANDING BATS & MINES RELATIONSHIPS

Historically, caves and cave analogs were rare, patchily distributed features with locations completely dependent on local geological and hydrological conditions. The roosting landscape likely remained unchanged through historical time as caves formed over prolonged periods with internal changes largely occurring over geologic rather than biological time scales. Even when caves were formed quickly (e.g., lava-tube caves), the end result was a relatively stable environmental feature likely to persist for thousands of years. Thus, the subterranean landscape of North America was relatively unchanged for millennia, providing a template of permanence upon which bats evolved. Caves represented permanent features that roosting colonies of bats would likely have come to depend upon over many generations. As such, patterns of distribution and population sizes of bats that are dependent on subterranean habitats likely remained relatively stable through historical time.

Underground mining was a major industry in parts of the eastern U.S. as early as 1830, and it grew rapidly. An estimated 600,000 underground mines had been created in the western United States alone by 1920. Most of these mines were merely prospects (with limited or no ore removed) and were abandoned shortly after mining began. Others, such as the Comstock Lode in Virginia City, Nevada (one of America's greatest strikes), dramatically influenced the regional landscape. For example, the Comstock came to be known as the graveyard of the great Sierra Forests as timber was harvested for hundreds of miles around to support mining activities. While we do not fully under-

stand how the rapid modification of the subterranean landscape affected all species of bats, it is clear that many species quickly incorporated abandoned mines into their roosting repertoires. Some, such as Townsend's big-eared bats, may have radically expanded their range.

**Step 2.3.1:
Species Guilds**

While nearly all of North America's 46 species of bats have roosted in subterranean features, including species generally considered tree-roosting specialists, some species depend on these features for survival. Bat species' associations with

subterranean habitat must be understood for optimal management of abandoned mines. We propose the assignment of specific guilds based on this degree of dependency. For some species, guild assignments may change as additional information becomes available.

Guild I, Obligate Use (Cavernicolous): Guild I includes species that are dependent on subterranean habitat for their long-term survival. Examples include major colonial species that typically roost in eastern or southwestern caves (e.g., gray myotis, Mexican free-tailed bats).

Truly cavernicolous species were historically constrained by the availability of caves, so their distribution, abundance and natural history were likely molded by the types, conditions and patterns of cave distribution. Because of their continued dependence on subterranean habitat, Guild I species have undoubtedly been profoundly impacted by changes in the availability of subterranean habitat that is the legacy of historical mining. Possible impacts of the enlargement of roosting opportunities in mines include range expansions into areas where caves never existed, changes in distribution within specific ranges, and even changes in the genetic landscape as connections have been facilitated between historically isolated populations.

Dependence of Guild I species on subterranean roosts can vary by season. While the Indiana myotis roosts in trees throughout much of the year, it is classified as a Guild I species because it collapses to a relatively few underground hibernacula during winter months. Similarly, dependency on subterranean roosts may vary across a species' range. For example, populations of Townsend's big-eared bat in the Great Basin region of the United States are largely limited to subterranean features, whereas coastal colonies are commonly found roosting in trees and buildings.



Early bat researchers captured *Indiana myotis* at Pilot Knob Mine, MO.

| Conservation | Scientific Name | Common Name | IUCN Status |
|--------------|---|-----------------------------|--------------|
| I | <i>Choeronycteris mexicana</i> | Mexican long-tongued bat | LR/nt |
| I | <i>Corynorhinus townsendii</i> | Townsend's big-eared bat | VU |
| I | <i>Leptonycteris nivalis</i> | Mexican long-nosed bat | EN |
| I | <i>Leptonycteris yerbabuenae</i> | Lesser long-nosed bat | VU |
| I | <i>Mormoops californicus</i> | California leaf-nosed bat | VU |
| I | <i>Mormoops megalophylla</i> | Peters's ghost faced bat | LR/lc |
| I | <i>Myotis grisescens</i> | Gray myotis | EN |
| I | <i>Myotis sodalis</i> | Indiana myotis | EN |
| I | <i>Myotis velifer</i> | Cave myotis | LR/lc |
| I | <i>Tadarida brasiliensis</i> | Mexican free-tailed bat | LR/nt |
| II | <i>Antrozous pallidus</i> | Pallid bat | LR/lc |
| II | <i>Corynorhinus rafinesquii</i> | Rafinesque's big-eared bat | VU |
| II | <i>Eptesicus fuscus</i> | Big brown bat | LR/lc |
| II | <i>Idionycteris phyllotis</i> | Allen's big-eared bat | LR/lc |
| II | <i>Myotis austroriparius</i> | Southeastern myotis | LR/lc |
| II | <i>Myotis californicus</i> | California myotis | LR/lc |
| II | <i>Myotis ciliolabrum</i> | Western small-footed myotis | LR/lc |
| II | <i>Myotis leibii</i> | Eastern small-footed myotis | LR/lc |
| II | <i>Myotis lucifugus</i> | Little brown myotis | LR/lc |
| II | <i>Myotis septentrionalis</i> | Northern myotis | LR/lc |
| II | <i>Myotis thysanodes</i> | Fringed myotis | LR/lc |
| II | <i>Myotis volans</i> | Long-legged myotis | LR/lc |
| II | <i>Myotis yumanensis</i> | Yuma myotis | LR/lc |
| II | <i>Nyctinomops macrotis</i> | Big free-tailed bat | LR/lc |
| II | ¹ <i>Perimyotis subflavus</i> | Tri-colored bat | LR/lc |
| III | <i>Artibeus jamaicensis</i> | Jamaican fruit-eating bat | LR/lc |
| III | <i>Euderma maculatum</i> | Spotted bat | LR/lc |
| III | <i>Eumops floridanus</i> | Florida bonneted bat | LR/lc |
| III | <i>Eumops perotis</i> | Greater bonneted bat | LR/lc |
| III | <i>Eumops underwoodi</i> | Underwood's bonneted bat | LR/nt |
| III | <i>Lasionycteris noctivagans</i> | Silver-haired bat | LR/lc |
| III | <i>Lasiurus blossevillii</i> | Western red bat | Not Reviewed |
| III | <i>Lasiurus borealis</i> | Eastern red bat | LR/lc |
| III | <i>Lasiurus cinereus</i> | Hoary bat | LR/lc |
| III | <i>Lasiurus ega</i> | Southern yellow bat | LR/lc |
| III | <i>Lasiurus intermedius</i> | Northern yellow bat | LR/lc |
| III | <i>Lasiurus seminolus</i> | Seminole bat | LR/lc |
| III | <i>Lasiurus xanthinus</i> | Western yellow bat | LR/lc |
| III | <i>Molossus molossus</i> | Pallas's mastiff bat | LR/lc |
| III | <i>Myotis auriculus</i> | Southwestern myotis | LR/lc |
| III | <i>Myotis evotis</i> | Long-eared myotis | LR/lc |
| III | <i>Myotis keenii</i> | Keen's myotis | LR/lc |
| III | <i>Myotis occultus</i> | Arizona myotis | Not Reviewed |
| III | <i>Nycticeius humeralis</i> | Evening bat | LR/lc |
| III | <i>Nyctinomops femorosaccus</i> | Pocketed free-tailed bat | LR/lc |
| III | ² <i>Parastrellus hesperus</i> | Canyon bat | LR/lc |

¹*Pipistrellus subflavus* Eastern pipistrelle

²*Pipistrellus hesperus* Western pipistrelle

Guild II, Casual Use: Guild II includes species that exhibit plasticity in roost use; they are commonly found in subterranean habitat, but are neither constrained to nor restricted by its availability. Guild II species include those that roost in trees, rock crevices and even subterranean habitats throughout their range (e.g., big brown bat, northern myotis [*Myotis septentrionalis*]).

Bats that have a casual relationship with subterranean habitat probably responded positively to changes to the landscape surrounding mining operations, since the mines represented a potential ecological release from historical roosting constraints. Many of these species also readily incorporated new surface features (e.g., buildings, bridges, etc.) into their roosting repertoires, perhaps in response to the large-scale removal of roost trees. Guild II species maintain a casual relationship with abandoned mines and in some areas may be dependent on them, but their use and impact are local in scale and do not have implications for species-level conservation.

Guild III, Incidental Use: Guild III includes species that occasionally are found in subterranean environments, but are not restricted to them in any portions of their ranges at any time of year. Guild III species include those that typically roost in trees, such as the Lasiurines (e.g., red bat [*Lasiurus borealis*], hoary bat [*L. cinereus*]).

Bats categorized as incidental users of subterranean habitat likely were not historically influenced by the distribution of caves, so changes in the subterranean landscape had no direct or profound impact on their distributions or current status. However, surface disturbances associated with mining probably had significant local and possibly regional impacts on this group, since mining operations required a tremendous input of resources and energy. Towns and cities were created to provide and support human labor. Logging operations were maintained. Water diversion projects removed water from underground mines or moved water into the mine site for steam power, cooking or a variety of other uses.

Step 2.3.2: Distribution Hypotheses

Understanding where bats roosted within a region before subterranean mining is a central and controversial issue in proactively managing mines for bats and in abandoned-mine reclamation projects. The argument is that abandoned mines were not a part of the historical landscape upon which bats evolved. Thus any modern association of bats with abandoned mines is artificial and does not warrant management consideration. While this question is sometimes aired in an attempt to avoid complexities and costs of mitigation, it is, in fact, an important issue that affects the approach and urgency placed upon addressing the regional loss of abandoned mines.

Ultimately, the historical availability of caves probably restricted the distribution of species that are strongly associated with subterranean habitats (Guild I). The distribution, abundance and natural history of Guild I species were, therefore, likely molded by the types, conditions and patterns of distribution of caves in the landscape. Because of their continued dependence on subterranean habitat, these species have undoubtedly been profoundly impacted by the subterranean landscape that resulted from historical mining operations. The relationship of bats with subterranean habitat can be used as a template to infer responses to local modifications of subterranean landscapes through mining.

Each of the following three hypotheses (Fig. 7) are based on historical constraints

that likely limited species distributions and abundance and of the probable impact of additional roost habitats created through underground mining. These hypotheses are not mutually exclusive and are manifested at different spatial and temporal scales within specific ranges. Determining which hypothesis is most applicable at local or regional scales will dictate the importance of appropriately managing abandoned mines in that region. Simplistic interpretations that conclude abandoned mines merely represent refugia or could only have positive effects are inappropriate and may have serious negative ramifications on species that depend on mines.

Displacement (Refugia) Hypothesis: This hypothesis assumes that abandoned mines represent refugia to which bats have been driven as a result of human disturbance at traditional cave roosts (Fig. 7A). Assuming that abandoned mines are functioning as refugia, the current population is, by definition, lower than the pre-disturbance levels.

There is little question that human visitation at roosts can negatively impact roosting bats and declines in colony sizes of many bat species have been attributed to human disturbance. Researchers report that simply entering a roost site of a maternity colony of Townsend's big-eared bats may cause roost abandonment. While such disturbance likely drives roost selection and site occupancy at local scales, it is unlikely to drive roost selection throughout a species' range (with the exception of species that are ecologically isolated or highly constrained to very specific roosts). For example, researchers have found that many highly disturbed bat colonies had not abandoned caves, despite the nearby presence of seemingly suitable abandoned mines. This suggests that some colonies may be capable of acclimating to human disturbance as long as it remains below a certain threshold.

Roost-limited (Range Expansion) Hypothesis: This hypothesis assumes that the presence of roosts is the ultimate constraint regulating both the distribution and population size of cavernicolous bats. The appearance of abandoned mines relaxed this constraint, and species responded to newly created roosts by changing patterns of distribution, range expansions, increased rates of dispersal and an increase in a species' overall population (Fig. 7B).

The net increase in potential roosts with the addition of underground mines probably resulted in colonies or populations in parts of species range that did not exist before extensive mining in the 19th century. In fact, some species of subterranean-roosting bats likely are now more evenly distributed within the boundaries of their ranges, while some may even have expanded the bounds of their ranges because of abandoned mines. For example, California leaf-nosed bats now roost year-round in regions of the desert Southwest of the United States. Furthermore, large colonies of little brown myotis hibernate in underground mines in the Great Lakes region, where there are no historical records of bats in these numbers in caves.

The Ultimate Constraint (Spilled Milk) Hypothesis: This hypothesis assumes that distributional patterns of cavernicolous species are regulated by the presence of roosts, whereas colony size and the overall population are governed by at least one additional, ultimate constraint (e.g., physiological limitations, available energy) (Fig. 7C). The creation of additional roosts produced a new template for a species distribution without

Fig. 7A. Displacement (Refugia) Hypothesis

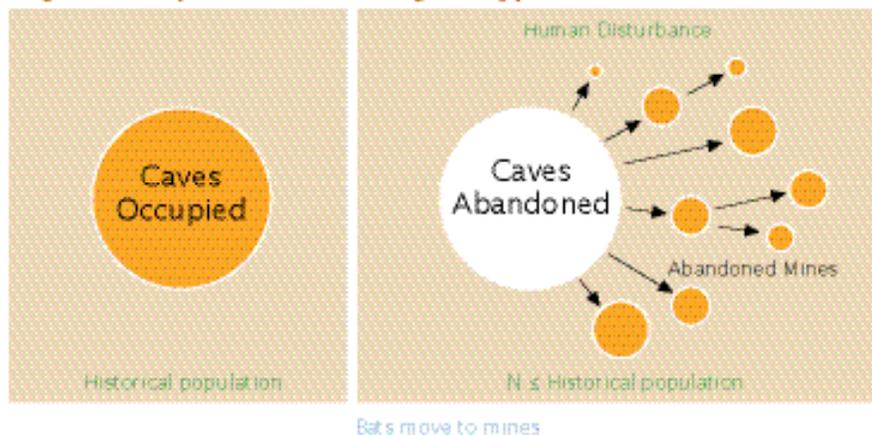


Fig. 7B. Roost-limited (Roost Expansion) Hypothesis

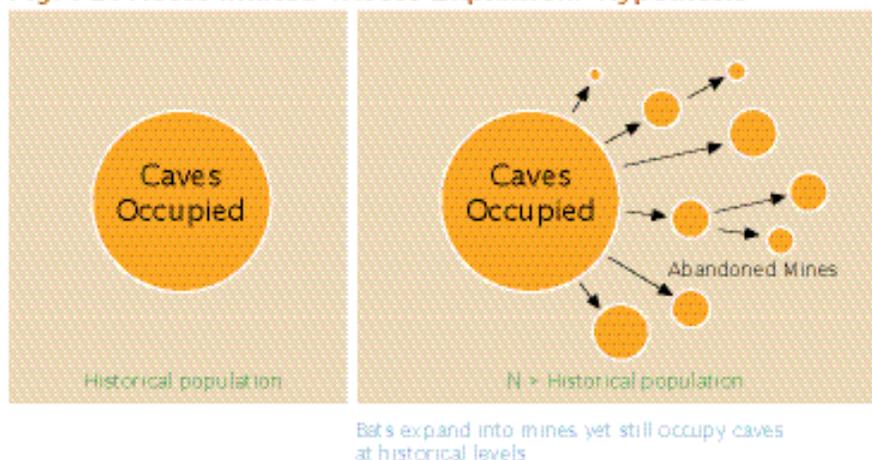
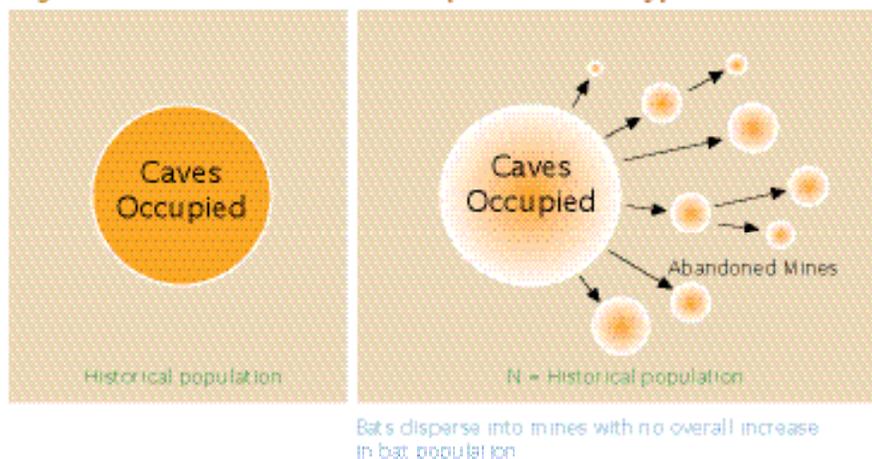


Fig. 7C. Ultimate Constraint (Spilled Milk) Hypothesis



necessarily improving the roosting landscape to allow population increases. In other words, the ultimate constraint remains in place.

If the roost landscape is modified through large-scale mine-closure programs on short timescales, there could be a net loss of bats as individual colonies are unable to adjust local distributions in response to mine closures. This is analogous to spilling milk from a cup, where the milk represents all colonies of bats and the cup all available roosts. The cup originally functioned as a constraint on the distribution of the milk, but by spilling the contents of the cup over the surface of the table, the distribution changes although the total volume of milk remains the same (analogous to an unchanged population of bats moving into abandoned mines). If the milk is then wiped off the table without replacing it in the cup (analogous to mine-closure programs with no regard to bats), the total volume of milk has now been reduced (just as the displaced bats would face a decrease in population).

This hypothesis is supported in Townsend's big-eared bats, where colonies in mines are smaller and more evenly distributed throughout a region than those in caves, suggesting that populations are not

responding to the increased availability of roosts by increasing colony and population sizes. This is further supported in that colonies in abandoned mines decrease in size as one moves further from portions of the range where caves exist.



California leaf-nose bat (*Macrotus californicus*)

Step 2.3.3: Mine Configuration and Mine Environments

Mean average surface temperature (MAST) is an important factor in determining internal mine temperatures. However, internal mine temperatures are also influenced by airflow, which is influenced by mine size, configuration and complexity (Text Box 5). Ultimately, airflow is largely determined by differential external and internal air temperatures and changes in barometric pressure, both of which may vary daily and/or seasonally.

While the processes described in Text Box 5 clearly occurs in many mines, generic models based on these variables have led to oversimplified predictions regarding internal mine temperatures. First, localized mean annual surface temperature is rarely available in remote areas, where many mines occur and major elevation changes can profoundly influence climatic patterns. Secondly, the internal complexity of many mines creates airflow that is contrary to these models. Further, geothermal heating and even solar radiation may influence internal mine conditions. The interactions of these variables on air-



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Bats, such as this tri-colored bat (*Perimyotis subflavus*) covered with condensation, roost in areas of a mine with optimal environmental conditions.

flow and mine temperature are complex and some mines have temperature profiles that are not easily explained. For example, the Tower of Sudan Mine is a large, underground iron mine with multiple openings in northern Minnesota. Its airflow is the opposite of predictions and underground regions are far warmer than predicted based on MAST; physicists familiar with this mine cannot explain why. Similarly, some mines in Alaska are much warmer than would be predicted with this model. Some in extreme southern New Mexico and Texas are either cooler or warmer than would be predicted. Caution, therefore, should be used when developing management plans based on general predictions without verification of site-specific data.

TEXT BOX 5:

SPOTLIGHT ON MINE TEMPERATURE AND AIRFLOW

Three key points help explain how airflow, air temperature and mine configuration interact and influence the internal mine environment. First, relatively heavy cool air sinks and may pool within a mine due to internal mine structures (cold air trap). Conversely, relatively light warm air rises and may be trapped within the upper sections of a mine (warm air trap). Finally, chimney-effect airflow is typically exhibited when a mine has at least two entrances at different surface elevations. In the winter, relatively warm interior air rises and escapes through an upper entrance, creating a vacuum that draws cooler external air into the mine through a lower entrance. In the summer, a reverse chimney effect occurs when cool interior air sinks and escapes from the mine through a lower entrance, creating a vacuum that draws relatively warmer external air into the mine through an upper entrance. More complicated airflow patterns can be exhibited based on local environmental patterns, mine size, configuration and complexity, and even local geography. The presence of strong airflow at an entrance when external air temperature differs significantly from MAST, either into or out of a mine, suggests there is at least one other entrance to the mine. However, the absence of airflow at an entrance does not necessarily mean there is not a second entrance.

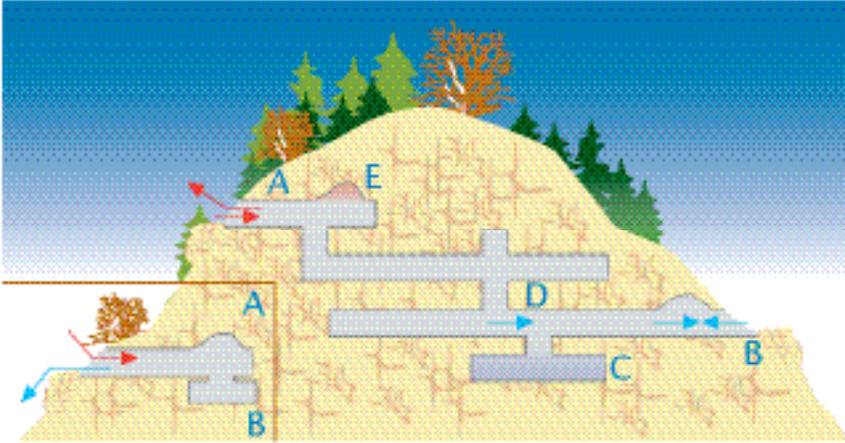
Example 1: Large Mines, Vertical Profile

In the winter, chimney-effect airflow is exhibited at this site as the relatively warm interior air exits from Upper Entrance A. This in turn creates a drop in pressure that pulls cold air into the mine through Lower Entrance B. This cold air is subsequently trapped in the lower sections of the mine (Area C). A reverse chimney-effect airflow pattern would be exhibited in the summer when the relatively cool interior mine walls cool the air, increasing its density. This cooler, denser air flows through lower levels of the mine (Area D) and out through Lower Entrance B when external air temperatures rise above MAST. Relatively warm air would be drawn into the mine through Upper Entrance A and be trapped in overhead stopes in the upper level (Area E). Over time, the air in the mine would be cooled by the walls and seasonally repeat the cycle. Area C would remain a cold-air trap during the summer because the heavier cold air trapped there in the winter is unable to escape.

Example 2: Large Mines, Plan View

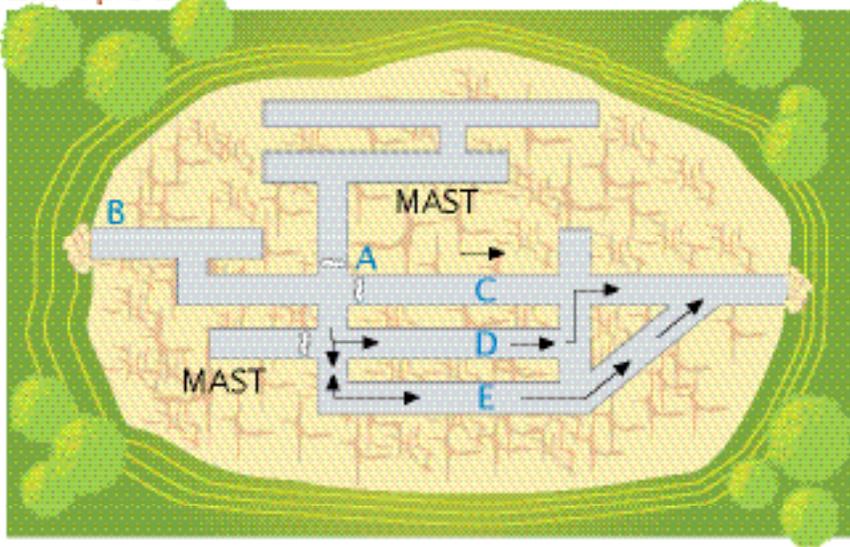
In general, airflow within a mine follows a path based on internal mine complexity and structures. Lateral workings beyond the area influenced by airflow (shaded area) remain relatively stable and reflect MAST. An air dam at Point A redirects airflow entering the mine from Entrance B through Passage C to Passages D and E.

Example 1



Example 3

Example 2



Example 3: Small Mines, Single Entrance

In the summer, airflow may occur in mines with single entrances when external air temperatures rise above MAST. Relatively cool interior air flows out of the mine, creating a drop in pressure, which in turn pulls relatively warmer external air into the mine. The rear of the passage (Area A) and lower chamber (Area B) exhibit relatively stable temperatures that approximate MAST, since external air is not drawn deeply into the mine. This airflow pattern may be repeated daily in the summer and expressed to various distances into the mine based on temperature differentials. In the winter, airflow generally will be limited at this type of mine. However, if the area outside the entrance warms sufficiently above MAST, it allows relatively cooler interior air to flow from the entrance and draws relatively warm external air into the mine in a manner similar to that observed in summer. This pattern has been documented when mine portals are located on warm aspects (generally south- and west-facing aspects), where solar radiation has larger localized influences.

Step 2.3.4: Episodic versus Continuous Use

Bats exhibit varying degrees of fidelity (loyalty) to individual roosts within and among seasons and across years. Furthermore, certain kinds of use are more difficult to detect than others. For example, casual use of an abandoned mine by solitary bachelor males often takes intensive surveys before a site can be ruled out as a non-roost, whereas maternity use is usually much easier to diagnose. This variability in fidelity can make it extremely difficult to accurately identify and quantify bats' use of a specific abandoned mine. That, in turn, greatly complicates efforts to determine the biological or management significance of the site (see Step 1), a key part of reaching appropriate management decisions (see Step 4).

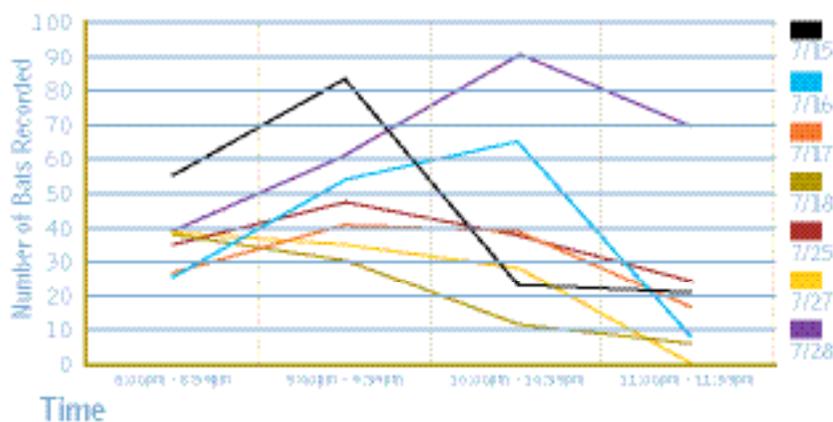
There are three general types of bat activity at abandoned mines in central Nevada (Fig. 8). Mines with Type I bat activity are relative easy to identify since that involves consistently high levels of bat activity. The relatively high levels of bat activity at mines with Type II bat activity are more difficult to correctly identify because the variability in activity (i.e., some nights with little use by bats) can be misleading. Mines with low activity levels are relatively easy to identify because few bats will ever be observed using the site. However, diagnosis is complicated if the bat activity is dynamic, with occasional high levels of use (Type III). Similar patterns of bat activity likely exist at abandoned mines in other regions of temperate North America, but the scale of activity may be dramatically different. Managers must be sensitive to constraints that influence the fidelity of local bats to specific abandoned mines and influence the levels of bat activity on any given night.

Step 2.3.5: Hide and Seek: Where the Bats Roost

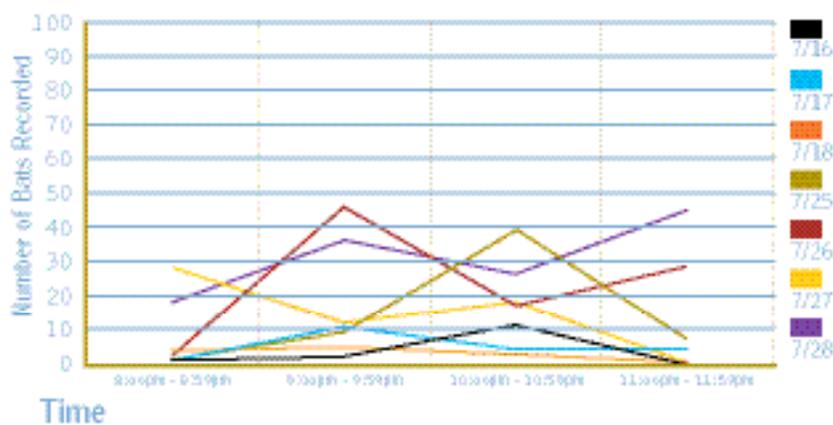
Temperature and humidity drive bats' selection of mines and are often a direct reflection of the mine's internal structure. Variation in the internal structure of abandoned mines is an important component of roosting habitat. Bats roost in a variety of mine locations, including small cracks and fissures (long-eared myotis [*Myotis evotis*]); open

Fig. 8: Three general patterns of bat activity in abandoned mines in Nevada.

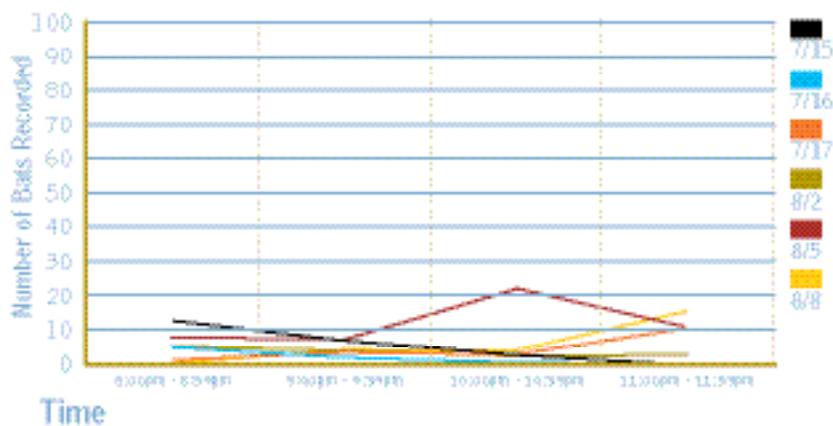
Type I: High-level & Consistent Use



Type II: High-level & Dynamic Use



Type III: Low-level & Dynamic Use



STEP 2: RESOURCE ASSESSMENTS

areas (Townsend's big-eared bat, Indiana myotis, gray myotis, fringed myotis and cave myotis); and spacious, vertical crevices (pallid bat).

The structure of these roosting areas and their spatial distribution within a mine may facilitate protection from predators or provide thermal gradients across different heights. The availability of different temperature regimes within a mine promotes its use by bats, since individuals of different species will be more likely to find preferred thermal conditions to meet seasonal biological needs. Temperature variation caused by a range of available heights has also been described as beneficial for thermoregulating bats, as variable heights allow them to move up and down within a roost to take advantage of thermal gradients. Additionally, many species of bats have strong affinities for particular regions of subterranean features, with some preferring areas of total darkness and others strongly associated with the entrance (twilight) area.

The size of the colony may also influence roost selection within a mine. In some regions, small maternity colonies of Townsend's big-eared bats are strongly associated with dome-like features where they apparently are able to modify their microclimate. However, larger maternity colonies (generally more than 50 mature females) are not associated with any specific roost feature.



Fringed myotis (*Myotis thysanodes*) and other species may seek shelter in crevices and are difficult to detect by inexperienced observers.

STEP 2.4: SINGLE LARGE OR SEVERAL SMALL

The efficacy of abandoned-mine closure programs can be enhanced through an understanding of management options. Within an area, managers are faced with a continuum of decisions ranging from closing all of the mines to protecting all of them for bats. The concept of protecting a single large mine or several small mines (SLOSS) provides a framework to guide management decisions. Protection of a large, complex mine may provide the variability in environmental conditions within that mine for at least several types of use by multiple species. Alternatively, protecting multiple small sites, each representing habitat for different types of use, is a viable alternative. This decision is strongly influenced by the availability and distribution of large and small mines with appropriate environmental conditions in a landscape.

Ultimately, a combined approach of protecting some large and some small mines may be required to ensure that all habitat types (e.g., hibernation sites, maternity sites, etc.) are maintained in a landscape through space and time. Since mines are relatively unstable, a decision to protect additional large and small mines as needed might be warranted to ensure adequate redundancy in the landscape in case a mine with a unique habitat is lost.

STEP 3:

IN THE FIELD



STEP 3: IN THE FIELD

Timing of surveys and preferred survey methods should have been addressed during project planning (Step 1) and are largely reflective of thresholds of significance and organization limitations (e.g., not authorized to enter abandoned mines). Ideally, surveyors will gauge both evidence of occupancy and habitat quality when determining a site's significance. Bat occupancy at time of survey can be assessed using external survey methods, whereas past use, current use and habitat potential can be determined during internal surveys. Habitat assessments require internal evaluation of the subterranean habitat and the collection of a suite of biotic and abiotic variables that can be used to infer quality (and associated significance). Following site evaluations, managers must base reclamation decisions on a balance between physical safety and the practicality of protection versus actual or potential roosting quality and the site's absolute or relative significance in the landscape.

Concept Planning Check Box

Step 3.1: Locating & Identifying Mine Features

Step 3.2: Season of Survey

Step 3.2.1: Cold-Season Surveys

Step 3.2.2: Warm-Season Surveys

Step 3.3: The Choice: Internal or External Surveys

Step 3.4: Internal Surveys

Text Box 6: Signs of Bats in Mines

Step 3.4.1: Internal Survey Techniques

Step 3.4.2: Evaluating Mine Shafts

Text Box 7: Procedures to Evaluate Vertical Workings

Step 3.5: External Surveys

Text Box 8: External Clues to Internal Conditions

Step 3.5.1: External Survey Techniques

Step 3.5.2: Exit Surveys

Text Box 9: What Does it Buy? Understanding the relative costs of internal and external surveys

STEP 3.1: LOCATING & IDENTIFYING MINE FEATURES

Regardless of the amount of pre-survey data collected, locating abandoned-mine openings in the field can be extremely difficult and time consuming. In many cases, portals are hidden by encroaching vegetation or have become partially closed because of erosion. Waste-rock piles (dumps) are often associated with mine portals and may provide a guide in arid landscapes with limited vegetation. That approach, however, is often ineffective in areas of dense vegetation. Even when vegetation is not a problem, many portals

do not have dumps associated with them (e.g., open stopes, ventilation shafts) or the dumps have disappeared (e.g., removed for further ore extraction or by erosion processes). Regardless of survey intensity, some openings without dump material (e.g., open stopes or raises driven from inside) may only be discovered during internal surveys.

In many circumstances, several field crews, including biologists, archaeologists, geologists, hydrologists, land surveyors and closure crews, will need to visit each mine opening scheduled for closure. Therefore, each opening included in a project must be clearly identified with an unambiguous, permanent monument or marker. Positioning a metal stake with a stamped feature number directly in the substrate at a mine opening, in conjunction with accurate Global Positioning System (GPS) coordinates, is the best long-term option for identifying individual openings. GPS coordinates alone, however, will be useless if GPS location error is greater than the distance between discrete mine openings, and if it is not clear at which part of the opening the GPS reading was taken. Furthermore, the position of the monument (in relation to the opening) should be recorded on pre-survey datasheets to limit confusion in the field. Short-term markers (e.g., paint, flagging, wooden stakes) are unreliable. They can quickly disappear, leading to confusion that can undermine conservation objectives and result in the protection of incorrect mines and even in the permanent destruction of important bat habitat. The authors have worked on many projects where careless recording and lack of clear site identification caused project delays, increased costs and even resulted in closures and gating of incorrect sites.

Upon locating and marking each opening, an initial site evaluation should be conducted (see Appendices). Crews should collect standardized pre-survey data, which at a minimum includes an accurate location, site description, photographs, map and detailed access information for each opening. Additional recorded data should include the type of opening (e.g., shaft, adit, open stope), dimensions of the opening, conditions of the opening and immediate surroundings. Inward or outward airflow is often an important indicator of internal complexity and perhaps of other, interconnected openings and should also be noted. Ranking the level of hazard associated with each mine opening can help prioritize them for management action (Nevada Bureau of Land Management's Hazard Identification⁹).



Reconnaissance teams that locate individual mine features in vast landscapes and collect critical data will expedite further assessments by specialized crews.

⁹Mine Hazard Rating: www.leg.state.nv.us/NAC/NAC-513.html#NAC513Sec320

STEP 3.2: SEASON OF SURVEY

The timing of surveys has been a critical discussion point among those actively involved in abandoned mine reclamation.

Step 3.2.1: Cold-Season Surveys

Cold-season mine surveys undertaken to find bats or evidence of bat use must, by definition, take place when bats are inactive. Hibernating bats leave limited or no trace of their presence, so entry is required to survey for them. An exception might be when pre-hibernation swarming is detected by external surveys. However, surveys during swarming periods may not reflect species composition or numbers of bats hibernating in the mine. Careful inspection of even tiny cracks or holes in the back and rib is necessary since several species of bats hibernate in such spaces. The evaluation of sign (e.g., guano, staining, discarded invertebrate parts, remains of dead bats), unless present in very large quantities, requires an experienced eye. But a veteran surveyor should be able to identify the guano of many species or most genera likely to be encountered.

Internal surveys are required to detect cold-season use.

If bats are encountered in a cold-season survey, they must be identified with the least possible disturbance. With few exceptions (i.e., California myotis [*Myotis californicus*] and western small-footed myotis), an experienced surveyor should be able to correctly and quickly identify any species found using an abandoned mine. Disturbance should be minimized by not orienting light beams directly on hibernating bats. Exact counts of clustered or scattered bats may not warrant the disturbance involved, and a quick estimate of numbers or of the size of a cluster is usually adequate for making abandoned-mine reclamation decisions.

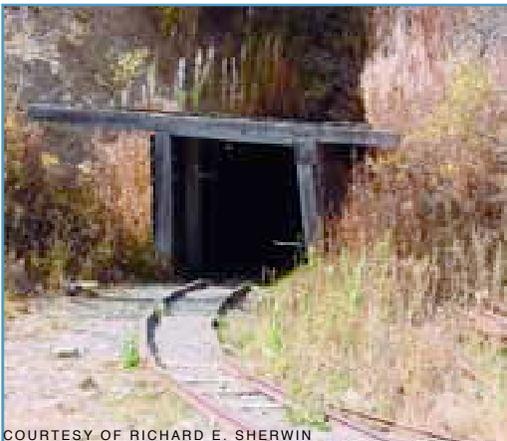
In these cases, experience is a key requirement for an underground surveyor. Only an experienced surveyor is likely to find the subtle signs of use produced by all but very large numbers of bats. Highly skilled underground explorers without bat experience (e.g. miners, geologists) are notorious for completely missing conspicuous bats and obvious sign simply because they are not trained to recognize such evidence.

Step 3.2.2: Warm-Season Surveys

In general, warm-season surveys are conducted when bats are active and flying on a regular basis. The exact time of year will vary geographically and by local climatic conditions, and some species remain active year-round (e.g., California leaf-nosed bats in the desert Southwest, southeastern myotis in the Southeast). An unusually cold or prolonged spring may delay maternity activity by many weeks and influence when and how bat use is exhibited at a mine. Consultation with local biologists is necessary to time warm (active) 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 the warm season should be conducted with extreme care. Mine openings should be approached carefully, then entered and explored quietly during a warm-season survey. In general, disturbing alert bats to facilitate identification or for colony counts is not warranted. If bats cannot be identified or roughly counted without disturbing them, then an external evaluation involving an experienced interpretation is warranted. However, surveyors must always keep in mind that the primary objective is to correctly identify bats' use of the mine so that an appropriate management decision can be reached. Thus, a short-term disturbance that produces the correct recommendation is preferable to avoiding any disturbance but reaching inaccurate conclusions and recommendations.

In many cases, internal surveys reveal evidence of bat use, although no bats are present at the time of the survey. This may indicate casual, seasonal use of a site, or it could be indicative of more eruptive but critical types of use (migratory sites, night roosts, etc.). In these cases, accurate diagnosis of the exact type of use (along with the significance of the site) may require more intensive survey efforts. If the reclamation-program objectives dictate, documenting specialized types of use may require refined techniques and extensive survey efforts. For example, bats are seldom encountered during internal surveys of mines that are used as migratory stopovers; their identification requires specific timing and particularly intense surveys. If the objectives dictate, repeated visits may be required in the time frame when such use is likely, so that surveyors increase their likelihood of identifying the timing of specific uses. Material (boards or drop cloths) placed on the floor where guano accumulates can often reveal the times of use and the relative amounts of guano deposition. The recent discovery of mines used entirely for complex reproductive behavior demonstrates highly significant, periodic use that was initially difficult to resolve. Repeated external and internal observations were required to clarify this highly significant use after evidence was noted on an internal survey. Furthermore, bats are rarely encountered during the day in mines used as night roosts. If



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Season of survey influences detection of bats' use of mines.

no bats are located in a mine during an internal, daytime assessment, surveyors should evaluate guano for the presence of invertebrate appendages and wings, which would suggest night roosting. If night roosting is suspected, the mine can be entered at night, or external surveys might be conducted at portals.

STEP 3.3: THE CHOICE: INTERNAL OR EXTERNAL SURVEYS

Decisions regarding the fate of abandoned-mine openings should never be taken lightly, as the selection of closure type may have long-term ramifications for bat populations throughout a broad geographical area. The person charged with making these decisions should acquire as much reliable information as possible about the internal conditions within each mine and conduct appropriate biological surveys to reveal how bats actually use the mine. When evaluating abandoned mines for use by bats, surveyors must decide if they can safely enter the mine (or will be allowed to) to conduct internal surveys. Alternatively, surveyors may choose external surveys. When safe and feasible, however, internal mine assessments are recommended over external surveys because they provide critical insights into what resources the subterranean habitat provides for bats.

Both internal and external survey methods have their place, and each should be used when appropriate to address specific questions of interest. However, it is inappropriate to assume that both methods can provide synonymous data. Quick and reliable diagnosis of past, present or likely future use of a mine can best be made through internal surveys. While external surveys have merit and applications, they are a poor tool for making many reclamation decisions about abandoned mines. However, in cases where access is precluded for any reason (e.g., due to safety concerns, regulations, lack of qualified surveyors), external surveys should be conducted under recommended protocols that collect adequate data for the scale of management.

As abandoned mines increasingly are recognized as important bat-roosting habitat, debate concerning the best survey methods also increases. Questions regarding survey intensity, timing and minimum types of data to collect are repeatedly aired. Numerous survey protocols have been written by state and federal management agencies, state bat working groups, consulting companies, individual surveyors and various contracting offices. However, these protocols are sometimes contradictory, may include erroneous information and have contributed to disagreements among partners who should be working together. Ultimately, much of the debate over specific survey protocols may simply reflect the fact that no generic protocol can possibly be effective for identifying all types of use of abandoned mines by all species of bats across temperate North America. Furthermore, if a comprehensive survey protocol were developed based on scientifically defensible data, most managers could not afford the financial expense of implementing it. In the end, management decisions should be based on sound data collected with appropriate techniques and with the limitations of the methods understood and accounted for in the decision-making process.

No single survey protocol can reliably identify all types of use.

Determination of preferred survey protocols and methods are best done during the planning phases. Clear articulation of absolute and relative significance (see Step 1) will drive selection of the type, duration and intensity of surveys that are required to achieve project objectives. The choice of survey technique and intensity of survey effort are reflections of budgets, time limitations and availability of qualified personnel. Typically, no single survey technique can address the objectives of every project, so a combination of approaches may be required. Management recommendations based on survey data should explicitly recognize the limitations of the technique(s) used to collect the data.

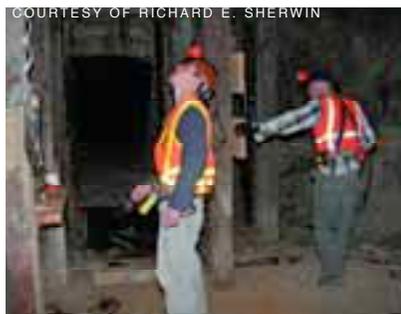
Emerging threats: Many bat species use abandoned mines as summer roosts and hibernation sites, often in large numbers, which leaves them susceptible to infectious disease. That risk became disastrously clear in 2006 with the discovery of White Nose Syndrome (WNS) among cave- and mine-roosting bats in the north-eastern United States. The syndrome, with mortality rates of 95% or more, has spread well beyond the region.

When deciding whether mine entry is necessary, the benefits of an internal survey must be carefully weighed against the potential risk of transferring WNS or other diseases. We strongly recommend that internal surveys follow accepted decontamination protocols for known infectious-disease risks.

STEP 3.4: INTERNAL SURVEYS

During internal surveys, researchers can directly observe evidence of current and past occupancy, such as roosting bats, guano, culled insect parts, staining, carcasses and odors (Text Box 6). Since biological residues of roosting can be detected, bats need not be present for use to be diagnosed. Surveyors can also collect information that will help determine the relative quality of the subterranean habitat for bats and infer likely types of use the mine could support. Internal size and complexity, environmental conditions and available resources (e.g., water, insects) in the mine can all be studied. Additionally, underground surveyors can determine subterranean connections to other surface openings, which could prove critical for complete protection of the habitat. Situations that favor internal surveys include:

- Large, complex underground mines with the possibility of multiple openings;
- Small, simple and stable mine prospects;
- Areas with many scattered openings where underground connections are unknown;
- When time for surveys is limited;
- When an understanding of interconnections is required to maintain airflow to support significant bat use;
- When diagnosing winter use.



Internal assessments offer the opportunity to better identify key uses of the mine by bats and develop more robust management recommendations.

TEXT BOX 6:

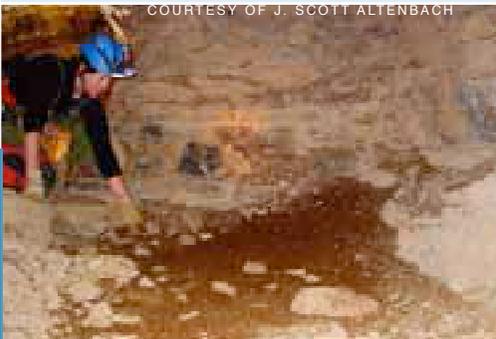
SIGNS OF BATS IN MINES

Evidence of bats in mines comes in many forms, including new and old guano, roost stain, culled insect parts, dead and/or live bats. Careful evaluation by an experienced professional will not only locate such evidence, but will interpret it in context, providing insights into the type of use it may represent.

The presence of bat guano typically indicates warm-season use by bats or at least use prior to the cold season. Surveyors must be able to distinguish bat guano from rodent feces.

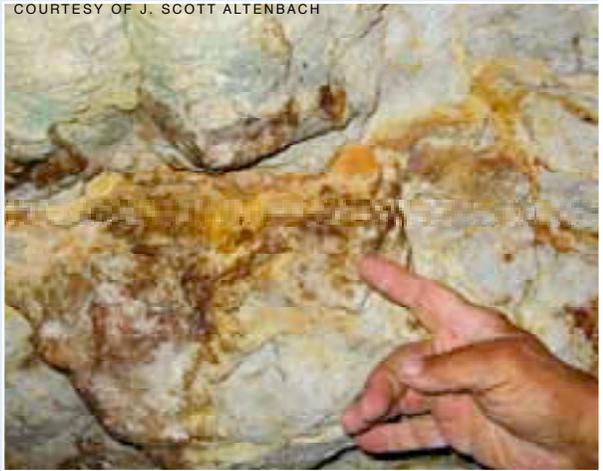


Conducting the Sparkle Test (crushing presumed guano pellets) can reveal shiny bits of insect exoskeletons and document use by bats. Rodent feces is most often composed of fibrous vegetative matter, a reflection of their diet.



Guano accumulations can be obvious when associated with large numbers of roosting bats (e.g., a maternity cluster), or guano can be so sparse that even noticing it requires an experienced surveyor.

Staining on a mine's rib, back and around cavities in the back can indicate warm-season use by bats. Staining can also be found in hibernacula that have been used by many bats for extended periods.



Discarded body parts of insect prey can be indicative of night-roosting activity.

In addition to visual clues, the odor of bats and their guano is also an important tool for surveyors. Some bat species have associated odors that can be diagnostic. For example, excrement of nectarivorous species in the desert Southwest (lesser long-nosed bats [*Leptonycteris yerbabuenae*], Mexican long-nosed bats [*L. nivalis*] and Mexican long-tongued bats [*Choeronycteris mexicana*]) produces strong, aromatic odors that are often detectable some distance away from the roost and in some cases, from outside of the mine. Similarly, glandular secretions produced by a variety of insectivorous species such as the pallid bat, Mexican free-tailed bat and cave myotis are equally diagnostic.

Step 3.4.1: Internal Survey Techniques

Before conducting an internal mine assessment, surveyors should:

- Be familiar with both the anticipated species and the mine resource (Step 2).
- Undertake safety training prior to entry into any abandoned mine, no matter how benign it may appear.
- Have an established safety plan. An individual stationed outside the portal can assess external weather conditions and remain in contact with underground crews on an established schedule. This individual should have sufficient training and expertise to determine when conditions might negatively impact the safety of underground crews. A project-specific protocol, with contingencies, should be established to dictate the monitor's responses to various conditions if timed contacts are not made. At a minimum, the location of the project mines and extraction protocols should be given to an offsite coordinator. The external monitor should record the start time of surveys and remain in the safe zone near the mine portal throughout the internal assessment. All communication with underground crews should be recorded and any changes in surface conditions described to underground crews. The responsibilities of the surface monitor are not trivial and should never be relegated to an untrained third party. Surface monitors should be prepared to terminate internal surveys whenever conditions become problematic.
- Become completely familiar with the pre-survey data (particularly if collected by others), with special attention to any historical documentation associated with the mine's interior. Mine maps, descriptions and other records can provide invaluable information about potential hazards, such as a propensity for bad air, accounts of internal water and the presence and extent of lower and upper levels.
- Confirm identification of openings by locating the installed monument. Any external data of interest that were not included in pre-surveys should be collected. Pre-survey data should be referenced and any changes to the opening (e.g., increased sloughing, collapse) or surrounding area (e.g., structures destroyed, site identification markers damaged) should be documented.
- Examine surface features to gain insight into the internal structure and to infer the presence of hazards in the mine.

Internal-survey crews should consist of at least two people. Each surveyor should be equipped with appropriate safety equipment and be thoroughly trained in its correct use and limitations. We recommend partitioning of assignments while underground. One individual should be tasked with conducting biological evaluations and collecting associated internal data, while another should focus solely on human safety. Surveyors should move slowly and meticulously through the workings and maintain constant communication. Red lights are inappropriate for use in abandoned mines; they do not provide suffi-

cient light to locate and avoid internal hazards. Likewise, surveyors should speak at sufficient volume to ensure that communication is maintained. If bats are encountered, hand gestures and light signals can be used for basic communication, provided they are specifically determined in advance. It is far more important to get safe, accurate data than it is to avoid short-term disturbance to bats. Careful searches of cracks and crevices can reveal saxicolous (bats living in rock crevices) species, while atypical features that alter the contour of the back (roof), such as stopes, raises and shot holes, should also be meticulously scanned as these are attractive to many species of bats.

Surveyors should use the “miner’s walk:” two steps forward followed by a pause as the next two steps are scanned for partially concealed winzes or other hazards and the ground scanned for guano, insect parts or other signs of bat use (see Text Box 6). Of course, the types and intensity of data collected during internal surveys are dictated by the objectives, as established in Step 1. At a minimum, surveyors should record the date and time of survey, names of surveyors, a sketch map of internal workings (including all openings with their unique identification numbers) and the location and specific identification (if known) of any bats or associated signs. Meteorological conditions at time of survey should be recorded throughout the mine. If needed, dataloggers can be installed so more accurate thermal profiles can be created. Notes should also be made of any internal hazards and whether or not the entire mine was surveyed.

Step 3.4.2: Evaluating Mine Shafts

In many mining districts, mine shafts are relatively common and may constitute a



rappelling into mine shafts should only be done by qualified individuals who can fully assess the mine collar for stability.

high proportion of abandoned workings. Because of the greater difficulties involved in surveying shafts, many are not evaluated before closure. Although some have been secured with non-destructive closures (e.g., air grates; see Step 4), many have been closed destructively with little or no biological evaluation. In general, when surveys of vertical workings are conducted, they are often limited to a few hours of external survey and a failure to detect bats is used to clear a site for destructive closure. Notable exceptions to this superficial consid-

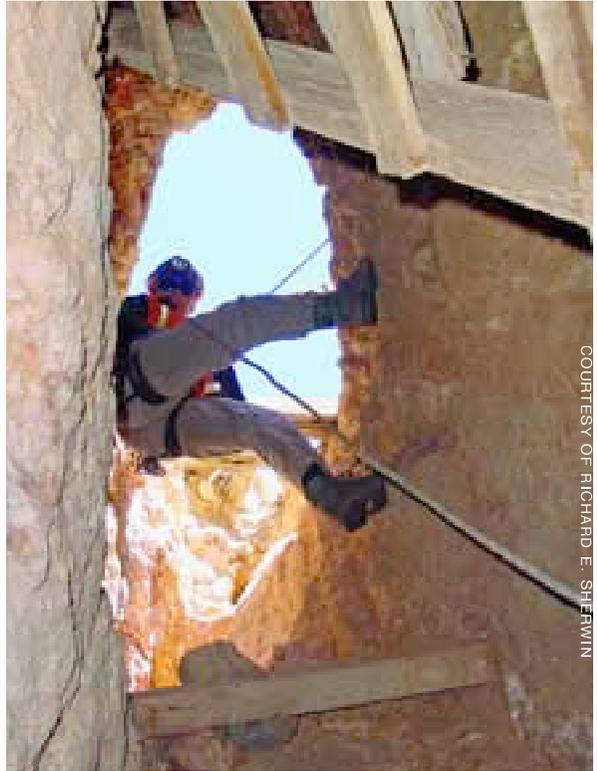
STEP 3: IN THE FIELD

eration of mine shafts as potential bat habitat have been the Abandoned Mine Lands programs in New Mexico and Utah, where shafts have been systematically evaluated, most internally, and bat-compatible closures have been constructed where use has been documented.

During more than 15 years, the authors (RES, JSA) have evaluated over 2,000 shafts in New Mexico, California, Nevada, Utah, Minnesota, Arizona and Texas and found that bats readily use these vertical resources. In some regions, shafts represent a significant amount of habitat, and the incidence of bat use can actually be higher than that found in horizontal workings. Even blind shafts (without lateral workings) trap cold air and can be ideal hibernation sites for bats. Other shafts are warmed at depth, providing suitable climates for all types of warm-season use.

If internal evaluation is not feasible in a specific shaft, it is prudent to assume that it represents potential habitat and that the mine feature should be surveyed externally. Alternatively, a down-the-hole video camera system, hard-wired to a surface viewing screen, can be an effective tool to determine whether a shaft is shallow and blind, and thus would not require time-consuming additional evaluation (see Step 3.5). However, this technique is not a substitute for internal evaluation of shafts with lateral workings, deep shafts or timbered shafts where bats or bat sign is probably not visible to the video camera. Highly significant hibernation sites for several species have been found to depths of nearly 3,000 feet and maternity and bachelor colonies at depths of more than 400 feet.

Although shafts and other vertical workings can provide bat habitat and be safely evaluated, managers must understand that such surveys require specialized equipment and a high level of experience. If these requirements cannot be met, then external-survey options (see below) are recommended. When adequate assessments of shafts cannot be made, managers should err on the side of caution within the objectives of the reclamation project and consider bat-compatible closures as the default reclamation method (Step 4).



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Rappelling in a mine shaft requires qualified people to carefully identify and avoid internal hazards during descent and ascent that may not have been visible from the surface.

TEXT BOX 7:

PROCEDURES TO EVALUATE VERTICAL WORKINGS

All easily accessible horizontal workings should be surveyed prior to any evaluation of vertical workings (shafts, winzes, etc.). In all cases, the benefits of potential data collected in vertical portions of mines should be weighed against the risks to human safety. Vertical work is much more difficult and dangerous because of the likelihood of material falling from the collar or rib. Surveyors must be fully trained and experienced before undertaking such activities. The following procedures should be followed to ensure safety while evaluating vertical mine workings.

Evaluation of Hazard

- State and condition of collar
- Determination of timber integrity (if present)
- Remote testing of air quality

Location of Anchor Point

- Nearest load-capable anchor point selected (conduct fall test)
- Preference is two, but minimum of one backup anchor point
- Inspect rope during each use
- All anchors and knots done by one surveyor
- All anchors and knots inspected by both surveyors

Joint Evaluation of Hazards

- Discuss hazards specific to each pitch
- Describe hazards to surface safety person
- Establish maximum amount of time before communication

During Descent or Ascent

- Remain constantly aware of hazards
- Abort survey immediately if safety must be compromised
- At least one surveyor remains at top of each pitch
- Maintain constant communication (voice or radio) with partner

The Altenbach Shaft Evaluation System

For more than 15 years, one of the authors (JSA) has safely conducted well over 1,000 comprehensive mine-shaft evaluations, using an apparatus of his design. It uses an off-road vehicle with a long boom assembly and hydraulic-drive hoist equipped with non-rotating cable. The surveyor's conveyance is a steel boatswain's chair (the "cage") that is attached to the cable with a carbon-steel protective screen above it. The screen and cage are designed to absorb and distribute forces from even a tremendous impact. The surveyor communicates with a hoist operator and a belayer via mine-rescue, voice-powered phones and is attached to a safety rope manned by the belayer. A second rope is attached to the cage and can be used for emergency pullout in case of hoist failure. Every component in the system is designed with a mechanical factor of safety of at least 10 and the hoist and hoist cable to a factor of 50. Every system has triple redundancy.

Critical to the use of this apparatus are detailed safety procedures and contingency protocols. For example, should phone communication fail, alternative whistle and rope-pull signals can be used. If the surveyor should fall off the cage and communication by phone is lost, a precise series of contingency plans are implemented that will eventually result in the extraction of the surveyor. Managers should be extremely cautious when considering working with any person who proposes using this type of system and should carefully weigh the qualifications and experience of the surveyors and their system against the value of the data that could be obtained.



Scott Altenbach prepares for a descent into a mine shaft. Note the rock guard located above his head that has deflected rocks that have been inadvertently knocked loose during internal surveys.

STEP 3.5: EXTERNAL SURVEYS

When internal access is not feasible or is prohibited, management recommendations must rely instead on external evaluations. Because surveyors must infer much more about internal structure based on external clues, they must become familiar with historical mining and the resource in question (Step 2). When relying on external evaluations to guide management decisions, managers must factor in the limitations of trying to quantify a resource that cannot be visually inspected. They should err on the side of caution when making closure recommendations.

External surveys involve actively or passively monitoring mine openings for bat activity, and analyzing the results to infer use and habitat quality of the mine's interior. The types of survey tools used and the intensity of the effort are determined by project objectives, budgets, time limitations and availability of qualified personnel. No single external-survey technique can do all things for all people, so a combination of approaches and tools usually will be most appropriate. When interpreting data, managers must always consider the limitations of the survey techniques.

Exit surveys provide no information about internal conditions or about past or potential use, and ultimately require surveyors to make assumptions regarding underground connections among openings. Despite this serious issue, external surveys are a powerful tool for resolving exit patterns (identifying portals most heavily used by bats) once connections have been established. They can provide behavioral data and non-invasive colony censuses and can be used to document changes in colony size and behavior following gate installation.

External surveys are based upon these underlying assumptions

- All openings to a mine have been identified (otherwise bats may exit through an unmonitored opening).
- Bats will use sampled openings.
- Any use of the mine by bats will be expressed during the survey.
- The survey method (e.g., night vision, red light, etc.) is sufficient to detect use.
- If bats are present in or use a mine, they will be active and observable at time of the survey.

In many cases, these assumptions are invalid or violated as logistical and financial constraints override the need for complete biological assessments of hundreds of mine features in a region. Situations that favor external surveys include:

- When accurate counts are required for subsequent determination of population trends.
- When data are needed to identify which of several entrances are used by bats.

TEXT BOX 8:

EXTERNAL CLUES TO INTERNAL CONDITIONS

Occupancy by active bats at time of survey should never be the sole gauge of habitat use or quality. Collecting extensive information on internal mine conditions is required, since bat activity can vary greatly at mine sites (Step 2) and because many species primarily use abandoned mines in winter, when exit surveys cannot be conducted in some regions. Even if surveyors are precluded from entering a mine, they can nonetheless utilize a variety of remote-monitoring tools to collect internal data.

Historical archives can be invaluable in understanding internal mine complexity, location of openings and even subterranean conditions. For example, mine maps are usually of sufficient quality that exact locations of all mine openings can be located. Airflow in or out of these openings is a likely indicator of maintained connections with other openings. Additionally, maps will indicate internal complexity, depth and volume, at least at the time the map was prepared.

Clues about a mine's interior can also be gathered through analysis of surface artifacts and the surface area surrounding the mine opening¹⁰. The following are potential indicators of internal mine complexity that can complement external surveys and provide a more comprehensive assessment of bat habitat:

- Airflow out of or into an opening suggests that at least one other opening into underground workings exists, either higher or lower than the one with airflow.
- A large dump indicates significant amounts of material were removed from underground. Conversely, a small dump does not necessarily imply low volume or non-complex internal workings since the material may have been removed.
- A dump containing distinctly different colors of waste rock is an indicator of possible lateral workings.
- The presence of short lengths of oversized rail (larger than mine rail) on the dump suggests the possibility of an ore pass or underground stoping.
- Pieces of small-diameter cable or large pulley blocks in waste rock or on the dump indicate the possibility of stoping.
- Parts of ore cars (e.g., wheels, broken wheels, axles, boxes) or a cage on a dump associated with a shaft indicates the possibility of lateral workings from the shaft.
- Ore bins associated with a head frame at a shaft and ore loadout suggest lateral workings and perhaps stoping underground.

¹⁰Twitty, E. 2000. Riches to rust: a guide to mining in the old West. Western Reflection Publishing Co., Montrose, Colorado. 392 pp.

- Trash (e.g., cans and other discarded items) from different historical eras suggests a large mining operation operated over an extended period of time and is an indicator of internal mine complexity.
- Evidence of structures such as mine offices and bunkhouses is indicative of relatively large mining operations, whereas tipples or ore bins reflect ore removal (producing stopes).



ALL IMAGES COURTESY OF J. SCOTT ALTENBACH

COURTESY OF J. SCOTT ALTENBACH



Knowledge of mining history allows individuals to better interpret external evidence of past mining to gain inference into the interior workings of a mine. Note: Even logical interpretation of external mining artifacts may yield inappropriate conclusions because miners often recycled their materials or moved waste rock removed from the mine.

Step 3.5.1: External Survey Techniques

In addition to the use of external clues to infer internal structure and habitat, a variety of tools will allow limited remote sensing of abandoned mines without requiring surveyors to break the plane of the mine opening.

Spotlights: High-powered spotlights can produce illumination similar to vehicle headlights. Simply shining a light of this type (1 million candlepower minimum) can easily illuminate underground workings to considerable depths. These lights are most effective at night, when surface contrast is minimized. Spotlights can provide some indication of internal structure and condition, including minimum depth, presence of standing water, possible lateral workings and ore passes. In some cases, spotlights may even reveal evidence of biological use in the form of flying bats, guano piles or culled insect remains. Spotlights are most appropriate for assessing easily observable portions of linear workings, and a lack of direct observation of biological signs in such areas should not be interpreted as evidence of the absence of bats.

Downhole Camera Systems:

Commercially available downhole camera systems include a closed-circuit camera (with temperature probe) that is connected to a monitor with 150 feet of coaxial cable (longer if modified). These cameras can be lowered down vertical workings using a pole-and-pulley system, and the camera can be operated from the surface, where the signal feeds to a monitor. With such a system, surveyors can differentiate blind shafts from those that include working levels, gauge internal stability and even collect temperature data with some models. However, shafts that are even slightly off vertical and those with plate timbers on the footwall are sometimes nearly impossible to evaluate with these camera systems. This same system can also be fed into an adit using a remote-controlled vehicle. Camera resolution and remote controls are sufficiently developed that lateral workings are readily apparent and with patience, clusters of bats, and even individuals, can be observed.



COURTESY OF RICHARD E. SHERWIN

Image from a downhole camera system.

Thermal Probes: Dataloggers can be lowered into shafts or placed into adits using a variety of techniques. A simple pole-and-pulley system can be used to lower dataloggers into shafts and anchor them at a desired depth. Dataloggers can be placed in horizontal workings by a tethered, remote-controlled vehicle or similar device. In either case, dataloggers can be left in place for a predetermined period of time and then retrieved using tethers. While dataloggers placed in this manner will hardly provide a thermal profile, they can provide insight into the degree of climatic buffer within the portions of the mine accessed through that portal.

Step 3.5.2: Exit Surveys¹¹

The most commonly used method for the external evaluation of abandoned mines involves the direct measure of bat activity at mine portals of interest, with bat activity as the sole gauge of site importance. A variety of tools have been used for this purpose with varying degrees of effectiveness.

Passive Methods

Drop Cloths: Bats readily defecate during flight, broadcasting evidence of their activities throughout their roosts. However, guano can quickly disappear among debris in and around mine portals. Drop cloths of plastic or other materials will intercept guano from bats flying through mine entrances before it is hidden by debris. Constructed on a simple frame, a drop cloth can be deployed into the mine entrance on the end of an extension pole and left in place for a specified period of time. Upon retrieval, relative levels of bat activity can be assessed; species may, in some cases, be qualitatively determined or they can be confirmed through genetic analysis. This low-cost approach can provide invaluable data about the relative use of a mine by bats, especially at adit portals.

Event Counters: Remote-monitoring devices (e.g., Trailmasters©) can be deployed in mine openings to quantify bat activity. These devices project an infrared beam and record the date and time whenever the beam is broken. While there is no way to distinguish how many individuals or even what organism caused each event, this nonetheless can be a powerful and cost-effective tool for revealing areas of “potential” bat activity and can help determine where additional survey resources should be deployed.

Active Methods

Unaided Visual Observation: This technique simply involves at least one individual watching an opening for bat activity for a period of time, usually until darkness makes reliable observation impossible. Hand counters can facilitate quantifying bat activity. This method is not generally recommended, however, because it is costly and usually provides data of limited value with no verifiable record to more accurately quantify and confirm the use.

Night-vision Scopes and Goggles: With quality night-vision equipment, surveyors can directly observe bat activity in and around an opening from a remote location. These devices can be used in the darkest of conditions. However, high-quality night-vision technology is expensive and provides no permanent record of data. This is an especially costly approach for external surveys since only one opening per night-vision device per person can be observed at a time.

Video Cameras: Low-light video cameras and night-vision cameras with built-in infrared LEDs and associated optics can be remotely deployed and provide a permanent

¹¹Kunz, T.H. 1988. Ecological and behavioral methods for the study of bats. Smithsonian Institution Press, Washington, D.C.

STEP 3: IN THE FIELD



Quality night-vision scopes can be powerful tools at some mines where the size of the opening limits the functionality of other methods.

anticipate the time and cost of video analysis and realize that final results and recommendations may take several months to complete. Further, the IR lights built into standard video cameras do not typically broadcast sufficient illumination for most survey needs; supplemental LED arrays are recommended to enhance video quality.

Capture Techniques (Mist Nets and Harp Traps): Capturing bats as they leave or enter mines can provide data that are not available through any passive survey method. Species, sex, reproductive condition and other natural-history data can be collected from captured animals and mine use inferred from those data. While various capture techniques can be valuable for assessing bat use, they are invasive and may influence patterns of use. Care must be taken to ensure the welfare of captured animals. Capture techniques tend to be relatively laborious and costly, as nets or traps must be closely monitored by people trained in handling bats. Surveyors may be required to obtain appropriate state and/or federal permits.



Infrared cameras, enhanced with supplemental infrared lighting, at the mine portal or even mounted on remote-control cars can provide a record of bats using a mine.

TEXT BOX 9:

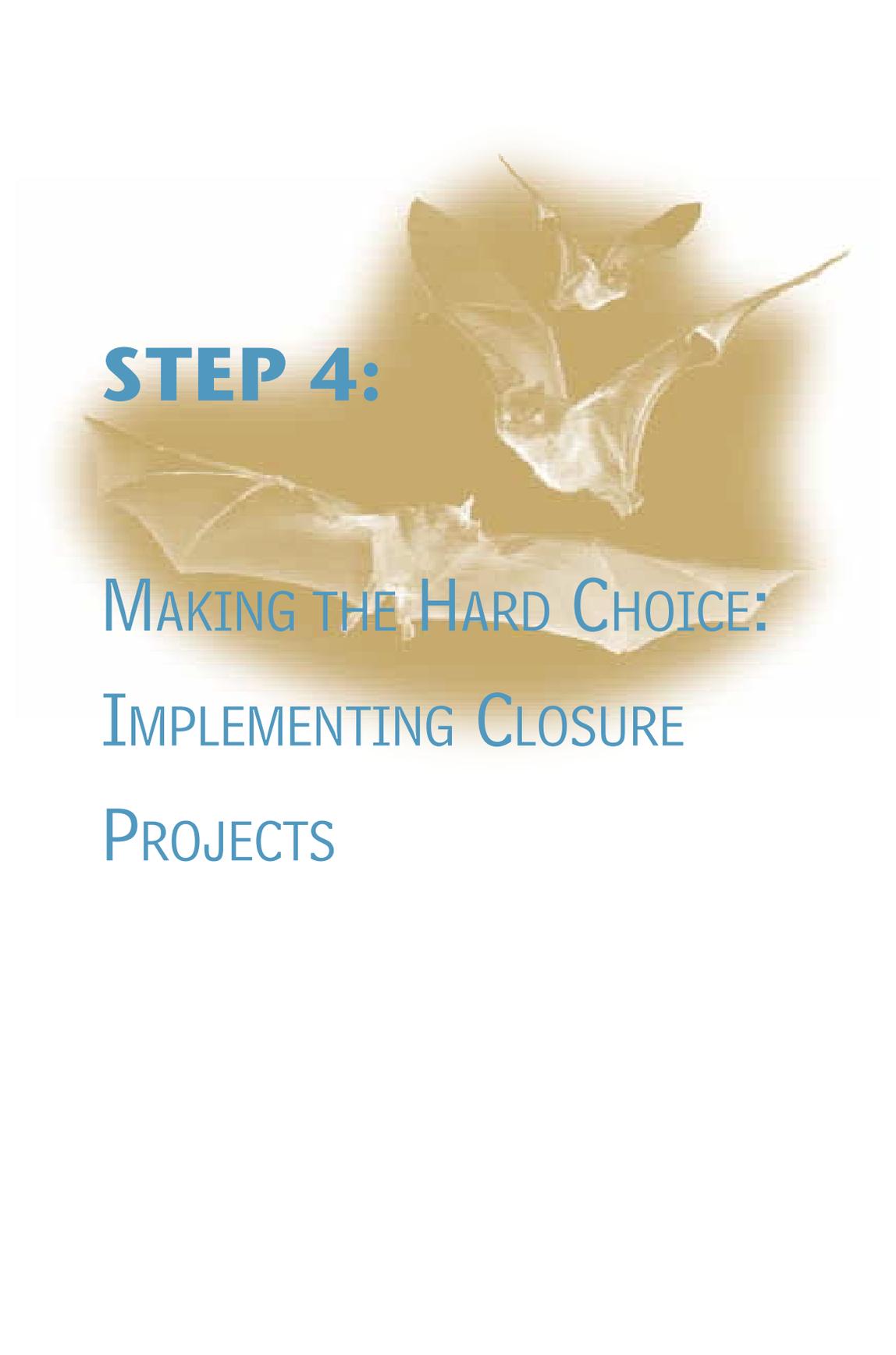
WHAT DOES IT BUY? UNDERSTANDING THE RELATIVE COSTS OF INTERNAL AND EXTERNAL SURVEYS

The authors (RES, JSA) diagnosed use of abandoned mines by bats through internal surveys and external IR video surveys at 24 mines in the western United States. With external surveys, 11 of 18 actual bat roosts (61%) were misidentified as non-roosts, while the external surveys cost more than seven times as much (\$32,000) as internal surveys (\$4,500) and ultimately resulted in more expensive management recommendations.

The external surveys provided false negatives more than half the time because they were extremely sensitive to spatial and temporal variation in use patterns and were dependent upon actual occupancy and use of the opening(s) being monitored at time of survey. Simply put, external-survey techniques did not provide any insights into closure recommendations when no bats were detected. Additionally, they provided no information on internal conditions (which might allow predictions of roost use in other seasons) and could not detect biological residues of past use (which were easily observed inside the mine).



A cluster of Townsend's big-eared bats (*Corynorhinus townsendii*)

The background of the slide features a warm, golden-yellow glow. In the upper right quadrant, two bats are captured in flight, their wings spread wide. The bat in the foreground is larger and more detailed, showing the texture of its wings and the shape of its ears. The second bat is positioned slightly higher and further back, appearing smaller. The overall composition is centered and evokes a sense of movement and transition.

STEP 4:

MAKING THE HARD CHOICE: IMPLEMENTING CLOSURE PROJECTS

The choice of which abandoned mines should be preserved through protective closures and which will be eliminated by destructive closures can have profound conservation implications. Identifying abandoned mines that represent critical roosting habitat is a vital step in ensuring the long-term integrity of bat communities within a region. Ultimately, though, only through the selection and installation of appropriate, bat-compatible closures will these colonies actually be protected. Unlike caves, where a bat-compatible closure is a last resort, most abandoned mines will only be maintained if human access is precluded by a physical barrier. It is strongly recommended that managers err on the side of caution and protect mines that contain potential habitat when closure is required with incomplete or no biological surveys (e.g., emergency closures). Individual mine portals are secured through either protective (bat-compatible) closures or destructive closures. Both approaches may be used at a single mine with multiple entrances to protect the site as well as to control airflow and enhance internal environmental conditions for bats (see Step 2).

Concept Planning Check Box

- Step 4.1: Timing of Closures
 - Step 4.2: Protective Closures
 - Step 4.2.1: No Action
 - Step 4.2.2: Signs
 - Step 4.2.3: Fencing
 - Step 4.2.4: Gating Adits (Vertical Openings)
 - Step 4.2.5: Gating Shafts (Horizontal Openings)
 - Step 4.2.6: Protecting Atypical Features
 - Step 4.2.7: Closures to Maintain Airflow
 - Step 4.2.8: Portal Stabilization
 - Step 4.3: Destructive Closures
 - Step 4.3.1: Timing of Exclusions
 - Step 4.3.2: Types of Destructive Closures
 - Step 4.3.3: Exclusions for Destructive Closures
 - Step 4.4: Mitigation for Destructive Closure Projects
 - Step 4.4.1: Protecting Replacement Habitat
 - Step 4.4.2: Reopening Closed Mines
 - Step 4.5: Maintaining Bats in Active Mines
 - Step 4.6: Creating Artificial Roosts
-

STEP 4.1: TIMING OF CLOSURES

Timing of the construction phase of a closure project can be critical in minimizing negative impacts on bats or other wildlife. Ideally, construction should be avoided when bats are using a mine, especially during maternity and hibernation periods and when important reproductive behaviors are known to occur. These recommendations should be considered in context of the ecology of the species and the location of the project. The actual timing of closures can vary by location, species and type of use.

- Schedule mine closures for periods when the bats are not present in mines where a single type of use occurs.
- In mines where multiple uses occur throughout the year, implement activities during a time when fewer bats are in the mine and impacts will be minimized.
- Minimize the impact of protective-closure activities when bats are present or it is not clear how bats may be using the mine by using exhaust fans to prevent fumes and debris from entering the mine or by temporarily blocking an entrance with a tarp or similar material.
- Bats should be excluded from all mines prior to destructive closures. Exclusions require that bats be active, so no destructive closures should be conducted during the cold season.

STEP 4.2: PROTECTIVE CLOSURES¹²

Step 4.2.1: No Action

Many mine features present insufficient risk (i.e., have low hazard rankings) to warrant expenditure of limited mine-closure dollars. Shallow adits in stable ground without slope-creep, shafts shallow enough to allow even a small person to climb in and out, and shallow open pits are good examples. But these must be evaluated by someone with abandoned-mine expertise, mine-closure experience and an understanding of liability issues.

Step 4.2.2: Signs

For some agencies and in some states, appropriate signs are considered an effective means of protecting the public from abandoned-mine hazards and provide at least a partial relief from liability. Unfortunately, the efficacy of signs can be quickly compromised since they are easily stolen or vandalized. Warning signs placed near abandoned-mine openings generally provide an effective warning to unsuspecting visitors. However, signs offer scant deterrence to those who choose to enter abandoned mines despite the risks. In fact, IR sensors placed in abandoned mines in Nevada before and after warning signs were installed revealed no significant reduction in human visitation.

¹²Vories, K.C., D. Throgmorton, and A. Harrington (editors). 2004. Proceedings of Bat Gate Design: a technical interactive forum held March 4-6, 2002 at the Red Lion Hotel, Austin, Texas. US Department of Interior, Office of Surface Mining, Alton, IL and Coal Research Center, Southern Illinois University, Carbondale, IL.

Step 4.2.3: Fencing

In some states, legislation recognizes that, under certain circumstances, fences that are properly installed, routinely inspected and clearly signed can provide appropriate safeguards. Unfortunately, fences often require intensive maintenance and are easily stolen or vandalized. In most circumstances, therefore, they should be viewed only as a temporary mitigation measure. However, fenced enclosures have been used at mine features with high cultural significance or where, for whatever reason, other types of closures were not acceptable. Consideration of fencing as a closure option requires a thorough understanding of state and local legal and liability issues.

Step 4.2.4: Gating Adits (Vertical Openings)

Protective closures include a variety of gate designs that have been built of a wide range of materials. Construction material and design usually can be selected during the planning phase of a project and modified as necessary. Construction material is largely determined by the type of closure and budget. In general, vandal-resistant materials cost more than less-resistant materials. Managers should be prepared to install more robust gates of the most vandal-resistant materials at mines near urban centers or where there is a long tradition of human visitation. Site-specific environmental conditions may limit the types of materials that can be used. Acidic soils or mine drainage, for example, may require installation of corrosion-resistant materials.

The costs of materials, labor and transportation vary around the county and often reflect the remoteness of a project. In general, bat gates and airflow-compatible closures are more expensive than destructive closures to mine entrances. This is not always the case, however, as protective-closure options can cost much less than destructive closures when large amounts of fill material must be transported on-site. Anyone involved in designing and installing protective closures should contact local, state, federal or private mine-reclamation programs and request current cost information. Well-organized, centralized programs such as the New Mexico Abandoned Mine Lands Bureau or Utah Division of Oil, Gas & Mining's Abandoned Mine Lands program can usually provide information about the costs of entire closure projects, including mandated surveys. Private contractors may be best equipped to give site-specific cost estimates.

Bat gates built with a 5 $\frac{3}{4}$ -inch horizontal spacing are generally recommended by Bat Conservation International. Within a single gate, however, bar spacing and other modifications to a standard design may be adjusted to meet site-specific requirements and to best accommodate the size of the colony utilizing the mine. Although other gate designs have proven successful for many species throughout the United States, care should be taken when modifying a design or applying it to a species without knowing how that species will tolerate the design.

The goal is to find the most appropriate closure that precludes human access while minimizing negative impacts on bats. Little research has been conducted on how readily temperate-zone bats will accept various gate designs and materials. In general, however, larger colonies of bats seem to be more negatively impacted by full gates than smaller colonies. Furthermore, recent research indicates that bats increase circling behaviors at mine portals following installation of bat gates; however, the implications of this are unknown. The research community should continue to refine gate designs to minimize

STEP 4: MAKING THE HARD CHOICE: IMPLEMENTING CLOSURE PROJECTS

impacts on roosting bats, while keeping in mind that even a problematic gate is better than the total loss of a critical bat roost through destructive closure.

Partial Gates: As the name implies, partial gates are bat-compatible closures with at least a portion of the top of the gate left open to allow greater flight paths for bats. Such gates may be used at large mine openings with large bat colonies or for species that do not tolerate full gates.

Full Gates: Thousands of full bat gates (bat-compatible closures that completely block a mine opening) have been installed in a wide variety of mine openings. Gate designs vary greatly in response to varied mine openings, varying degrees of portal stability, individual agency preferences and even the kinds of donated or otherwise-available materials.

Step 4.2.5: Gating Shafts (Horizontal Openings)

Shafts are common in mining districts worldwide. In the western United States, roughly half of all abandoned mine opening are shafts and in some districts, nearly all mines are shafts. Intensive internal and external surveys find no significant differences in bats' use of shafts in comparison to other types of openings. The primary engineering challenge when gating shafts is often the need to provide stable support for a bat-compatible closure in what is often unstable collar material.

Horizontal Shaft Grates: Shafts have been closed with various types of horizontal grates at or below collar level by rotating standard gate designs used at adits by 90 degrees. Angle-iron bars in such grates are placed with the apex of the angle oriented upward so water and debris does not accumulate in the bar. Square tubing and heavy rebar have also been used.

Cable Netting: An alternative to a bar-type horizontal closure is the use of cable netting or other varieties of steel "mesh" with 4-inch-square (101-mm) or smaller openings. These have been readily accepted by Townsend's big-eared bats at hibernation sites, and species such as California myotis and western small-footed myotis will fly through them readily. A modification, used in New Mexico, is the installation of bat windows in large expanses of net-type closures. These are angle-iron rectangles with one or several 5/8-inch opening(s) perpendicular to their long axis.



Cable netting



Final stages in the construction of a large cupola gate.

Cupola Gates: An alternative to a horizontal grate is a cupola-type closure that has multiple (typically four) vertical sides with standard bar-type closures and a top, with either some type of small-opening grating, standard bars or a solid surface. The multiple sides minimize danger from predators, and bat species that tolerate vertical gates at adits readily accept these structures.

Step 4.2.6: Protecting Atypical Features

Abandoned mine openings come in a bewildering variety of shapes, sizes and configurations. Large, open stopes, large shaft collars or large adit portals present serious challenges to engineers. If these openings are bat flyways, construction may be problematic, as they often require complicated, bat-compatible closures that can be very expensive. Large expanses of cable netting or horizontal grates with bat-windows are viable closure options, but the sides eventually fail and compromise the attachment at very large shafts. Cupolas have been constructed on top of horizontal grates to facilitate use by little brown myotis in Michigan. In New Mexico, the Abandoned Mine Safeguard Program has used an innovative option: old auto tires are compressed and forced into the opening around a culvert with a bat-compatible gate installed inside. When the tires expand, the sides of the opening are stabilized against failure. The tires are covered with material to provide additional protection.

Step 4.2.7: Closures to Maintain Airflow

In mines with multiple openings, any significant bat use probably is at least partially dependant on airflow. It is critical that existing airflow patterns be maintained in these situations. When multiple mine openings are all used by bats, bat-compatible



A grate is placed on a vertical culvert to maintain airflow in the mine.

STEP 4: MAKING THE HARD CHOICE: IMPLEMENTING CLOSURE PROJECTS

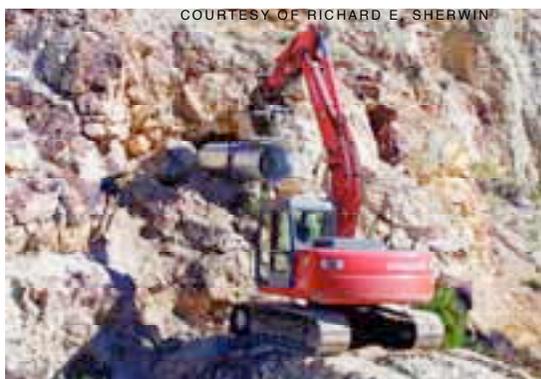
closures will allow necessary airflow. However, bats often only use a single opening and preserving airflow with more bat-compatible gates at other openings may not be financially justified. Airflow-preserving closures may be small, can use culvert stabilization and can employ a variety of materials, such as expanded metal grills or heavy screens that allow airflow.

Step 4.2.8: Portal Stabilization

Many mine openings require stabilization before installing a bat-compatible closure. For example, many adit portals are located in unstable ground or are being slowly closed through slope creep. Timbering at many shaft collars was often extended above the original ground level and backfilled with muck to create a flat surface for working and equipment. After the mine is abandoned, the timber rots and the muck eventually falls into the shaft. Most coal-mine slopes and shafts are located in sedimentary material and typically require stabilization to permit bat-compatible closures.

Culverts are widely used in stabilizing mine openings. Although they can be made of a variety of materials, the most readily available and commonly used culverts in construction are of corrugated steel. Culverts used in closures range from about one foot to more than 10 feet in diameter. Hundreds of culvert stabilizations have proven invaluable in facilitating bat-compatible closures of shafts, adits and open stopes in the United States and Canada. They have been used to protect mines housing a variety of bat species for hibernation, maternity, migratory stopover and night roosts. Post-closure evaluations indicate no negative impact on protected bat colonies when culverts are used in shaft collars, open stopes or adit portals.

Polyurethane foam is increasingly used in many protective and destructive mine closures. It has been used to secure culvert gates and to stabilize and/or produce destructive closures. Although foam facilitates closure of some otherwise very difficult openings, it is relatively costly and care must be taken with its use. Because foam is sensitive to ultraviolet radiation, it must always be armored with backfill or some other covering. Personnel must be adequately trained in the hazards associated with handling the material and working around the fumes, and it must be carefully stored according to manufacturer recommendations.



Culverts can be used to stabilize the entrance to a mine and provide a solid substrate for the attachment of a bat gate.

STEP 4.3: DESTRUCTIVE CLOSURES

Many abandoned mines, including large numbers known to be used by bats, require destructive closures. Some abandoned mines face such profound internal failure that stabilization and securing the portals are not warranted. Many mines are located on private

lands where liability may outweigh all biological concerns, and some active mining operations may have reclamation plans that do not include maintenance of open mines after mining activities end. Additionally, open stopes, glory holes and other large openings may make the installation of bat-compatible closures impossible. In cases of emergency closure following human injuries, fatalities or severe environmental impacts, concern for bats is often set aside and destructive closure of all portals is mandated. In other cases, lethal internal environments (e.g., toxic gases, combustion, internal collapse, radon) may cause individual sites to become population sinks for bats and should not be maintained.

Step 4.3.1: Timing of Exclusions

The exact timing of exclusions and site closures is best determined locally, given the variability in types of use by different species. As a general rule, bats must be active for exclusions to be effective, so all exclusions should be conducted outside of the hibernation season. In general:

- The best time to implement exclusions and portal closures is during late summer or early fall, after cessation of maternity activities and before the onset of hibernation.
- Early-fall closures will best ensure a window for bats to find alternate hibernacula and will give females a full spring season to locate alternate maternity sites.
- When maternity roosts must be closed, the exclusions should not be conducted at the end of the hibernation period as that may result in reduced fecundity and associated reproductive success. Exclusions at this time force females to seek an alternate maternity site while they are physiologically stressed due to the initiation of pregnancy and stresses following hibernation. It is possible that stressed females will even reabsorb embryos, delay fetal development or discard stored sperm to reduce system stress.

Step 4.3.2: Types of Destructive Closures

Permanent, destructive closures can be accomplished with methods that range from backfilling and construction of block walls to installation of foam plugs. Backfilling (closing the opening with fill material) is one of the most common closure methods for abandoned mines. It can be accomplished by hand at small, remote openings, or through the use of heavy equipment at larger adits and shafts. To keep humans from reopening closed mines, backfill material should be pushed as far into the mine as possible. Extreme care should be taken when backfilling shafts because fill material can become suspended in the shaft, creating a more dangerous mine feature as the plug may eventually fail and either reopen the shaft or cause an unstable subsidence.

A cinder-block wall, several layers thick and reinforced with rebar, will withstand all but the most serious and well-equipped vandals. Building a block wall in a portal is an excellent closure method when backfill material is not locally available. Furthermore, a

STEP 4: MAKING THE HARD CHOICE: IMPLEMENTING CLOSURE PROJECTS

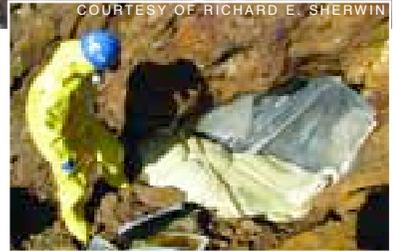
reinforced block wall behind fill material may help keep the closure from being breached. Drain pipes may be installed through the wall and backfill if the mine has sufficient water flow that water management is needed to prevent erosion from breaching the closure.

Foam plugs have become increasingly popular for destructive closures of horizontal and vertical portals. The material is strong enough to provide a suspended plug in a shaft that, when covered with backfill material, will withstand the weight of vehicles driving over the closure.



Step 4.3.3: Exclusions for Destructive Closures

Regardless of the reason for a destructive closure of known or potential bat roosts, steps must be taken to ensure significant bat colonies are not destroyed as a direct result of closure activities. Managers should include adequate exclusions as a routine part of mine-reclamation programs to minimize the risk of entombing bats in closed workings. Further, closures should be conducted immediately following exclusion to limit the chance of bats becoming reestablished in the mine. In general, these three guidelines can help determine whether exclusions should be conducted and how intense the exclusion effort should be.



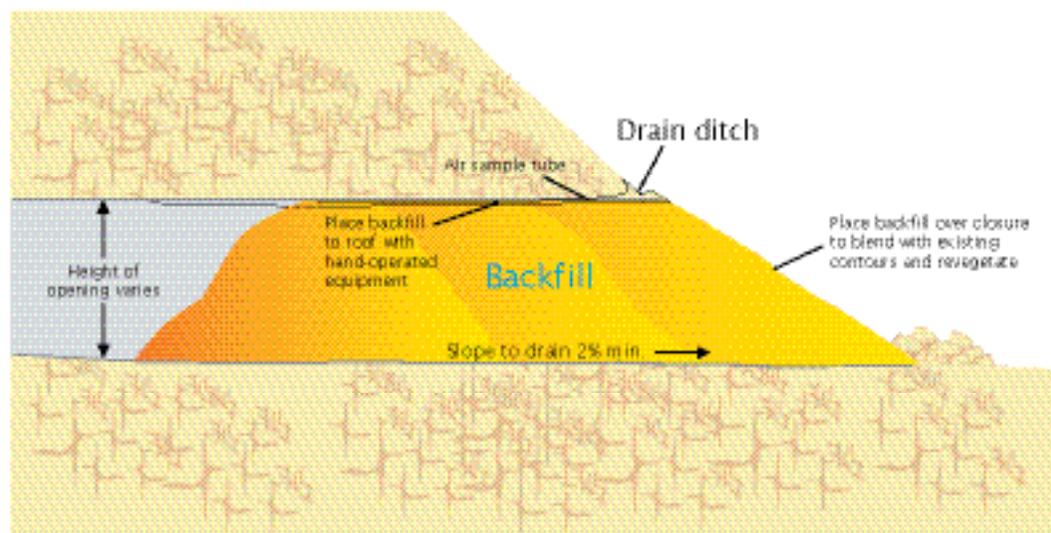
Workers using foam material to seal mine portals should carefully follow instructions and wear recommended protective gear to limit risk of respiratory distress and eye and skin irritations.

Exclusions Not Required: Exclusions are generally not required if a mine does not offer potential bat habitat, as mutually agreed upon by all partners involved in the mine-closure project in Step 1.

Standard Exclusions: In general, exclusions are recommended at all mines that represent habitat for bats. Given the ephemeral and episodic use of some roosts, it is prudent to err on the side of caution and conduct standard exclusions efforts, especially if significant time has elapsed since biological assessments were conducted.

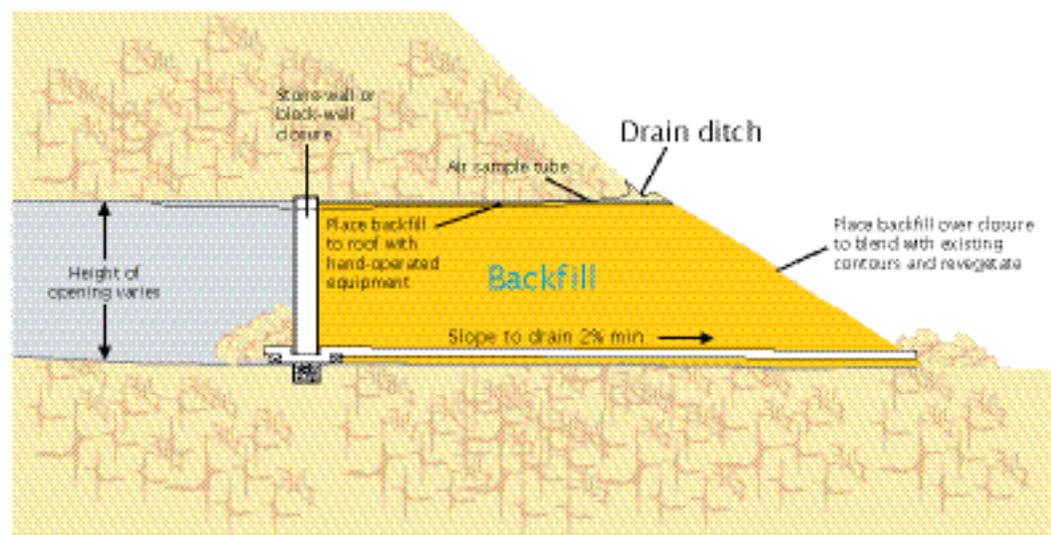
The use of one-inch mesh material (e.g., chicken wire, polypropylene or similar material) is most often used to exclude bats from a mine. Lighter-weight material may be used for remote mines that require physically transporting the material over long distances or rough terrain. Although this material is very effective for excluding bats, it may

Backfill



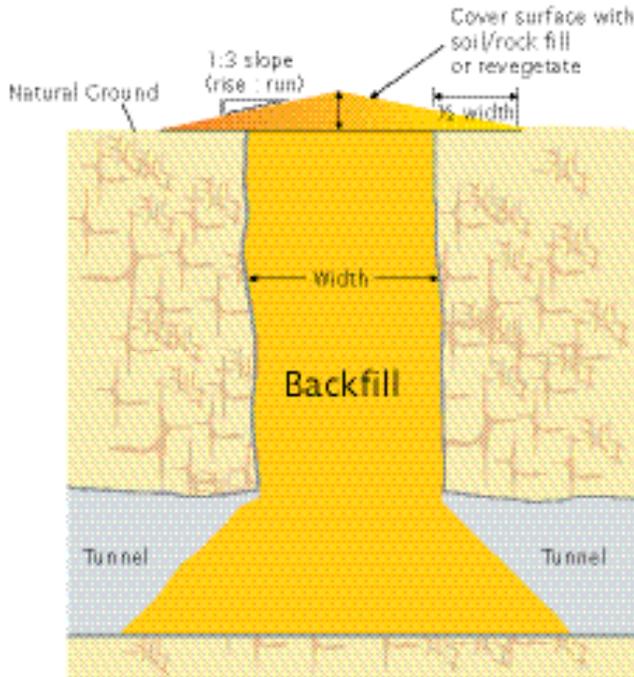
Not to scale

Reinforced Backfill

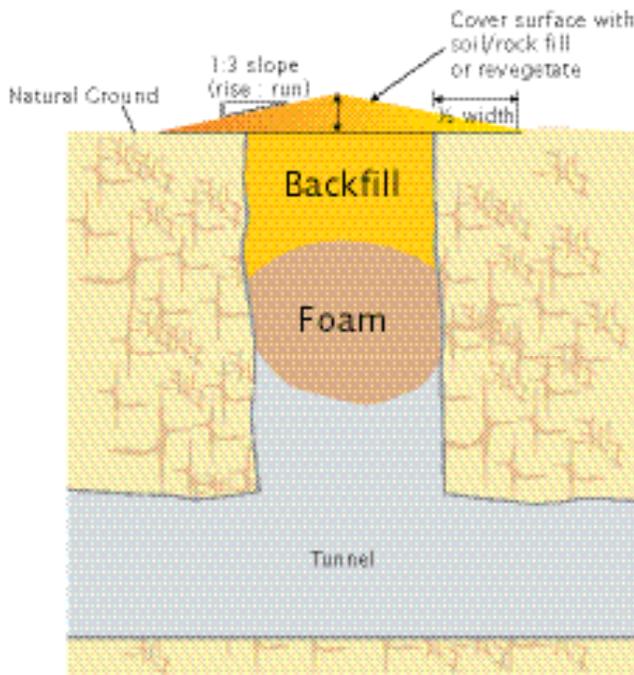


Not to scale

Shaft Closure



Shaft Foam Closure

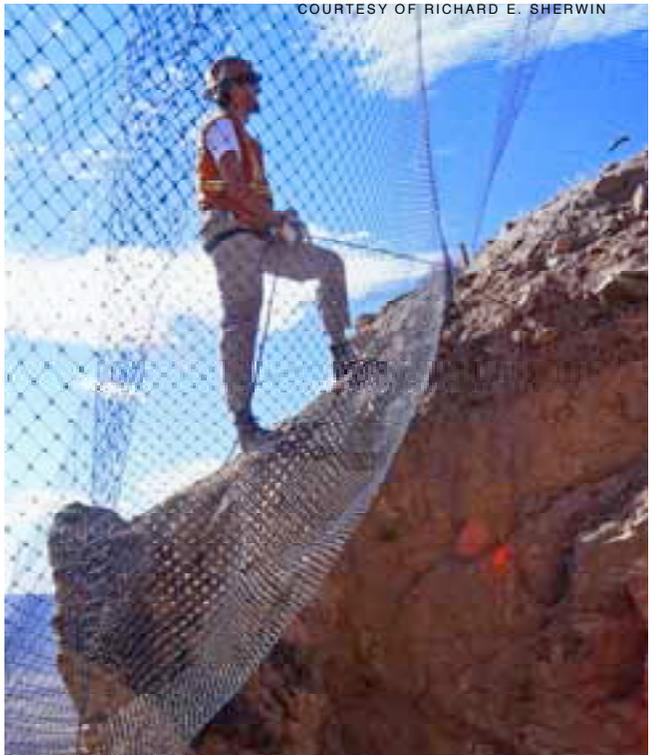


also entangle bats and other wildlife. Managers may need to develop a plan to periodically check exclusion materials at sites with large bat colonies or high use by other wildlife to prevent loss of entangled bats, amphibians, reptiles or birds.

Exclusion materials should be maintained for at least three nights prior to portal closure at mines that provide habitat and where little or no bat use has been detected. Simultaneously covering all external openings with exclusion materials and leaving it in place for at least one week is an effective method for excluding most bat species from roosts. Difficulties in navigating through exclusion materials should cause bats to seek alternate roosts rather than continuing to access the mine through the wire.

For most species, simply spreading exclusion materials across portals will be sufficient to allow bats to exit a mine while effectively discouraging their return. However, not all bats in all roosts across all landscapes will respond in an identical manner. As a general rule, smaller colonies in areas where roosts are abundant tend to quickly abandon roosts after exclusion materials are installed. For example, exclusion materials left in place for three to five nights will usually cause small colonies of Townsend's big-eared bat roosting in small mines in Nevada to abandon the roosts.

Intensive Exclusions Evicting Significant Colonies of Bats: Intensive exclusion efforts should be conducted at all heavily used roosts. Exclusions at significant roosts are more complicated because larger colonies and those with limited alternative roosts can be extremely difficult to exclude. For example, a large colony of Townsend's big-eared bats roosting in a large mine required maintenance of exclusion materials for up to five weeks, and total abandonment ultimately required manually removing approximately 20% of the total colony. Successful exclusion of significant colonies will be enhanced if managers develop baseline data regarding the type and timing of roost use, exit behaviors and patterns, expected dates of occupancy and colony size.



Proper installation and monitoring of exclusion materials can result in bats and other wildlife being excluded from abandoned mines.

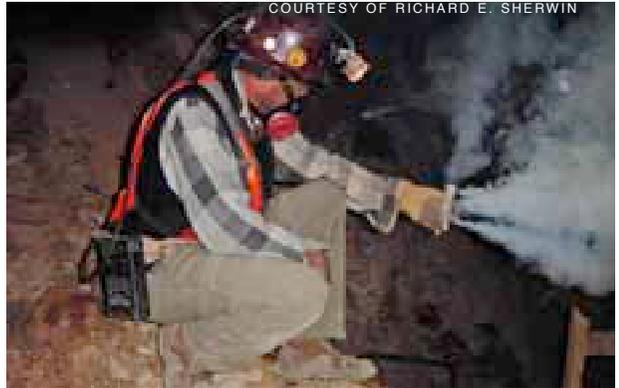
STEP 4: MAKING THE HARD CHOICE: IMPLEMENTING CLOSURE PROJECTS

It is strongly recommended that adequate and appropriate mitigation sites be selected and protected prior to conducting destructive closures at significant roosts so the displaced animals have alternative roosts maintained in the landscape. Excluding bats from a complex, multi-entrance mine is most effectively accomplished by first closing all but one of the openings.

- When possible, allow the majority of a large colony to first exit the mine and then close the opening that is most often used by bats. Closing the favored opening will force bats to exit through alternate portals and may cause some bats to abandon the site.
- Exclusion materials should be placed over the remaining openings. The closure of most remaining openings will further restrict bat access to the mine and force them to exit from the opening identified for final closure.
- In general, the remaining opening from which bats will exit the mine should be the one that is most accessible by humans and bats, easily covered with exclusion materials and safest to work around.

Exclusion materials should be left in place until the site is vacated by all bats of all species. At major roost sites, the materials should be monitored nightly because bats may ignore acoustic information when emerging from roosts, which could result in bats colliding with exclusion material, causing stress, injury or death if left unattended. At significant roosts in complex mines, both internal and external surveys are recommended to confirm that all bats have vacated the roost. In some cases, it may be necessary to physically remove remaining bats.

Non-toxic smoke bombs have been effective in driving bats from known roosts. They can be very effective when used in conjunction with exclusion materials. It is recommended that non-toxic smoke bombs be discharged throughout the mine on the evening before closure. Of course, the internal atmosphere must be checked for particulates and volatile gases prior to firing bombs. If there is any uncertainty about bats remaining in the mine, a final internal survey might be conducted in the morning, followed immediately by sealing the opening.



Non-toxic smoke bombs deployed in the interior of a mine can drive bats from the mine's depths. **Note:** Do not deploy smoke bombs from the exterior of a mine as it may drive bats deeper into the mine. Also, do not use smoke bombs in mines with a flammable atmosphere.

STEP 4.4: MITIGATION FOR DESTRUCTIVE CLOSURE PROJECTS

The National Environmental Policy Act stipulates that direct or indirect impacts of proposed actions which have a federal nexus should be avoided, minimized or mitigated. While excluding bats from sites scheduled for destructive closure will minimize direct mortality associated with mine closures, it does not adequately mitigate for the loss of actual roosting habitat through these processes.

Mitigation, as defined under the NEPA (40 CFR Section 1508.20)¹³, includes:

1. Avoiding the impact altogether by not taking a certain action or parts of an action.
2. Minimizing impacts by limiting the degree or magnitude of the action and its implementation.
3. Rectifying impacts by repairing, rehabilitating or restoring the affected environment.
4. Compensating for the impacts by replacing or providing substitute resources or environment.

Step 4.4.1: Protecting Replacement Habitat

To minimize the loss of critical mine habitats, mitigation sites (replacement habitat) should be identified, if possible, for mines that have significant bat use and are scheduled for destructive closure. Mitigation plans typically require the approval of management agencies with project oversight. Strategies and protocols for identifying potential mitigation sites should be developed as part of the planning process, and all project partners should agree on the scale and intensity of these efforts. For large-scale mine reclamation projects, mitigation should apply over broad areas to allow maximum flexibility for identifying and protecting mitigation habitat. Inadequate planning can result in potential mitigation sites being lost in the reclamation process.

The process of mitigating for habitat loss associated with abandoned-mine closure projects is two-fold. First, conduct exclusions at all sites scheduled for destructive closure. Second, identify and protect replacement habitat for significant roosts that will be lost. The objective of roost mitigation is to find existing abandoned mines or caves that will provide suitable replacement habitat and then secure them for the bats in perpetuity. The following steps can help guide managers in this process:

- Develop a list of potential mitigation roosts to be surveyed. This effort should include cave habitats, which may represent the historic bat roosts in an area.
- Survey potential mitigation roosts. A comprehensive evaluation of potential mitigation sites will help determine whether they will function as planned. At significant bat roosts, the use of dataloggers to develop comprehensive temperature profiles at mitigation sites may be warranted to help ensure that they offer appropriate internal conditions.

¹³National Environmental Policy Act: www.NEPA.gov

STEP 4: MAKING THE HARD CHOICE: IMPLEMENTING CLOSURE PROJECTS

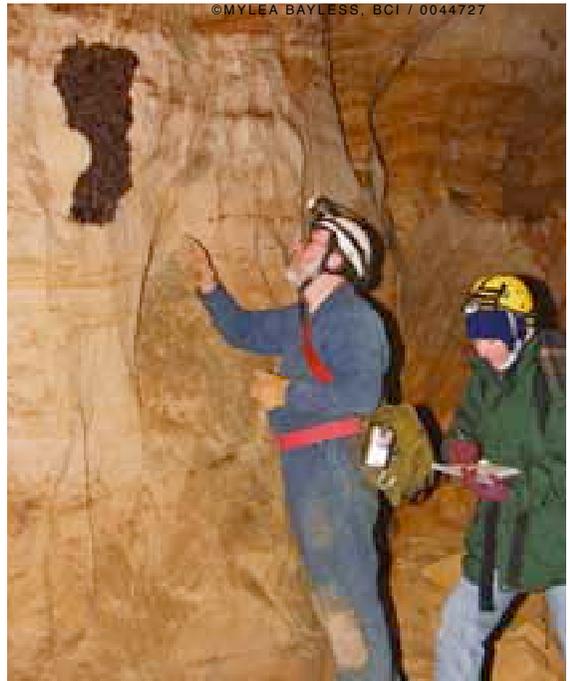
- Select suitable mitigation roosts from the pool of surveyed sites. Mitigation sites should offer similar roosting opportunities and conditions as those being destroyed. Sites should offer the same type of habitat (e.g., hibernacula, maternity) and should be located within the potential dispersal area of the evicted bats. It may be necessary to select multiple locations for protection if no single mine complex or cave system will adequately mitigate the loss of a specific site.
- Develop a schedule to complete gating or other site-appropriate protection activities. Mitigation roosts will usually require gating to ensure that the replacement habitat will protect bats.

Step 4.4.2: Reopening Closed Mines

In some landscapes, the best option for providing quality mitigation sites may be reopening previously closed mines that contain the needed habitat. Reopening mines can restore subterranean-roosting opportunities in landscapes with wholesale closure of abandoned mines, or where no other appropriate resource is readily available. Mine portals may also be reopened to restore or modify internal environmental conditions where openings were previously closed. For example, reopening a lower haulage level can profoundly alter airflow, drainage and associated internal conditions in a mine.

Of course reopening a mine or a single portal should be done only after careful planning. Ownership must be determined and access granted. Typically, the portal will need to be stabilized, air quality must be confirmed and water may need to be drained.

Opening previously closed mines will often be a viable management alternative for maintaining bats in a landscape. Excluded bats have been observed to repeatedly investigate portal locations that had been closed years earlier, suggesting that at least some component of the current bat community may still evaluate historic locations of portals. Furthermore, bats readily re-colonize mines where closure failed through erosion, subsidence or human vandalism.



In some cases, large numbers of bats can be maintained in remote sections of active mines where they are subjected to limited disturbance.

Large colonies of bats can be protected in large mines with active mining through careful planning.

STEP 4.5: MAINTAINING BATS IN ACTIVE MINES

Mitigation may, in some circumstances involving significant colonies of bats in active mines, be achieved within the mine. In one scenario, mining operations could occur seasonally when the bats are not in the mine, thus preventing any conflict or threat. The mining operation should take care not to change environmental conditions within the section of the mine used by bats. Miners should avoid altering airflow through air dams, new entrances or modifications to existing entrances.

Alternatively, mining activities might be isolated from areas where bats roost in larger mines. Bats are more at risk when they are present during mining operations, so greater care should be taken to limit disturbance within sections of the mine where bats roost. For example, in Wisconsin, a mining company actively protects the old sections of the Bay City and Maiden Rock mines with seasonal closures and bat gates where tens of thousands of little brown myotis hibernate as they continue extracting ore in new sections of the mine. This continuing protection over the years at one of the mines is a testament to the mining company's dedication to these bats.

Furthermore, the impacts of some mining activities, such as subterranean blasting or use of heavy equipment, may reach across greater distances than anticipated. For example, air can be forced through mine passages and impact roosting bats, and tremors might disturb bats during critical periods such as hibernation. Since the impacts for many mining activities are poorly understood, managers are urged to use great caution when continuing mining activities while large numbers of bats roost within a mine.

STEP 4.6: CREATING ARTIFICIAL ROOSTS

The creation of artificial subterranean roosts is another approach that may provide mitigation sites or enhance the availability of subterranean habitat. Although structures have been built by burying culverts, truck tires and cement-truck drums under waste rock, such sites have not been routinely monitored to determine their efficacy. The concept of creating artificial subterranean habitat is intriguing, but design and implementation of moderately inexpensive and functional artificial subterranean-roost habitat requires additional research to understand its potential conservation value.

The chances of successfully installing an artificial roost increase if the habitat is created specifically for a target species. Regional information on mean annual surface temperatures and how airflow can be passively controlled within the structure should provide an appropriate temperature profile for the intended use. Temperature profiles should be developed for new artificial roosts, with adjustments made to the structure as needed (e.g., air dams to modify air flow, increasing overburden material to insulate the site). Adequate roost surfaces for target species should be provided in areas that offer protection from predators as well as appropriate environmental conditions. A lack of attention to these small but critical details could undermine the entire project.

The image features three bats in flight, positioned in the upper and middle sections of the page. They are rendered in a light, golden-brown color, appearing as if they are flying through a misty or ethereal atmosphere. The background is a soft, light yellowish-white gradient. The text is overlaid on the left side of the image.

STEP 5:

MANAGING
FOR THE FUTURE

Completing physical closure of a mine does not end the project. Managers should develop a monitoring plan to ensure that protective and/or destructive closures achieve the objectives of reducing liability and protecting important bat habitat. Monitoring is critical to all management activities at abandoned mines, but it too often receives little or no attention during planning and subsequent on-site activities.

Monitoring involves the periodic evaluation of specific activities to understand the status or result of a specific action (e.g., bat colony response to a gate, integrity of a mine closure). It should be objective driven rather than technique driven. Data collected without clearly articulated goals and established study designs will often fail to accomplish objectives, regardless of the techniques used. Quality monitoring can provide critical information to guide future management efforts, rectify past management mistakes and provide information about past successes in an adaptive management framework.

Concept Planning Check Box

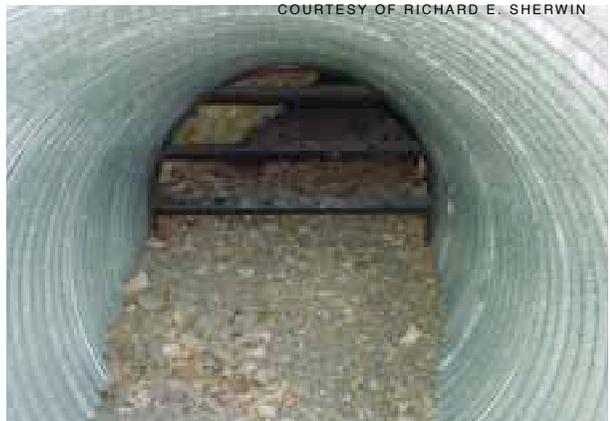
Step 5.1: Protecting Your Investment

Step 5.2: Observing the “Bang for Your Buck”

STEP 5.1: PROTECTING YOUR INVESTMENT

All permanent closures, particularly those involving large shaft openings and adits with a history of human visitation, require periodic monitoring and may require maintenance long after initial closure. A monitoring program that targets the structural integrity of gates or other types of closures, including destructive closures, should be planned and implemented at all mine-reclamation projects to ensure closures continue to function as designed. Gates and destructive closures can fail for several reasons. Humans can vandalize and breach gates to gain access. Also, animal or human excavation or erosion can create new access points behind, under or around gates and destructive closures or where external mine openings were not previously identified. Further, protected mine entrances may become non-functional to bats when erosion or vegetation blocks the portal.

In general, the integrity of closures should be monitored annually for the first four to five years, with the timing adjusted after that to meet local needs. Sites with a history of human visitation, especially in regions where gate vandalism is prevalent, may require three to four visits during periods of peak public use during the



COURTESY OF RICHARD E. SHERWIN

Protective closures (e.g., bat gates, fencing, etc.) must be routinely monitored to ensure their structural integrity and that they function as designed. This culvert with a bat gate has been blocked by erosion and requires maintenance.

first post-closure year, when a new closure is most likely to be vandalized or breached. Additional site visits may be warranted in areas with high rates of erosion following major storms. If repairs are required at a destructive closure, appropriate exclusion efforts should be implemented for bats, other wildlife and humans who may have entered the mine through the breach.

STEP 5.2: OBSERVING THE “BANG FOR YOUR BUCK”

Monitoring bat colonies and populations is often problematic. Project managers should review the colonial-monitoring sections of the USGS bat-monitoring publication¹⁴ for help in developing and implementing a monitoring project. Personnel who plan and implement mine-reclamation projects may not be the best choices for monitoring efforts. Biological

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Indiana myotis (*Myotis sodalis*).

monitoring – time-intensive and closely aligned with research objectives – may best be accomplished in collaboration with academic or other institutions with relevant expertise.

Despite the best of intentions and years of effort, considerable resources have been invested in monitoring colonial bats in caves and mines without producing meaningful data that address the primary issues of the bats’ response to management activities or trends in colony size. These failures are due mostly to fundamental flaws in the designs of monitoring studies and associated

lack of intensity, duration and repeatability. In many cases, these well-intentioned surveys actually prevented appropriate monitoring efforts that could have yielded valuable data because managers assumed their surveys were achieving monitoring objectives.

Monitoring bat responses to management activities requires absolute focus on the primary objectives within the broader project. If the objective is to accurately count bats within a hibernation site, count the bats. Do not allow secondary or tertiary objectives, such as exploring for new sections of a mine or photographing the bats or mine, to undermine achieving priority objectives.

- Monitoring projects must have well-planned study designs that address questions of interest or specific project objectives.

¹⁴O’Shea, T.J., and M.A. Bogan (editors). 2003. Monitoring Trends in Bat Populations of the United States and Territories: Problems and Prospects. U.S. Geological Survey, Biological Resources Discipline, Information and Technology Report, USGS/BRD/ITR—2003—0003, 274 pp.

MANAGING ABANDONED MINES FOR BATS

- Select the most appropriate technique for the question of interest, not the most convenient. Techniques that provide records of the data (e.g., video recordings) are preferred as they can be reviewed later to enhance interpretation.
- Obtain measures of observer bias to understand error and help interpret the data.
- In general, monitoring should be conducted when the colony or population is most stable (e.g., prior to the birth of pups). Adjust accordingly to meet other project objectives.
- Isolate variables of interest and control for confounding factors. For example, major closures of mines in the surrounding landscape would influence a monitoring study designed to evaluate bat response to gates at protected mines.
- Determine the sampling frequency that's needed to meet project objectives. For example, multiple nights of sampling may be required to address activity levels at a site.
- Define the spatial scale of interest and incorporate that into the study design.
- Understand and apply appropriate inference of the monitoring data.



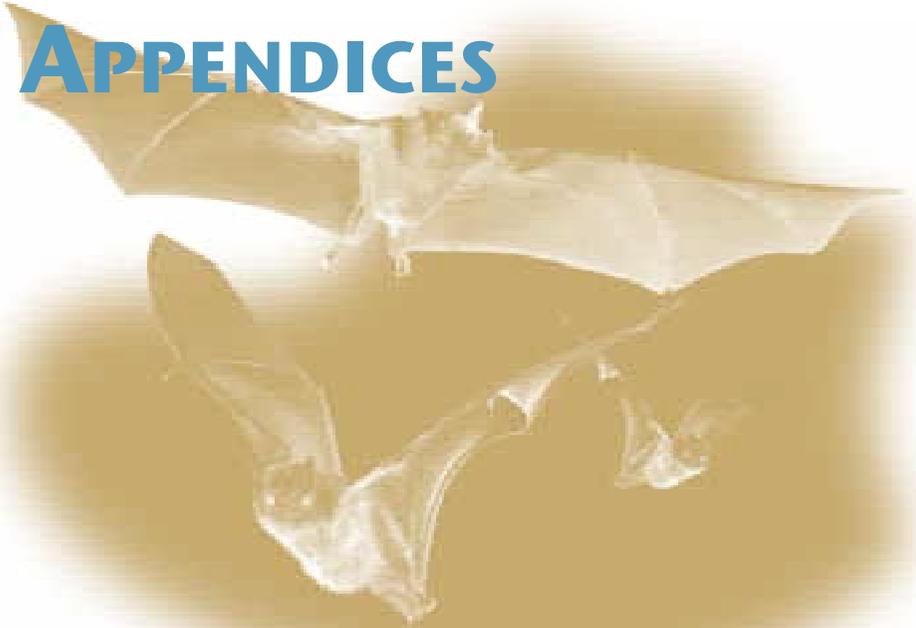
Abandoned and even active mines can provide critical roosts for significant colonies of bats. Careful understanding of the resource can help managers make informed decisions that can promote conservation, safety and even mining objectives.

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APPENDICES



APPENDICES

Abandoned Mine External Survey Data Sheets

| | | |
|----------------|-----------|-------------|
| Portal ID: | Date: | Start Time: |
| Mine Name: | Observer: | End Time: |
| Location (UTM) | | Elevation |

| | |
|-------------------------|---------------------|
| Start Time Temperature: | Weather Conditions: |
| End Time Temperature: | |
| Moon Phase: | |

| | |
|---------------------------|-----------------------------|
| Equipment Used in Survey: | Number of Openings in View: |
| | |
| | |
| | |
| | |

Sketch of Equipment Setup (indicate portal(s) and placement of equipment):

SAMPLE

Observations/Notes:

| |
|--|
| |
| |
| |
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| |
| |
| |
| |
| |
| |

External Wildlife Mine Survey Data Sheet

Mine Name _____ Survey Date(s) _____
 ID # _____ Surveyor(s) _____
 Mountain Range _____ County _____
 Topographic Sheet _____ Land Owner _____
 Lat Long/NAD83 UTM _____
 Distance to nearest OHV road _____ Road Type _____

Type of Working - (adit, shaft, prospect, decline, stope)
 Dimensions of opening _____ Approximate depth/length (ft) _____
 Aspect ** _____ Declination *** _____
 Photos taken (Y or N) _____ Photo folder location _____
 Mine is too dangerous to Approach (Y or N) _____ Haz-Mat is present (Y or N) Present
 Mining Claim (Y or N)*** _____ Historic material is present (Y or N)
 Is ALL of mine visible (Y or N) _____ Known Multiple Entrances (Y or N)
 Cribbing (Wood Sides) (Y or N) _____ Water in mine (Y or N)
 Wood or debris in mine (Y or N) _____ Trash in mine (Y or N)
 Rock crevices in mine (Y or N) _____ Is mine fenced (Y or N)
 Notes (Wildlife, historic material in or around mine) _____

Mine Rating (A - D) * _____ Exclusion/Survey Prior to Closure is needed: (Y or N)
 Closure recommendations: _____

Night Survey Done (Y or N) Date(s) _____
 Type of equipment used (n.v. goggles, n.s. camera, other) _____
 Number of bats seen _____ Other Wildlife seen: _____
 Acoustic recordings taken (Y or N) Anabat # _____ Cloud cover % _____
 Temperature at sunset: _____ Wind speed (1-5) or mph _____
 Moon phase (%) _____ Time of moon rise _____

* A = Bats present; B = Possible bat habitat (needs further survey); C = Can see all of mine (bat habitat is limited to crevices); D = No wildlife habitat potential

** If you were looking out from the portal, the aspect is the direction you are facing.

*** Zero degrees is horizontal, positive numbers refer to degrees below the horizontal.

SAMPLE

APPENDICES

MINE DATA SHEET

| | | | | | | |
|---|------------|--|--------------------------------------|--|---|------------------------|
| Date | Time | Site | Project | Ownership | District/Region | State |
| County | Mtn. Range | Quad Name | GPS ID | Latitude | Longitude | Alt. |
| Type of Mine adit shaft stope prospect decline | | Aspect n ne e se s sw w nw | | Human Disturbance none low medium high | | Vegetation Zone/Notes |
| # of Entrances 1 2 3 more | | Portal Width/Height | Portal Stability Solid Collapsing | | Extent of Survey 0=not entered; 1=partial; 2=all of mine seen. 0 1 2 | |
| Total Length/Depth | | Mine Moisture dry wet | If wet, large pool? yes no | | Crevice Scale 1 2 3 4 5 | |
| Mine Complexity 1 2 3 4 5 | | # of Est. Drifts | # Mine Levels | Airflow Y N | Mine Temp | Outside Temp |
| Hazards 0 1 2 3 | | Type of Hazard Winze Rockfall Other | | Hazard Notes | | Mine on Topo Yes No |
| Historical Items: | | | Other Wildlife/Road Notes: | | | |
| <div style="font-size: 2em; color: red; opacity: 0.5; transform: rotate(-15deg); display: inline-block;">SAMPLE</div> | | | | | | |

BAT DATA:

| Species: | # Bats | Sex (m, f, u) | Age (A, J, U) | Repro (p, t, n) | Guano (1-5) | Height of Bat | Temp at Bat: | Roost type (D, N, H, M, C) | ID Method (vis, g, n, e, vid) |
|----------|--------|------------------|------------------|--------------------|----------------|------------------|-----------------|-------------------------------|----------------------------------|
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

NOTES:

Roost Type: D=day N=night C=colonyship ID: vis=visual e=capture Sex: m=male f=female Age: A=adult J=juvenile U=unknown Repro: p=pregnant t=testes
 H=hibernaculum M=maternity g=guano Vid=video v=ovulflight U=unknown n=non l=lactating gl=postlactating
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