A Conservation Plan for Bats in Wyoming

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EXECUTIVE SUMMARY

Bat conservation is a relatively new phenomenon in Wyoming. Before 1994, bats were not legally protected in the state. In 1994, the Wyoming Game and Fish Commission approved a nongame wildlife regulation protecting several wildlife species, including bats. In 1998, the Wyoming Game and Fish Department (WGFD) joined efforts with other western states to develop the Species Conservation Assessment and Conservation Strategy for the Townsend's Big-eared Bat (Pierson and others 1999). The resulting document has served as the foundation and the guiding force behind bat conservation efforts in Wyoming.

The development of the Western Bat Working Group soon followed this unprecedented proactive conservation initiative. The participating states have since each developed state working groups that are subsets of the Western Bat Working Group. The Wyoming Bat Working Group (WYBWG) was developed in 1998. This multi-agency group meets annually to prioritize and discuss bat conservation efforts in Wyoming. In 2003, the WGFD and the WYBWG initiated the development of this document, A Conservation Plan for Bats in Wyoming (Bat Plan). Nearly 2 years later, this Bat Plan was finalized.

The overall goal of the WGFD and the WYBWG in developing this Bat Plan was to consolidate what is known about bats in Wyoming and collate this information into a single document that would be available to everyone that is interested in bat conservation in Wyoming. This plan is intended to be implemented at local levels and to be utilized by land and resource managers, biologists, bat researchers, and other interested parties as a technical cooperative framework to identify and coordinate actions to facilitate the conservation of bat species in Wyoming. This Bat Plan delineates specific concerns for management, inventory and monitoring, and education that should be addressed in Wyoming.

Much still needs to be accomplished to secure the future of bats in Wyoming and this planning effort represents a necessary step to achieve this goal. Information on bats and survey techniques are continually improving and will undoubtedly greatly enhance our ability to manage bats and their habitats in the future. As a result, this document must be updated regularly to stay abreast of new developments.

Funding for this planning effort was provided to the WGFD by the US Fish and Wildlife Service through the State Wildlife Grants program.

Cited References

Pierson ED, Wackenhut MC, Altenbach JS, Bradley P, Call P, Genter DL, Harris CE, Keller BL, Lengus B, Lewis L, and others. 1999. Species conservation assessment and strategy for Townsend's big-eared bat (*Corynorhinus townsendii townsendii* and *Corynorhinus townsendii pallescens*). Boise: Idaho Conservation Effort, Idaho Department of Fish and Game. 68 p.

WYOMING BAT WORKING GROUP PARTICIPANTS

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WYOMING BAT CONSERVATION STRATEGY

Background

Declines in many bat populations at both the continental and local levels have led to concern for the future of migratory and resident bats in Wyoming. The reasons for declines are complex: habitat loss, modification, and fragmentation; loss of wintering and migratory habitat; roost disturbances; and pesticide use have all been implicated. Early conservation efforts for species at risk allows opportunities for state and federal agencies and other interested parties to stabilize and recover these species and their ecosystems before listing becomes a high priority. Addressing the conservation needs of at-risk species maintains management flexibility, reduces potential conflict and restrictive land use policies, avoids the confrontational atmosphere often associated with listing, and provides an ecologically sound and cost-effective means to conserve species.

The objectives developed in this plan are consistent with current Western Bat Working Group (WBWG) conservation efforts and direction. The WBWG is comprised of agencies, organizations, and individuals interested in bat research, management, and conservation from 13 western states and the provinces of British Columbia and Alberta. The WBWG grew from an effort in 1994 through 1996 to develop a range-wide conservation strategy for the Townsend's big-eared bat as part of a proactive conservation approach to avoid a formal listing of the species under the Endangered Species Act.

The mission of the WBWG is to:

- facilitate communication among interested parties and reduce the risks of species decline or extinction;
- provide a mechanism by which current information regarding bat ecology, distribution, and research techniques can be readily accessed; and
- develop a forum in which conservation strategies can be discussed, technical assistance provided, and education programs encouraged.

The Wyoming Bat Working Group (WYBWG) is a subset of the WBWG and is comprised of state and federal agencies, non-government organizations, and individuals interested in bat conservation, management, and research in Wyoming (see the list of WYBWG participants on page 4).

Purpose and Intent

This document, A Conservation Plan for Bats in Wyoming (Bat Plan), is primarily intended to be utilized by land and resource managers, biologists, bat researchers, and other interested parties as a technical cooperative framework to identify and coordinate actions to facilitate the conservation of bat species in Wyoming. The Bat Plan delineates specific areas of concern for management, research, inventory and monitoring, and education that need to be addressed in Wyoming. The Bat Plan uses the most current available data to provide information and recommendations for conservation actions to benefit bat species and their habitats. Inventory, monitoring, and research needs are listed that relate directly to management questions. The Bat Plan is a dynamic document that will be updated and revised as new information surfaces. Thus, inventory, monitoring, and research will fulfill critical links in the adaptive nature of the Bat Plan.

No priority ranking has been established for the objectives, strategies, and management recommendations in this Bat Plan. Instead, resource managers and landowners should implement those strategies and recommendations that are most applicable and urgent in their area and situation. The actions resource managers or landowners take will depend on their goals, resources, and commitment, as well as the physical characteristics of their management area or property and the bat species that occur in the area.

This document will be reviewed annually on an informal basis by the Wyoming Game and Fish Department (WGFD) Nongame Program staff. If it is determined in these informal annual reviews that significant changes are necessary, formal revisions with input from the WYBWG will be made. The formal revisions may address changes in the status of bat species, adopt new information and methods, and/or respond to other factors that may influence the conservation of bat species in Wyoming.

Goal and Objectives

The purpose of the Bat Plan is to: (1) identify early conservation measures to reduce, eliminate, or mitigate those factors considered to be limiting the well-being of bat species; (2) provide information to reduce the threats to bat populations and their habitats and to diminish the likelihood that any bat species in Wyoming will require protection under the Endangered Species Act; (3) encourage state and federal agencies, private landowners, and other interested parties to voluntarily maintain or enhance habitat for bat species; and (4) provide managers and researchers standardized methodologies and techniques for collecting, storing, and interpreting data, to ensure that data collected in Wyoming is compatible with ongoing efforts. The management objectives listed below were established as a starting point to facilitate planning and provide an ecological basis for management. Objectives may change over time, as coordination with the WBWG and the WYBWG progresses; as inventories establish a more accurate picture of bat abundance, distribution, and threats; and as the status of bat species changes.

The definitions of goal and objective used in this document are adapted from the Wyoming Game and Fish Department Strategic Plan (WGFD 1995). The goal is a general statement indicating the intent of the Bat Plan. The objectives are statements that provide measurable targets for the Bat Plan to meet, and are quantified in the strategies in the following section.

Goal:

Maintain the current abundance and distribution of bat species in Wyoming.

Objectives:

1. **Determine the population status and trends of all bat species that occur in Wyoming.**

2. **Develop and maintain a cooperative framework for state and federal agencies and other interested parties to manage caves and abandoned mines to protect significant maternity roosts, hibernacula, and other roosts.**

3. **Avoid significant loss of habitat associated with the alteration of manmade roost sites.**

4. **Document and protect crucial habitat in the state that is not associated with caves and abandoned mines.**

5. **Develop and disseminate Wyoming-specific guidelines for bat surveys and monitoring.**

6. **Increase information and education efforts to improve both professional and public awareness of the ecological role of bats.**

Problems and Strategies

Problems (that is, issues and concerns) are barriers that potentially preclude accomplishment of the objectives. The following problems were adapted from the WGFD Nongame Bird and Mammal Plan (Oakleaf and others 1996) and identified by WYBWG participants. They are numbered and presented in bold below; corresponding objectives are listed in parentheses. The strategies below were developed by first identifying problems that must be addressed in order to attain the objectives outlined above. Strategies for mitigation of the problems are assigned a letter and listed below each problem.

1. **Effective management cannot be undertaken unless the best available methods for inventory and monitoring of bat populations are practiced by all interested parties in a consistent and standardized manner throughout the state (Objectives 2, 3, 4, and 5).**

    A. Review and evaluate current methodologies for inventorying and monitoring bat populations and determine their applicability to Wyoming bat populations.

    B. Based on the above review, develop a standardized set of guidelines for use by all bat biologists and resource managers in Wyoming.

        1. Make guidelines available to all interested parties through the Bat Plan and/or other methods (such as the Internet).

        2. Review existing methodologies every 5 years or as new methodologies are developed and, if necessary, revise the Wyoming guidelines.

    C. Develop and maintain a publicly accessible bat call library specific to Wyoming and the nearby Rocky Mountains, to facilitate use and interpretation of acoustic monitoring in the state.

2. **Population status, trends, and distribution of most bat species are poorly understood or are currently unknown in Wyoming, precluding effective management (Objectives 1, 2, 4, and 6).**

    A. Continue conducting statewide surveys of caves, abandoned mines, and buildings to confirm presence, population size, distribution, and population trends for each bat species in Wyoming.

        1. Identify data gaps for Wyoming bat species and prioritize conservation needs accordingly to determine status, trend, and distribution of all cave- and abandoned mine-dwelling bat species.

    B. Increase statewide surveys of habitats not associated with caves, abandoned mines, or buildings to confirm presence, population size, distribution, and population trends for each bat species in Wyoming.

1. Identify data gaps for Wyoming bat species and prioritize conservation needs accordingly to determine status, trend, and distribution of all bat species that are not associated with cave and abandoned mine habitat.

C. Identify important foraging and roosting habitat besides caves, abandoned mines, and buildings (such as water sources, snags, and cliffs).

D. Maintain liaisons with the public, private veterinarians, and wildlife professionals through the WYBWG, Wyoming Wildlife magazine, news releases, and public presentations to receive information about bat colonies and acquire specimens**.**

3. Bat roosting habitat has been lost in Wyoming and continues to be threatened by abandoned mine reclamation and the removal of old buildings and bridges (Objectives 2, 3, and 6).

A. Utilize the WYBWG to enhance current cooperative efforts and communication between land management agencies, the Abandoned Mine Lands Division of the Department of Environmental Quality (AML), WGFD, and private landowners to reduce impacts from reclamation of abandoned mines that provide bat habitat.

B. Develop and maintain contacts between public entities and the general public to reduce impacts from the removal of bridges and buildings that provide bat habitat.

1. Develop contacts with the Wyoming Department of Transportation and county road and bridge departments to receive advance notification of bridge removal so the disturbance can be quantified and mitigated by the installation of bat shelters or design modifications on the replacement bridge.

2. Through the WYBWG, Wyoming Wildlife magazine, school programs, and public education programs, inform the public and agency personnel of the value of buildings for bats, and solicit their assistance in identifying bat-occupied buildings and preserving them or mitigating their loss.

3. In cooperation with Bat Conservation International (BCI), maintain and distribute current information on bat shelter construction and placement, and provide state coordination for BCI's North American Bat House Research Project.

4. Some caves and abandoned mines in Wyoming have a gate or other permanent or temporary closure that does not allow access for some bat species (Objectives 2 and 3).

A. Cooperate with land management agencies, AML, WGFD, and private landowners to identify caves and abandoned mines that have gates or other closures that exclude bats and appear to have significant bat habitat potential.

1. Conduct a field review of problem sites and develop a plan and funding to correct them as needed.

5. Recreation in caves and abandoned mines impacts roosting bats (including hibernacula, maternity, and other roosts) and may result in a loss of sub-populations in Wyoming (Objectives 2 and 6).

A. Integrate ongoing Office of Surface Mining and AML abandoned mine safety campaigns with bat habitat education programs and actively discourage recreation in abandoned mines.

B. In cooperation with land management agencies, wildlife agencies, and private landowners, review the current human use level for caves that support roosting bats, evaluate the potential impact on bats, and if necessary, develop a management scenario to reduce or eliminate impacts on bats.

C. Maintain contact with caving organizations statewide to collect information on bat-occupied caves, recreational use levels of individual caves, and to provide information on guidelines to reduce or prevent impacts on bats.

D. Develop and implement guidelines for recreational caving in bat-occupied caves.

E. Facilitate the protection of significant bat roosts in caves and abandoned mines by providing additional resources on bat-friendly closures to land and resource managers.

1. In cooperation with the WYBWG and WGFD, provide the most up-to-date and accepted designs for bat-friendly closures to facilitate project planning.

2. Utilize existing WGFD expertise and resources (such as dedicated gating equipment) to facilitate project development.

F. Through the WYBWG, Wyoming Wildlife magazine, school programs, and public education programs, inform the public and agency personnel of the threats associated with irresponsible recreation and on the value of caves and abandoned mines as habitat for bats.

6. Crucial range designation will be necessary to achieve long-term habitat protection (Objectives 2 and 4).

A. Initially, assume all locations utilized by bats in Wyoming are crucial to the preservation of local sub-populations and the statewide population.

B. Develop criteria for the designation of crucial range for each bat species in Wyoming.

C. In cooperation with land management and wildlife agencies, designate and map crucial range for each species and provide this map in a useful format for resource managers to track and conserve bat populations.

D. Review and update mapping efforts as new information becomes available.

7. Timber harvest may impact bat foraging and roosting areas, and increase human access to caves and abandoned mines occupied by bats (Objective 4).

A. In cooperation with land management agencies, wildlife agencies, and private landowners, develop a system to review proposed timber harvest plans, evaluate the potential impact on bats, and, if necessary, develop a management scenario to reduce or eliminate impacts on bats**.**

B. In cooperation with land management agencies, wildlife agencies, and private landowners, develop a system to close or apply seasonal restrictions to new roads that may increase public access to vulnerable bat habitat.

8. Insect control projects against forest defoliators (such as gypsy moths), agricultural pests (such as Mormon crickets), and other insects (such as mosquitoes) may impact the forage base of bats (Objectives 4 and 6).

A. In cooperation with land management agencies, wildlife agencies, Wyoming Department of Agriculture Weed and Pest Control Districts, Wildlife Services (APHIS), and private landowners, develop a system to evaluate site-specific insect control projects to determine the potential impact on bats, and, if necessary, develop a management scenario to reduce or eliminate impacts on bats.

B. Promote and cooperate with the WBWG, BCI, private veterinarians, and wildlife professionals through Wyoming Wildlife magazine, news releases, and public presentations to increase awareness of the benefits of bats and the importance of their ecological roles.

9. Vandalism and removal of bats that are considered pests, resulting from a poor understanding of bats by the general public, impacts individual bat populations and may result in a loss of sub-populations in Wyoming (Objectives 3 and 6).

A. In cooperation with wildlife professionals, utilize Wyoming Wildlife magazine, school and adult education programs, news releases, and public presentations to educate the public about the beneficial value of bats for insect control, their place in the local ecology, and the small probability of disease transmission from bats to humans.

B. Develop a program to inform home and business owners of proper methods for removing bats from buildings, and ways to accommodate bat colonies without impacting personal or business interests.

C. Develop contacts with pest control authorities to enlist support in minimizing impacts to bat populations.

D. Explore opportunities for the WYBWG to get involved with public education (such as the Wyoming Bat Festival and the WGFD Expo).

10. Lack of information on potential threats to individual bats and populations, such as West Nile virus, wind turbines, and others yet to be identified, may preclude effective management (Objective 6).

A. Identify information gaps that preclude evaluation of the perceived threat and develop research projects to address it.

B. Evaluate threats to bats and develop strategies to reduce them as new information becomes available.

C. Maintain contact with the public and wildlife professionals through the WYBWG, Wyoming Wildlife magazine, news releases, and public presentations to disseminate new information about possible threats to bats.

Cited References

Oakleaf B, Cerovski AO, Luce B. 1996. Nongame bird and mammal plan: a plan for inventories and management of nongame birds and mammals in Wyoming. Wyoming Game and Fish Department, Nongame Program. 183 p.

INTRODUCTION

Worldwide, there are over 925 species of bats (Koopman 1993). Of these, 45 are found in the United States (Wilson and Ruff 1999) and 18 in Wyoming (Luce 1998). Even though Wyoming is far from what most would consider ideal bat habitat, bats are found in all areas of the state and constitute 15% of all of Wyoming's mammal species, thus contributing extensively to Wyoming's biological diversity. However, despite their great diversity, bats have historically been poorly studied, misunderstood, persecuted, and, in general, there is great concern about potential declines throughout their ranges. While the past 2 decades have seen important positive steps in bat conservation, a lack of information about many species and suspected declines in populations of others suggest that a concerted effort is needed to promote conservation of bats and their habitats continent-wide.

Bats, like many other species of wildlife, have been subjected to the pressures of human population growth and development. Loss of habitat, pollution, and persecution by humans have all contributed to population declines of numerous species of bats. Efforts to reverse population declines are hampered by public misconceptions about bats, lack of funding, and by fundamental aspects of bat biology.

Bat species have several characteristics that combine to make them highly sensitive to the adverse effects of human impacts. First, although bat species are often widely distributed across the landscape, their populations are usually only abundant in small, local areas, not across their entire range. Second, many bat species roost in large aggregations and concentrate into relatively few roosts, which greatly increases their vulnerability. Third, unlike other small mammals, bats are long-lived, sometimes more than 30 years (O'Shea and Bogan 2003), and have low reproductive rates, usually only 1 or 2 pups per year. Under normal circumstances, their long lifespans counter their low reproductive rates and populations are built up over a long span of time. However, these factors reduce the rate and probability of recovery from severe losses, and they also mean that factors affecting reproduction and life history may not be recognized for many years. Finally, some species that form colonies in caves exhibit a "passenger pigeon effect," wherein a reduction in colony size increases the cost of heating the roost and reduces survival (Tuttle 1996). For all of these reasons, scientists and managers need to act conservatively and in the best interest of bat populations.

Ecological and Economic Importance of Bats

Bats are important but often overlooked components of healthy ecosystems, biological diversity, and agricultural economics in the United States. The decline in bat populations, as well as that of many other species, represents much more than just a decrease in a population of organisms; it also reflects a decline in our overall quality of life.

As the primary predator of nocturnal insects, bats likely play an important role in regulating insect populations and insect-related ecological processes. Many of the insects bats eat are among North America's most costly agricultural and forest pests. The Brazilian free-tailed bat, for example, preys on corn earworm moths (*Helicoverpa zea*), and the big brown bat consumes cucumber beetles (*Diabrotica* spp.), the larvae of which are the destructive corn rootworm (Kurta 2000). Bats are also known to eat potato beetles (*Leptinotarsa decemlineata*) and snout beetles (Curculionidae); spruce budworm (*Choristoneura fumiferana*), corn borer (Pyralidae), cutworm (Noctuidae), and grain moths (*Sitotroga* spp.); leafhoppers (Homoptera); and mosquitoes (Culicidae) (Tuttle and Taylor 1998). Little brown myotis are able to consume 500 insects in less than an hour (Adams 2003), and a single colony of 150 big brown bats conservatively consumes 1,287,000 insects during a single season (Kurta 2000). Conserving and enhancing bat populations could decrease our dependence on expensive pesticides, which currently threaten our environmental and personal health.

Guano produced by insectivorous bats is rich in nitrogen and has long been used as fertilizer. It may also be an important part of nutrient cycling. In some caves, entire ecosystems exist that are dependent on bat guano (Hinman and Snow 2003).

Because bats travel longer distances from their roosts to their foraging areas than most other small mammals and birds, their ecologic and economic impacts may affect a large area. Bats frequently forage in high-productivity environments (such as near water), roost in nutrient-poor environments, and consume up to 100% of their body mass per night. Therefore, they may play a significant role in nutrient transfer by acting as “pepper shakers,” distributing nutrients throughout their home range (Pierson 1998). Consequently, sustaining the ecological role of bats may require a shift in attitudes toward conservation. Most conservation efforts to date have focused on rare and endangered species. While these efforts have generally been successful and are essential to the survival of these species, they often overlook the potentially critical ecological role played by more abundant and common species. From an ecosystem perspective, the most important species may be the most widespread and locally abundant, such as big brown bats and little brown myotis (Pierson 1998).

Bats’ small size, mobility, and longevity combine to make them well suited as indicator species of general environmental conditions (Fenton 1997; 2003). Environmental conditions can be tracked both indirectly, because of the high sensitivity of some bat species to habitat disturbances, and directly, by, for example, measuring the annual accumulation of mercury and other metals in the fur of bats (Fenton 2003). The response by bat communities to changes in the environment can potentially be examined at a variety of spatial scales, making them a very powerful and practical tool for evaluating the broader effects of resource management, conservation, and restoration activities, or environmental degradation. Greater knowledge of the impacts of bats and of their movement is needed to determine overall ecological, environmental, and economic importance.

Bat Biology

Bats are the only mammals with true powered flight. Their wings are made up of a thin elastic membrane stretched between elongated finger bones. This ability to fly has allowed them to become widely distributed and has probably contributed to their diversity in foraging and roosting habits and other behaviors (Hinman and Snow 2003). Bats with long, narrow wings, such as the hoary bat, are adapted for flying swiftly in open habitats, but have limited maneuverability. Species with shorter, broader wings, such as the western small-footed myotis, are adapted for slower, more agile flight in forests, where higher maneuverability is necessary. Other species have wings that are intermediate in form and allow for exploitation of both forested and open areas (Adams 2003).

At rest, bats roost head down, which allows them to occupy unique roost locations, makes them less vulnerable to predators, and facilitates flight. Their hind legs are rotated 180º, and they have a specialized arrangement of ligaments and leg muscles that allows them to hang passively from their perch while sleeping. They also have unique cavities in the cranium that pool blood and other fluids away from the brain (Richardson 2002; Adams 2003; Hinman and Snow 2003).

Although their echolocation abilities make vision secondary in importance, bats are not blind. Their vision is particularly sensitive to low light conditions, and they use it for navigation, orientation, surveying for predators, and regulation of circadian rhythms (Richardson 2002; Adams 2003; Hinman and Snow 2003).

All of Wyoming's bats have the ability to echolocate, producing high frequency calls (usually inaudible to humans) and listening for the echoes of those calls reflected by obstacles and prey. Fleshy facial features and ornamentations help focus these sounds, while specialized ear shapes assist in reception of the echoes. Some bats also rely on hearing prey-generated sounds to detect them (Hinman and Snow 2003).

Bats exhibit a great diversity of food habits, both within and among species. Although all of Wyoming's bats are insectivorous, the variety of preferred food types is still enormous. In general, nocturnal flying insects are the most common prey, including moths (Lepidoptera), beetles (Coleoptera), flies (Diptera), midges (Chironomidae), mosquitoes (Culicidae), termites (Isoptera), and ants (Formicidae). Some bat species also take non-flying insects, which they glean off of foliage or the ground (Kurta 2000; Hinman and Snow 2003). Although some bats may specialize to some extent, most are opportunistic foragers, concentrating on whatever insects of the correct size are within their habitat and the limits of their morphology and echolocation abilities (Brigham and others 1992).

Most of Wyoming's bats mate in late summer or autumn, and the females store the sperm in the uterine lining until the following spring, when fertilization takes place. Gestation lasts only a few weeks, and the pups are born in May, June, or July, when insects are available. Most western bats give birth only once a year to a single young, although a few species have litters of 2 to 4 pups. In general, parental care is solely the responsibility of the mother, with females often forming large maternity colonies while males form smaller separate bachelor colonies or roost alone. Young become volant within about 3 to 6 weeks (Harvey and others 1999; Adams 2003; Hinman and Snow 2003).

Many species of bats are heterothermic, which means they are able to enter torpor, or change their body temperature and heart rate to lower their metabolism. Torpor is an energy-saving measure that allows bats to store enough fat for hibernation or to undertake long migrations. Males may use this behavior on a daily basis throughout the summer. After the young are independent, both juveniles and adult females also begin to seek cooler day roosts that allow torpor (Bogan 2000; Adams 2003; Hinman and Snow 2003).

An extended period of torpor in winter is known as hibernation. Bat species whose winter habitat cannot supply enough insects for sustenance, and for whom migration is not an option, hibernate during winter. During hibernation, the bat's body temperature drops to the ambient temperature of the hibernaculum, and oxygen consumption, breathing rate, and other body functions slow, conserving energy that would otherwise have to be used to maintain a high body temperature. Nevertheless, by the end of winter, almost no fat remains, and protein may be catabolized as an energy source. The hibernaculum must maintain a stable set of conditions, even if the temperature outside changes, to keep the bats from waking and wasting energy. Depending on the species, bats hibernate at temperatures ranging from a few degrees above freezing to around 10 °C (50 °F). High humidity is also essential, as bats can easily dehydrate during hibernation, and airflow is equally important to replenish the air supply, although too much airflow can destabilize the climate of the hibernaculum. Moreover, the hibernaculum must provide security from predators and other danger because it often takes a half hour or more for bats to become alert and able to fly after being awakened. Habitats offering these conditions are usually underground sites, such as caves or abandoned mines, or cavities deep within old trees (Richardson 2002; Adams 2003; Hinman and Snow 2003).

Most western species probably migrate short distances from their summer roosts to their hibernacula. However, some species, such as the hoary bat, silver-haired bat, and Brazilian free-tailed bat, escape winter by migrating long distances to areas where temperature and insect populations remain high enough for continued activity. Species that undergo long-distance seasonal migrations usually do not hibernate (Bogan 2000; Adams 2003).

Roosts

Many bat species spend more than half of their lives roosting. Because of their small size, the high energetic demands of flight, a limited ability to store fat, and the seasonal abundance of their prey, bats have an annual energy budget that is difficult to balance. Energy expenditures are regulated through roost selection. Consequently, reproductive success and overwinter survival of individuals and populations may largely depend on the availability of suitable roosts. Therefore, roosts are critical to the long-term survival of bat populations and are probably a limiting resource. Overall distribution and abundance of suitable roost sites (summer and winter) may ultimately determine the distribution and abundance of many bat species (Chung-MacCoubrey 1996; Bogan 2000).

Bats need roosts for day shelter, raising young, and, for many species, hibernation. Bats may also need night roosts—places to rest, digest food, and socialize while foraging. Some species use transitory roosts during migration, and others perform courtship and mating inside roosts. The characteristics of these roost types may differ greatly (Hinman and Snow 2003).

Roosts must provide shelter from the elements, a microclimate suited to the needs of bats, and protection from predators. Roost requirements in some species are very specific in terms of temperature regimes, humidity, protection from predators, substrate, and light. Also, males and females have different requirements during summer; typically, reproductive females must select very warm roosts to facilitate growth of the embryos and young. In addition, roosts must be in close proximity to foraging habitat and water, usually within 10 to 15 km (6 to 9 mi) (Adams 2003; Hinman and Snow 2003).

Roosting environments may vary widely, both between and within species. Natural roosts include caves, rock crevices, cliffs, tree cavities, loose bark, and foliage. With settlement and development of the West, bats have lost some natural roosts but now also roost in manmade structures such as abandoned mines, buildings, bridges, culverts, and bat houses. Some bat species, such as the hoary bat, are roost specialists and are restricted to only 1 or a few types of roosts, while other species, such as the big brown bat, are generalists, using a variety of roost types at any 1 time of the year (Bogan 2000; O'Shea and Bogan 2003; Tuttle 2000; Hinman and Snow 2003).

Bats are usually extremely loyal to traditional areas of both summer and winter habitat (Tuttle 2000). However, fidelity to specific roosts can vary widely among and within species, depending on the season and type of roost. High fidelity appears to be directly related to roost permanency and inversely related to roost availability. Bats that occupy roosts that are abundant but ephemeral, such as tree foliage, are likely to switch roosts frequently. On the other hand, bats often show high fidelity to roosting sites that are uncommon and permanent, such as caves (Lewis 1995).

Foraging Habitat

Foraging habitat requirements are complex and vary greatly among species and even, seasonally and spatially, within species. For insectivorous bats, prey availability is probably the strongest influence on foraging habitat selection and may change considerably between seasons or habitat types. Although bats may travel long distances between roosting and foraging sites, proximity to appropriate roosts may influence the suitability of a particular area for bat foraging. Also, the availability of night roosts near a foraging area may increase bat usage. Predictability of the insect prey base can affect the appeal of an area for foraging; for example, habitats such as riparian areas and agricultural fields may have predictably large populations of certain insects, whereas other areas may have more ephemeral populations. Bats are also susceptible to predation and disturbances when foraging, so choice of foraging area may be affected by the protection it provides from these threats. Frequently, insectivorous bats forage near forest edges, which, aside from supplying insect prey, may provide shelter from predators and wind. The wing shape and echolocation call type of bats may also dictate foraging habitat, as some bats cannot forage in highly cluttered environments, such as dense forests, and must forage in more open areas (Hinman and Snow 2003).

Surface water for drinking is another critical component of bat habitat. Because of their high protein diet, most insectivorous bats require water to excrete toxic nitrogenous waste products. In addition, arid environments cause high rates of evaporative water loss through wing membranes and respiratory exchange. Based on their physiological adaptations to water conservation, or lack thereof, most bats must find roosts and foraging areas that have water within close proximity (Chung-MacCoubrey 1996).

Bat management must be comprehensive to be effective. The definition of bat habitat as a single location in space and time (such as a roost or foraging site) should be expanded to reflect the movement of bats over large areas of the landscape on a daily and seasonal basis. Protecting large maternity or hibernation roosts without considering other habitat components will not protect bat populations in the long term. In order for successful bat reproduction and survival to occur, all required habitat components must be available in relative proximity to one another. The ideal interspersion of habitat components to support a thriving bat community consists of a closely spaced complex of open water; vegetative diversity; and suitable summer, winter, and other roosts. In addition, a diversity of bat species means a diversity of diets, foraging areas, and roost types. Bat management should address all species that are dispersed across the landscape in small, inconspicuous groups, as well as those that form large colonies (Anonymous 1999; Kurta 2000).

Overview of Wyoming

Elevations in Wyoming range from a low of 969 m (3232 ft) in the northeast corner of the state to 4207 m (13,804 ft) at the summit of Gannett Peak in the Wind River Mountains. The mean elevation is 2030 m (6700 ft); 37% of the state consists of elevations greater than 2134 m (7000 ft) (Knight 1994).

A multitude of different soils exist in Wyoming, reflecting the influences of geologic substrate, topography, climate, wildlife, vegetation, and time (Knight 1994). Soils in mountainous areas are often shallow and not well developed; granites, basalts, and quartzites in mountain ranges weather very slowly, resulting in shallow, coarse soils. Deep soils occur where topography is lower. Sedimentary rocks are more frequently exposed in foothills and lowlands of the state, although sedimentary strata also occur in mountain ranges. Weathering of sandstone contributes to the formation of coarse-textured, sandy soil with a high infiltration rate, while fine-textured and deeper soils often develop from easily eroded shales, mudstones, and siltstones. Organic matter content increases from lowland up to montane grassland, then decreases to the alpine zone. Vegetation patterns in Wyoming are determined by the following soil features: infiltration rate, depth, water-holding capacity, salinity, and aeration.

Because of the varied topography of the state, temperatures vary greatly and are inversely correlated with elevation (Knight 1994). The mean daily high temperature in July ranges from 32 ºC (90 ºF) on the Great Plains and in the Bighorn Basin to less than 24 ºC (75 ºF) in the mountains. The mean frost-free period varies from 125 days on the Great Plains, in the Bighorn Basin, and in the Wind River Basin to fewer than 25 days in the mountains. Freezing temperatures are possible at any time of the year at higher elevations. Strong westerly winds frequently blow, particularly in the southern part of the state.

Wyoming is semi-arid—summer drought often occurs, especially in the lowlands (Knight 1994). Mean precipitation varies from 15 to 150 cm (6 to 59 in) per year, with the mountains receiving more precipitation than the lowlands. Intermountain basins in the western two-thirds of the state are drier (15 to 30 cm [6 to 12 in] precipitation per year) than the Great Plains region in the eastern one-third of the state, which averages 30 to 40 cm (12 to 16 in) per year. Mountains and foothills throughout the state receive 40 to 150 cm (16 to 59 in) per year. Precipitation is often in the form of snow at higher elevations, especially during winter months.

In Wyoming, 49% of the total 25,248,931 ha (62,343,040 ac) of land surface is federally managed (Table 1), 5% is managed by state agencies, and 46% of the land surface is in private ownership.

Table 1. Land surface ownership in Wyoming.

Surface Ownership	Hectares	Acres	Percentage
Private	11,605,905	28,677,798	46%
Bureau of Land Management[a]	7,453,420	18,417,149	30%
US Forest Service	3,745,214	9,254,297	15%
State agencies	1,261,511	3,117,152	5%
National Park Service	974,880	2,408,895	3.9%
Bureau of Reclamation	231,834	572,853	0.9%
US Fish and Wildlife Service	20,019	49,466	0.08%
Naval Petroleum Reserve	3837	9481	0.02%
US Army	3830	9464	0.02%
US Air Force	2465	6091	0.01%
Bureau of Indian Affairs	524	1296	0.002%
Agricultural Research Service	297	734	0.001%
Federal Aviation Administration	239	591	0.0009%
Veterans' Administration	140	346	0.0005%
Western Area Power Administration	93	231	0.0003%
US Postal Service	7	17	0.00003%
General Services Administration	2.4	6	0.00001%
Bonneville Power Administration	1.6	4	0.000006%
Energy Research and Development Admin.	0.8	2	0.000003%
Total	25,248,931	62,343,040	

[a]Includes some acreage (approximately 202,500 ha [500,000 ac]) assigned to other agencies but administered by the BLM.

Bat Conservation in Wyoming

Bat conservation is a relatively new phenomenon in Wyoming. Before 1994, bats were not legally protected in the state. In 1994, the Wyoming Game and Fish Commission approved a nongame wildlife regulation protecting several wildlife species, including bats. That regulation protects all of Wyoming's bats from intentional take except under scientific collection permits or in instances where the Wyoming Game and Fish Department (WGFD) approves control measures to address public health concerns (Luce 1998). All of Wyoming's resident bat species are classified as Species of Special Concern by the WGFD because of their low reproductive rates and high conservation needs.

Between 1982, when the Office of Surface Mining-Abandoned Mine Reclamation Program (AML) was initiated in Wyoming, and 1989, when an agreement to conduct pre-reclamation bat inventories was initiated, a minimum of about 300, and possibly as many as 400, abandoned mine adits and shafts were closed (Oakleaf and others 1996). This represents a significant loss of potential bat habitat. In 1990, the WGFD's Nongame Program, in cooperation with the AML, began evaluating abandoned mines scheduled for reclamation. Similar cooperative evaluations have been conducted on Natural Resources Conservation Service, Rural Abandoned Mine Program projects as a cooperative effort between that agency, WGFD, and the US Fish and Wildlife Service (USFWS) (Luce 1994).

From 1994 to 1998, in cooperation with the Bureau of Land Management, the US Forest Service-Shoshone National Forest, and the USFWS, the WGFD conducted a project to inventory caves and abandoned mines in Wyoming to determine their potential as bat habitat. This project was the first phase of collection of bat distribution and habitat information under the 1996 Nongame Bird and Mammal Plan (Oakleaf and others 1996). The objectives of the project were to determine: 1) use of individual caves, abandoned mines, and buildings by bats; 2) species composition and number of bats; 3) bat habitat potential; 4) roost type and season of use; and 5) amount of human traffic and disturbance. Although there are many questions about bat distribution and habitat use that the cave and abandoned mine surveys did not address, the project added significantly to our knowledge of the distribution and abundance of bat species that use buildings and underground roosts in Wyoming. A large proportion of the underground bat roosts in the state have been identified, but many have not yet been surveyed. The second phase of the program, development of an active management program to preserve the bat populations and habitat, and potentially improve the habitat at each important site, was initiated in 1998 (Priday and Luce 1999).

In 1998, the WGFD joined efforts with other western states and assisted in developing the Species Conservation Assessment and Conservation Strategy for the Townsend's Big-eared Bat (Pierson and others 1999). The goal of the effort was to proactively preclude the need to list the species under the Endangered Species Act. The development of the Western Bat Working Group (WBWG) soon followed this unprecedented proactive conservation initiative. The participating states have since each developed state working groups that are subsets of the WBWG.

The Wyoming Bat Working Group (WYBWG) was developed in 1998 out of an effort to increase support for bat conservation in Wyoming. Initially, the WYBWG included only a few biologists primarily from the WGFD, but the group grew quickly to include individuals committed to bat conservation from several land and resource management agencies, the Department of Environmental Quality, non-government organizations, and at least 1 Wyoming Conservation District.

The WYBWG meets annually to discuss and prioritize bat conservation issues in Wyoming. This relatively new conservation initiative has drastically increased knowledge about bats and helped bring a unified approach to bat conservation in Wyoming. Conservation of critical roosts and conservation education programs has commenced in nearly all parts of the state, and the WYBWG has facilitated the culmination of several interagency bat conservation projects. However, much still needs to be accomplished. Conservation of Wyoming's bat communities will only improve in the future, as additional data is collected, threats are identified and addressed, and new partnerships are developed.

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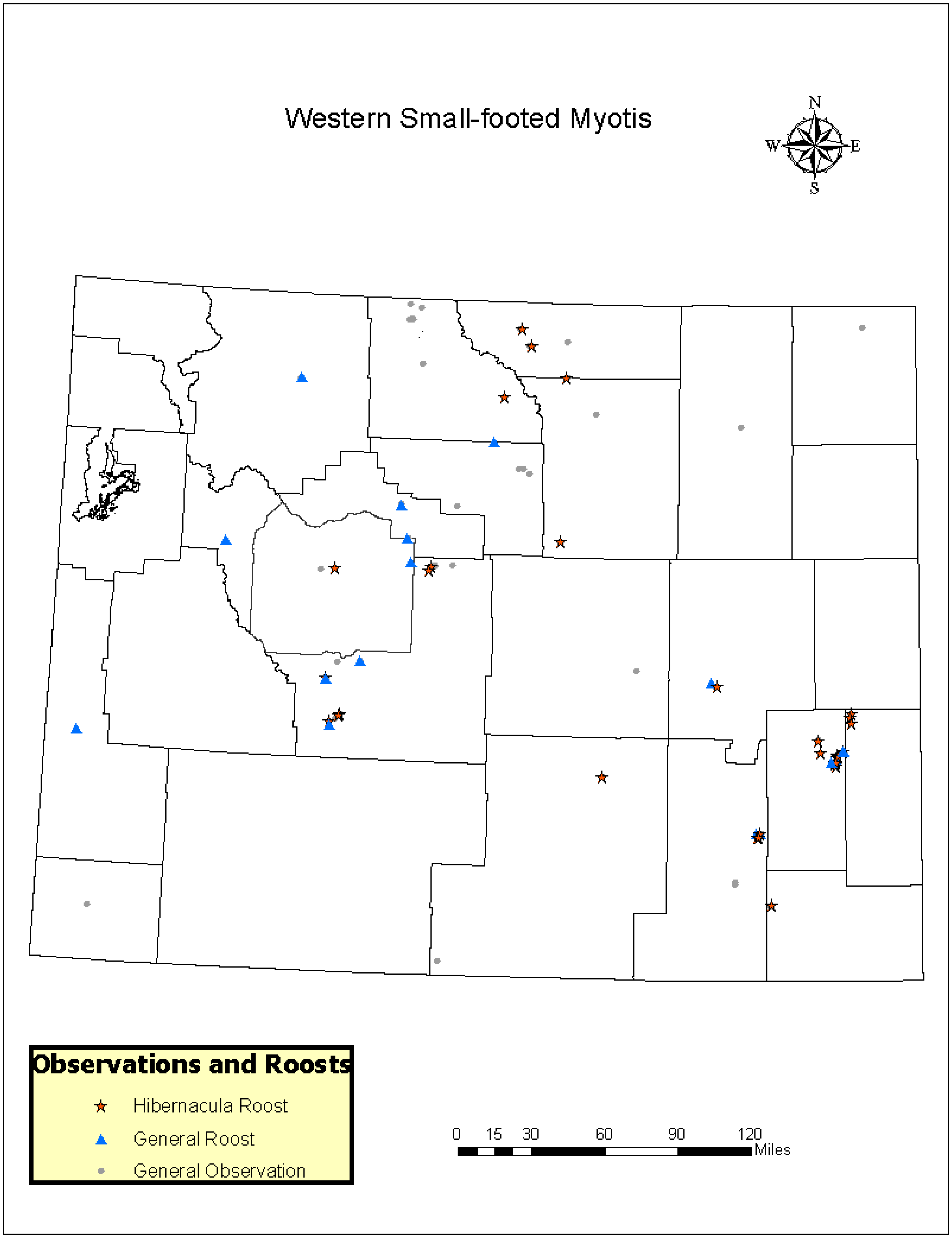
WYOMING BAT SPECIES:
INFORMATION, ISSUES, AND RECOMMENDATIONS

Forty-five species of bats are found in the United States. Of these, 18 species have been documented in Wyoming. Twelve species are considered residents, 4 are considered peripheral species, and 2 are considered accidental species.

Table 2. Resident, peripheral, and accidental bat species that occur in Wyoming.

Common Name	**Scientific Name**	**Status**
Western small-footed myotis	*Myotis ciliolabrum*	Resident
Long-eared myotis	*Myotis evotis*	Resident
Northern myotis	*Myotis septentrionalis*	Resident
Little brown myotis	*Myotis lucifugus*	Resident
Fringed myotis	*Myotis thysanodes*	Resident
Long-legged myotis	*Myotis volans*	Resident
Hoary bat	*Lasiurus cinereus*	Resident
Silver-haired bat	*Lasionycteris noctivagans*	Resident
Big brown bat	*Eptesicus fuscus*	Resident
Spotted bat	*Euderma maculatum*	Resident
Townsend’s big-eared bat	*Corynorhinus townsendii*	Resident
Pallid bat	*Antrozous pallidus*	Resident
California myotis	*Myotis californicus*	Peripheral
Yuma myotis	*Myotis yumanensis*	Peripheral
Eastern red bat	*Lasiurus borealis*	Peripheral
Brazilian free-tailed bat	*Tadarida brasiliensis*	Peripheral
Eastern pipistrelle	*Pipistrellus subflavus*	Accidental
Big free-tailed bat	*Nyctinomops macrotis*	Accidental

Species accounts for each of the 18 bat species in Wyoming are presented in this section. Species accounts include information pertaining to identification, distribution and status, natural history, habitat requirements, and management recommendations for each species. Species accounts are based on research conducted in Wyoming when available, as well as research conducted elsewhere.


Western Small-footed Myotis
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General Roost
General Observation
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Western Small-footed Myotis (***Myotis ciliolabrum***)

Range

Formerly considered a subspecies of the eastern small-footed myotis (*M. leibii*), the western small-footed myotis inhabits most of western North America from British Columbia, Alberta, and Saskatchewan in Canada, throughout most of the United States west of the 100th meridian, and into central Mexico. It occurs throughout most of Wyoming at elevations between 915 and 2500 m (3000 and 8000 ft), but is rarely reported in high mountains (Luce 1998). It is a year-round resident throughout its summer range, including Wyoming. Clark and Stromberg (1987) show occurrence in 13 counties throughout most of the state, and Cerovski and others (2004) show occurrence in 24 of the state's 28 latilongs, although confirmed or suspected breeding has only been recorded in 5 latilongs.

Description

The western small-footed myotis is a small bat with long, glossy golden-brown to pale blond fur. Its dark ears and black facial mask contrast with its medium to light coloration. The wings and interfemoral membrane are black and hairless, and the calcar has a distinct keel. The ear reaches or exceeds the tip of the nose by about 1 mm when laid forward. The tragus is slender, tapering, and about half as long as the ear. External measurements are as follows: wingspan, 210 to 250 mm; total length, 80 to 99 mm; tail, 34 to 49 mm; hind foot, 6 to 9 mm (less than half the length of the tibia); ear, 11 to 16 mm; forearm, 31 to 36 mm; and weight, 3 to 6 g (Holloway and Barclay 2001; Schmidt 2003).

Except for the California myotis, all of the other *Myotis* species in Wyoming are larger than the small-footed myotis, lack a dark facial mask, and have larger hind feet. The small-footed myotis most closely resembles the California myotis and the two are very difficult to distinguish in the field. One difference between the two species is the slope of the forehead, which is flattened in the small-footed myotis and rises more abruptly in the California myotis. The best way to use this characteristic in the field is to measure the distance from the tip of the nostrils to the hairline, which is greater in the small-footed myotis (1.5 times the width between the nostrils) than in California myotis (equal to the width between the nostrils) (Holloway and Barclay 2001). Also, the tail of some small-footed myotis extends beyond the interfemoral membrane by about 1.5 to 2.5 mm, while that of the California myotis is completely enclosed within the membrane (Constantine 1998; Holloway and Barclay 2001). In addition, the California myotis has a smaller thumb (less than 4.2 mm) than the small-footed myotis (thumb is greater than 4.2 mm) (Hinman and Snow 2003).

Associated Species

Other species that may benefit from management for this species include the California myotis, long-eared myotis, northern myotis, little brown myotis, fringed myotis, long-legged myotis, Yuma myotis, big brown bat, spotted bat, Townsend's big-eared bat, pallid bat, and the Brazilian free-tailed bat. Although the eastern pipistrelle and the big free-tailed bat are accidental species in Wyoming, they may also benefit from management for this species.

Habitat

The western small-footed myotis inhabits a wide variety of habitats in Wyoming. It is most commonly associated with arid, rocky areas (such as canyons, cliffs, rock outcrops, and badlands) within a variety of habitats, such as montane forest, juniper woodlands, sagebrush steppe, and shortgrass prairie. It is usually found at lower and intermediate elevations (Finley and others 1983).

The small-footed myotis typically forages along cliffs and rocky slopes in dry areas. It also forages over water when not in association with the California myotis, which usually hunts over and near water (Harvey and others 1999).

In summer, the small-footed myotis roosts in a variety of settings, although it is usually associated with rock shelters (such as crevices, overhangs, cliffs, and under rocks), caves, and/or abandoned mines. It also will occasionally roost in buildings, bridges, or under loose tree bark. Maternity roosts in rock crevices are usually small, dry, shallow, and maintain a fairly uniform high temperature (Schmidt 2003). This is one of only a few species of bats that often roosts in cavities and crevices at ground level (Schmidt 2003). The small-footed myotis also uses a variety of night roosts during summer, including caves, abandoned mines, rock overhangs, bridges, and buildings.

The small-footed myotis hibernates in caves and abandoned mines, and its reliance on these sites is significant. Of 37 hibernacula documented in Wyoming between 1994 and 1999, 27 were located in abandoned mines, 9 were in caves, and 1 was in a tunnel (Priday and Luce 1999a).

Life History

The western small-footed myotis mates in the fall and the female retains the sperm over winter. In spring, females ovulate and fertilization occurs. A single pup is born each year in about June or July. Within about 3 weeks, young are able to fly and forage on their own.

The small-footed myotis usually begins foraging at dusk, shortly after sunset, with peaks of activity between 10:00 and 11:00 PM and 1:00 and 2:00 AM (Harvey and others 1999). It is highly maneuverable in flight, often foraging among boulders, shrubs, and trees within 1 to 3 m (3 to 10 ft) of the ground (Harvey and others 1999). It flies slowly and erratically in irregular circles as it pursues aerial insects. Its diet consists of a variety of small, soft-bodied insects, particularly moths (Lepidoptera), but also beetles (Coleoptera), ants (Formicidae), bugs (Hemiptera), and others.

The small-footed myotis hibernates within its summer range over most of North America, including Wyoming. At least in some areas, it may tolerate drier and colder hibernacula than other small bats. However, it probably selects hibernacula with temperatures that vary little temporally or spatially, reflecting its need to conserve energy (Genter 1986). Individuals typically wedge into cracks and crevices in the ceiling of hibernacula and position their undersides against the ceiling, with their heads facing outward (Holloway and Barclay 2001).

This species does not often occur in large groups and in fact is normally seen roosting and hibernating alone (Schmidt 2003). Although females may form small maternity colonies of up to 30 bats, they also often rear their young alone. Adult males are segregated from maternity colonies and usually roost alone. In hibernacula, individuals typically roost alone in small cracks and crevices throughout the cave or abandoned mine, although 3 or 4 individuals may roost together in larger crevices, and they may occasionally form larger aggregations. Hibernacula found in Wyoming averaged 3.6 bats (range 1 to 33) (Priday and Luce 1999).

Status

In general, the western small-footed myotis is widely distributed but not abundant throughout its range (Schmidt 2003). It is one of the species most commonly found during bat surveys of abandoned mines throughout the year in Wyoming (Oakleaf and others 1996). It has been observed at 66 sites throughout the state, including 37 hibernacula roosts, 40 summer night roosts, and 6 summer day roosts, although no maternity colonies have yet been found (Priday and Luce 1999a).

The western small-footed myotis is classified as a nongame species in Wyoming and is protected from take in Section 11, Chapter 52 of the Wyoming Game and Fish Commission Regulations. The Wyoming Game and Fish Department classifies it as a Species of Special Concern with a Native Species Status of 3 (NSS3).

Conservation Issues

The primary threat to the western small-footed myotis is the disturbance or loss of roost sites in caves and abandoned mines. For example, in the 1990s the desiccated remains of 53 small-footed myotis were documented in Wyoming in a reclaimed mine that had been sealed in 1987 (Priday and Luce 1999a). The fact that this species often roosts in sites at ground level also makes it vulnerable to disturbance from many sources, such as off-road vehicles, livestock trampling, and flooding. Other potential threats include pesticides and other contaminants.

Survey and Monitoring Issues and Techniques

The recommended survey methods for most habitats are mist netting or harp trapping at ground level. The small-footed myotis is readily captured in nets in Wyoming. It is easy to detect acoustically, but is not easily distinguishable from other 40-kHz *Myotis* (WBWG 2003). However, where acoustic surveys are combined with visual surveys by an experienced observer, the species can sometimes be distinguished in flight by its small size and slow, erratic flight pattern.

Management Recommendations

1. Implement inventory and monitoring to determine population status and habitat requirements of the western small-footed myotis in Wyoming, as additional information is necessary to guide management actions.

2. Manage lands where western small-footed myotis occur in such a way that provides adequate roosting and foraging habitat to maintain stable populations (that is, secure roosting sites; diverse, native foraging habitat; and uncontaminated water sources).

3. Implement Best Management Practices for natural caves (see page 152), abandoned mines (see page 161), and rock shelters (see page 168) in areas where western small-footed myotis roost.

4. Avoid timber harvest activities in close proximity to known roosting sites of small-footed myotis, as they often roost on or close to ground level and could easily be disturbed or harmed by the passage of large vehicles. Use small patch cuts to provide temporary foraging areas within commuting distance of known roosting sites, particularly in areas near water sources (Schmidt 2003).

5. Avoid recreational activities (such as off-road vehicle travel, dirt biking, horseback riding, and rock climbing) that could disturb ground-level roost sites, or that lead to erosion and degradation of water sources in areas where significant small-footed myotis roosts are known to occur.

6. Use livestock grazing to reduce tall, dense vegetation around known roost sites, which could block access to roosts and create a higher fuel load and risk of fire (Schmidt 2003). However, avoid disturbance of significant roost sites by removing livestock from the area during the season that roosts are in use.

7. Avoid or minimize pesticide use in areas where the western small-footed myotis is known to occur to avoid direct poisoning and to maintain a food source for this species and other insectivores.

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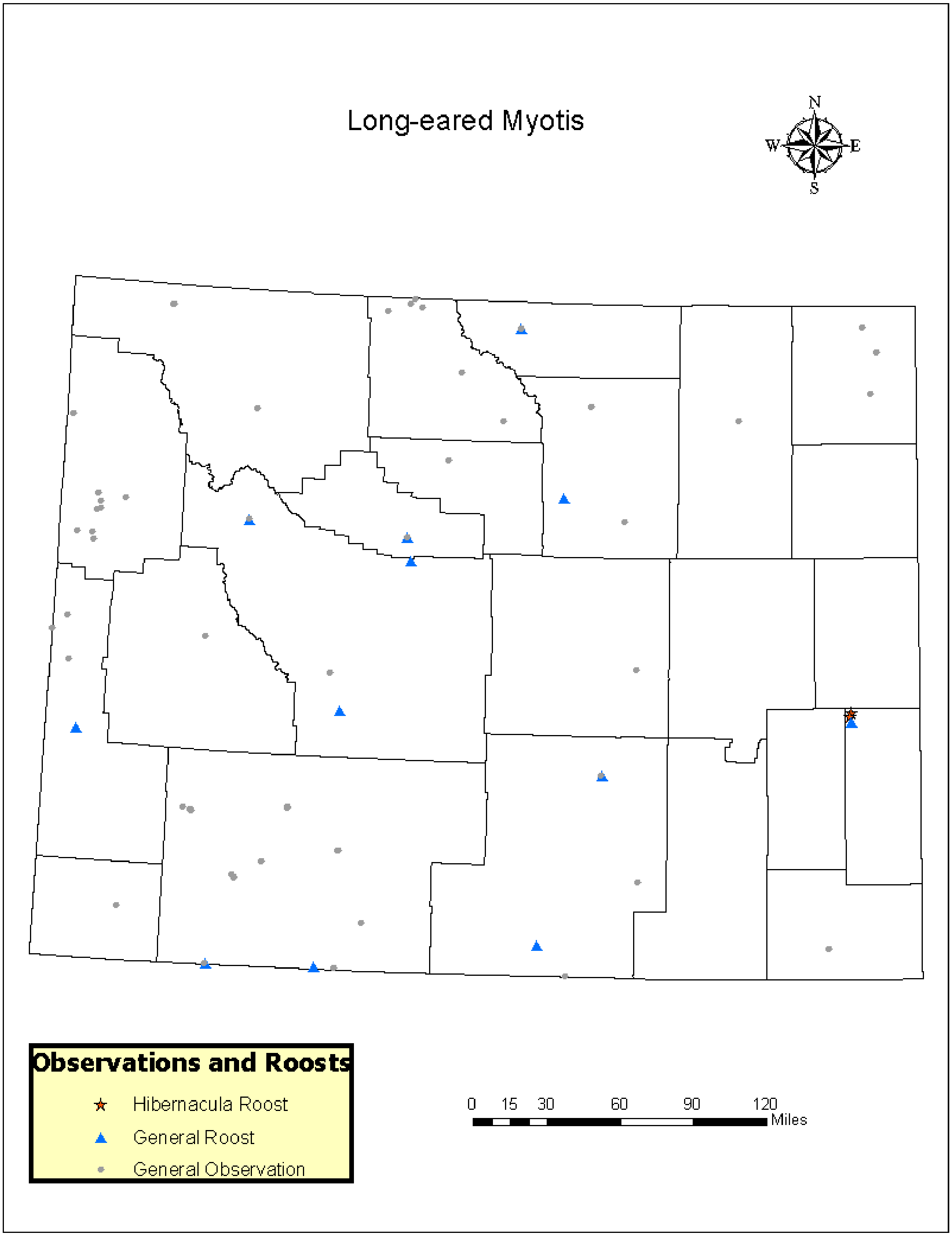

Long-eared Myotis
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Observations and Roosts
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<u>Long-eared Myotis</u> (*Myotis evotis*)

Range

The long-eared myotis inhabits most of western North America from central British Columbia and southern Alberta, south to Baja California, and east to northeastern Arizona and western South Dakota. It occurs throughout most of Wyoming at elevations between 1525 and 2990 m (5000 and 9800 ft) (Luce 1998). Clark and Stromberg (1987) show occurrence in 11 counties scattered throughout the state, and Cerovski and others (2004) show occurrence in 23 of the state's 28 latilongs, although confirmed or suspected breeding has only been recorded in 3 latilongs. Its winter range is not known, although 1 hibernaculum and 1 possible hibernaculum have been found in Wyoming (Priday and Luce 1999).

Description

The long-eared myotis is a large *Myotis* with long, glossy medium- to light-brown dorsal fur and pale buff ventral fur. The ears, wings, and interfemoral membrane are black and contrast with the lighter fur. The ears are longer than those of any other *Myotis* in Wyoming, and extend at least 5 mm beyond the tip of the nose when laid forward. The tragus is long and slender. The interfemoral membrane has only an inconspicuous fringe of minute hairs on the trailing edge. The calcar extends about halfway from the foot to the tip of the tail, and is not keeled or only slightly so. External measurements are as follows: wingspan, 250 to 300 mm; total length, 87 to 100 mm; tail, 34 to 45 mm; hind foot, 8 to 11 mm (less than half the length of the tibia); ear, 17 to 25 mm; forearm, 36 to 41 mm; and weight, 5 to 8 g (Manning and Jones 1989; Luce 1998). The fringed myotis also has long ears, but its interfemoral membrane has a fringe of stiff hairs on the trailing edge. The northern myotis has smaller, lighter-colored ears.

Associated Species

Other species that may benefit from management for this species include the California myotis, western small-footed myotis, northern myotis, little brown myotis, fringed myotis, long-legged myotis, Yuma myotis, silver-haired bat, big brown bat, Townsend's big-eared bat, pallid bat, and the Brazilian free-tailed bat. Although the eastern pipistrelle is an accidental species in Wyoming, it may also benefit from management for this species.

Habitat

The primary habitat of the long-eared myotis is coniferous forest and woodland, including juniper, ponderosa pine, and subalpine spruce-fir. It is also occasionally found in cottonwood riparian areas, basins, and sagebrush grasslands where roost sites are available (Oakleaf and others 1996; Wilson and Ruff 1999). It is most likely to be found in areas close to a water source (Hinman and Snow 2003). It may also occur more frequently in suitable habitat near rock outcroppings or cliffs (Manning and Jones 1989).

The long-eared myotis primarily forages over rivers, streams, and ponds within the forest-woodland environment. It also forages over open areas such as campgrounds, small forest openings, and edges (Schmidt 2003), although foraging areas are most likely to be close to a water source.

During summer, the long-eared myotis roosts in a wide variety of structures, including cavities in snags, under loose bark, stumps, buildings, rock crevices, caves, and abandoned mines. Waldien and others (2000) found that large-diameter conifer snags provide primary roosting habitat for the long-eared myotis when these structures are present in the landscape, and they suspect that the use of large conifer snags and stumps as day-roosts is typical of long-eared myotis in western coniferous forests. The only maternity site so far found in Wyoming was in an abandoned building, although 2 other summer day roosts have been found, both in caves (Priday and Luce 1999a).

After feeding, the long-eared myotis often gathers in night roosts that are near, but separate from, day roosts. It has been observed at 24 summer night roosts in Wyoming—11 in caves, 9 in abandoned mines, 3 in rock shelters, and 1 in a building (Priday and Luce 1999).

Little is known about the winter habitat of the long-eared myotis, although it probably hibernates primarily in caves and abandoned mines. In Wyoming, it has been documented at 1 hibernaculum and was suspected at another, both in caves (Priday and Luce 1999).

Life History

The long-eared myotis mates during autumn, the female stores the sperm over winter, and delayed fertilization takes place in spring. Gestation is about 60 days, and the young is born in about June or July. Females give birth to 1 pup per year.

The long-eared myotis has a flexible foraging strategy (Altenbach and others 2002), catching insects both by aerial pursuit and by hovering and gleaning from the surface of foliage, tree trunks, rocks, or the ground. Its flight is slow and maneuverable as it forages within and near vegetation and over water. It uses both echolocation and passive listening to locate prey (Wilson and Ruff 1999). Foraging times probably vary with prey availability, ambient temperature, and reproductive status (Hinman and Snow 2003). Its ability to hunt moths at rest allows it to live at higher elevations than other bat species, where cooler nighttime temperatures cause moths and other insects to rest earlier (Adams 2003). The long-eared myotis primarily eats moths (Lepidoptera) and small beetles (Coleoptera), although it is an opportunistic feeder and takes a variety of other prey, such as flies (Diptera), spiders (Araneidae), lacewings (Neuroptera), wasps (Hymenoptera), true bugs (Hemiptera), and leafhoppers (Homoptera) (Manning and Jones 1989).

Very little is known about the migration and hibernation patterns of the long-eared myotis. It probably migrates short distances from its summer roost to hibernate, although the winter range is not known (Manning and Jones 1989).

The long-eared myotis is a colonial species, although it generally forms only small colonies. In summer, females form maternity colonies up to about 40 individuals (Altenbach and others 2002), whereas males and non-pregnant females roost alone or in small groups nearby.

Status

The long-eared myotis is a widespread species (Barbour and Davis 1969), and although it is not common everywhere in its range, it is usually moderately common in areas where its habitat requirements are met (Wilson and Ruff 1999). It is widespread in Wyoming as well, but is uncommon compared to other bat species in the state (Luce 1998).

The long-eared myotis is classified as a nongame species in Wyoming and is protected from take in Section 11, Chapter 52 of the Wyoming Game and Fish Commission Regulations. The Wyoming Game and Fish Department classifies it as a Species of Special Concern with a Native Species Status of 2 (NSS2). The Wyoming Natural Diversity Database classifies it as S1B, S1?N (Fertig and Beauvais 1999). The Bureau of Land Management in Wyoming considers it a Sensitive Species (BLM 2002).

Conservation Issues

Potential threats include timber harvest, recreational caving and other roost disturbances, mine reclamation, renewed mining, building demolition and remodeling, and pesticides and other contaminants.

Survey and Monitoring Issues and Techniques

The recommended survey method is mist netting. The long-eared myotis is readily captured in mist nets at both aquatic and terrestrial sites, particularly along roads and cut lines through trees. It is easy to detect acoustically, and a subset of its calls is diagnostic (WBWG 2003).

Management Recommendations

1. Implement inventory and monitoring to determine population status and habitat requirements of the long-eared myotis in Wyoming, as additional information is necessary to guide management actions.

2. Manage lands where long-eared myotis occur in such a way that provides adequate roosting and foraging habitat to maintain stable populations (that is, secure roosting sites; open, mature forest with standing dead trees; and uncontaminated water sources).

3. Avoid removing and fragmenting mature and old-growth forests, impacting long-eared myotis foraging and roosting areas, and increasing human access to caves and abandoned mines through timber harvesting activities. Use selective harvesting to reduce the understory and maintain areas of lower density, large-diameter trees. Use small patch cuts to provide temporary foraging areas for long-eared myotis, particularly in areas close to standing, open water. Avoid harvest activities in areas close to known roosting sites of long-eared myotis during the maternity roosting period, and retain all known roost trees (Schmidt 2003).

4. Implement Best Management Practices for forests and woodlands (see page 190) that retain all large-diameter snags as potential roost sites for long-eared myotis and other snag-users. Waldien

and others (2000) found that large-diameter conifer snags provide primary roosting habitat for long-eared myotis when they are available, and that retaining snags in clusters may be particularly beneficial for this species.

5. Create tall stumps during timber harvest operations to provide possible roost sites for long-eared myotis in areas where there are relatively few large snags. Because the use of stumps increases when surrounding vegetation does not obstruct them, manage vegetation around stumps or for stumps located in natural openings and on steeper slopes. However, because the use of stumps by bats is probably ephemeral and because stumps probably provide limited roosting or nesting opportunities for other species of bats and other snag-dependent species, managing for mature forest and large-diameter snags across the landscape is the best option (Vonhof and Barclay 1997; Waldien and others 2000).

6. Use prescribed fire to maintain open, mature forest with standing dead trees in areas where long-eared myotis occur. Maintain a reduced fuel load and use low-intensity fires so that large snags and trees are not burned. Where possible, use prescribed fire from September to March to avoid directly impacting roosting bats.

7. Implement Best Management Practices for natural caves (see page 152), abandoned mines (see page 161), buildings (see page 174), bridges (see page 180), and rock shelters (see page 168) in areas where long-eared myotis roost.

8. Avoid or minimize pesticide use in areas where the long-eared myotis is known to occur to avoid direct poisoning and to maintain a food source for this species and other insectivores.

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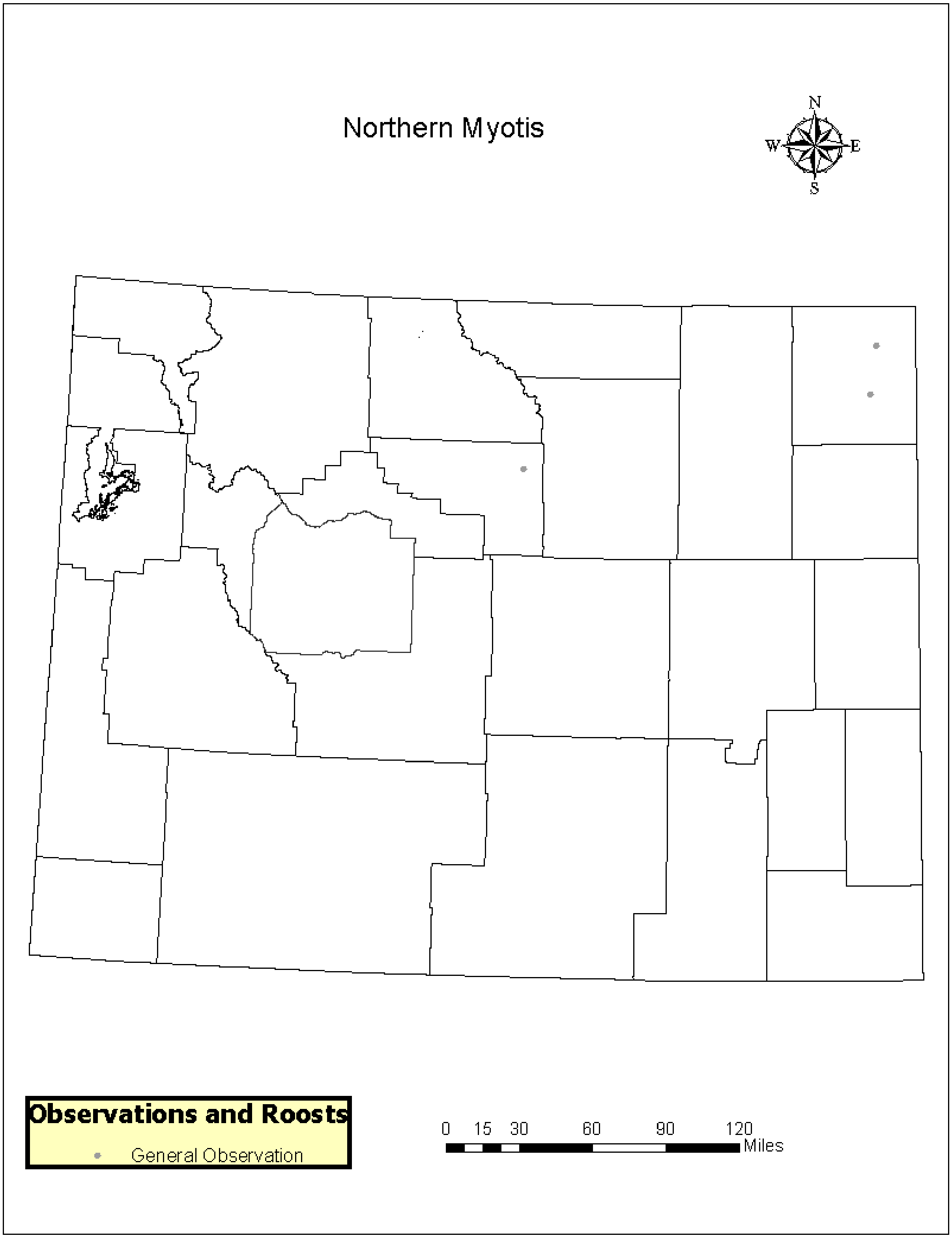
Northern Myotis
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Observations and Roosts
General Observation
0 15 30 60 90 120
Miles

<u>Northern Myotis</u> (*Myotis septentrionalis*)

Range

Formerly considered a subspecies of Keen's myotis (*Myotis keenii*), the northern myotis is widely distributed across eastern North America. It occurs from Manitoba across southern Canada to Newfoundland, south to northern Florida, and west to Wyoming. In Wyoming it is restricted to the Black Hills, the Big Horn Mountains, and possibly the Bear Lodge Mountains in the northeastern corner of the state (Oakleaf and others 1996). Its summer and winter ranges appear to be the same (Barbour and Davis 1969), and it is probably a year-round resident in northeastern Wyoming. Clark and Stromberg (1987) show occurrence in 2 counties in northeastern Wyoming. Although Cerovski and others (2004) show occurrence in 2 latilongs in northeastern and southeastern Wyoming and historical occurrence in 1 latilong in northwestern Wyoming, breeding has only been documented in northeastern Wyoming.

Description

The northern myotis is a medium-sized bat with dull, medium brown fur. The ears, wings, and interfemoral membrane are also medium brown, giving the northern myotis an overall brown look. The ears are long, reaching about 4 mm beyond the tip of the nose when laid forward. The calcar is either not keeled or only slightly keeled, and the tragus is long and pointed. External measurements are as follows: wingspan, 228 to 258 mm; total length, 77 to 99 mm; tail, 35 to 43 mm; hind foot, 8 to 10 mm (less than 60% of the length of the tibia); ear, 14 to 19 mm; forearm, 32 to 39 mm; and weight, 5 to 8 g (Barbour and Davis 1969; Caceres and Barclay 2000; Schmidt 2003).

The two bats with which the northern myotis might be most easily confused are the little brown myotis and the long-eared myotis. It can be distinguished from the little brown myotis by its longer ears and tragus, longer tail, and duller pelage. It can be distinguished from the long-eared myotis by its darker fur; paler membranes; and longer, pointed tragus (Caceres and Barclay 2000).

Associated Species

Other species that may benefit from management for this species include the western small-footed myotis, long-eared myotis, little brown myotis, fringed myotis, long-legged myotis, hoary bat, silver-haired bat, big brown bat, Townsend's big-eared bat, and the Brazilian free-tailed bat.

Habitat

The northern myotis primarily inhabits forested regions. In Wyoming, at the western edge of its range, it can be found in wooded riparian zones in badlands and prairies to higher elevation conifer and deciduous woodlands. In the Black Hills region, this species has been captured at elevations ranging from 1200 to 1950 m (4000 to 6500 ft) (Schmidt 2003).

The northern myotis typically forages in forested habitats. It uses the habitat in a variety of ways, foraging above, within, and below the canopy, as well as within forest openings; over water; along forest trails, roads, and riparian areas; and at the forest edge (Caceres and Barclay 2000; NatureServe 2003; Schmidt 2003).

The northern myotis forms maternity colonies in crevices and cavities of trees, under loose bark, and occasionally in buildings. It typically roosts in tall, large-diameter snags or trees (mean dbh of 39 cm [15 in] in the Black Hills); snags that are not very decayed and have a large amount of bark remaining; and in areas with greater than 80% canopy coverage (Sasse and Pekins 1996; Foster and Kurta 1999; Lacki and Schwierjohann 2001; Schmidt 2003).

Most males and non-reproductive females roost in trees separately from maternity colonies, although they also may roost in buildings, behind shutters, under shingles, or in other available crevices (Caceres and Pybus 1997). Lacki and Schwierjohann (2001) found that male northern myotis selected roosts in cavities of smaller-diameter trees than maternity colonies.

The northern myotis also uses a variety of night roosts in summer, including caves, abandoned mines, and buildings. Priday and Luce (1999) documented 2 summer night roosts in Wyoming—1 in an abandoned mine, and 1 in a building.

The northern myotis usually hibernates in caves and abandoned mines (Caceres and Barclay 2000), although hibernacula have not been documented in Wyoming.

Life History

The northern myotis mates during autumn, the female stores the sperm over winter, and delayed fertilization takes place in spring. Gestation is about 50 to 60 days, and the young is born in about June or July. Females give birth to 1 pup per year.

The northern myotis usually begins foraging an hour or 2 after sunset, rests intermittently in a night roost, and then has a second peak of activity just before dawn (Clark and Stromberg 1987). It hawks for aerial insects (catches them in the air) and also gleans prey from foliage and other substrates. It has a longer tail and larger wing area than bats that only use aerial hawking, which allows it to be more maneuverable during slow flight and is beneficial for flying in cluttered areas. It also uses passive listening as well as echolocation to locate insects resting on leaves, tree trunks, or against buildings (Caceres and Barclay 2000).

The northern myotis feeds on moths (Lepidoptera), small beetles (Coleoptera), lacewings (Neuroptera), flies (Diptera), true bugs (Hemiptera), leafhoppers (Homoptera), and wasps (Hymenoptera). It is an opportunistic forager and is probably limited only by the size of insects it can take. Its diet varies with geographic location, with season, and among individuals (Caceres and Barclay 2000).

The northern myotis hibernates through the winter and does not migrate long distances; the distance between summer habitat and the hibernaculum may be up to 56 km (35 mi) (Caceres and Barclay 2000). In general, it selects hibernacula with relatively constant, low temperatures;

high humidity; and no air currents (Caceres and Pybus 1997), although northern myotis have been recorded in hibernacula at temperatures ranging from 0.6 to 13.9 °C (33 to 57 °F) (Webb and others 1996). It usually wedges into cracks and crevices within the hibernaculum, and may move between hibernacula throughout the winter (Caceres and Barclay 2000).

The northern myotis is more solitary than most other *Myotis*; it usually roosts alone or in small groups. Reproductive females form small maternity colonies of up to 60 individuals, while adult males and nonreproductive females roost singly or in small groups of less than 10 individuals (Caceres and Barclay 2000). It is usually not found in large aggregations during hibernation, perhaps because it tends to wedge into small cracks and crevices (Schmidt 2003).

Individual bats roosting in trees frequently switch among a number of roost trees, sometimes even on a daily basis, although roost trees tend to be within a few hundred meters of each other (Foster and Kurta 1999; Caceres and Barclay 2000). On the other hand, the northern myotis often returns to the same hibernaculum, although not always in sequential years (Caceres and Barclay 2000).

Status

The northern myotis is widespread, but locally and irregularly distributed (Barbour and Davis 1969). In addition, colonies rarely comprise even as many as 50 bats, suggesting that populations may be quite small (NatureServe 2003). Caceres and Barclay (2000) suggested that it is uncommon at the western extremes of its range, which includes Wyoming. According to Luce (1998), it is probably rare in Wyoming, as surveys during the 1990s found it in only 2 night roosts.

The northern myotis is classified as a nongame species in Wyoming and is protected from take in Section 11, Chapter 52 of the Wyoming Game and Fish Commission Regulations. The Wyoming Game and Fish Department classifies it as a Species of Special Concern with a Native Species Status of 2 (NSS2).

Conservation Issues

Potential threats include timber management practices that allow removal of maternity roosts and loss of foraging habitat, recreational caving and other roost disturbances, and mine reclamation.

Survey and Monitoring Issues and Techniques

The recommended survey method is acoustic monitoring. Its calls are of intermediate intensity and many sequences are diagnostic, but there is overlap with other 40-kHz *Myotis*, particularly the little brown myotis and the long-eared myotis. Visual observation in conjunction with acoustic monitoring may be helpful in distinguishing it from small-eared *Myotis* species, although it often flies in cluttered settings where identification can be difficult. Harp traps set in gaps between trees have been effective in South Dakota and Wyoming. In eastern deciduous forests, netting is more successful in the forest interior than over water (WBWG 2003). This species may be easily overlooked in hibernacula because it often roosts in deep crevices, which are difficult to survey (Caceres and Barclay 2000).

The echolocation calls are relatively low in intensity. With most bat detectors, the echolocation calls of these bats are typically detectable at distances of about 2 m (compared to 10 or more meters for the calls of little brown myotis) (Wilson and Ruff 1999).

Management Recommendations

1. Implement inventory and monitoring to determine population status and habitat requirements of the northern myotis in Wyoming, as additional information is necessary to guide management actions.

2. Manage lands where northern myotis occur in such a way that provides adequate roosting and foraging habitat to maintain stable populations (that is, secure roosting sites; diverse, native foraging habitat; and uncontaminated water sources).

3. Avoid timber harvest activities in areas close to known roosting sites of northern myotis during the maternity roosting period, and retain all known roost trees (Schmidt 2003). Use patch cuts and selective harvesting to provide regenerating forest and retain large-diameter snags (Lacki and Schwierjohann 2001).

4. Retain all large-diameter snags, particularly those greater than 21 cm (8 in) dbh (Schmidt 2003), as potential roost sites for northern myotis and other snag-dependent species. Provide large-diameter snags in early states of decay, particularly snags with large amounts of exfoliating bark (Lacki and Schwierjohann 2001). Retain mature and decadent trees for future snag production, particularly where existing snags are few. Because the northern myotis switches tree roosts frequently and may need several suitable roosts over the course of a summer (Foster and Kurta 1999; Caceres and Barclay 2000), it is necessary to retain all snags in areas where bats are known to roost.

5. Implement Best Management Practices for natural caves (see page 152) and abandoned mines (see page 161) in areas where northern myotis roost.

6. Avoid or minimize pesticide use in areas where the northern myotis is known to occur to avoid direct poisoning and to maintain a food source for this species and other insectivores. Where possible, allow insect outbreaks to proceed naturally.

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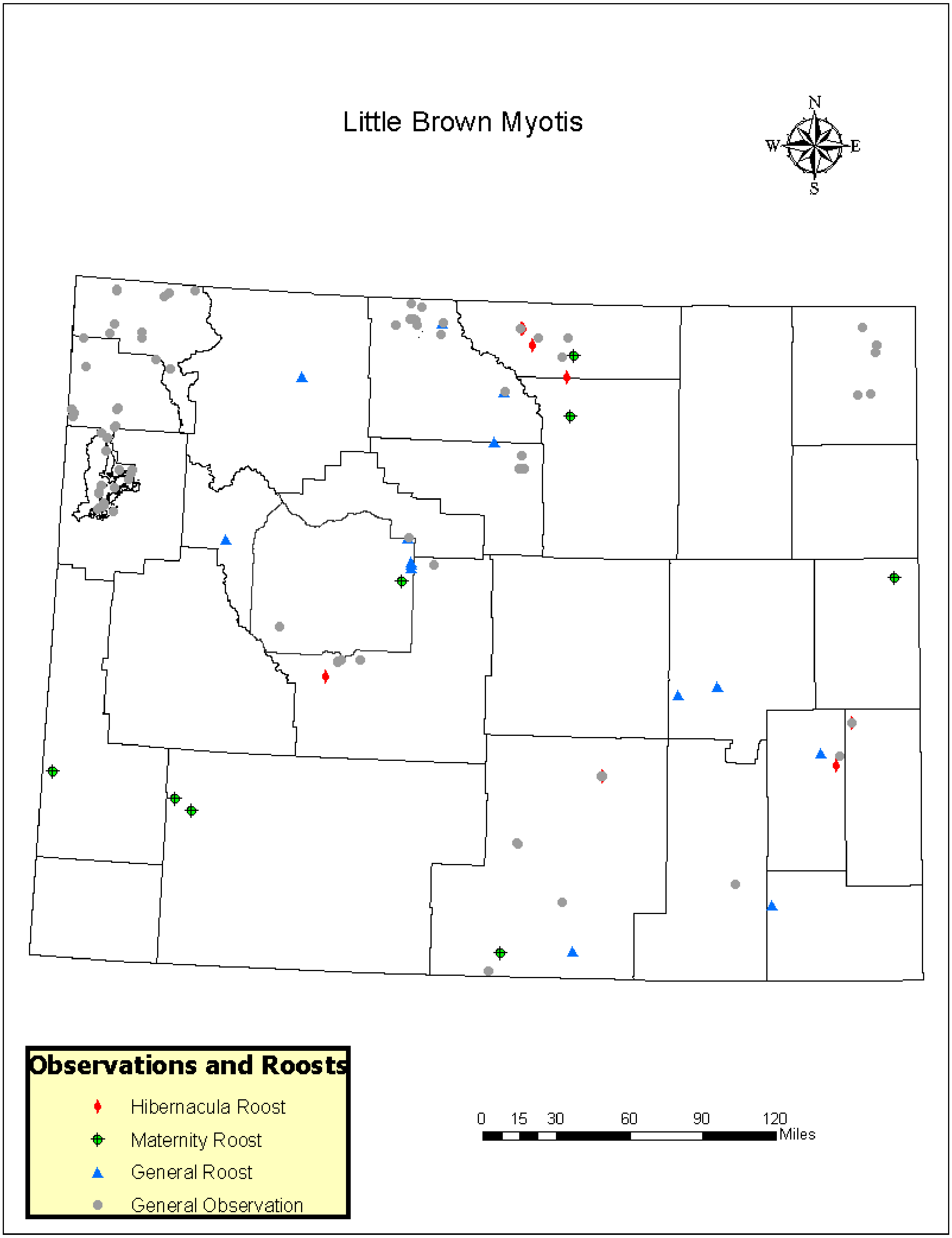
Little Brown Myotis
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Observations and Roosts
Hibernacula Roost
Maternity Roost
General Roost
General Observation
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Miles

Little Brown Myotis (*Myotis lucifugus*)

Range

The little brown myotis inhabits most of North America from Alaska and northern Canada to central Mexico. It is a year-round resident in Wyoming and is found throughout the state (Luce 1998). Clark and Stromberg (1987) show occurrence in 18 counties throughout Wyoming and Cerovski and others (2004) show occurrence in 27 of Wyoming's 28 latilongs, although confirmed or suspected breeding has only been recorded in 14 latilongs.

Description

The little brown myotis is a medium-sized bat with long, glossy fur that varies from pale to dark brown. The ventral fur is usually slightly paler than the dorsal fur, and the ears, wings, and interfemoral membrane are dark brown. The ears are medium length and do not extend past the tip of the nose when laid forward, and the tragus is blunt and about half as long as the ear. The calcar usually lacks a keel or is only slightly keeled. External measurements are as follows: wingspan, 200 to 270 mm; total length, 83 to 103 mm; tail, 31 to 44 mm; hind foot, 8 to 10 mm (about 55% of the length of the tibia); ear, 11 to 15 mm; tragus, 7 to 9 mm; forearm, 33 to 41 mm; and weight, 5 to 8 g (Fenton and Barclay 1980; Clark and Stromberg 1987; Luce 1998). Although the little brown myotis can be difficult to separate from other *Myotis* species, it often can be distinguished by the brassy sheen of its fur and the hairs on its toes, which extend beyond the tips of the claws (Luce 1998).

Associated Species

Other species that may benefit from management for this species include the California myotis, western small-footed myotis, long-eared myotis, northern myotis, fringed myotis, long-legged myotis, Yuma myotis, silver-haired bat, big brown bat, spotted bat, Townsend's big-eared bat, pallid bat, and the Brazilian free-tailed bat. Although the eastern pipistrelle and the big-free-tailed bat are accidental species in Wyoming, they may also benefit from management for this species.

Habitat

The little brown myotis occupies coniferous forest, riparian areas in the mountains and lower valleys, woodlots, shelterbelts, and urban areas up to about 3350 m (11,000 ft) in Wyoming. It is seldom found far from open water and is usually absent from hot, arid lowlands (Clark and Stromberg 1987; Luce 1998; WBWG 1998). It primarily forages over water but also forages in open woodlands and forest openings (Humphrey 1982).

During summer, the little brown bat exploits a wide variety of natural and manmade roost sites, including buildings, tree cavities, loose tree bark, bridges, rock crevices, caves, and abandoned mines (Fenton and Barclay 1980; Luce 1998). It is 1 of the species most commonly found in human structures (Barclay and Cash 1985; Neilson and Fenton 1994). Temperature and shelter are the most important factors for bats in day roosts, especially for maternity colonies. Maternity roosts are usually in very warm sites, which encourage rapid growth of the embryos and young. Males and nonreproductive females usually select cooler roost sites (Fenton and Barclay 1980). Priday and Luce (1999) documented 20 maternity roosts in Wyoming—19 in buildings and 1 in a cliff. They also found 5 other day roosts—4 in caves, and 1 in an abandoned mine.

After feeding, the little brown myotis often flies to a night roost to rest, which can be in a wide variety of structures. Often large numbers of bats pack tightly into confined night roosts, which increases roost temperatures (Fenton and Barclay 1980). Priday and Luce (1999) documented 24 night roosts in Wyoming—12 in caves, 5 in abandoned mines, 4 in buildings, 2 in rock shelters, and 1 in a railroad tunnel.

The little brown myotis hibernates primarily in caves and abandoned mines (Fenton and Barclay 1980). Priday and Luce (1999) documented 6 hibernacula in Wyoming, all in caves.

Life History

The little brown myotis mates during autumn, the female stores the sperm over winter, and delayed fertilization takes place in spring. Gestation is about 50 to 60 days, and the young is born between late May and mid June. Females give birth to 1 pup per year (Barbour and Davis 1969; Luce 1998).

The little brown myotis emerges at dusk to begin foraging, often following the same foraging route repeatedly through the night and on successive nights (Luce 1998). It is small, slow, and highly maneuverable, which allows it to forage close to obstacles or surfaces and pursue insects over very short distances (Barclay 1986). It usually forages over or near water, although it may vary its strategy somewhat, from foraging within 1 or 2 m (3 or 7 ft) of the water's surface, foraging along the edges of streams and ponds, to foraging among vegetation 2 to 5 m (7 to 16 ft) above the ground (Fenton and Barclay 1980).

Although this species primarily eats small, soft-bodied insects, it is otherwise an opportunistic feeder. Its prey include a variety of flying insects, particularly aquatic insects, such as caddisflies (Trichoptera), mayflies (Ephemeroptera), midges (Chironomidae), moths (Lepidoptera), flies (Diptera), and mosquitoes (Culicidae) (Fenton and Barclay 1980; Clark and Stromberg 1987; Luce 1998).

The little brown myotis hibernates throughout its range, although it may migrate up to a few hundred kilometers to a suitable hibernaculum (Clark and Stromberg 1987). Migratory movements are not necessarily latitudinal; they may be elevational and in any direction (Humphrey 1982). Hibernacula usually provide high humidity; very slow air currents; and cool, stable temperatures (4 to 10 ºC [40 to 50 °F]), although there are records of little brown myotis hibernating at temperatures below freezing (Fenton and Barclay 1980; Humphrey 1982; Tuttle and Taylor 1998).

The little brown myotis often forms large colonies of hundreds or even thousands of individuals at maternity roosts, night roosts, and hibernacula (Barbour and Davis 1969). One summer night roost documented in Wyoming contained over 500 individuals, and 2 abandoned buildings had maternity roosts of at least 1500 females (Priday and Luce 1999). Adult males and nonreproductive females often roost alone or in small groups (Fenton and Barclay 1980).

The little brown myotis shows strong fidelity to roosts that are physically stable, and individuals may return for many years (WBWG 1998). Kalcounis and Hecker (1996) suggest that little brown myotis roosting in trees show fidelity to a group of trees rather than a single roost tree, because these roosts are relatively ephemeral.

Status

The little brown myotis is one of the most common bats throughout much of the northern United States and Canada; its ability to exploit a wide range of roosts and prey probably contributes to large populations of this species in many parts of its range (Fenton and Barclay 1980). However, local distribution and abundance is spotty in some areas and may be related to water and roost availability (Barbour and Davis 1969). In Wyoming, it is probably the most common bat species (Oakleaf and others 1996; Bogan and Cryan 2000).

The little brown myotis is classified as a nongame species in Wyoming and is protected from take in Section 11, Chapter 52 of the Wyoming Game and Fish Commission Regulations. The Wyoming Game and Fish Department classifies it as a Species of Special Concern with a Native Species Status of 3 (NSS3).

Conservation Issues

Although common and widespread, this species suffers continuous loss of habitat through building demolition and remodeling, as well as exclusion from buildings. Other potential threats include timber harvest, mine reclamation, renewed mining, and pesticides and other contaminants. Because the little brown myotis often gathers in large colonies, any disturbance or destruction of roost sites could have profound impacts to the regional population as a whole.

Survey and Monitoring Issues and Techniques

The recommended survey method is mist netting. The little brown myotis is readily netted in most areas, although it may successfully avoid nets in other areas. It is highly colonial and easy to detect in manmade roosts. It is easy to detect acoustically, although it can be difficult to distinguish from other 40-kHz *Myotis*. Its flight behavior is sometimes distinctive to experienced observers, particularly over water (WBWG 2003).

Management Recommendations

1. Implement inventory and monitoring to determine population status and habitat requirements of the little brown myotis in Wyoming, as additional information is necessary to guide management actions.

2. Manage lands where little brown myotis occur in such a way that provides adequate roosting and foraging habitat to maintain stable populations (that is, secure roosting sites; diverse, native foraging habitat; and uncontaminated water sources).

3. Implement Best Management Practices for buildings (see page 174) in areas where little brown myotis roost. Although this species sometimes accepts properly built and located artificial roosts, females that are excluded from their nursery roosts often fail to appear in their traditional sites for hibernation; presumably most excluded bats die (Humphrey 1982). Also, Neilson and Fenton (1994) showed that females exhibit strong fidelity to specific roost sites and recommended that excluding little brown myotis from building roosts should be a last resort.

4. Implement Best Management Practices for natural caves (see page 152), abandoned mines (see page 161), bridges (see page 180), and rock shelters (see page 168) in areas where little brown myotis roost.

5. Avoid timber harvest activities in areas close to known maternity roosts of little brown myotis during the maternity roosting period, and retain all known roost trees.

6. Implement Best Management Practices for forests and woodlands (see page 190) that retain all large-diameter snags as potential roost sites for little brown myotis and other snag-users. Kalcounis and Hecker (1996) found that little brown myotis roosting in tree cavities often switch roosts frequently and may need several suitable roosts over the course of a summer, making it necessary to retain all snags in areas where bats are known to roost.

7. Avoid or minimize pesticide use in areas where the little brown myotis is known to occur to avoid direct poisoning and to maintain a food source for this species and other insectivores.

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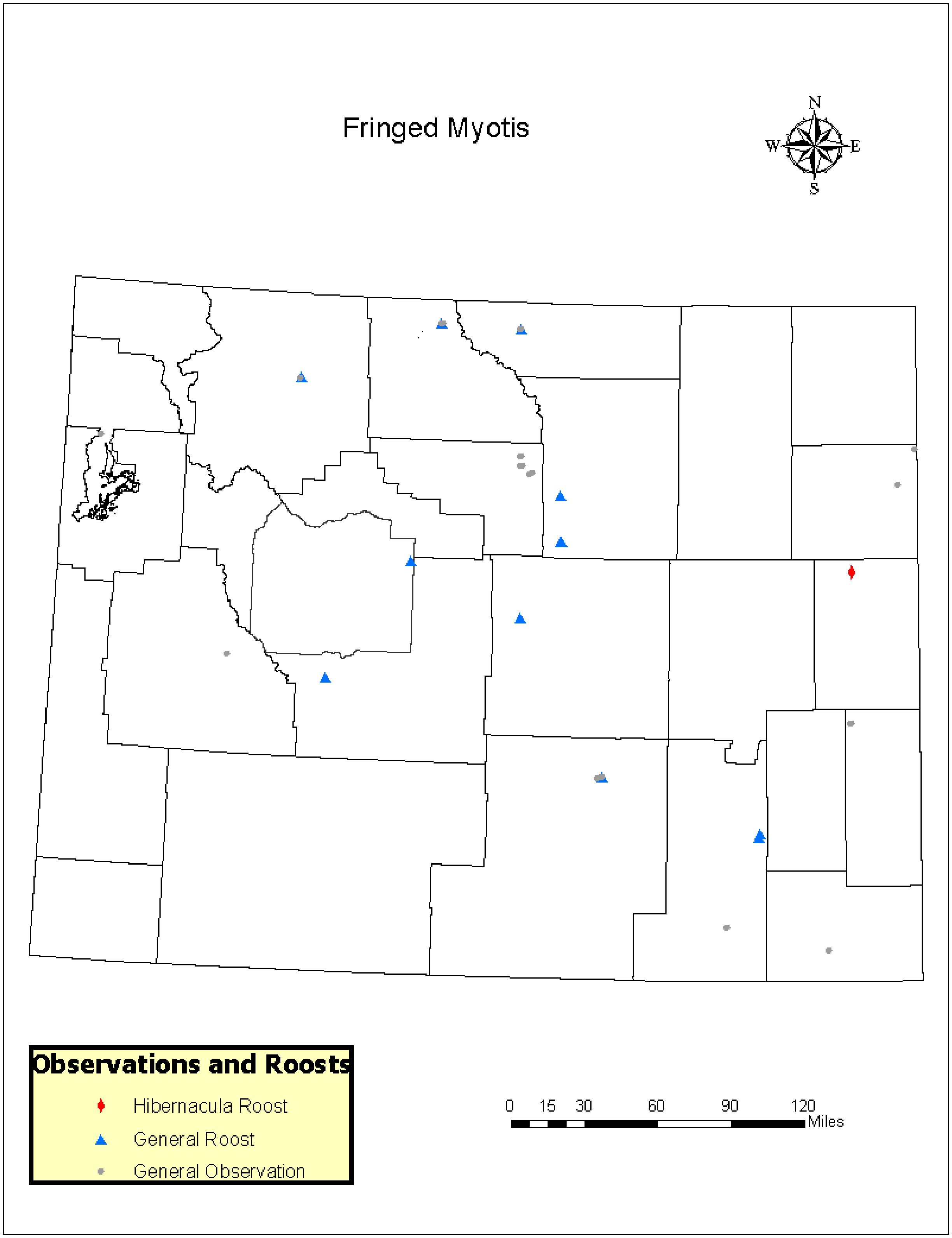
Fringed Myotis
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<u>Fringed Myotis</u> (*Myotis thysanodes*)

Range

The fringed myotis inhabits most of the western United States, north into south central British Columbia, south into southern Mexico, east to the Rocky Mountains, and west to the Pacific coast. A disjunct population of this species, recognized as a distinct subspecies, *Myotis thysanodes pahasapensis*, occurs in the Black Hills region of Wyoming and South Dakota and extends into western Nebraska (Schmidt 2003). The fringed myotis probably occurs in suitable habitat over much of Wyoming (Luce 1998). However, there have been no current sightings of fringed myotis in the northwestern portion of the state, where there are several historical records (Keinath 2004). Clark and Stromberg (1987) show occurrence in 4 counties in eastern Wyoming and Cerovski and others (2004) show occurrence in 8 of the state's 28 latilongs in central and eastern Wyoming, although no breeding has been recorded. Although its winter range is poorly known, it is probably a year-round resident in Wyoming (Priday and Luce 1999; Keinath 2004).

Description

The fringed myotis is a large myotis with yellowish-brown, dark olive-brown, or reddish-brown dorsal fur and slightly paler ventral fur. Color varies geographically, with a tendency towards darker shades in northern populations. The interfemoral membrane has a conspicuous fringe of hair along the posterior edge; this fringe is not just a few scattered hairs but several hundred hairs, clearly visible, each 1 to 2 mm long, and usually much lighter in color than the interfemoral membrane. The ears are long, black, and reach 3 to 5 mm beyond the muzzle when laid forward. The robust calcar is not distinctly keeled. External measurements are as follows: wingspan, 265 to 300 mm; total length, 77 to 104 mm; tail, 34 to 45 mm; hind foot, 7 to 9 mm; ear, 16 to 20 mm; forearm, 39 to 47 mm; and weight, 6 to 7 g (Barbour and Davis 1969; O'Farrell and Studier 1980; Clark and Stromberg 1987). The fringed myotis may be distinguished from other *Myotis* species by the conspicuous fringe on its interfemoral membrane and by its long ears (except for the long-eared myotis, which has longer ears).

Associated Species

Other species that may benefit from management for this species include the California myotis, western small-footed myotis, long-eared myotis, northern myotis, little brown myotis, long-legged myotis, Yuma myotis, silver-haired bat, eastern pipistrelle, big brown bat, Townsend's big-eared bat, pallid bat, Brazilian free-tailed bat, and big free-tailed bat.

Habitat

The fringed myotis is found in a wide range of habitats, including coniferous forests, juniper woodlands, grasslands, and basin-prairie shrublands. It usually occurs at middle elevations, but occasionally as high as spruce-fir habitats (O'Farrell and Studier 1980; Clark and Stromberg 1987). It is probably most common in xeric woodlands, such as juniper, ponderosa pine, and Douglas-fir (WBWG 1998; Adams 2003). Although it is often found in arid environments, it has a lower urine-concentrating ability than most bats, so probably must remain within commuting distance of drinking water (Keinath 2004). It typically forages over water, along forest edges, or within forests and woodlands (Schmidt 2003; Keinath 2004).

During summer, the fringed myotis uses a variety of roost types, including rock crevices, tree cavities, caves, abandoned mines, and buildings (Barbour and Davis 1969; Schmidt 2003). Maternity roosts have been found in sites that are cooler and wetter than is typical for most other vespertilionids (WBWG 1998). Bats that roost in trees usually select areas near a water source with a high density of large snags (at least 30 cm [12 in] dbh) and lower canopy cover than the surrounding forest (Weller and Zabel 2001). Roosts in rock crevices typically face southeast or southwest and are in low elevation forests or woodlands (Schmidt 2003). Like maternity colonies, males and nonreproductive females use a variety of roosts (Christy and West 1993; Schmidt 2003), but may roost at higher elevations (Keinath 2004).

After feeding, the fringed myotis often uses night roosts, which may be in buildings, caves, rock crevices, bridges, or abandoned mines (O'Farrell and Studier 1980; WBWG 1998). Priday and Luce (1999) found 2 summer night roosts in Wyoming, both in caves.

The fringed myotis hibernates in caves, abandoned mines, buildings, and possibly rock crevices (Christy and West 1993; Keinath 2004). Priday and Luce (1999) found small numbers of fringed myotis in 1 hibernaculum and 1 possible hibernaculum in Wyoming, both in caves.

Life History

The fringed myotis mates in autumn and the female carries the sperm over winter. In spring, females ovulate and fertilization occurs. A single pup is born each year in about late June or early July after a gestation of 50 to 60 days. The young can fly within about 17 days and they are independent after about 21 days (O'Farrell and Studier 1980; Luce 1998; Keinath 2004).

Fringed myotis often begin foraging shortly after sunset. Feeding activity peaks about 2 hours after dark, and may continue until about 4 hours after dark (Luce 1998; Adams 2003). Its flight is slow and maneuverable and it probably forages primarily by gleaning insects from vegetation and other surfaces (Hinman and Snow 2003), as well as aerial pursuit over short distances. Its echolocation patterns; short, broad wings; and thick wing membranes that are resistant to puncture allow it to forage and fly in dense vegetation (Wilson and Ruff 1999). The fringed myotis feeds primarily on beetles (Coleoptera), although it will take a variety of other insects when they become abundant, including moths (Lepidoptera), flies (Diptera), lacewings (Neuroptera), bees (Hymenoptera), leafhoppers (Homoptera), crickets (Gryllidae), harvestmen (Phalangidae), craneflies (Tipulidae), spiders (Araneidae), and true bugs (Hemiptera) (Clark and others 1989; WBWG 1998; Keinath 2004).

In temperate regions, the fringed myotis probably migrates short distances to winter hibernacula that are lower in elevation and/or more southern than its summer roosts (Keinath 2004). Although it has been reported to be migratory (O'Farrell and Studier 1980), its slow, energetically-demanding flight makes extensive migrations unlikely (WBWG 1998; Keinath 2004). The fringed myotis often hibernates in caves or areas of caves that are not heavily occupied by other species of bats; it is not known whether they are actively avoiding other bats, or selecting relatively unique microclimatic conditions (Schmidt 2003).

The fringed myotis is a colonial species and roosts in groups of 10 to 2000 individuals, although large colonies are exceedingly rare (WBWG 1998). During summer, maternity colonies usually consist of about 30 to 35 adult females, while males roost either alone or in small groups (Adams 2003). The fringed myotis hibernates in small clusters, possibly consisting of the same individuals that roosted together during summer (Keinath 2004).

The fringed myotis exhibits high fidelity to breeding and hibernating sites, returning to the same geographic areas year after year. However, individuals may switch specific roosts or switch locations within roost sites multiple times within a given season, probably depending on thermoregulatory conditions and the permanence of available roost structures (O'Farrell and Studier 1980; Weller and Zabel 2001; Keinath 2004).

Status

Although the fringed myotis is widespread, it is rare and patchily distributed throughout most of its range, including Wyoming (Luce 1998; NatureServe 2003). Bogan and Cryan (2000) are aware of fewer than 20 specimens of this species from Wyoming, and it is possible that populations in the state have become smaller and more isolated in recent decades (Keinath 2004).

The fringed myotis is classified as a nongame species in Wyoming and is protected from take in Section 11, Chapter 52 of the Wyoming Game and Fish Commission Regulations. The Wyoming Game and Fish Department classifies it as a Species of Special Concern with a Native Species Status of 2 (NSS2). The Wyoming Natural Diversity Database classifies it as S1B, S1N (Fertig and Beauvais 1999). Region 2 of the US Forest Service and the Bureau of Land Management in Wyoming both consider it a Sensitive Species (BLM 2002; USFS 2003).

Conservation Issues

Potential threats include recreational caving and other roost disturbances, mine reclamation, renewed mining, timber harvest practices that remove large-diameter snags, building demolition and remodeling, bridge replacement, and pesticides and other contaminants. This species is extremely sensitive to disturbance at roost sites, particularly maternity colonies, more so than other *Myotis* species (O'Farrell and Studier 1980).

Survey and Monitoring Issues and Techniques

The recommended survey method is netting. The fringed myotis is readily captured in mist nets (often on secondary streams in the northwestern portion of its range). Although many of its calls are diagnostic, they are of intermediate intensity, and there can be some confusion with pallid bat calls. Its flight behavior, in combination with call morphology, can be helpful to experienced observers (WBWG 2003). Because fringed myotis females become highly secretive about 1½ weeks prior to parturition and established roost clusters break up during this period, exit counts might best be conducted around the time of parturition, and prior to when the juveniles begin to fly (Keinath 2004).

Management Recommendations

1. Implement inventory and monitoring to determine population status and habitat requirements of the fringed myotis in Wyoming, as additional information is necessary to guide management actions.

2. Manage lands where fringed myotis occur in such a way that provides adequate roosting and foraging habitat to maintain stable populations (that is, secure roosting sites; diverse, native foraging habitat; and uncontaminated water sources).

3. Implement Best Management Practices for natural caves (see page 152), abandoned mines (see page 161), buildings (see page 174), and bridges (see page 180) in areas where fringed myotis roost.

4. Avoid timber harvest activities in areas close to known roosting sites of fringed myotis during the maternity roosting period, and retain all known roost trees.

5. Implement Best Management Practices for forests and woodlands (see page 190) that retain all tall, large-diameter snags, particularly those greater than 30 cm (12 in) dbh, as potential roost sites for fringed myotis and other snag-dependent species (Weller and Zabel 2001). Because the fringed myotis switches tree roosts frequently and may need several suitable roosts over the course of a summer (Weller and Zabel 2001), it is necessary to retain all snags in areas where bats are known to roost.

6. Avoid or minimize pesticide use in areas where the fringed myotis is known to occur to avoid direct poisoning and to maintain a food source for this species and other insectivores.

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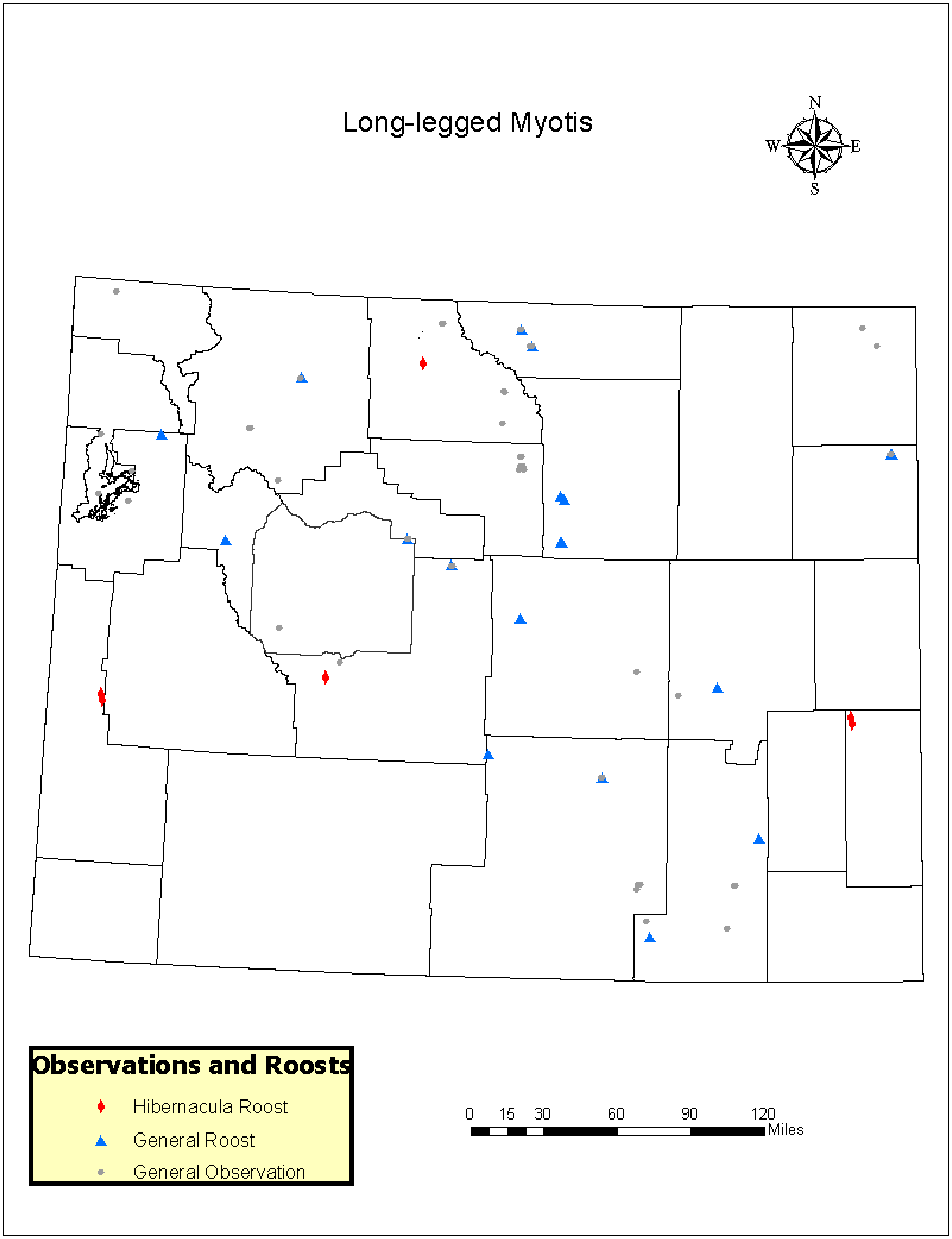

Long-legged Myotis
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Observations and Roosts
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<u>Long-legged Myotis</u> (*Myotis volans*)

Range

The long-legged myotis inhabits most of western North America from southeastern Alaska, southern British Columbia, and Alberta; south to Baja California and central Mexico; and east to the western edge of the Great Plains and central Texas. In Wyoming, it occurs in suitable habitat over most of the state (Luce 1998). Although very little is known about the winter range of this species and it has not been documented hibernating in Wyoming, it has been found hibernating in the Black Hills of South Dakota and it is possible that it occurs in Wyoming in winter as well (Bogan and Cryan 2000). Clark and Stromberg (1987) show occurrence in 12 counties throughout most of Wyoming and Cerovski and others (2004) show occurrence in 25 of the state's 25 latilongs, although confirmed or suspected breeding has only been recorded in 7 latilongs.

Description

The long-legged myotis is a medium-sized bat with medium to dark brown fur, occasionally with a red or orange cast. The ventral fur is sometimes, but not always, paler than the dorsal fur. The ears, wings, and interfemoral membrane are black. The underwing has long, dense fur that extends from the body to a line joining the elbow and the knee. The short, rounded ears barely reach the nostrils when laid forward. The calcar is distinctly keeled, and the tragus is long and pointed. External measurements are as follows: wingspan, 250 to 270 mm; total length, 83 to 106 mm; tail, 32 to 49 mm; hind foot, 5 to 11 mm; ear, 10 to 15 mm; tragus, 6 to 8 mm (41% of the length of the tibia); forearm, 34 to 41 mm; and weight, 5 to 10 g (Warner and Czaplewski 1984; Clark and Stromberg 1987). The long-legged myotis is similar in appearance to other *Myotis* species in Wyoming, but the well-furred underwing; distinctive keel on the calcar; and short, rounded ears help to distinguish it (Luce 1998; Schmidt 2003).

Associated Species

Other species that may benefit from management for this species include the California myotis, western small-footed myotis, long-eared myotis, northern myotis, little brown myotis, fringed myotis, hoary bat, big brown bat, Townsend's big-eared bat, and the Brazilian free-tailed bat. Although the eastern pipistrelle is an accidental species in Wyoming, it may also benefit from management for this species.

Habitat

The long-legged myotis inhabits montane and subalpine forest, ponderosa pine and juniper woodlands, and montane shrubs and willows near forested areas (Luce 1998). In Wyoming, it primarily occurs at mid to high elevations, from 1500 to more than 3300 m (5000 to 11000 ft), although it has been found at lower elevations in Wyoming at cooler times of the year (Luce 1998; Bogan and Cryan 2000). The long-legged myotis usually selects the most mature forest stands available, primarily open, mature forest with standing dead trees (Taylor 1999; Schmidt 2003). It usually forages over open areas such as campgrounds and small forest clearings; over vegetated riparian areas; and within, above, and under the forest canopy (Warner and Czaplewski 1984; Schmidt 2003).

During summer, females form maternity colonies in tree cavities, buildings, rock crevices, and under loose bark. Most roosts are in tall, large-diameter (37 to 66 cm [15 to 26 in] dbh) snags with loose bark, are near forest openings, and are within 0.5 km (0.3 mi) of permanent water. Areas with long-legged myotis roosts usually have a high-density of snags (Ormsbee 1996; Herder 2000; Schmidt 2003). Although reproductive females are not known to roost in caves or abandoned mines (Bogan and Cryan 2000), males and nonreproductive females often do roost in caves and mines, as well as trees, buildings, rock crevices, and bridges (Christy and West 1993; Schmidt 2003; Priday and Luce 1999).

After feeding, the long-legged myotis often flies to a night roost to rest, usually in caves, abandoned mines, bridges, buildings, or rock crevices (Bogan and Cryan 2000; Altenbach and others 2002; Schmidt 2003). Priday and Luce (1999) documented 26 night roosts in Wyoming—17 in caves, 6 in abandoned mines, 2 in rock shelters, and 1 in a building.

Although the long-legged myotis has not been documented hibernating in Wyoming (Luce 1998), elsewhere it is known to hibernate primarily in caves and abandoned mines (Warner and Czaplewski 1994)

Life History

The long-legged myotis mates in autumn and the female carries the sperm over winter. Fertilization occurs in late April or May and the females form small maternity colonies. A single pup is born in June or July after a 50- to 60-day gestation (Luce 1998; WBWG 1998).

The long-legged myotis emerges relatively early in the evening to begin foraging, often while it is still twilight (Barbour and Davis 1969). It is active throughout most of the night, but activity peaks about 3 or 4 hours after sunset (WBWG 1998). This species is a rapid, direct flier that pursues prey over relatively long distances through, around, under, and over the forest canopy. Individuals may follow the same foraging route through the evening and on successive nights. It consumes primarily moths (Lepidoptera) when they are available, but feeds opportunistically on other, primarily soft-bodied, insects, including flies (Diptera), termites (Isoptera), lacewings (Neuroptera), wasps (Hymenoptera), true bugs (Hemiptera), leafhoppers (Homoptera), and small beetles (Coleoptera) (Warner and Czaplewski 1984).

Very little is known about the migration and hibernation patterns of the long-legged myotis, although it probably migrates short distances from its summer roost to hibernate (Bogan and Cryan 2000; Altenbach and others 2002).

The long-legged myotis is moderately gregarious. Although it is sometimes known to roost alone, it usually roosts in colonies ranging from a few to several dozen and sometimes hundreds of individuals (Barbour and Davis 1969; Schmidt 2003).

Individual bats roosting in trees may remain in 1 roost for several days, or may switch frequently among a number of roost trees, although roost trees tend to be within a few hundred meters of each other (Ormsbee 1996).

Status

The long-legged myotis is a common bat in the western US, and in some areas is probably the most abundant species (Barbour and Davis 1969). In Wyoming, it is the most common myotis at high elevations (Luce 1998).

The long-legged myotis is classified as a nongame species in Wyoming and is protected from take in Section 11, Chapter 52 of the Wyoming Game and Fish Commission Regulations. The Wyoming Game and Fish Department classifies it as a Species of Special Concern with a Native Species Status of 2 (NSS2).

Conservation Issues

Potential threats include timber management practices that remove large-diameter snags, recreational caving and other roost disturbances, mine reclamation, renewed mining, building demolition and remodeling, and pesticides and other contaminants.

Survey and Monitoring Issues and Techniques

Recommended survey methods are mist netting and roost surveys. The effectiveness of mist netting varies regionally, and the setting makes a difference; in Wyoming, it can be captured over water. It can be found in manmade roosts, and is often found in night roosts. It is easy to detect acoustically, and many of its calls are diagnostic. Its long tail membrane makes it readily distinguishable in flight to experienced observers (Clark and Stromberg 1987; WBWG 2003).

Management Recommendations

1. Implement inventory and monitoring to determine population status and habitat requirements of the long-legged myotis in Wyoming, as additional information is necessary to guide management actions.

2. Manage lands where long-legged myotis occur in such a way that provides adequate roosting and foraging habitat to maintain stable populations (that is, secure roosting sites; open, mature forest with standing dead trees; and uncontaminated water sources).

3. Implement Best Management Practices for forests and woodlands (see page 190) that maintain large stands of mature and old-growth forests and woodlands with an open canopy in areas where long-legged myotis occur (Taylor 1999; Herder 2000). Maintain blocks that are relatively close to other forest fragments or are part of large, region-wide networks of forest habitat, rather than maintaining scattered small blocks of mature and old-growth habitat (Taylor 1999).

4. Implement Best Management Practices for buildings (see page 174) in areas where long-legged myotis roost. Where protection of roosts in buildings is not an option, ensure safe evacuation of long-legged myotis and other bats, including creating alternate roost sites. However, because long-legged myotis occupancy of alternate roost sites has not been documented in Wyoming, protection of existing roosts remains the best option.

5. Implement Best Management Practices for natural caves (see page 152), abandoned mines (see page 161), bridges (see page 180), and rock shelters (see page 168) in areas where long-legged myotis roost.

6. Avoid timber harvest activities in areas close to known maternity roosts of long-legged myotis during the maternity roosting period, and retain all known roost trees. Provide a 240-m (790-ft) buffer around known maternity roosts (Ormsbee 1996).

7. Implement Best Management Practices for forests and woodlands (see page 190) that retain all large-diameter snags, particularly those greater than 29 cm (11 in) dbh (Schmidt 2003), as potential roost sites for long-legged myotis and other snag-users. Long-legged myotis roosting in tree cavities sometimes switch roosts frequently and may need several suitable roosts over the course of a summer, making it necessary to retain all snags in areas where bats are known to roost (Ormsbee 1996). Where existing snags are few, retain mature and decadent trees for future snag production, and, if necessary, create snags out of live trees by girdling (Taylor 1999).

8. Use prescribed fire to maintain open, mature forest with standing dead trees in areas where long-legged myotis occur (Herder 2000; Schmidt 2003). Maintain a reduced fuel load and use low-intensity fires so that large snags and trees are not burned.

9. Avoid or minimize pesticide use in areas where the long-legged myotis is known to occur to avoid direct poisoning and to maintain a food source for this species and other insectivores.

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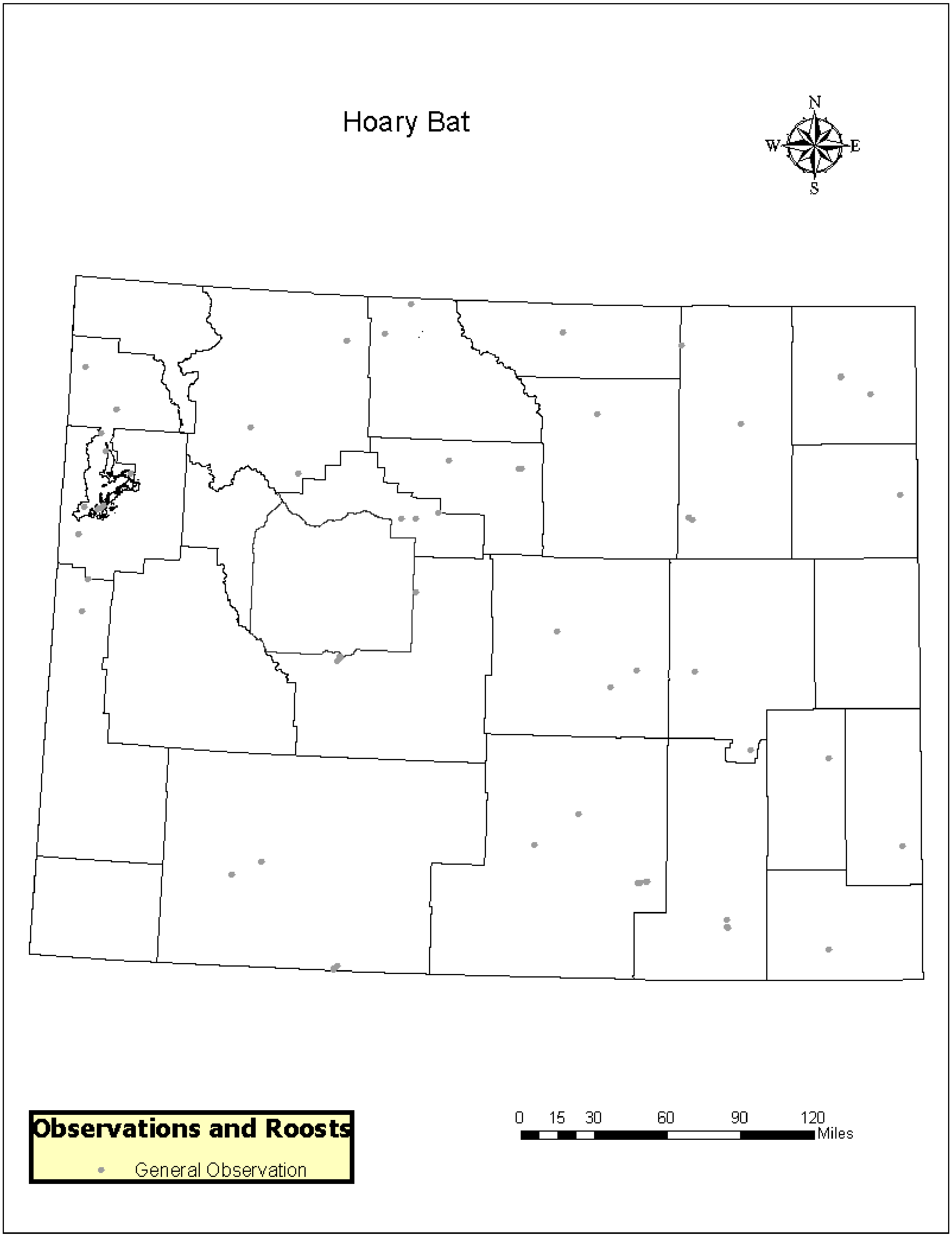
Hoary Bat
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Hoary Bat (***Lasiurus cinereus***)

Range

The hoary bat is the most widespread of all American bats. It occurs throughout the US, north to the limit of trees in Canada, and south to Argentina and Chile (Shump KA and Shump AU 1982). It is also found in Hawaii and the Galapagos Islands. During summer, males occur primarily in mountainous regions of western North America, whereas females occupy more eastern areas. However, adults of both sexes occur during summer in the Black Hills and surrounding areas of the Great Plains (Cryan 2003). It winters in southern California, the southeastern United States, and probably much of Mexico (Shump KA and Shump AU 1982).

In Wyoming, the hoary bat occurs statewide during summer, from the low elevations of the eastern plains to 3000 m (10000 ft) in the mountains (Luce 1998). Clark and Stromberg (1987) show occurrence in 7 counties scattered throughout most of Wyoming and Cerovski and others (2004) show occurrence in 22 of the state's 28 latilongs, although breeding has only been documented in 4 latilongs.

Description

The hoary bat is a large bat with distinctive coloring. Its long, glossy dorsal fur is black, with bands of yellow and brown on the hairs, and white tips, giving the bat a frosty or hoary appearance. The ventral fur is yellowish in the neck area, brown on the chest, and white on the abdomen. The wrist and shoulder patches are whitish. The interfemoral membrane is heavily furred on the entire dorsal surface. The ears are very short, rounded, furred, edged with black, and do not reach as far as the nostrils when laid forward. The tragus is short and broad. The calcar is distinctly though narrowly keeled, and is twice as long as the hind foot. External measurements are as follows: wingspan, 400 mm; total length, 130 to 145 mm; tail, 55 to 58 mm; hind foot, 9 to 11 mm (half as long as the tibia); ear, 17 to 19 mm; tragus, 9 mm; forearm, 48 to 52 mm; and weight, 20 to 35 g (Shump KA and Shump AU 1982; Clark and Stromberg 1987). The hoary bat is not usually confused with other species because of its large size and distinctive color. The only other bat resembling it is the much smaller silver-haired bat, which lacks fur on the feet, ears, and underside of the wings.

Associated Species

Other species that may benefit from management for this species include the California myotis, long-eared myotis, northern myotis, little brown myotis, fringed myotis, long-legged myotis, Yuma myotis, eastern red bat, silver-haired bat, and big brown bat. Although the eastern pipistrelle is an accidental species in Wyoming, it may also benefit from management for this species.

Habitat

The hoary bat is highly associated with forested habitats, both deciduous and coniferous. It can be found in montane forests, cottonwood riparian forests, shelterbelts, tree rows, juniper woodlands, and urban parks. Diverse forest habitats with a mixture of forest and small open areas that provide edges are ideal habitat for this species (Hart and others 1993; Ports and Bradley 1996; Luce 1998; WBWG 1998; Altenbach and others 2002).

The hoary bat usually forages in areas associated with forested habitat, such as along forest edges, roads, streams, or lake edges; or in openings within the forest (Christy and West 1993; Hart and others 1993). According to Furlonger and others (1987), the hoary bat is more active over sites with cover than those without cover and is associated with edge situations. It often forages in the glow of streetlights, especially in non-urban areas, and in some areas permanent lights may provide important concentrations of prey (Fenton and others 1983).

The hoary bat roosts primarily in the foliage of both deciduous and coniferous trees. It usually roosts at the edge of a clearing, about 3 to 12 m (10 to 40 ft) above ground, near the end of a branch, and well hidden from above but visible from below (Shump KA and Shump AU 1982; WBWG 1998). Females with pups may roost higher in the canopy than solitary adults (Christy and West 1993).

During migration, the hoary bat may be found in riparian corridors and other wooded areas (Clark and Stromberg 1987; Altenbach and others 2002). Females precede the males in migration, moving through lowland areas and coastal valleys, while most males travel through foothills and mountains. Although it probably migrates outside of Wyoming to hibernate, hibernacula in other areas can include tree trunks, tree cavities, clumps of Spanish moss, and squirrel nests (Tuttle 1995).

Life History

The hoary bat mates in late summer and fall, perhaps during migration, and the female carries the sperm over winter. Fertilization occurs in spring and the pups are born between mid May and July after a 90-day gestation. Usually 2 pups are born each year, although between 1 and 4 are possible (Clark and Stromberg 1987; WBWG 1998; Wilson and Ruff 1999; NatureServe 2003).

During summer, the hoary bat often begins foraging late in the evening, 2 to 5 hours after sunset (Clark and Stromberg 1987; WBWG 1998). With its long, narrow wings, it usually relies on speed rather than agility, hunting large insects in open areas and pursuing prey over relatively long distances (Barclay 1986; Tuttle 1995). It sometimes establishes feeding territories, indicating that at times prey is scarce enough and prey patches are important enough to defend them (Barclay 1985). It often makes a distinctive, audible chatter during feeding flights, probably as warning calls to other bats (Tuttle 1995; Luce 1998).

Although the hoary bat primarily eats moths, it is an opportunistic feeder and its diet varies daily, seasonally, and geographically. Besides moths, it is also known to eat dragonflies (Odonata), beetles (Coleoptera), flies (Diptera), grasshoppers (Orthoptera), termites (Isoptera), and wasps (Hymenoptera) (Shump KA and Shump AU 1982; Barclay 1985).

The hoary bat is a migratory species (Cryan 2003). Although its thick body fur and well-furred interfemoral membrane allow it to tolerate air temperatures as low as freezing, it has not been found hibernating in Wyoming and probably migrates to warmer climates for the winter (Clark and Stromberg 1987; WBWG 1998). It probably migrates from and through the state in about August, hibernates in its winter range, and returns to Wyoming in April (Clark and Stromberg 1987; Luce 1998). During migration, it can sometimes be seen flying in swarms in late afternoon and early evening (Shump KA and Shump AU 1982; Clark and Stromberg 1987).

The hoary bat is solitary (Shump KA and Shump AU 1982), except when mothers are accompanied by their young and during migration. During migration, particularly in autumn, both sexes travel together, often in groups of hundreds (Tuttle 1995).

Some females with pups change roosts frequently, while others do not. Movements are usually less than 100 m (325 ft) from the previous roost. Females may use the same maternity site in successive years (Tuttle 1995; NatureServe 2003).

Status

The hoary bat is considered uncommon throughout most of the eastern United States and in the northern Rockies, but common in the prairie states and the Pacific Northwest (Shump KA and Shump AU 1982). According to Clark and Stromberg (1987), these bats are known in Wyoming from fewer than a dozen specimens collected in the last 120 years.

The hoary bat is classified as a nongame species in Wyoming and is protected from take in Section 11, Chapter 52 of the Wyoming Game and Fish Commission Regulations. The Wyoming Game and Fish Department classifies it as a Species of Special Concern with a Native Species Status of 4 (NSS4). The Wyoming Natural Diversity Database classifies this species as S2B, SZ?N (Fertig and Beauvais 1999).

Conservation Issues

Potential threats include degradation, fragmentation, and loss of forest habitats; pesticides and other contaminants; and human-caused mortality during migration (such as wind turbines and communications towers). According to Gruver (2002), the hoary bat was the most commonly found bat during mortality searches at a wind power facility in south central Wyoming, and most mortalities were probably migrants.

Survey and Monitoring Issues and Techniques

The recommended survey method is active acoustic monitoring with visual observation. The hoary bat is easy to detect acoustically, and many of its calls are diagnostic, although a subset of its calls overlap with those of the Brazilian free-tailed bat. The hoary bat flies high and is often under-represented in net captures, and often forages in areas that cannot be feasibly netted (WBWG 2003). Its swift, direct flight pattern makes it readily identifiable to experienced observers, and its distinctive, audible chatter can also be useful in identifying it in flight (Tuttle 1995).

Management Recommendations

1. Implement inventory and monitoring to determine population status and habitat requirements of the hoary bat in Wyoming, as additional information is necessary to guide management actions.

2. Manage lands where hoary bats occur in such a way that provides adequate roosting and foraging habitat to maintain stable populations (that is, secure roosting sites; diverse forest habitats with a mixture of forest and small open areas; and uncontaminated water sources).

3. Avoid timber harvest activities in areas close to known maternity roosts of hoary bats during the maternity roosting period, and retain all known roost trees, as females may use the same maternity sites in successive years. In areas where hoary bats are known to occur, conduct timber harvest operations during October through mid April if feasible, to avoid impacting breeding and migrating populations.

4. Maintain and restore low and mid elevation riparian woodland areas, tree plantings in low elevation urban areas, and shelterbelts on farms, as hoary bats may rely on these habitat corridors during migration.

5. Avoid or minimize pesticide use in forest habitats where the hoary bat is known to occur to avoid direct poisoning and to maintain a food source for this species and other insectivores. Where possible, allow insect outbreaks to proceed naturally.

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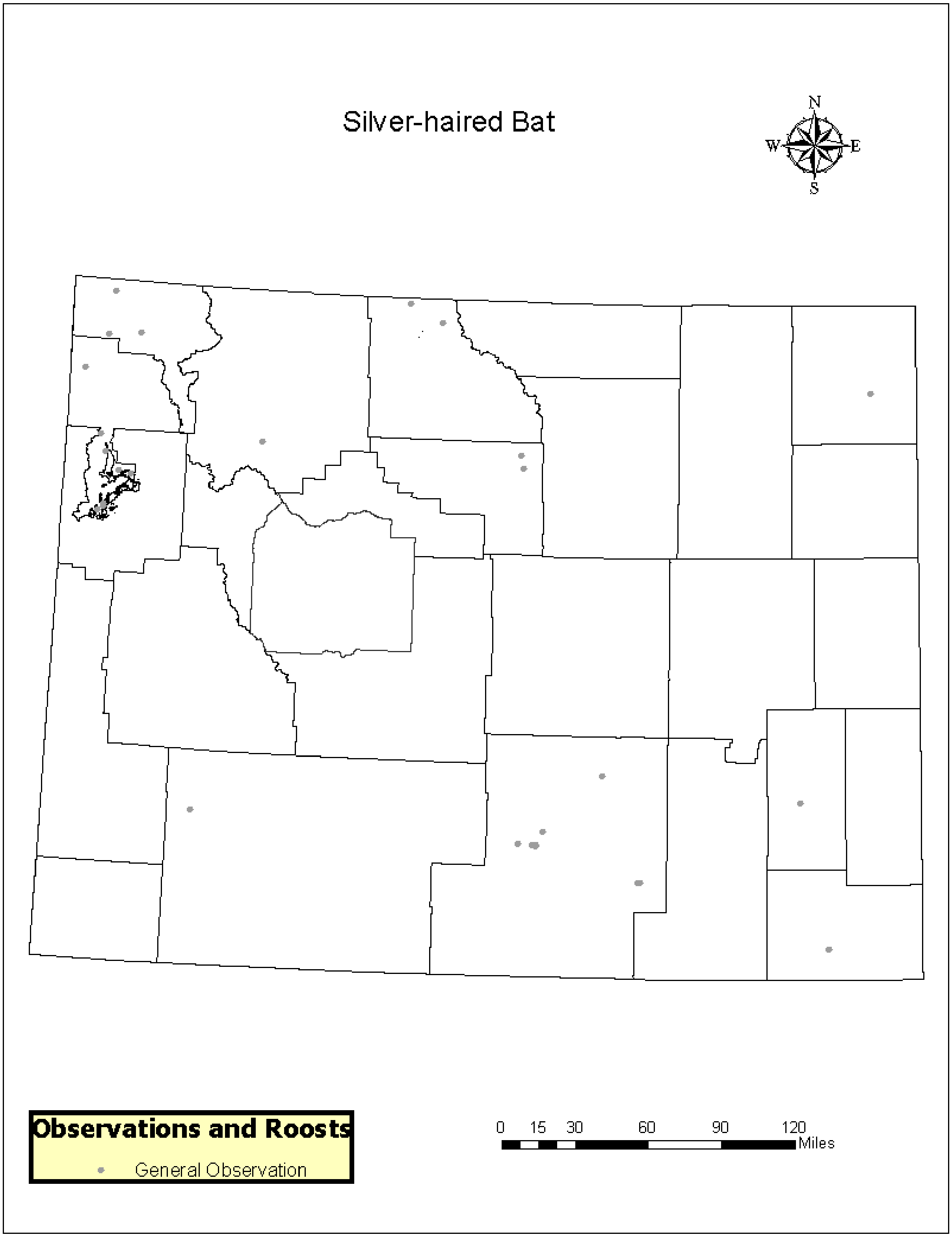
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Silver-haired Bat (*Lasionycteris noctivagans*)

Range

The silver-haired bat is found throughout most of North America from southeastern Alaska across the southern half of Canada, and south into Georgia, Arizona, and northeastern Mexico. The species summers in the northern United States, including the Rocky Mountains, and north into Canada nearly to the treeless zone. It winters mostly in the southern third of North America, plus areas of relatively mild coastal climate as far north as Alaska, British Columbia, and New York. The silver-haired bat occurs throughout Wyoming during the summer months, from the eastern plains to over 3050 m (10000 ft) (Luce 1998). Clark and Stromberg (1987) show occurrence in 8 counties scattered throughout most of the state, and Cerovski and others (2004) show occurrence in 22 of the state's 28 latilongs, although no breeding has been documented.

Description

The silver-haired bat is a medium-sized vespertilionid with distinctive coloring. Its long, glossy dorsal fur is dark brown or black, and almost every hair has a prominent silver-white tip, which gives the animal a unique frosted-black color. The ventral fur is slightly paler. The interfemoral membrane is black and furred on the basal half of the dorsal surface, with hairs sparse enough that the membrane can be easily seen. The ears are naked, black, short, and rounded, with a broad, blunt tragus. The leading edge of the ear is often pale. The face is black, and the wings are black and hairless. External measurements are as follows: wingspan, 270 to 320 mm; total length, 91 to 115 mm; tail, 35 to 45 mm; hind foot, 7 to 10 mm; ear, 9 to 17 mm; tragus, 5 to 9 mm; forearm, 37 to 44 mm; and weight, 8 to 13 g (Kunz 1982; Schmidt 2003). The only species with which this bat might be confused is the hoary bat, which is much larger, has patches of hair on the ears and wings, and has an interfemoral membrane that is thickly furred over the entire dorsal surface.

Associated Species

Other species that may benefit from management for this species include the California myotis, long-eared myotis, northern myotis, little brown myotis, fringed myotis, long-legged myotis, Yuma myotis, eastern red bat, hoary bat, and the big brown bat. Although the eastern pipistrelle is an accidental species in Wyoming, it may also benefit from management for this species.

Habitat

The silver-haired bat is known from a wide variety of habitats in Wyoming. It is most commonly associated with forested and montane habitats adjacent to lakes, ponds, and streams. It can be found in coniferous and mixed deciduous-coniferous forests and woodlands, including juniper, subalpine fir, Engelmann spruce, limber pine, Douglas-fir, aspen, cottonwood, and willow. The silver-haired bat occurs most frequently in stands of late-successional forest and may be reliant on older forests for roost trees. However, it is possible that it will inhabit forests of any age that contain sufficient numbers of large cavity-bearing trees (Betts 1998).

The silver-haired bat typically forages over ponds, slow streams, and other bodies of water and in openings surrounded by forest. It requires open, still water for drinking. Silver-haired bats in the Black Hills region preferred to forage in grassy valleys surrounded by well-forested hillsides of ponderosa pine and containing a source of standing water (Schmidt 2003).

The silver-haired bat roosts almost exclusively in trees. Reproductive females normally roost in small colonies within cavities in trees and snags. These roosts are usually on the south side of the tree and are often in cavities that were excavated by woodpeckers (Mattson and others 1996). The silver-haired bat selects maternity roost trees that are large-diameter, are taller than the surrounding trees, occur in low-density stands or are relatively far away from surrounding trees, are surrounded by sparse and short understory vegetation, and are located near water (Schmidt 2003). Forest stands supporting silver-haired bat roosts typically have a snag density of at least 21 snags/ha (8 snags/ac) (Mattson and others 1996). Males and nonreproductive females usually roost singly under the loose bark of trees or within tree cracks or crevices.

During migration, roosts are less carefully selected and the silver-haired bat may be encountered in a wide variety of shelters (Hinman and Snow 2003). Although it typically roosts singly in narrow crevices in tree trunks, it may also be found in buildings, caves, and even woodpiles, railroad ties, and fenceposts, especially when migrating through grassland habitats where shelters are scarce. During migration, the silver-haired bat is often found in lower elevation, more xeric habitats than in summer (WBWG 1998).

Although the silver-haired bat probably migrates outside of Wyoming to hibernate, hibernacula in other areas can include large trees, buildings, rock crevices, caves, and abandoned mines. Protected crevices in trees probably serve as the usual shelter (Barbour and Davis 1969).

Life History

The silver-haired bat mates in late summer and fall, and the female carries the sperm over winter. In spring, fertilization occurs and the females form small maternity colonies. Two pups are born from June to mid July after a 50- to 60-day gestation. Lactation lasts about 36 days and the young can fly by 3 or 4 weeks of age (Clark and Stromberg 1987).

The silver-haired bat uses a slow, methodical foraging strategy, generally staying close to the ground but occasionally rising to nearly 12 m (40 ft) (Luce 1998). It is a relatively late flier and often begins foraging 2 to 4 hours after sunset; it may also forage again 6 to 8 hours after sunset. This temporal pattern allows the silver-haired bat to forage when other bats are roosting. Each individual bat has its own feeding route, covering about 46 to 91 m^2 (495 to 980 ft^2) (Kunz 1982), which it repeats throughout the evening. The silver-haired bat is a slow, highly maneuverable flier that relies on higher, frequency-modulated echolocation calls; these characteristics allow it to detect and pursue small, swarming insects at short distances (Barclay 1985).

The silver-haired bat is an opportunistic feeder (Kunz 1982), consuming a wide variety of flying insects, including moths (Lepidoptera), midges (Chironomidae), flies (Diptera), leafhoppers (Homoptera), beetles (Coleoptera), caddisflies (Trichoptera), lacewings (Neuroptera), termites

(Isoptera), and wasps (Hymenoptera). It probably selects mostly small, soft-bodied species, especially those that swarm in groups, although at times moths may feature prominently in its diet. Prey availability is probably the strongest influence on the diet of silver-haired bats and may change considerably between seasons or habitat types.

The silver-haired bat is a migratory species. Although 1 individual was recovered on January 13 from Cheyenne (Bogan and Cryan 2000) and 1 individual has been recorded during winter from the Black Hills of South Dakota (Schmidt 2003), it has not been found hibernating in Wyoming and probably migrates to warmer climates for the winter. It probably migrates from and through the state in August and September, hibernates in its winter range, and returns to Wyoming in March and April (Luce 1998).

Although the silver-haired bat has historically been known as a solitary species, it often forms small colonies. In particular, females are known to form small maternity colonies in summer, and these cohesive groups often return to the same roost trees year after year (Fenton 2003). The silver-haired bat is also known to fly in small groups during migration. On the other hand, males and nonreproductive females usually roost singly during summer, and there have been no reliable reports of large winter aggregations.

Solitary-roosting silver-haired bats switch roosts regularly and even maternity colonies often switch at least once during the reproductive period. Although they may change roosts frequently, individuals and colonies often use multiple roosts within a limited area throughout the summer (WBWG 1998), and often use the same roost trees year after year (Fenton 2003).

Status

Throughout its range the silver-haired bat is considered common, although local density estimates are largely lacking (Schmidt 2003) and are probably usually low. Barbour and Davis (1969) characterized the silver-haired bat as erratic in abundance throughout much of its range, but suggested that its highest abundance occurs in the northern Rockies from Wyoming and Idaho northward. It is probably abundant in Wyoming (Clark and Stromberg 1987) in the summer.

The silver-haired bat is classified as a nongame species in Wyoming and is protected from take in Section 11, Chapter 52 of the Wyoming Game and Fish Commission Regulations. The Wyoming Game and Fish Department classifies it as a Species of Special Concern with a Native Species Status of 4 (NSS4).

Conservation Issues

Potential threats include timber management practices that remove large-diameter snags; degradation of foraging habitat and water sources in riparian areas; and pesticides and other contaminants.

Survey and Monitoring Issues and Techniques

Recommended survey methods are mist netting and active acoustic monitoring with visual observation. The silver-haired bat is generally very susceptible to capture, depending on habitat, and particularly over water sources. It is easy to detect acoustically, and some of its calls are distinctive in areas without Brazilian free-tailed bats or big brown bats. However, where acoustic surveys are combined with visual surveys by an experienced observer, the species can sometimes be distinguished in flight (WBWG 2003).

Management Recommendations

1. Implement inventory and monitoring to determine population status and habitat requirements of the silver-haired bat in Wyoming, as additional information is necessary to guide management actions.

2. Manage lands where silver-haired bats occur in such a way that provides adequate roosting and foraging habitat to maintain stable populations (that is, secure roosting sites; diverse forest habitats; and uncontaminated water sources).

3. Implement forest Best Management Practices that maintain large stands of mature and old-growth forests and woodlands in areas where silver-haired bats occur. Manage lands that contain roosting habitat in such a way that provides adequate roosting sites to maintain stable populations of silver-haired bats (that is, large areas of forest with large-diameter trees, sparse understory, an open nature, and structural complexity).

4. Avoid removing and fragmenting mature and old-growth forests through timber harvest. Use timber harvest to promote forests with a lower density of trees overall; a reduced understory; and relatively greater numbers of mature, large-diameter trees. Small patch cuts may provide temporary foraging areas for silver-haired bats, particularly if they are close to roosting areas and standing, open water. In areas where silver-haired bats are known to occur, conduct timber harvest operations during October through mid April if feasible, to avoid impacting breeding and migrating populations (Schmidt 2003).

5. Implement Best Management Practices for forests and woodlands (see page 190) that retain all large-diameter snags, particularly those greater than 29 cm (11 in) dbh (Schmidt 2003), as potential roost sites for silver-haired bats and other snag-dependent species. Maintain a minimum snag density of 21 snags/ha (8.5 snags/ac) (Mattson and others 1996) in areas where silver-haired bats occur. Create or preserve snags at least 10 m (33 ft) in height and 39 cm (15 in) or greater in diameter (Mattson and others 1994). Expand snag retention guidelines from riparian areas into upland areas, as silver-haired bats often roost farther than 100 m (330 ft) from riparian zones (Campbell and others 1996). Betts (1996) found that silver-haired bats roosting in tree cavities often switch roosts frequently and may need several suitable roosts over the course of a summer, making it necessary to retain all snags in areas where bats are known to roost.

6. Retain all trees with existing roost sites, since silver-haired bats have been documented to roost in the same tree over a period of years. Delineate roost locations and determine the local

features that offer suitable roosting habitat (such as snags, tree species, and age of timber stand), so these features can be provided in the future.

7. Maintain and restore low and mid elevation riparian woodland areas, tree plantings in low elevation urban areas, and shelterbelts on farms, as silver-haired bats may rely on these habitat corridors during migration (Bogan and Cryan 2000; Altenbach and others 2002).

8. Conserve the habitat required by woodpecker species throughout Wyoming, as silver-haired bats rely on these primary cavity excavators to create suitable maternity roosts (Mattson and others 1994, 1996; Vonhof and Barclay 1996).

9. In areas where safety is a concern, cut snags to a height of about 3 m (10 ft), rather than totally removing them. This technique, known as “high-stumping”, provides a limited number of possible roost sites for solitary (that is, male and nonreproductive female) silver-haired bats, which will sometimes roost on trees close to the ground (Mattson and others 1994).

10. Use prescribed fire to maintain open, mature forest with standing dead trees in areas where silver-haired bats occur. Maintain a reduced fuel load and use low-intensity fires so that large snags and trees are not burned. Where possible, use prescribed fire from September to March to avoid directly impacting roosting bats.

11. Avoid recreational activities (such as off-road vehicle travel, dirt biking, and discharging firearms) that could disturb maternity colonies, or that lead to erosion and degradation of water sources in areas where silver-haired bat roosts are known to occur.

12. Avoid or minimize pesticide use in forest and riparian habitats where the silver-haired bat is known to occur to avoid direct poisoning and to maintain a food source for this species and other insectivores. Where possible, allow insect outbreaks to proceed naturally.

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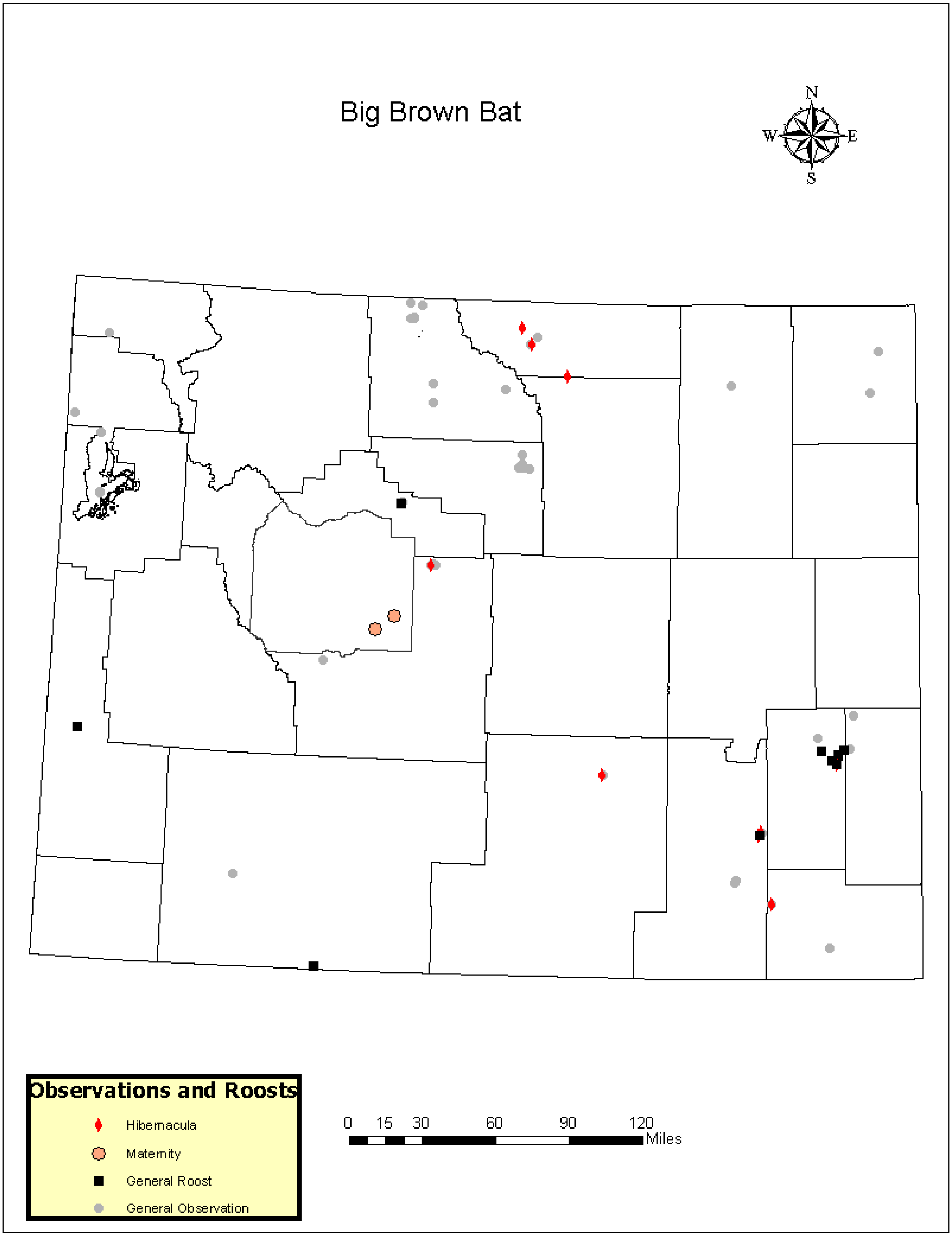

Big Brown Bat
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<u>Big Brown Bat</u> (*Eptesicus fuscus*)

Range

The big brown bat inhabits most of North America from Alaska and southern Canada through Mexico and into South America. It is a year-round resident in Wyoming and is found throughout the state, from the eastern plains to over 3050 m (10,000 ft) in the mountains (Luce 1998). Clark and Stromberg (1987) show occurrence in 14 counties scattered throughout most of Wyoming, and Cerovski and others (2004) show occurrence in 25 of the state's 28 latilongs, although breeding has only been documented in 6 latilongs.

Description

The big brown bat is a medium-sized, heavy-bodied vespertilionid with glossy, pale to dark brown dorsal fur. The ventral fur is distinctly paler, and the wings and interfemoral membrane are dark brown to black and hairless. The ears are black and rounded, and barely reach the nostrils when laid forward. The muzzle is broad and dark brown to black. The calcar is keeled, and the tragus is blunt and rounded. The tip of the tail extends about 3 mm beyond the interfemoral membrane. External measurements are as follows: wingspan, 325 to 350 mm; total length, 87 to 138 mm; tail, 34 to 57 mm; hind foot, 8 to 14 mm; ear, 10 to 20 mm; tragus, 6 to 10 mm; forearm, 39 to 54 mm; and weight, 12 to 20 g (Kurta and Baker 1990; Luce 1998). The big brown bat is not usually confused with other species.

Associated Species

Other species that may benefit from management for this species include the California myotis, western small-footed myotis, long-eared myotis, northern myotis, little brown myotis, fringed myotis, long-legged myotis, Yuma myotis, silver-haired bat, Townsend's big-eared bat, pallid bat, and the Brazilian free-tailed bat. Although the eastern pipistrelle and the big free-tailed bat are accidental species in Wyoming, they may also benefit from management for this species.

Habitat

The big brown bat occupies a wide variety of habitats and elevations, including cottonwood riparian woodlands, sagebrush steppe, juniper woodlands, conifer forests, and aspen woodlands. It is better adapted to human habitation than most bat species, and can often be found in urban areas and around manmade structures. It may be more abundant in deciduous forests and woodlands than coniferous areas (Kurta and Baker 1990).

This species forages in a variety of habitats; it shows no preference for feeding over water versus over land, edge versus non-edge habitats, areas with versus without canopy enclosures, and urban versus rural environments (Kurta and Baker 1990). It often forages over meadows, pastures, and tree canopies; around ranch buildings; along tree-lined streets and riparian areas; and under streetlights.

Although the big brown bat is well known for its tendency to roost in buildings, it also uses a wide variety of other manmade and natural roosts, including tree cavities, rock crevices, caves, abandoned mines, and bridges. Priday and Luce (1999) documented 3 maternity roosts in Wyoming, all in buildings. They also found 5 summer day roosts—1 in a cave, and 4 in buildings. Brigham (1991) suggested that the big brown bat's use of buildings might be a result of the loss of natural roost sites. Betts (1996) and Vonhof (1996) both found that tree-roosting big brown bats prefer either large-diameter or tall trees that are relatively far away from surrounding trees.

After feeding, the big brown bat usually flies to a night roost to rest, usually in more open settings in buildings, abandoned mines, and bridges, including porches, breezeways, and open garages. Priday and Luce (1999) found big brown bats in 16 night roosts in Wyoming, including 6 in caves, 7 in abandoned mines, and 3 in buildings.

In winter, the big brown bat hibernates primarily in caves, buildings, and abandoned mines where air temperatures remain cool but above freezing. Whitaker and Gummer (1992, 2000) suggest that the big brown bat commonly hibernates in tree cavities. In Wyoming, Priday and Luce (1999) found 13 hibernacula—3 in caves and 10 in abandoned mines.

Life History

The big brown bat mates in September and the female carries the sperm over winter. In spring, fertilization occurs and the females form small maternity colonies. Two young are produced in the eastern United States, but 1 pup is the general rule in the West, including Wyoming. Pups are born from May through July after a 60-day gestation period (Luce 1998; Wilson and Ruff 1999). Young can fly by about 3 or 4 weeks of age (Clark and Stromberg 1987).

The big brown bat usually forages most intensely within the first 2 hours after sunset, but may feed anytime during the night (Kurta and Baker 1990). After emergence, it usually flies a steady, nearly straight course at a height of about 6 to 9 m (20 to 30 ft) to the foraging area, up to several hundred meters away from the day roost (Barbour and Davis 1969). Individuals often follow identical feeding patterns on different nights (Harvey and others 1999).

The big brown bat feeds primarily on flying beetles (Coleoptera), although it will take other flying insects, including flies (Diptera), moths (Lepidoptera), ants (Formicidae), caddisflies (Trichoptera), stoneflies (Plecoptera), mayflies (Ephemeroptera), and crickets (Gryllidae) (Phillips 1966; Kurta and Baker 1990; Oakleaf and others 1996). Its large jaw and robust teeth allow it to take large insects with tough exoskeletons, such as beetles (Whitaker 1995).

The big brown bat is not a migratory species; it rarely moves more than 80 km (50 mi) between summer and winter roosts (Kurta and Baker 1990). It is extremely hardy and is often the last species to enter hibernation in late autumn or early winter (Barbour and Davis 1969); it remains active throughout the winter in the southern parts of its range (Adams 2003). This species often hibernates in sites with low humidity, variable temperature, and exposure to air movements (Phillips 1966). It frequently hibernates at temperatures below freezing and is often found in cracks or crevices or beneath rocks in the hibernaculum floor (Kurta and Baker 1990).

The big brown bat is a colonial species, although colonies are usually relatively small. Maternity colonies can vary from around a dozen to several hundred, but the largest found so far in Wyoming had 53 females (Priday and Luce 1999). During summer, males usually roost alone or in small bachelor colonies (Barbour and Davis 1969). The big brown bat may hibernate either alone or in small clusters; Phillips (1966) suggested that clustering might be a metabolic advantage to bats, particularly in cold hibernacula.

Female big brown bats show fidelity to their maternity roosts and often return year after year (Wilson and Ruff 1999).

Status

The big brown bat is abundant throughout most of its range (Barbour and Davis 1969). It is probably the most abundant and widespread bat in Wyoming and 1 of the species most often encountered by humans (Luce 1998).

The big brown bat is classified as a nongame species in Wyoming and is protected from take in Section 11, Chapter 52 of the Wyoming Game and Fish Commission Regulations. The Wyoming Game and Fish Department classifies it as a Species of Special Concern with a Native Species Status of 3 (NSS3).

Conservation Issues

Although common and widespread, this species suffers continuous loss of habitat through building demolition and remodeling, as well as exclusion from buildings. Other potential threats include timber harvest, bridge replacement and demolition, recreational caving and other roost disturbances, mine reclamation, renewed mining, and pesticides and other contaminants.

Survey and Monitoring Issues and Techniques

Recommended survey methods are mist netting and active acoustic monitoring with visual observation. The big brown bat is readily captured in mist nets, but can be difficult to catch in open areas, especially where water is abundant. It is easy to detect acoustically, and a subset of its calls are diagnostic, although there is overlap with the silver-haired bat and the Brazilian free-tailed bat (WBWG 2003). Its large size and strong, direct flight make it recognizable to experienced observers (Barbour and Davis 1969).

Management Recommendations

1. Implement inventory and monitoring to determine population status and habitat requirements of the big brown bat in Wyoming, as additional information is necessary to guide management actions.

2. Manage lands where big brown bats occur in such a way that provides adequate roosting and foraging habitat to maintain stable populations (that is, secure roosting sites; diverse, native foraging habitat; and uncontaminated water sources).

3. Implement Best Management Practices for buildings (see page 174) in areas where big brown bats roost. Where protection of roosts in buildings is not an option, ensure safe evacuation of big brown bats and other bats, including creating alternate roost sites. Although this species readily accepts properly built and located artificial roosts, Brigham and Fenton (1986) showed that reproductive success tends to decrease when bats are forced to shift to a new site prior to parturition, and the bats are usually significantly less loyal to the new site. In addition, occupancy of artificial roosts by big brown bat maternity colonies in Wyoming has been sporadic (M Grenier, Wyoming Game and Fish Department, personal communication). Therefore, protection of existing roosts remains the best option.

4. Implement Best Management Practices for natural caves (see page 152), abandoned mines (see page 161), and bridges (see page 180) in areas where big brown bats roost.

5. Avoid timber harvest activities in areas close to known maternity roosts of big brown bats during the maternity roosting period, and retain all known roost trees.

6. Implement Best Management Practices for forests and woodlands (see page 190) that retain and encourage regeneration of mature aspen stands across the landscape. Even aspen stands that cover small areas are important because of the high use of aspen by primary cavity nesters, which provide roosts for big brown bats (and other secondary cavity users) (Kalcounis and Brigham 1998).

7. Implement Best Management Practices for forests and woodlands (see page 190) that retain all large-diameter snags as potential roost sites for big brown bats and other snag-users. Betts (1996) found that big brown bats roosting in tree cavities often switch roosts frequently and may need several suitable roosts over the course of a summer, making it necessary to retain all snags in areas where bats are known to roost.

8. Avoid or minimize pesticide use in areas where the big brown bat is known to occur to avoid direct poisoning and to maintain a food source for this species and other insectivores.

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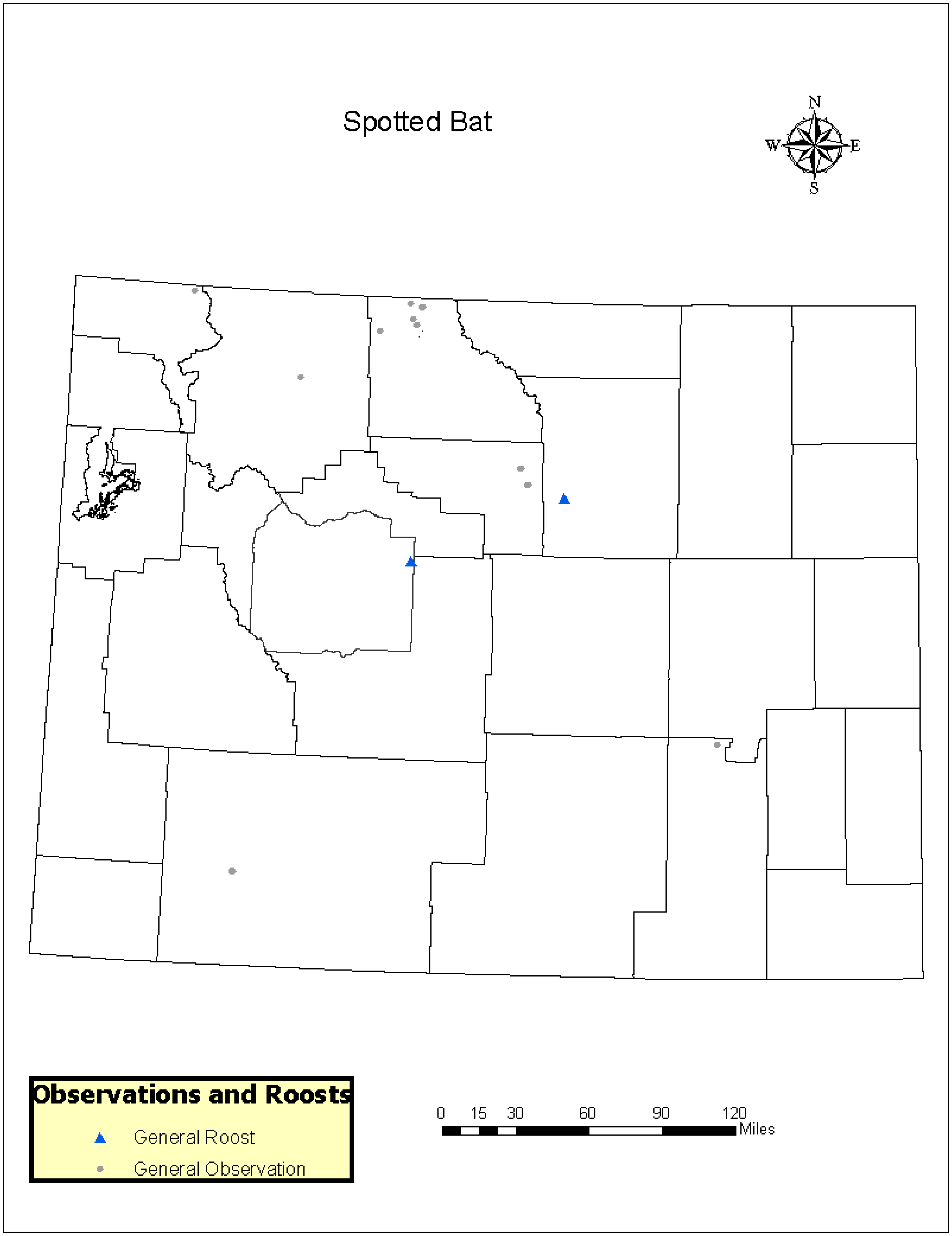
Spotted Bat
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<u>Spotted Bat</u> (*Euderma maculatum*)

Range

The spotted bat inhabits western North America from southern British Columbia through most of the western states to central Mexico. Its winter range is unknown. Its distribution in Wyoming is still unknown (Priday and Luce 1999a), although Clark and Stromberg (1987) suggest that it may be expected to occur throughout western Wyoming, and Bogan and Cryan (2000) suggest that it could occur statewide in suitable habitat. Clark and Stromberg (1987) show occurrence in 1 county in north central Wyoming and Cerovski and others (2004) show occurrence in 5 latilongs in north central Wyoming and 1 latilong in southwestern Wyoming, although confirmed or suspected breeding has only been recorded in 2 latilongs in north central Wyoming.

Description

The spotted bat is a medium-sized to relatively large bat with striking and very distinctive markings. The dorsal fur is black with a white spot on each shoulder and a large white spot on the rump, and the ventral fur is white with black bases. The enormous, pink, hairless ears are almost as long as the body and are joined at the base. The wings and interfemoral membrane are pinkish-red, and the eyes and tragi are large. It has a 10-mm naked patch on its throat that is usually hidden by the surrounding fur. External measurements are as follows: wingspan, 250 mm; total length, 107 to 126 mm; tail, 47 to 55 mm; hind foot, 9 to 12 mm; ear, 45 to 50 mm; forearm, 48 to 54 mm; and weight, 14 to 22 g (Watkins 1977; Clark and others 1989; Priday and Luce 1999b; Wilson and Ruff 1999). The spotted bat is not easily confused with other species because of its enormous ears and unique markings.

Associated Species

Other species that may benefit from management for this species include the California myotis, western small-footed myotis, little brown myotis, Yuma myotis, big brown bat, pallid bat, and the Brazilian free-tailed bat. Although the big free-tailed bat is an accidental species in Wyoming, it may also benefit from management for this species.

Habitat

The spotted bat occupies a wide variety of habitats, from desert scrub to coniferous forest, although it is most often observed in low deserts and basins and juniper woodlands (Clark and Stromberg 1987; Oakleaf and others 1996). It often occurs in association with canyons, prominent rock features, and permanent water sources (WBWG 1998; Priday and Luce 1999a, 1999b). The ability of the spotted bat to concentrate its urine indicates that it may have evolved in arid environments such as deserts and grasslands (Chung-MacCoubrey 1996). In desert environments, the spotted bat forages in canyons, in the open, or over riparian vegetation; in montane habitats, it forages over meadows, along forest edges, or in open coniferous woodland (Navo and others 1992; Storz 1995; WBWG 1998; Altenbach and others 2002).

The spotted bat roosts in cracks and crevices in high cliffs and canyons. It also may occasionally roost in buildings, caves, or abandoned mines (Oakleaf and others 1996; Altenbach and others 2002), although cliffs are the only roosting habitat in which reproductive females have been documented (Schmidt 2003). All recorded occurrences of spotted bats in Wyoming were associated with canyons containing cracks and fissures, high bare rock walls, and rock ridges close to a permanent water source (Priday and Luce 1999b). Little is known about its winter habitat, although it may roost in caves and abandoned mines to some extent (Altenbach and others 2002).

Life History

The spotted bat produces 1 pup per year, usually in June. Otherwise, very little is known about the reproductive patterns of this species (WBWG 1998; Altenbach and others 2002; Adams 2003).

The spotted bat usually emerges after sunset to begin foraging and continues to forage throughout the night (Wai-Ping and Fenton 1989; WBWG 1998; Schmidt 2003). Early studies suggested that the spotted bat gleans insects from surfaces (Watkins 1977; Wilson and Ruff 1999), but later studies indicate that it forages in continuous flight and does not land on the ground or glean prey from surfaces (Leonard and Fenton 1983; Wai-Ping and Fenton 1989; Storz 1995). It often forages in a circular or elliptical pattern, usually about 10 m (33 ft) above the ground (Wai-Ping and Fenton 1989; Navo and others 1992; Schmidt 2003). It makes a low-frequency echolocation call that is effective for rapid flight, long-range detection in open areas, and feeding on moths that are able to detect ultrasonic sounds; it is also audible to many humans (Clark and others 1989; Storz 1995). It usually forages alone and may defend foraging territories from other spotted bats (Schmidt 2003). It feeds primarily on moths (Lepidoptera) from 5 to 11 mm in size (Snow 1974; Watkins 1977; Hinman and Snow 2003).

The winter habits of the spotted bat are poorly understood. It probably hibernates through most of the winter, although populations in the northern part of its range probably migrate to suitable hibernacula that are lower in elevation and/or more southern than its summer roosts (WBWG 1998; Altenbach and others 2002; NatureServe 2003).

This species is mostly solitary, but may hibernate in small clusters (Hinman and Snow 2003; NatureServe 2003; Schmidt 2003). It appears to exhibit fidelity to suitable roost sites (Leonard and Fenton 1983; Wai-Ping and Fenton 1989).

Status

Although the spotted bat is widespread, it is rare and patchily distributed throughout most of its range, including Wyoming (Luce 1998; Schmidt 2003). Populations may be locally abundant in areas with available roosting habitat (Priday and Luce 1999b).

The spotted bat is classified as a nongame species in Wyoming and is protected from take in Section 11, Chapter 52 of the Wyoming Game and Fish Commission Regulations. The Wyoming Game and Fish Department classifies it as a Species of Special Concern with a Native

Species Status of 2 (NSS2). The Wyoming Natural Diversity Database classifies it as S1B, SZ?N (Fertig and Beauvais 1999). Region 2 of the US Forest Service and the Bureau of Land Management in Wyoming both consider it a Sensitive Species (BLM 2002; USFS 2003).

Conservation Issues

Potential threats include recreational climbing and other roost disturbances; mining and quarry operations that destroy roosting habitat; water impoundments; and pesticides and other contaminants.

Survey and Monitoring Issues and Techniques

The recommended survey method is active acoustic monitoring with visual observation. Mist netting over water can be effective where water is a limiting factor in xeric conditions (WBWG 2003), although the spotted bat often forages too high to be caught in mist nets (Bogan and Cryan 2000). It is easy to detect acoustically (with microphones sensitive to audible frequencies), most of its calls are diagnostic, and its low-frequency calls are audible to many people at distances up to 250 m (825 ft) (Navo and others 1992; Adams 2003; WBWG 2003). Its flight characteristics are distinctive to experienced observers (WBWG 2003).

Management Recommendations

1. Implement inventory and monitoring to determine population status and habitat requirements of the spotted bat in Wyoming, as additional information is necessary to guide management actions.

2. Manage lands where spotted bats occur in such a way that provides adequate roosting and foraging habitat to maintain stable populations (that is, secure roosting sites; diverse, native foraging habitat; and uncontaminated water sources).

3. Implement Best Management Practices for rock shelters (see page 168) in areas where spotted bats roost, and minimize human disturbances to spotted bat roost sites in cliffs and rock crevices.

4. Use timber harvesting, prescribed burning, and proper grazing practices to create and maintain open areas and herbaceous plant diversity as foraging habitat in areas where spotted bats occur (Schmidt 2003).

5. Establish and maintain permanent water sources in areas where spotted bats occur (Snow 1974).

6. Avoid or minimize pesticide use in areas where the spotted bat is known to occur to avoid direct poisoning and to maintain a food source for this species and other insectivores.

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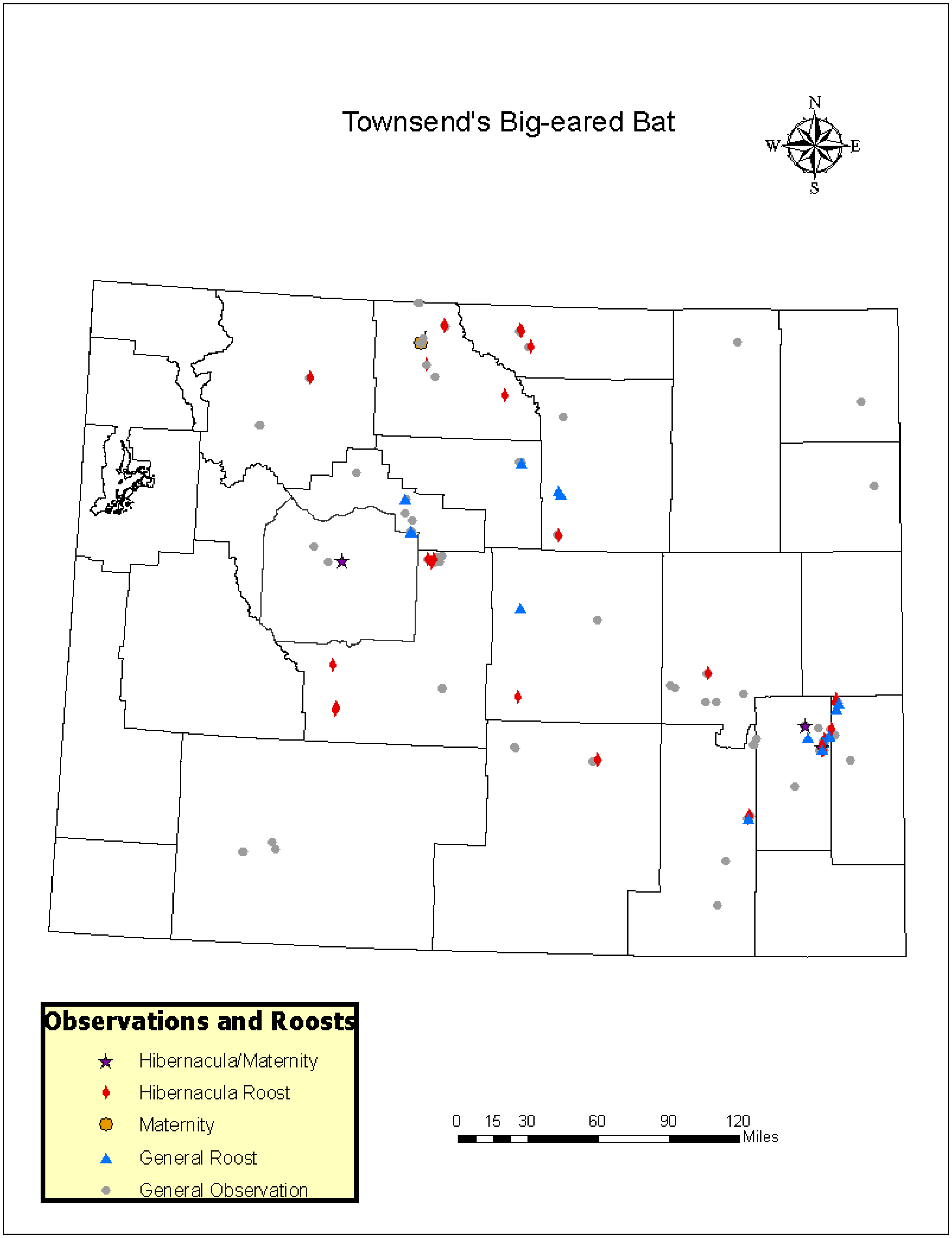
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<u>Townsend's Big-eared Bat</u> (*Corynorhinus townsendii*)

Range

Formerly known as *Plecotus townsendii*, the Townsend's big-eared bat inhabits most of western North America from British Columbia to central Mexico, and east to western South Dakota and Texas. Isolated populations occur in the south central and Appalachian states. It is a year-round resident throughout most of Wyoming, but is concentrated in the southeastern and north central portions of the state (Bogan and Cryan 2000; Luce 2001). Clark and Stromberg (1987) show occurrence in 7 counties scattered through most of the northern 2/3 of Wyoming and Cerovski and others (2004) show occurrence in 18 of the state's 28 latilongs, although breeding has only been documented in 5 latilongs.

Description

The Townsend's big-eared bat is a medium-sized bat with long, soft, gray or brown fur. The dorsal hairs are gray at the bases with pale cinnamon-brown to dark brown tips, and the ventral hairs are gray or brownish at the bases with brownish or buff tips. The wings, ears, and interfemoral membrane are gray or light brown. The ears are long, wide, and joined across the forehead. During torpor, the ears are sometimes curled against the head in the shape of ram's horns while the tragi remain erect, which can lead to misidentification. The face has large, fleshy sebaceous glands on both sides of the snout. The calcar is not keeled. External measurements are as follows: wingspan, 297 to 320 mm; total length, 90 to 112 mm; tail, 35 to 54 mm; hind foot, 9 to 13 mm; ear, 30 to 39 mm; tragus, 11 to 17 mm; forearm, 39 to 48 mm; and weight, 5 to 13 g (Barbour and Davis 1969; Kunz and Martin 1982; Pierson and others 1999). The large lumps on the muzzle and the large, joined ears can be used to distinguish the Townsend's big-eared bat from other species.

Associated Species

Other species that may benefit from management for this species include the western small-footed myotis, long-eared myotis, northern myotis, little brown myotis, fringed myotis, long-legged myotis, Yuma myotis, big brown bat, pallid bat, and the Brazilian free-tailed bat. Although the eastern pipistrelle is an accidental species in Wyoming, it may also benefit from management for this species.

Habitat

The Townsend's big-eared bat occupies a variety of xeric to mesic habitats, including coniferous forests, juniper woodlands, deciduous forests, basins, and desert shrublands, and is absent only from the most extreme deserts and highest elevations (Clark and Stromberg 1987; Pierson and others 1999). It usually occurs between 1120 and 2530 m (3675 and 8300 ft) in Wyoming (Luce 1998). Although it is often associated with xeric habitats, it may be limited to areas with reliable, accessible sources of drinking water (Gruver and Keinath forthcoming). It forages primarily along forest and woodland edges, riparian corridors, and in open areas near wooded habitat, although it may avoid open, grazed pasture land (WBWG 1998; Sherwin and others 2000; Fellers and Pierson 2002; Gruver and Keinath forthcoming).

Although the Townsend's big-eared bat occurs in a wide variety of habitats, its distribution is strongly correlated with the availability of caves and abandoned mines for roost sites (Pierson and others 1999). Occasionally it will roost in other cavern-like structures, such as buildings or large tree cavities, particularly along the Pacific Coast (Gruver and Keinath forthcoming). This species requires caves or abandoned mines during all stages of its life cycle, including maternity roosts, day and night roosts, reproduction, and hibernacula. These activities require different microclimatic conditions, so populations must have multiple sites available for different seasons (Dobkin and others 1995)

Priday and Luce (1999) found 3 maternity roosts in Wyoming—2 in caves and 1 in an abandoned mine. Maternity roosts are usually in spacious caves or abandoned mines, often in relatively warm ceiling pockets or along the walls just inside the roost entrance (Kunz and Martin 1982; Pierson and others 1999). Temperature appears to be the most critical factor in the selection of maternity roosts. The Townsend's big-eared bat prefers cooler maternity roosts than most other vespertilionids; the average July temperature recorded from maternity roosts in Colorado was 15.2 ºC (59.36 ºF) (Adams 2003). Other important factors in the selection of maternity roosts include roost dimensions, light quality, and airflow (Pierson and others 1999).

During summer, males and nonreproductive females use a wider variety of roosts than maternity colonies, including caves, buildings, bridges, abandoned mines, and tree cavities (Pierson and others 1999). Priday and Luce (1999) found 24 day roosts in Wyoming—8 in caves, 12 in abandoned mines, 1 in a tunnel, and 3 in buildings.

After feeding, the Townsend's big-eared bat often uses a night roost to rest, usually in more open settings with large entrances and deep passages. It does not form large night-roosting aggregations like some other species, but gathers in small numbers in a variety of sites, including caves, open buildings, rock shelters, bridges, culverts, and abandoned mines (Pierson and others 1999; Altenbach and others 2002). Priday and Luce (1999) found Townsend's big-eared bats in 35 night roosts in Wyoming, including 19 in abandoned mines, 11 in caves, 4 in rock shelters, and 1 in a tunnel.

The Townsend's big-eared bat hibernates primarily in caves and abandoned mines. Priday and Luce (1999) found 44 hibernacula in Wyoming—15 in caves, 28 in abandoned mines, and 1 in a tunnel. Hibernacula usually have stable, cold temperatures; moderate airflow; high humidity; and multiple, shaded, north-facing entrances (WDOW 1993, 1994; Pierson and others 1999; Luce 2001). This species hibernates at temperatures from –2 to 13 °C (28 to 55 ºF), although it prefers temperatures below 10 °C (50 ºF) (Pierson and others 1999).

Life History

The Townsend's big-eared bat mates in the hibernaculum from October to February and the female carries the sperm until fertilization in spring. A single pup is born between May and July after a gestation of 56 to 100 days, depending on climatic conditions. Young can fly after about

3 weeks, and are fully weaned at 6 weeks of age (Barbour and Davis 1969; WBWG 1998; Pierson and others 1999).

The Townsend's big-eared bat is a late flier, usually emerging from the roost to begin foraging after dark, about 45 minutes after sunset (Pierson and others 1999). After night-roosting, it forages again just before sunrise (Kunz and Martin 1982). It is a slow, maneuverable flier, and typically forages within and around the forest canopy and at forest edges. It probably forages by capturing insects in the air, as well as by gleaning insects from foliage (Adams 2003). It feeds primarily on moths (Lepidoptera) about 6 mm in length, although it probably forages opportunistically and takes small quantities of lacewings (Neuroptera), small beetles (Coleoptera), flies (Diptera), and wasps (Hymenoptera) (Kunz and Martin 1982; Gruver and Keinath forthcoming).

The Townsend's big-eared bat is a relatively sedentary species that does not make long-distance migrations. The longest documented movements between summer and winter roosts are in the order of 32 to 64 km (20 to 40 mi) (Pierson and others 1999). Throughout its range it escapes the harsh conditions and lack of prey during winter by hibernating (Gruver and Keinath forthcoming). It prefers relatively cold places for hibernation and often roosts near entrances and well-ventilated parts of caves and abandoned mines, although it may move to deeper, more stable areas if temperatures become too extreme (Kunz and Martin 1982). It often hibernates with its ears coiled like a ram's horns, possibly to reduce surface heat loss (Wilson and Ruff 1999).

During summer, females roost in colonies that range in size from a few dozen to several hundred individuals, while males roost alone. Winter colonies are usually smaller than maternity colonies, but can range in size from a single individual to several hundred (WBWG 1998; Pierson and others 1999). Most Townsend's big-eared bats observed by Priday and Luce (1999) in Wyoming were solitary individuals or small groups; maternity colonies ranged from 27 to 200 bats and winter colonies ranged from 1 to 54 individuals.

This species has a high degree of site fidelity, with most individuals returning to the same sites year after year (Kunz and Martin 1982). However, most bats use multiple roosts within the area, shifting roosts throughout the year, and even within a single season, in search of optimal temperatures (Pierson and others 1999; Fellers and Pierson 2002). Some populations exhibit strong fidelity to specific roosts while others express fidelity to groups of roosts but not to any single roost (Sherwin and others 2003).

Status

Although it is widespread in North America (Barbour and Davis 1969), the Townsend's big-eared bat is relatively uncommon (Gruver and Keinath forthcoming). Throughout its range, local populations, apparently abundant historically, have declined dramatically in the past 40 years (Pierson and others 1999; Gruver and Keinath forthcoming). Although there is little historical data on bat numbers or locations in Wyoming (Pierson and others 1999), significant loss of abandoned mine habitat has been documented in the state (Oakleaf and others 1996).

The Townsend's big-eared bat is classified as a nongame species in Wyoming and is protected from take in Section 11, Chapter 52 of the Wyoming Game and Fish Commission Regulations. The Wyoming Game and Fish Department classifies it as a Species of Special Concern with a Native Species Status of 2 (NSS2). The Wyoming Natural Diversity Database classifies it as S1B, S2N (Fertig and Beauvais 1999). Region 2 of the US Forest Service and the Bureau of Land Management in Wyoming both consider it a Sensitive Species (BLM 2002; USFS 2003).

Conservation Issues

The primary threat to the Townsend's big-eared bat is the disturbance or loss of roost sites in caves and abandoned mines (such as recreation in caves, mine reclamation, and renewed mining). This species is extremely sensitive to disturbance at maternity roosts and hibernacula, which can cause abandonment of roost sites and death of young and adults (Kunz and Martin 1982). Other potential threats include degradation or loss of foraging habitat in forests and woodlands, and pesticides and other contaminants.

Survey and Monitoring Issues and Techniques

Although the recommended survey method is roost surveys, roost surveys should only be performed by trained individuals. The Townsend's big-eared bat is adept at avoiding mist nets. Its low-intensity calls are difficult to detect acoustically, although, when detected, its calls are diagnostic (WBWG 2003). Roost surveys are probably most effective, although maternity roosts should never be entered unless absolutely necessary, and hibernacula should not be entered more than once every 2 years (Pierson and others 1999).

Management Recommendations

1. Implement inventory and monitoring to determine population status and habitat requirements of the Townsend's big-eared bat in Wyoming, as additional information is necessary to guide management actions.

2. Manage lands where Townsend's big-eared bats occur in such a way that provides adequate roosting and foraging habitat to maintain stable populations (that is, secure roosting sites; diverse, native foraging habitat; and uncontaminated water sources).

3. Because the Townsend's big-eared bat uses multiple roosts, shifting roosts throughout the year and sometimes even within a single season, protect and maintain all known and potential roosts in areas where it is known to occur (Pierson and others 1999; Sherwin and others 2000; Fellers and Pierson 2002).

4. Implement Best Management Practices for natural caves (see page 152), abandoned mines (see page 161), buildings (see page 174), bridges (see page 180), and rock shelters (see page 168) in areas where Townsend's big-eared bats roost.

5. Avoid prescribed burning or other alteration of vegetation in pinyon-juniper or shrub-steppe habitats within a 2.5-km (1.5-mi) radius of Townsend's big-eared bat roost sites. Avoid burning

more than half of the forested habitat within a 0.8-km (0.5-mi) radius of Townsend's big-eared bat roosts sites per decade. Use prescribed burning only when roosts are unoccupied (Pierson and others 1999).

6. Avoid timber harvest activities within 150 m (500 ft) of Townsend's big-eared bat roosts while the roosts are occupied (approximately April 1 to October 1 for maternity roosts, and November 1 to April 1 for hibernacula). Construct logging roads so as to minimize visibility of roost entrances from the road (Pierson and others 1999).

7. Maintain or improve riparian and wetland habitats within a 16-km (10-mi) radius of Townsend's big-eared bat roosts to achieve a healthy and diverse structure (Pierson and others 1999).

8. Avoid or minimize pesticide use in areas where the Townsend's big-eared bat is known to occur to avoid direct poisoning and to maintain a food source for this species and other insectivores.

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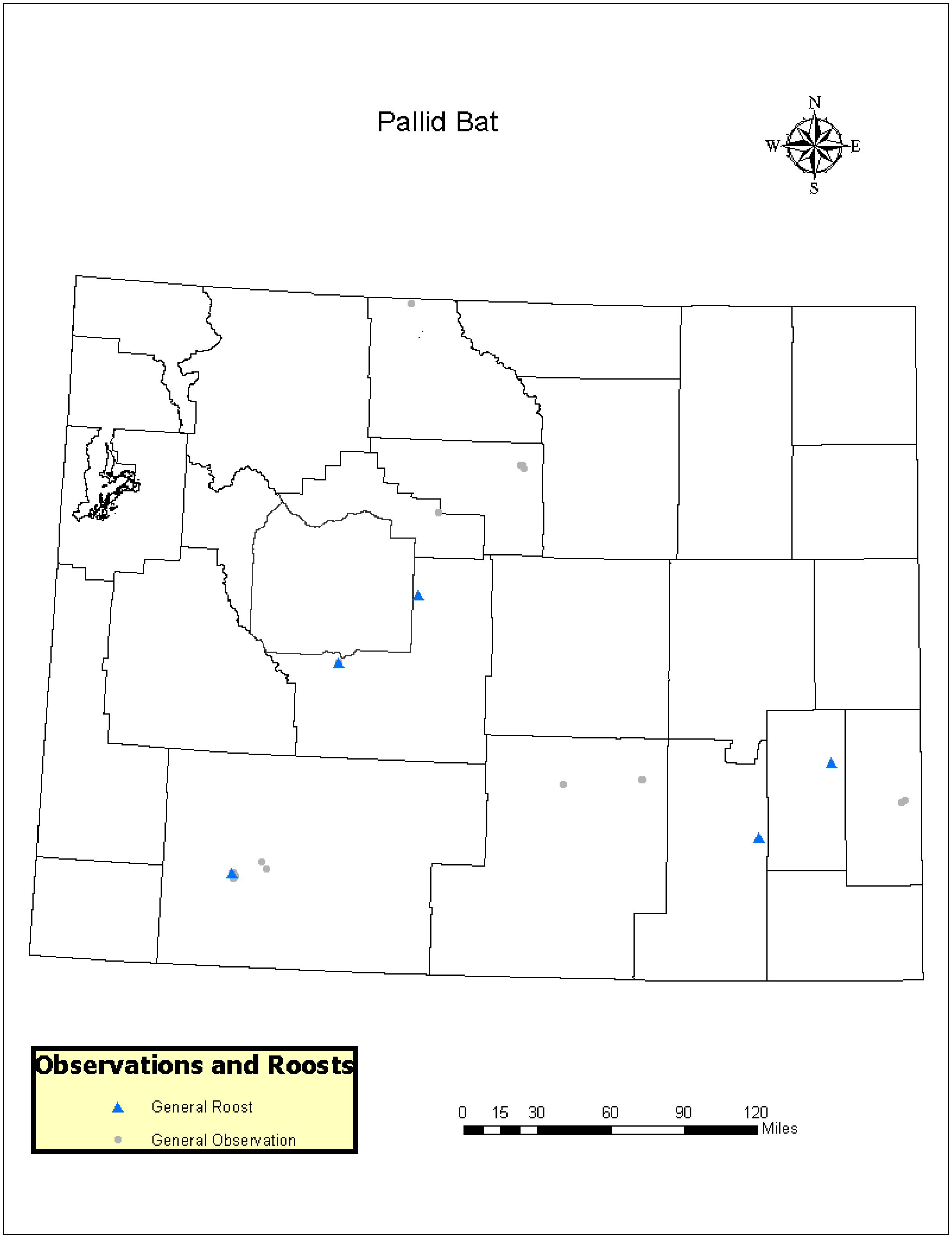

Pallid Bat
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Observations and Roosts
General Roost
General Observation
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Miles

<u>Pallid Bat</u> (*Antrozous pallidus*)

Range

The pallid bat inhabits western North America from southern British Columbia to central Mexico and east to Kansas and Oklahoma. Although records of this species are patchy in Wyoming, it probably inhabits suitable habitat statewide (Oakleaf and others 1996). It occurs up to about 2100 m (7000 ft), most commonly in the low elevations of the eastern plains and basins of the state (Luce 1998). Clark and Stromberg (1987) show occurrence in 2 counties in southeastern and southwestern Wyoming. Cerovski and others show occurrence in 9 latilongs scattered throughout the state, although breeding has only been documented in 1 latilong in north central Wyoming. Although it is a year-round resident in much of its range, it probably migrates out of Wyoming during the cold season (Luce 1998).

Description

The pallid bat is a large, pale bat that is not easily confused with other species. Its dorsal fur is pale yellow tipped with gray or brown, and its ventral fur is creamy yellow to almost white. The wings and interfemoral membrane are pale brown. The ears are quite long and broad, and are not joined at the base. In flight, the ears are clearly visible in profile. The eyes are large, and the face is covered with wart-like sebaceous glands. The pig-like snout and skunk-like odor are distinctive. External measurements are as follows: wingspan, 360 to 410 mm; total length, 92 to 135 mm; tail, 35 to 53 mm; hind foot, 11 to 16 mm; ear, 21 to 37 mm; forearm, 45 to 61 mm; and weight, 13 to 29 g (Hermanson and O’Shea 1983).

Associated Species

Other species that may benefit from management for this species include the California myotis, western small-footed myotis, little brown myotis, fringed myotis, long-legged myotis, big brown bat, spotted bat, Townsend’s big-eared bat, and the Brazilian free-tailed bat. Although the eastern pipistrelle is an accidental species in Wyoming, it may also benefit from management for this species.

Habitat

The pallid bat generally inhabits low desert shrublands, juniper woodlands, and grasslands, and occasionally cottonwood-riparian zones in those habitats. It is most common in low, arid regions with rocky outcroppings, particularly near water, although it has been found in ponderosa pine habitat as high as 2100 m (7000 ft) in Wyoming (Clark and Stromberg 1987). Riparian areas may serve as important foraging habitat (Altenbach and others 2002).

In summer, the pallid bat usually roosts in rock crevices and buildings, but also uses rock piles, tree cavities, shallow caves, and abandoned mines. It minimizes its daily use of energy by being highly selective in its choice of roosting sites. Suitable sites typically provide thermally stable crevices with temperatures close to 30 °C (86 °F), protection from precipitation and predators, shelter from direct sunlight, a space large enough for more than 2 dozen bats, and an unobstructed entrance at least 1.5 m (5 ft) above the ground to allow the bats to drop for flight (Vaughan and O'Shea 1976).

After feeding, the pallid bat also gathers in night roosts that are often near, but separate from, day roosts. Night roosts can be found in rock shelters, bridges, open buildings, porches, shallow caves and abandoned mines, and other sheltered but accessible places. They are usually selected for a stable temperature that remains warmer than the ambient temperature (Wilson and Ruff 1999). Night roosts can usually be recognized by a pile of guano with arthropod body parts (such as mandibles and hind legs of Jerusalem crickets [Stenopelmatidae], and tails and pincers of scorpions [Scorpiones]) below the roost (Lewis 1994). In Wyoming, the pallid bat has been documented at 5 summer night roosts, including 1 in a rock shelter, 2 in caves, 1 in a mine, and 1 in a building (Priday and Luce 1999).

Little is known about the hibernacula of the pallid bat, but it probably roosts in narrow crevices within caves and abandoned mines during winter.

Life History

The pallid bat mates during October through December, the female stores the sperm over winter, and delayed fertilization takes place in spring. Gestation is about 60 days, and the pups are usually born in June, sometimes in late May or early July. Usually 2 young are born each year, but a single pup is produced in about 20% of births (Barbour and Davis 1969). The young are independent by about 6 to 8 weeks of age, and maternity colonies disband between August and October (WBWG 1998).

About an hour after sunset, the pallid bat emerges to forage. It primarily forages for prey on the ground, but also forages in flight within about 3 m (10 ft) of the ground, and on the surfaces of vegetation. It uses echolocation, passive sound, and vision to locate prey, and sometimes emits a series of clicks that are audible to the human ear (Luce 1998). Although this species is a slow flier without especially good maneuverability, it is able to walk on the ground with a variety of strides and gaits, and it can hover or glide momentarily (Harvey and others 1999). Because the pallid bat frequently forages on the ground, it is particularly susceptible to predation and, perhaps, insecticides.

Aside from a size preference for insects larger than 20 mm (0.8 in) (Hermanson and O'Shea 1983), the pallid bat probably selects no particular species as prey. Food items are primarily large ground-dwelling arthropods, such as scorpions, centipedes (Chilopoda), millipedes (Diplopoda), grasshoppers (Orthoptera), beetles (Coleoptera), Jerusalem crickets, and spiders (Araneidae), but also include large moths (Lepidoptera) (Altenbach and others 2002). It may also occasionally take small vertebrates, including lizards, small mice, and even other bats (Luce 1998). The pallid bat's kidneys are well developed to concentrate urine, so it may need to drink only rarely (Clark and Stromberg 1987).

Little is known about the winter habits of the pallid bat. It is not known to perform long migrations, and probably hibernates within a few kilometers of its summer range in most areas

(Barbour and Davis 1969). However, it has not been found hibernating in Wyoming, and probably migrates out of the state during the cold season (Luce 1998).

The pallid bat is a gregarious species and social roosting plays an important role in metabolic savings. It engages in complex and probably energetically costly rallying behavior to locate roost mates, but pallid bats roosting in groups have significantly lower metabolic rates than those roosting singly (Lewis 1993; Vaughan and O'Shea 1976). The pallid bat forms small colonies, generally from a dozen to 100 individuals, in all seasons of the year. Maternity colonies of females and young form the largest groups, but males roosting apart from females are also gregarious. Winter hibernacula usually contain the smallest colonies (Hermanson and O'Shea 1983).

The pallid bat has a high variability in its fidelity to roost sites. It often shows fidelity to roosts that are highly advantageous or less abundant. However, it also often shifts about among roosts without apparent provocation. Also, this species has a rich vocal repertoire, which may have evolved to maintain social bonds during frequent roost switching (Lewis 1995).

Status

The pallid bat has a large range in western North America, and is fairly common in many areas. However, regional population trends are poorly known, including in Wyoming. Statewide surveys in the 1990s found this species roosting in only 5 sites in the state, although 1 building in southeastern Wyoming is a major roost site (Priday and Luce 1999).

The pallid bat is classified as a nongame species in Wyoming and is protected from take in Section 11, Chapter 52 of the Wyoming Game and Fish Commission Regulations. The Wyoming Game and Fish Department classifies it as a Species of Special Concern with a Native Species Status of 2 (NSS2). The Wyoming Natural Diversity Database classifies it as S1B, SZ?N (Fertig and Beauvais 1999).

Conservation Issues

The pallid bat is sensitive to human disturbance and even minimal human presence has led to the permanent abandonment of night and maternity roosts (Luce 1998). Potential threats include recreational caving, rock climbing, and other roost disturbances; building demolition and remodeling; exclusion from buildings; and pesticides and other contaminants.

Survey and Monitoring Issues and Techniques

The recommended survey method is mist netting at ground level. The pallid bat flies close to the ground and is readily captured in nets, often in upland habitats. It is easy to detect acoustically and a subset of its calls is diagnostic, particularly if it gives a "directive" call (WBWG 2003). Pallid bat night roosts can be easily recognized by accumulations of guano and the body parts of prey, which can make night roosts a good marker for censusing pallid bat populations (Lewis 1994). It is difficult to detect day roosts in most natural locations, such as trees and rock crevices.

Management Recommendations

1. Implement inventory and monitoring to determine population status and habitat requirements of the pallid bat in Wyoming, as additional information is necessary to guide management actions.

2. Manage lands where pallid bats occur in such a way that provides adequate roosting and foraging habitat to maintain stable populations (that is, secure roosting sites; diverse, native foraging habitat; and uncontaminated water sources).

3. Implement Best Management Practices for natural caves (see page 152), abandoned mines (see page 161), buildings (see page 174), bridges (see page 180), and rock shelters (see page 168) in areas where pallid bats roost.

4. Avoid or minimize pesticide use in areas where the pallid bat is known to occur to avoid direct poisoning and to maintain a food source for this species and other insectivores.

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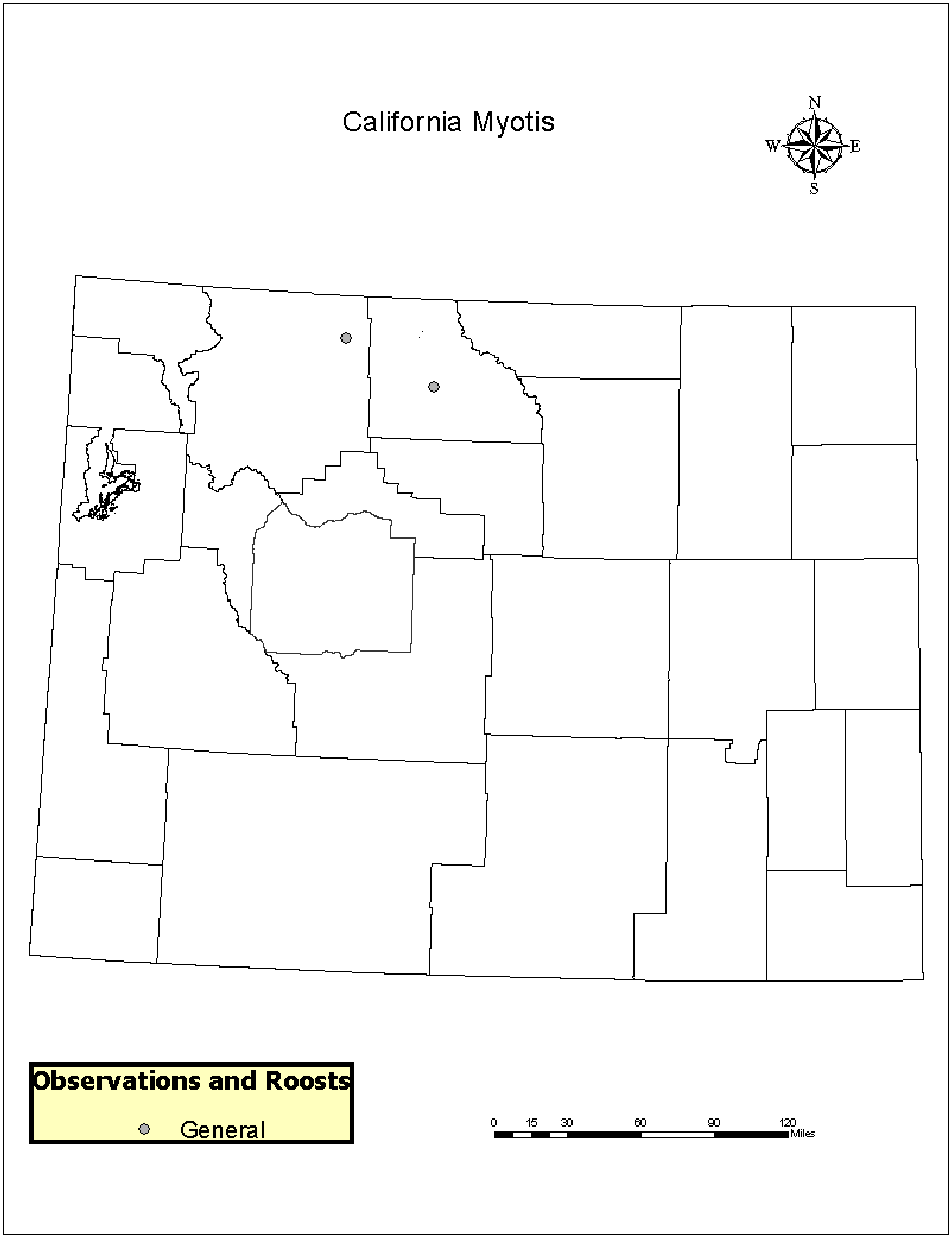
California Myotis
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Observations and Roosts
General
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Miles

<u>California Myotis</u> (*Myotis californicus*)

Range

The California myotis inhabits much of western North America from the Alaskan panhandle, through most of the United States west of the Rocky Mountains, and south to southern Mexico and Guatemala (WBWG 1998). Wyoming is at the eastern edge of its range (Bogan and Cryan 2000), and it has been documented in only 2 latilongs in north central and southwestern Wyoming, although no breeding has been recorded (Cerovski and others 2004). Its winter range is poorly known and there are no winter records of this bat in Wyoming, although it is probably a year-round resident throughout most of its summer range (CDOW 1984; Clark and others 1989; Bogan and Cryan 2000).

Description

The California myotis is a very small bat with reddish-blond fur that can vary from light buff to dark chestnut. The hair bases are darker than the tips. The ears, wings, and interfemoral membrane are almost black, contrasting with the lighter fur. The ears extend beyond the nostrils by 1 to 4 mm when laid forward, and the base of the interfemoral membrane is hairless. The calcar is slender, is prominently keeled, and ends in a projecting lobule. The hind feet are small, slender, and weak. External measurements are as follows: wingspan, 230 mm; total length, 74 to 95 mm; tail, 34 to 41 mm; hind foot, 5 to 8 mm (less than half the length of the tibia); ear, 11 to 15 mm; forearm, 32 to 35 mm; and weight, 3.3 to 5.4 g (Simpson 1993; Hinman and Snow 2003).

The California myotis differs from most other *Myotis* species in Wyoming in having a keeled calcar, small ears, and pale, reddish-blond fur (Bogan and Cryan 2000). It most closely resembles the western small-footed myotis and the 2 are very difficult to distinguish in the field. One difference between the 2 species is the slope of the forehead, which is flattened in the small-footed myotis and rises more abruptly in the California myotis. The best way to use this characteristic in the field is to measure the distance from the tip of the nostrils to the hairline, which is greater in the small-footed myotis (1.5 times the width between the nostrils) than in the California myotis (equal to the width between the nostrils) (Holloway and Barclay 2001). Also, the tail of some small-footed myotis extends beyond the interfemoral membrane by about 1.5 to 2.5 mm, while that of the California myotis is completely enclosed within the membrane (Constantine 1998; Holloway and Barclay 2001). In addition, the California myotis has a smaller thumb (less than 4.2 mm) than the small-footed myotis (thumb is greater than 4.2 mm) (Hinman and Snow 2003).

Associated Species

Other species that may benefit from management for this species include the western small-footed myotis, long-eared myotis, little brown myotis, fringed myotis, long-legged myotis, Yuma myotis, hoary bat, silver-haired bat, big brown bat, spotted bat, Townsend’s big-eared bat, pallid bat, and the Brazilian free-tailed bat. Although the big free-tailed bat is an accidental species in Wyoming, it may also benefit from management for this species.

Habitat

This species can be found in a wide variety of habitats. While it is typical of deserts, grasslands, juniper woodlands, and arid interior basins, it also occurs in forested and montane regions up to the elevation of ponderosa pine (Clark and Stromberg 1987; Chung-MacCoubrey 1996; WBWG 1998; Wilson and Ruff 1999). It often inhabits rock-walled canyons where water is available and where it can forage among trees, such as cottonwood and willow (Barbour and Davis 1969). It forages primarily along margins of tree clumps, around the edge of the tree canopy, over water, and in open country (Simpson 1993).

In summer, the California myotis typically roosts in crevices in a wide variety of situations, including rocks, cliffs, trees, and buildings. It also sometimes roosts on small desert shrubs and on the ground (Simpson 1993). Brigham and others (1997) and Barclay and Brigham (2001) found that tree-roosting California myotis prefer tall, large-diameter trees in intermediate stages of decay that are in relatively open areas. The California myotis also uses a variety of night roosts during summer, including porches, barns, garages, bridges, desert shrubs, and trees (Barbour and Davis 1969; Hirshfeld and others 1977).

Although there have been no winter records of the California myotis in Wyoming, elsewhere they are known to hibernate in caves, mines, and buildings (Christy and West 1993; Bogan and Cryan 2000).

Life History

The California myotis mates in autumn and the female retains the sperm over winter. In spring, the female ovulates and fertilization occurs. A single pup is born each year in about May or June and is able to fly about 1 month after birth (Clark and others 1989; Simpson 1993; Wilson and Ruff 1999).

The California myotis emerges shortly after sunset to begin foraging; it is most active early in the evening, with possibly another peak of activity after midnight. It is small, slow, and highly maneuverable, which allows it to forage close to obstacles and surfaces and pursue insects over very short distances; it often feeds on swarms of insects. It has a very erratic flight pattern and usually feeds within about 1.5 to 3 m (5 to 10 ft) of the ground (Clark and others 1989; Hinman and Snow 2003; NatureServe 2003). It feeds primarily on small flying insects, including moths (Lepidoptera), flies (Diptera), caddisflies (Trichoptera), small beetles (Coleoptera), and true bugs (Hemiptera) (Simpson 1993).

The winter ecology of the California myotis is poorly known (Clark and others 1989). It is known to hibernate, particularly at high elevations and latitudes, but individuals periodically arouse and actively forage and drink throughout the winter, even at temperatures below freezing (WBWG 1998; Wilson and Ruff 1999).

The California myotis is less gregarious than other western *Myotis* species. During summer, females usually form small maternity colonies, while males and nonreproductive females roost alone. During winter, it usually roosts either alone or in small groups (Clark and others 1989; WBWG 1998).

The California myotis has flexible roosting habits and shows little roost site fidelity (Chung-MacCoubrey 1996). Individuals and even maternity colonies frequently switch roosts, so that single observations at a roost may not indicate whether it is used in a particular season (Barclay and Brigham 2001).

Status

Although the California myotis is probably common throughout most of its range (Harvey and others 1999), it is considered peripheral in Wyoming. The only reports of it in the state are 8 Wyoming State Vet Lab records from Rock Springs and Green River (Luce 1998).

The California myotis is classified as a nongame species in Wyoming and is protected from take in Section 11, Chapter 52 of the Wyoming Game and Fish Commission Regulations.

Conservation Issues

Potential threats include recreational caving and other roost disturbances, mine reclamation, renewed mining, timber harvest practices that remove large-diameter snags, and pesticides and other contaminants.

Survey and Monitoring Issues and Techniques

Recommended survey methods are mist netting and active acoustic monitoring with visual observation. The California myotis is readily captured in mist nets. It is easy to detect acoustically, but it is difficult to distinguish from the Yuma myotis. For experienced observers, its flight behavior distinguishes it from the Yuma myotis in most settings (WBWG 2003).

Management Recommendations

1. Implement inventory and monitoring to determine population status and habitat requirements of the California myotis in Wyoming, as additional information is necessary to guide management actions.

2. Manage lands where California myotis occur in such a way that provides adequate roosting and foraging habitat to maintain stable populations (that is, secure roosting sites; diverse, native foraging habitat; and uncontaminated water sources).

3. Identify and protect hibernacula and significant maternity roosts of California myotis in Wyoming, if they exist.

4. Implement Best Management Practices for natural caves (see page 152), abandoned mines (see page 161), buildings (see page 174), bridges (see page 180), and rock shelters (see page 168) in areas where California myotis roost.

5. Avoid timber harvest activities in areas close to known maternity roosts of California myotis during the maternity roosting period, and retain all known roost trees.

6. Implement Best Management Practices for forests and woodlands (see page 190) that retain all large-diameter snags as potential roost sites for California myotis and other snag-users. Brigham and others (1997) and Barclay and Brigham (2001) found that California myotis roosting in tree cavities often switch roosts frequently and may need several suitable roosts over the course of a summer, making it necessary to retain all snags in areas where bats are known to roost.

7. Avoid or minimize pesticide use in areas where the California myotis is known to occur to avoid direct poisoning and to maintain a food source for this species and other insectivores.

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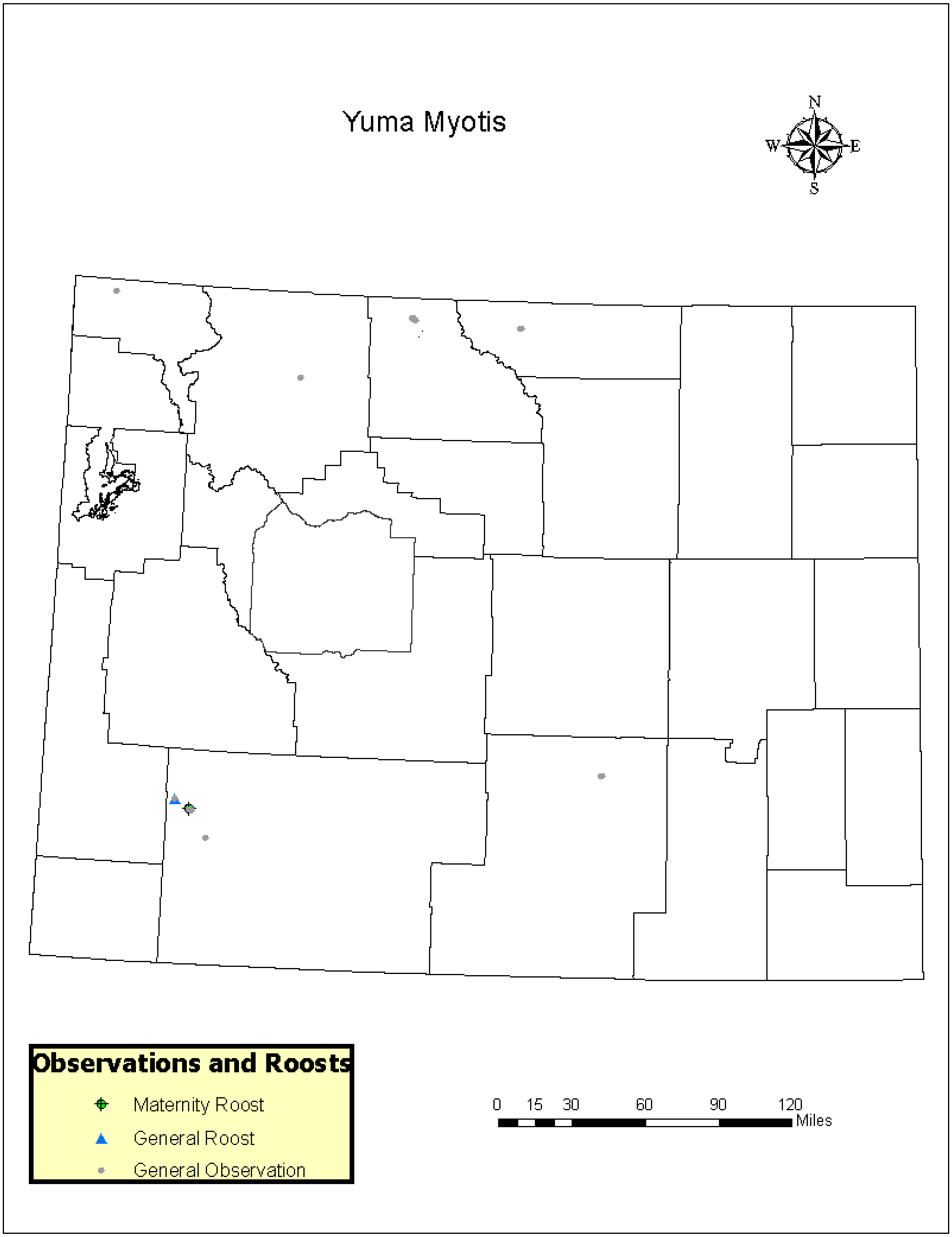

Yuma Myotis
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Observations and Roosts
Maternity Roost
General Roost
General Observation
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<u>Yuma Myotis</u> (*Myotis yumanensis*)

Range

The Yuma myotis inhabits the western third of North America, from southwestern British Columbia, through the western states, and into central Mexico. Its range approaches Wyoming from the south and west (Clark and Stromberg 1987), and it has only been documented once in the southwestern part of the state (Priday and Luce 1999). Cerovski and others (2004) show occurrence and documented breeding in 1 latilong in southwestern Wyoming. The winter range of this bat is poorly known and there are no winter records of it in Wyoming.

Description

The Yuma myotis is a small bat with dull, medium to light brown dorsal fur and paler ventral fur. The interfemoral membrane is lightly furred nearly to the knee, and the tail barely extends beyond the interfemoral membrane. The ears are relatively short, and the hind feet are large. The calcar is lobed and lacks a keel. External measurements are as follows: wingspan, 220 to 260 mm; total length, 85 to 88 mm; tail, 37 to 39 mm; hind foot, 8 to 11 mm; ear, 14 to 15 mm; forearm, 32 to 38 mm; and weight, 5 to 9 g (Clark and Stromberg 1987; Hinman and Snow 2003). The Yuma myotis most closely resembles the little brown myotis and the 2 are very difficult to distinguish in the field. One difference between the 2 species is the dorsal fur, which is a matte color in the Yuma myotis and has a brassy sheen in the little brown myotis (Clark and Stromberg 1987). Also, the little brown myotis may be slightly larger than the Yuma myotis (Barbour and Davis 1969).

Associated Species

Other species that may benefit from management for this species include the California myotis, western small-footed myotis, long-eared myotis, little brown myotis, fringed myotis, big brown bat, spotted bat, Townsend's big-eared bat, pallid bat, and the Brazilian free-tailed bat. Although the big free-tailed bat is an accidental species in Wyoming, it may also benefit from management for this species.

Habitat

The Yuma myotis is found in a wide variety of habitats from low to mid elevations, including deserts, woodlands, grasslands, sagebrush steppe, and riparian habitats (Clark and Stromberg 1987; Altenbach and others 2002). Although it often inhabits arid areas (Brigham and others 1992), it is closely associated with water features, and usually occurs near permanent sources of water, such as streams and rivers (Barbour and Davis 1969; WBWG 1998). It forages almost exclusively over water features (Brigham and others 1992), and may require medium to large bodies of water for foraging (Altenbach and others 2002).

In summer, the Yuma myotis usually roosts in close proximity to open water (Christy and West 1993). Maternity colonies and other day roosts may be in buildings, trees, caves, abandoned mines, bridges, or cliff crevices (WBWG 1998). Night roosts are usually associated with buildings, bridges, or other manmade structures (Altenbach and others 2002); Priday and Luce (1999) observed a colony of 50 night-roosting under a bridge in southwestern Wyoming. Although little is known of its winter habits, the Yuma myotis probably hibernates in caves and abandoned mines (Christy and West 1993).

Life History

The Yuma myotis mates in autumn and the female retains the sperm over winter. In spring, the female ovulates and fertilization occurs. A single pup is born each year from about May to July (Barbour and Davis 1969; WBWG 1998).

The Yuma myotis emerges just after sunset to begin foraging (WBWG 1998). It usually feeds over ponds and streams, often just a few centimeters above the water's surface (Clark and Stromberg 1987). Its low aspect ratio and wing loading allow it to forage close to surfaces and among cluttered habitats, although it will readily forage in open habitats when prey is abundant. It feeds opportunistically on a variety of insects, primarily aquatic and soft-bodied insects, including caddisflies (Trichoptera), mayflies (Ephemeroptera), flies (Diptera), moths (Lepidoptera), and small beetles (Coleoptera) (Brigham and others 1992; Wilson and Ruff 1999).

There are few winter records of the Yuma myotis and little is known of its winter habits (Clark and Stromberg 1987). It is known to hibernate, although it is not known whether or how far it migrates to its hibernaculum (Barbour and Davis 1969; Christy and West 1993; Altenbach and others 2002).

The Yuma myotis is a colonial species. Maternity colonies may range in size to several thousand, although males usually roost alone in summer (WBWG 1998).

Status

Throughout its range, the Yuma myotis can be locally abundant in very large colonies, although it seems to be absent from many apparently suitable areas (Barbour and Davis 1969; NatureServe 2003). It is considered peripheral in Wyoming. The only documented occurrence in the state was a colony of 50 night-roosting under a bridge in southwestern Wyoming (Priday and Luce 1999).

The Yuma myotis is classified as a nongame species in Wyoming and is protected from take in Section 11, Chapter 52 of the Wyoming Game and Fish Commission Regulations. The Wyoming Natural Diversity Database classifies it as S1?B, SZ?N (Fertig and Beauvais 1999).

Conservation Issues

The Yuma myotis is sensitive to disturbance to nursery colonies and frequently abandons colonies following disturbance (Barbour and Davis 1969). Other potential threats include building demolition and remodeling, exclusion from buildings, timber harvest, bridge replacement, mine reclamation, renewed mining, and pesticides and other contaminants.

Survey and Monitoring Issues and Techniques

Recommended survey methods are mist netting and active acoustic monitoring with visual observation. Its water-skimming foraging strategy makes the Yuma myotis highly vulnerable to capture in mist nets set low over water. It is easy to detect acoustically, but difficult to distinguish from the California myotis, although some calls are diagnostic. Its flight behavior, particularly water skimming, can be distinctive to experienced observers (WBWG 2003).

Management Recommendations

1. Implement inventory and monitoring to determine population status and habitat requirements of the Yuma myotis in Wyoming, as additional information is necessary to guide management actions.

2. Manage lands where Yuma myotis occur in such a way that provides adequate roosting and foraging habitat to maintain stable populations (that is, secure roosting sites; diverse, native foraging habitat; and uncontaminated water sources).

3. Identify and protect hibernacula and significant maternity roosts of Yuma myotis in Wyoming, if they exist.

4. Implement Best Management Practices for natural caves (see page 152), abandoned mines (see page 161), buildings (see page 174), bridges (see page 180), and rock shelters (see page 168) in areas where Yuma myotis roost.

5. Avoid timber harvest activities in areas close to known maternity roosts of Yuma myotis during the maternity roosting period, and retain all known roost trees.

6. Avoid or minimize pesticide use in areas where the Yuma myotis is known to occur to avoid direct poisoning and to maintain a food source for this species and other insectivores.

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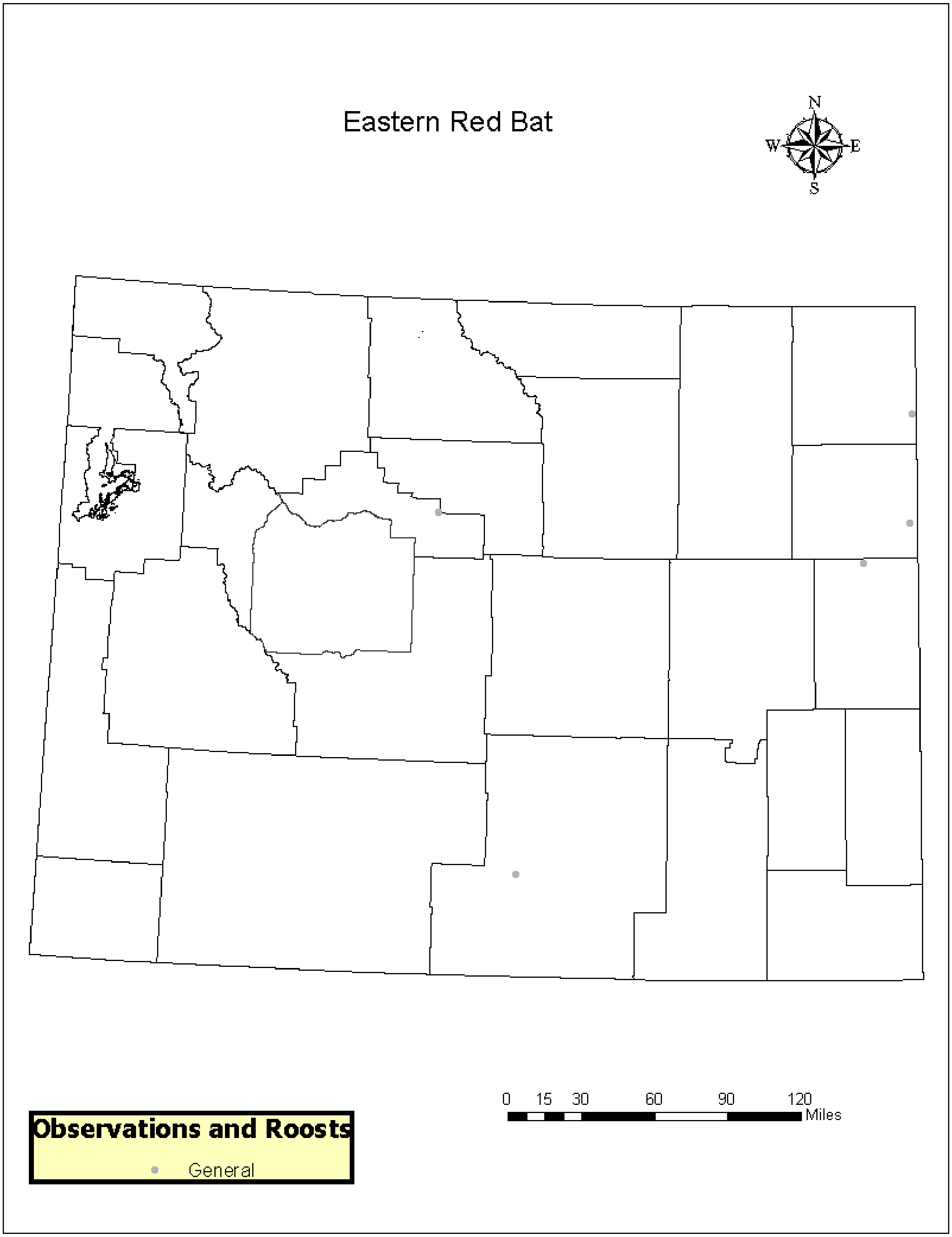

Eastern Red Bat
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Miles
Observations and Roosts
General

<u>Eastern Red Bat</u> (*Lasiurus borealis*)

Range

The eastern red bat inhabits most of eastern North America, primarily east of the Continental Divide from southern Canada south to northeastern Mexico. During winter, it occurs throughout the southeastern US and northeastern Mexico, but concentrations are highest in coastal Atlantic and Gulf of Mexico regions. During spring and summer, its range expands into the Great Lakes and Great Plains regions, followed by further expansion to the north and west during summer (Cryan 2003). It is uncommon in Wyoming, probably because it is at the western margin of its range (Bogan and Cryan 2000), and because the majority of records occur in more mesic eastern areas (Cryan 2003). Cerovski and others (2004) show occurrence in 7 latilongs scattered throughout the state, although no breeding has been documented.

Description

The eastern red bat is a medium-sized bat with soft, dense fur. The dorsal fur is brick red to rusty red, washed with white, and the ventral fur is slightly paler. The shoulder has a buffy white patch. Males are usually more brightly colored than females. The tail is distinctly long, and the interfemoral membrane is heavily furred. The wings are long and pointed and the long tail extends straight behind the body during flight. The ear is low, broad, and rounded, and the tragus is triangular. The ears reach a little more than halfway from the angle of the mouth to the nostril when laid forward. The calcar is about twice as long as the foot. External measurements are as follows: wingspan, 290 to 332 mm; total length, 90 to 120 mm; tail, 36 to 65 mm; hind foot, 6 to 9 mm (less than half as long as the tibia); ear, 9 to 11 mm; tragus, 6 mm; forearm, 35 to 45 mm; and weight, 7 to 13 g (Barbour and Davis 1969; Shump KA and Shump AU 1982; Clark and Stromberg 1987). The red bat is not usually confused with other species because of its distinctive color, long tail, and furred interfemoral membrane.

Associated Species

Other species that may benefit from management for this species include the northern myotis, little brown myotis, hoary bat, silver-haired bat, and the big brown bat.

Habitat

The eastern red bat is highly associated with forested areas, particularly deciduous forests. Large, mature forests are the most important habitat because they provide tall, large-diameter trees for roosting and interior forest with fewer predators (Hutchinson and Lacki 2000). However, urban trees and shelterbelts in intensively farmed areas; and wooded parks, residential areas, and riparian corridors with mature trees provide important habitat as well, particularly when they are interspersed with lawns and fields that provide foraging habitat (Mager and Nelson 2001).

The red bat forages in a variety of habitats, including riparian corridors, at or above the forest canopy, forest edges, open meadows, and cropland (Humphrey 1982; Hutchinson and Lacki

2000; NatureServe 2003). It often forages around streetlights and floodlights with a high density of insects (Shump KA and Shump AU 1982; Hickey and Fenton 1990).

During summer, the eastern red bat roosts in foliage, primarily in mature bottomland hardwood communities (Menzel and others 2000). Hanging by 1 foot from a leaf petiole or twig, and wrapped in its furry interfemoral membrane, it is well concealed and resembles a dead leaf. In rural and agricultural landscapes it is commonly found roosting close to or even on the ground in vines, shrubs, and trees, both coniferous and deciduous (Shump KA and Shump AU 1982). However, Hutchinson and Lacki (2000) found that the red bat primarily roosts in the upper canopy of tall, large-diameter deciduous trees. Its roosting preferences include dense vegetation above; unobstructed space below, allowing bats to drop to gain flight; no potential perches beneath, which could aid detection by predators; dark-colored ground cover, minimizing reflected sunlight; surrounding vegetation to provide protection from wind and retain heat and humidity; and southern exposure (Barbour and Davis 1969).

During winter, the red bat roosts primarily in trees, although it has been found in tree cavities and leaf litter (Shump KA and Shump AU 1982; Harvey and others 1999).

Life History

The eastern red bat mates while in flight in August and September, and the female carries the sperm over winter. Fertilization occurs in spring and the pups are born from May to mid June after an 80- to 90-day gestation. Litter size ranges from 1 to 5 pups, with an average of 3. The young can fly between 3 and 6 weeks and are weaned between 4 and 6 weeks (Clark and Stromberg 1987; Wilson and Ruff 1999; Adams 2003; NatureServe 2003).

The red bat emerges and begins foraging early in the evening, although its peak activity is usually 1 to 2 hours after sunset (Clark and Stromberg 1987). It is a fast flier with limited maneuverability, and usually forages from treetop level up to about 200 m (650 ft) high, with occasional arcs down to ground level (Humphrey 1982; Clark and Stromberg 1987). It often forages over the same territory on successive nights (Barbour and Davis 1969). Although the red bat primarily eats moths (Lepidoptera), it is an opportunistic feeder and also eats a variety of insects such as leafhoppers (Homoptera), small beetles (Coleoptera), wasps (Hymenoptera), flies (Diptera), crickets (Gryllids), true bugs (Hemiptera), and cicadas (Cicadidae) (Shump KA and Shump AU 1982).

Although southern populations of the red bat may remain in the same areas year-round, northern populations, including those in Wyoming, migrate to warmer climates for winter. On its winter range, it hibernates in trees and is well adapted for surviving drastic temperature fluctuations, even well below freezing (Barbour and Davis 1969). It responds to subfreezing temperatures by increasing its metabolism just enough to maintain its body temperature above the critical low limit of -5 °C (23 ºF). Other adaptations for surviving low temperatures include short, rounded ears, which minimize heat loss; thick fur; and a heavily furred interfemoral membrane, which adds about 15% insulation when wrapped over the body. During warm winter days when the temperature rises to 13 to 20 ºC (55 to 68 ºF) or higher and insects are available, it arouses from hibernation to feed (Shump KA and Shump AU 1982).

The red bat usually roosts alone or in family groups consisting of a female and her young (Humphrey 1982). However, it congregates in groups during migration, and it may forage in close association with other individuals during summer (Shump KA and Shump AU 1982). Also, an area with good roosts may attract several bats, and individuals are probably attracted to the area by sounds made by other red bats (Clark and Stromberg 1987).

The red bat probably shows greater fidelity to individual woodlots and clusters of trees than to specific roosts. During summer, it rarely uses the same roost on consecutive days (Hutchinson and Lacki 2000; Mager and Nelson 2001). However, summer roost sites may often be used by different individuals on different days (Shump KA and Shump AU 1982).

Status

The eastern red bat is abundant in the eastern US, but rare in the West (Humphrey 1982). In Wyoming, it has been documented only 4 times (Bogan and Cryan 2000) and is considered a peripheral species.

The eastern red bat is classified as a nongame species in Wyoming and is protected from take in Section 11, Chapter 52 of the Wyoming Game and Fish Commission Regulations. The Wyoming Game and Fish Department classifies it as a Species of Special Concern with a Native Species Status of 4 (NSS4).

Conservation Issues

Potential threats include degradation, fragmentation, and loss of forest habitats; timber management practices that remove tall, large-diameter deciduous trees; and pesticides and other contaminants.

Survey and Monitoring Issues and Techniques

The recommended survey method is active acoustic monitoring with visual observation. The eastern red bat is easy to detect acoustically, and most of its calls are diagnostic. In flight, its long tail and interfemoral membrane are distinctive to experienced observers. In the eastern US, it is readily captured over water and in side channels (Shump KA and Shump AU 1982; WBWG 2003).

Management Recommendations

1. Implement inventory and monitoring to determine population status and habitat requirements of the eastern red bat in Wyoming, as additional information is necessary to guide management actions.

2. Manage lands where eastern red bats occur in such a way that provides adequate roosting and foraging habitat to maintain stable populations (that is, secure roosting sites; mature forest and woodland habitats; and uncontaminated water sources).

3. Identify and protect maternity roosting areas of eastern red bats in Wyoming, if they exist.

4. Implement forest Best Management Practices that maintain large stands of mature and old-growth forests and woodlands in areas where eastern red bats occur. Mature and old-growth forests provide tall, large-diameter trees that are suitable as roosting sites. Large stands provide interior forest with fewer predators, and provide adequate numbers of roost trees as individuals switch roosts through the summer (Hutchinson and Lacki 2000).

5. Maintain mature bottomland hardwood communities to provide roosting habitat in areas where eastern red bats are known to occur (Menzel and others 2000).

6. In urban areas where eastern red bats are known to occur, maintain mature shade trees with dense canopies and open understories to provide roosting habitat. Wooded parks, residential areas, and riparian corridors with mature trees provide suitable roosts and are particularly valuable when they are interspersed with lawns and fields that provide foraging habitat (Mager and Nelson 2001).

7. Avoid timber harvest activities in areas close to known maternity roosts of eastern red bats during the maternity roosting period. Mager and Nelson (2001) found that eastern red bats often switch roosts frequently and may need several suitable roosts over the course of a summer, making it necessary to retain all suitable trees in areas where bats are known to roost.

8. Avoid or minimize pesticide use in forest and woodland habitats where the eastern red bat is known to occur to avoid direct poisoning and to maintain a food source for this species and other insectivores. Where possible, allow insect outbreaks to proceed naturally.

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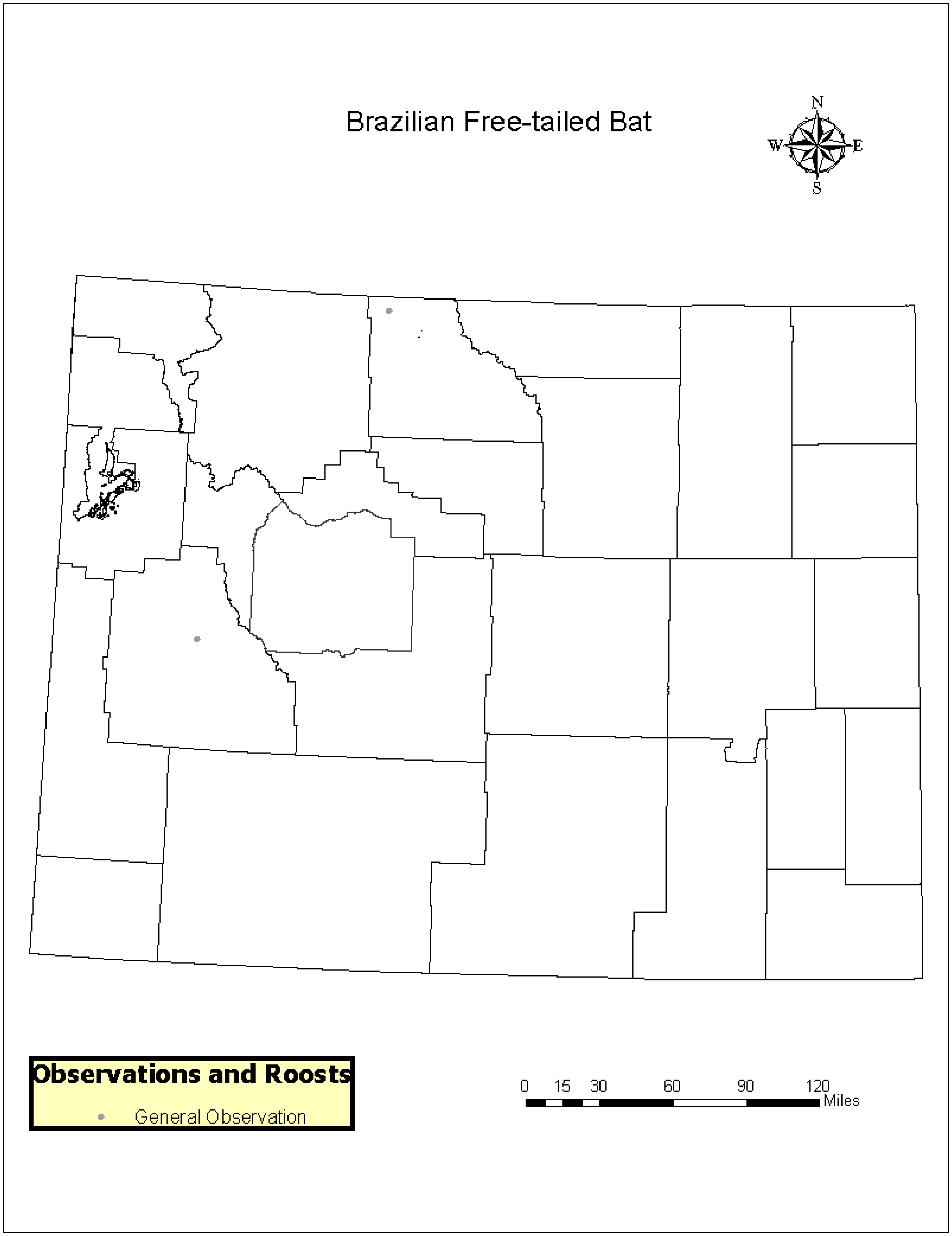
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<u>**Brazilian Free-tailed Bat**</u> **(*Tadarida brasiliensis*)**

Range

The Brazilian free-tailed bat inhabits central North America, south through Mexico and Cuba to northern South America. In winter, North American populations migrate south, probably to Central America and southern Mexico. In autumn, individuals often wander great distances and are likely to appear outside the usual range (Barbour and Davis 1969). In Wyoming, the species has been documented only a few times in scattered locations around the state, and is considered peripheral (Luce 1998; Bogan and Cryan 2000). Clark and Stromberg (1987) show occurrence in 1 county in southeastern Wyoming. Cerovski and others (2004) show occurrence in 3 latilongs in north central, southwestern, and southeastern Wyoming, although no breeding has been documented.

Description

The Brazilian free-tailed bat is a small molossid with short, velvety chocolate brown to dark gray fur. The distal half of the tail extends freely beyond the interfemoral membrane. The ears almost meet at the base but are not connected, and have a series of wart-like papillae on the rims; the ears do not extend beyond the muzzle when laid forward. The calcar is not keeled, and the tragus is short and blunt. Hooked, bristly hairs as long as the foot extend from the toes. The wings are long and narrow, and the upper lip is deeply grooved. External measurements are as follows: wingspan, 290 to 325 mm; total length, 90 to 109 mm; tail, 29 to 44 mm; hind foot, 7 to 14 mm; ear, 10 to 20 mm; forearm, 40 to 46 mm; and weight, 10 to 15 g (Barbour and Davis 1969; Wilkins 1989; Hinman and Snow 2003). The big free-tailed bat, the only other free-tailed bat that occurs in Wyoming, is larger than the Brazilian free-tailed bat and its ears are joined at their bases (Barbour and Davis 1969).

Associated Species

Other species that may benefit from management for this species include the California myotis, western small-footed myotis, long-eared myotis, northern myotis, little brown myotis, long-legged myotis, Yuma myotis, big brown bat, spotted bat, Townsend’s big-eared bat, and the pallid bat. Although the eastern pipistrelle and the big free-tailed bat are accidental species in Wyoming, they may also benefit from management for this species.

Habitat

In the western US, the Brazilian free-tailed bat is most commonly associated with dry, lower elevation habitats, but it also occurs in a variety of other habitats, and is found up to at least 3000 m (9800 ft) in some of the western mountain ranges (WBWG 1998). Associated plant communities include juniper woodlands, arid grasslands, desert shrublands, and coniferous forests (Chung-MacCoubrey 1996; Luce 1998; Hinman and Snow 2003). The Brazilian free-tailed bat also forages over a wide range of habitats, including woodlands, open fields, prairies, deserts, and riparian areas (Humphrey 1982; Clark and Stromberg 1987).

During summer, the Brazilian free-tailed bat may roost in a variety of situations, including caves, abandoned mines, buildings, bridges, culverts, cliff crevices, and tree cavities (Wilkins 1989; Altenbach and others 2002). Maternity colonies are primarily in caves or buildings, and are usually warmer and larger than the roosts of males and nonreproductive females (Barbour and Davis 1969; WBWG 1998). Because the Brazilian free-tailed bat is a strong, fast flier, it may roost farther from water and foraging habitat than other bat species (Tuttle and Taylor 1998). Also unlike most other bat species, it rarely uses a separate night roost (Barbour and Davis 1969; Hirshfeld and others 1977).

During migration, the Brazilian free-tailed bat may be encountered in a variety of roosts, including tree cavities, caves, abandoned mines, bridges, buildings, rock crevices, and Cliff Swallow nests (Humphrey 1982; Hinman and Snow 2003; NatureServe 2003).

Life History

The Brazilian free-tailed bat probably mates in February or March in its winter range. A single pup is born between about mid June and mid July. Lactation lasts about 45 days and the young can fly by about 5 to 6 weeks of age (WBWG 1998; NatureServe 2003).

The Brazilian free-tailed bat emerges at dusk to begin foraging, and may travel more than 50 km (30 mi) from the roost (WBWG 1998). In areas where it roosts in large colonies, it emerges in long columns of bats and forages in large groups. It is a strong, fast flier; usually forages in open, uncluttered areas; and may forage up to 700 m (3000 ft) above the ground (Humphrey 1982; Altenbach and others 2002). It feeds primarily on moths (Lepidoptera) between 5 and 9 mm long (Wilkins 1989), but may also take flying ants (Formicidae), weevils (Curculionidae), stinkbugs (Pentatomidae), beetles (Coleoptera), and other insects (WBWG 1998). Isotopic studies of their feces indicate that they consume large numbers of insects that are agricultural pests (Wilson and Ruff 1999).

In autumn, the Brazilian free-tailed bat migrates away from colder regions to areas where insects are available throughout the winter (Humphrey 1982). Migrations of up to 1840 km (1140 mi) have been documented. Many males do not migrate northward in spring but remain in their winter range throughout the summer (Wilkins 1989). Some populations in California, southern Oregon, and the southeastern US do not migrate, but are year-round residents and hibernate in cold weather (Wilson and Ruff 1999).

This species is highly colonial, with maternity colonies ranging in size from a few hundred to 20 million (WBWG 1998). The activity of so many individuals in these very large colonies raises the temperature of the roost environment, thereby lowering the energy expenditure per bat and encouraging rapid growth of the young (Barbour and Davis 1969). Bachelor colonies and winter aggregations are usually smaller than maternity colonies (Wilkins 1989; NatureServe 2003).

Status

Although the Brazilian free-tailed bat is one of the most common species in some parts of the southwestern US, its abundance is local and there is evidence for major declines in numbers at some of these sites over the past few decades (Barbour and Davis 1969; O'Shea and others 2003). These include complete losses of colonies as well as order-of-magnitude drops in abundance at others (O'Shea and others 2003). In Wyoming, it has been reported only a few times and is considered peripheral. No colony is known to exist in the state (Luce 1998).

The Brazilian free-tailed bat is classified as a nongame species in Wyoming and is protected from take in Section 11, Chapter 52 of the Wyoming Game and Fish Commission Regulations. The Wyoming Game and Fish Department classifies it as a Species of Special Concern with a Native Species Status of 4 (NSS4).

Conservation Issues

Pesticide poisoning is probably the primary threat to some populations of Brazilian free-tailed bats, especially since they frequently eat crop pests. Young-of-the-year are at particular risk of pesticide poisoning during their first migratory flight because the post-weaning diet includes insects carrying a pesticide burden and the diet of milk contains high concentrations of residues (Wilkins 1989). Other potential threats include roost disturbance and destruction due to recreational caving, mine reclamation, bridge replacement, and pest control exclusion; and loss of foraging habitat to suburban expansion. Its tendency to roost in large numbers in relatively few roosts makes it especially vulnerable to human disturbance and habitat destruction (WBWG 1998).

Survey and Monitoring Issues and Techniques

The recommended survey method is acoustic monitoring. While the Brazilian free-tailed bat is sometimes captured in mist nets, it generally flies high and is more abundant than net captures would suggest. It is easy to detect acoustically, and in most settings this is the easiest way to detect the species. Although some of its calls overlap with the silver-haired bat, big brown bat, and hoary bat, a fair proportion are diagnostic. Its flight is distinctive to experienced observers (WBWG 2003).

Management Recommendations

1. Implement inventory and monitoring to determine population status and habitat requirements of the Brazilian free-tailed bat in Wyoming, as additional information is necessary to guide management actions.

2. Manage lands where Brazilian free-tailed bats occur in such a way that provides adequate roosting and foraging habitat to maintain stable populations (that is, secure roosting sites; diverse, native foraging habitat; and uncontaminated water sources).

3. Identify and protect significant roosts of Brazilian free-tailed bats in Wyoming, if they exist.

4. Implement Best Management Practices for natural caves (see page 152), abandoned mines (see page 161), buildings (see page 174), bridges (see page 180), and rock shelters (see page 168) in areas where Brazilian free-tailed bats roost.

5. Avoid or minimize pesticide use in areas where the Brazilian free-tailed bat is known to occur to avoid direct poisoning and to maintain a food source for this species and other insectivores.

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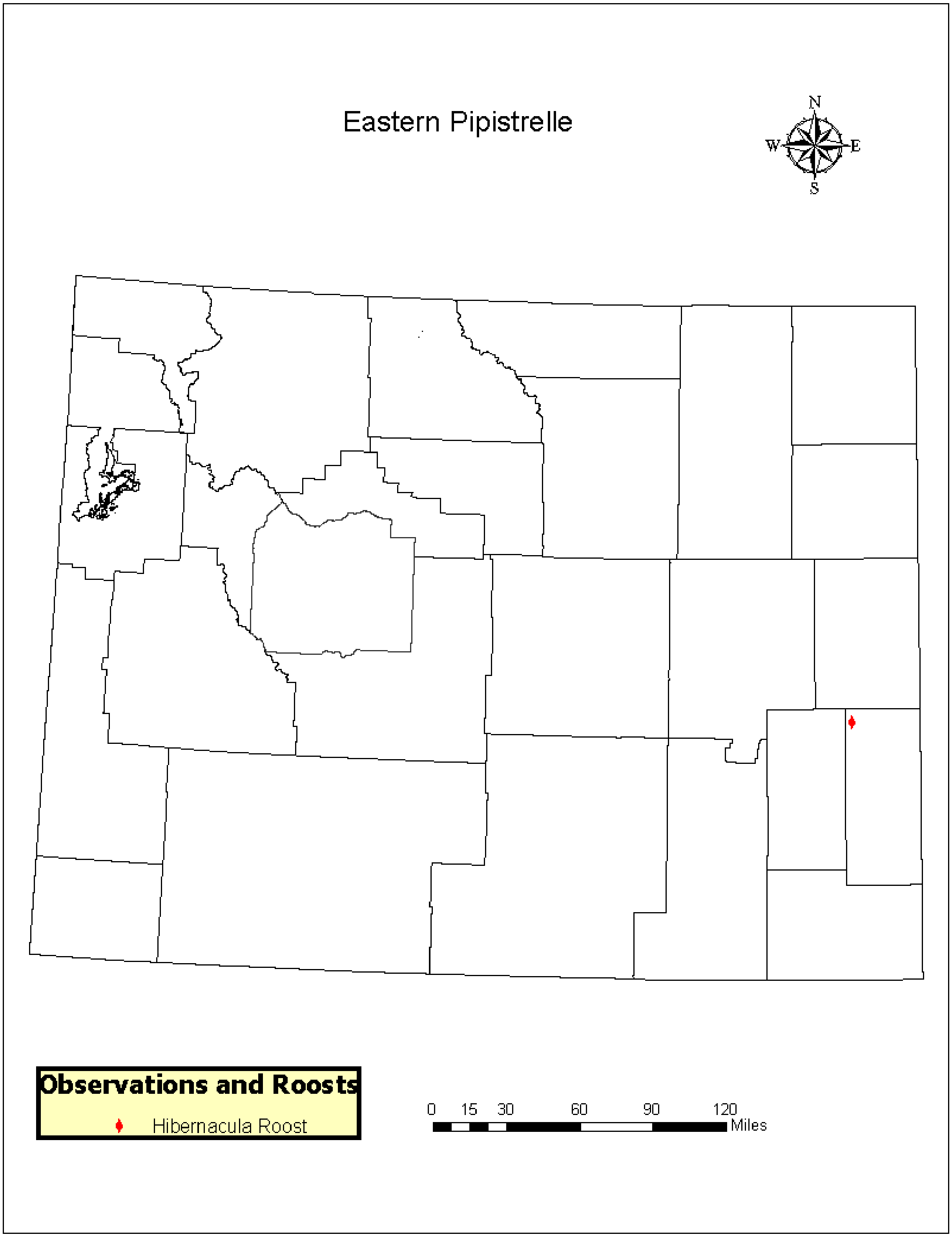

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Eastern Pipistrelle (*Pipistrellus subflavus*)

Range

The eastern pipistrelle occurs in eastern Canada, most of eastern and central United States, and along the Caribbean coast of Mexico to Guatemala and Belize (Adams 2003). It is a year-round resident throughout its summer range (Barbour and Davis 1969). It was first documented in Wyoming in 1996, hibernating in a cave in the southeastern part of the state (Priday and Luce 1999). Whether the eastern pipistrelle has always been in Wyoming or whether it followed riparian vegetation westward more recently is not known (Bogan and Cryan 2000). Cerovski and others (2004) show occurrence in 1 latilong in southeastern Wyoming, although no breeding has been documented.

Description

The eastern pipistrelle is a very small bat with distinctly tricolored hairs that are dark at the base, lighter and yellowish-brown in the middle band, and dark at the tip. The overall fur color is yellowish-brown to grayish-brown, with paler ventral fur. The ear is longer than it is wide, with a moderately rounded tip; when laid forward it extends just beyond the tip of the nose. The tragus is blunt, straight, and slightly less than half the length of the ear. The anterior third of the interfemoral membrane is furred, and the calcar lacks a keel. External measurements are as follows: wingspan, 208 to 258 mm; total length, 70 to 90 mm; tail, 32 to 42 mm; hind foot, 7 to 11 mm; ear, 12 to 14 mm; forearm, 30 to 35 mm; and weight, 4 to 8 g (Barbour and Davis 1969; Fujita and Kunz 1984; Adams 2003). The eastern pipistrelle can be confused with some of the smaller *Myotis* species, but can be recognized by its unique tricolored hairs (Barbour and Davis 1969). When hibernating, it can be recognized by its distinctive orange forearm (TPWD).

Associated Species

Other species that may benefit from management for this species include the western small-footed myotis, long-eared myotis, little brown myotis, fringed myotis, long-legged myotis, big brown bat, Townsend's big-eared bat, pallid bat, and the Brazilian free-tailed bat.

Habitat

The eastern pipistrelle inhabits open country with large trees and woodland edges. It forages primarily along forest edges and riparian corridors (Fujita and Kunz 1984), and probably avoids forest interiors and open fields and grasslands (Barbour and Davis 1969; NatureServe 2003).

During summer, the eastern pipistrelle roosts primarily in foliage and tree cavities, although it also occasionally roosts in buildings, and less often in rock crevices and caves (Barbour and Davis 1969; Whitaker 1998; Veilleux and others 2003). It sometimes uses caves, abandoned mines, and rock crevices as night roosts (Barbour and Davis 1969).

During winter, the eastern pipistrelle hibernates primarily in caves and abandoned mines, although it has also been known to hibernate in rock crevices, culverts, and other manmade structures (Barbour and Davis 1969; Fujita and Kunz 1984; Sandel and others 2001). It usually selects deeper parts of caves where ambient temperatures are relatively constant (Fujita and Kunz 1984). In 1996, 3 eastern pipistrelles were documented hibernating in a cave in southeastern Wyoming (Priday and Luce 1999).

Life History

The eastern pipistrelle mates in autumn and the female carries the sperm over winter. In spring, fertilization occurs and the young are born in June or July after a gestation of at least 44 days. Litter size is usually 2, and rarely 1. The pups are able to fly within about a month, and females and juveniles begin to disperse from the maternity roost in late July and August (Barbour and Davis 1969; Fujita and Kunz 1984; Adams 2003).

The eastern pipistrelle emerges to begin foraging early in the evening. Its flight is slow, weak, fluttery, and erratic, and it is so small that it may sometimes be mistaken for a large moth. It forages at about treetop level, and its foraging area is so small that it may be constantly in view (Barbour and Davis 1969; Fujita and Kunz 1984). Its diet primarily consists of small insects ranging from 4 to 10 mm in length, including ground beetles (Carabidae), leafhoppers (Homoptera), mosquitoes (Culicidae), midges (Chironomidae), ants (Formicidae), and moths (Lepidoptera) (Fujita and Kunz 1984).

The eastern pipistrelle performs short annual migrations between its hibernaculum and summer roost (Fujita and Kunz 1984). However, it is not known to travel more than 135 km (85 mi) and averages 50 km (31 mi) or less (Barbour and Davis 1969; TPWD). During hibernation, it usually awakens and moves less frequently than other species, and may remain in 1 position for weeks, although individuals hibernating in drafty sites may awaken and move more frequently than others (Barbour and Davis 1969).

This species is usually solitary, although it sometimes forms small colonies of a few individuals using the same tree (Adams 2003). Although large numbers may hibernate in the same cave, individuals roost alone and do not cluster (Barbour and Davis 1969). During summer, males roost alone (Fujita and Kunz 1984).

During summer, the eastern pipistrelle switches roosts frequently, even while young are still unable to fly (Whitaker 1998). However, it shows greater fidelity during winter, and may use the same hibernaculum, and even the same roosting spots, in consecutive years (Barbour and Davis 1969).

Status

The eastern pipistrelle is abundant over much of the eastern US (Barbour and Davis 1969). However, in Wyoming, it is at the far western edge of its range and is considered an accidental species. Only 3 individuals have been documented in a cave in Wyoming (Priday and Luce 1999), and further data are needed to confirm its status in the state (Luce 1998).

The eastern pipistrelle is classified as a nongame species in Wyoming and is protected from take in Section 11, Chapter 52 of the Wyoming Game and Fish Commission Regulations.

Conservation Issues

Potential threats include timber management practices that allow removal of maternity roosts and loss of foraging habitat, recreational caving and other roost disturbances, and mine reclamation.

Survey and Monitoring Issues and Techniques

Recommended survey methods are mist netting and active acoustic monitoring with visual observation. Little information exists on specific survey techniques for this species, but mist net surveys in riparian areas and along watercourses may be effective. Its calls are probably diagnostic, and its small size and weak, erratic flight make it recognizable to experienced observers (Wilson and Ruff 1999).

Management Recommendations

1. Conduct additional inventory and monitoring surveys in order to determine population status, as the eastern pipistrelle is an accidental species in Wyoming and additional information is necessary to guide management actions. If additional records of the species are documented, determine its habitat requirements in Wyoming.

2. Manage lands where eastern pipistrelles are likely to occur and where other associated bat species occur in such a way that provides adequate roosting and foraging habitat to maintain stable populations (that is, secure roosting sites; diverse, native foraging habitat; and uncontaminated water sources).

3. Identify and protect hibernacula and maternity roosting areas of eastern pipistrelles in Wyoming, if they exist.

4. Implement Best Management Practices for natural caves (see page 152) and abandoned mines (see page 161) in areas where eastern pipistrelles roost.

5. Avoid timber harvest activities in areas close to known maternity roosts of eastern pipistrelles during the maternity roosting period, if they exist. Whitaker (1998) found that eastern pipistrelles often switch roosts frequently and may need several suitable roosts over the course of a summer, making it necessary to retain all suitable trees in areas where bats are known to roost.

6. Avoid or minimize pesticide use in areas where the eastern pipistrelle is likely to occur and other associated bat species occur to avoid direct poisoning and to maintain a food source for bat species and other insectivores.

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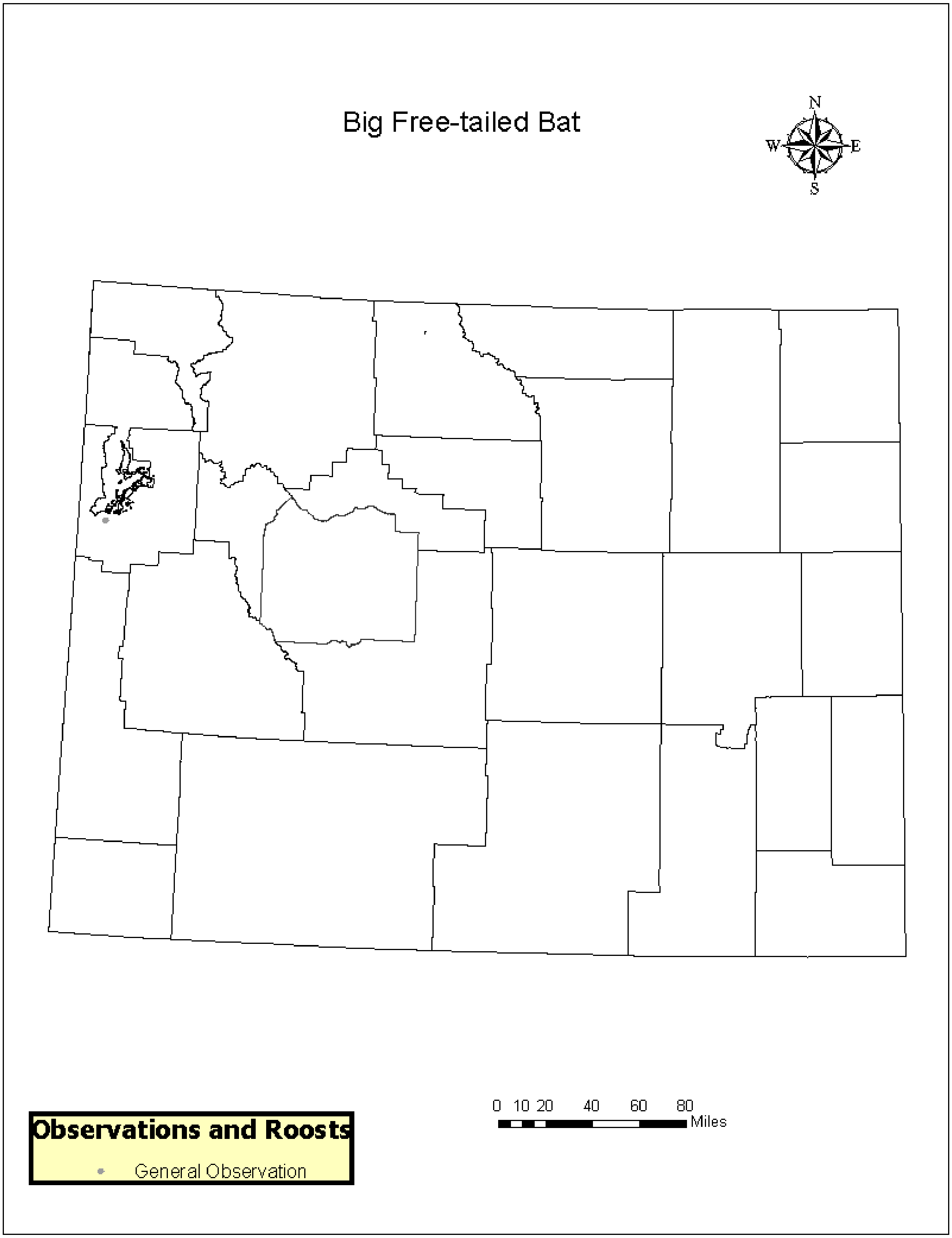
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<u>Big Free-tailed Bat</u> (*Nyctinomops macrotis*)

Range

The big free-tailed bat inhabits South America and the Caribbean islands northward into the southwestern United States. It is known to breed in New Mexico, Arizona, Texas, and Utah, but individuals often wander great distances in late summer and fall, and extralimital records exist as far north as British Columbia. The northern limits of its winter range are not known (Milner and others 1990; Hinman and Snow 2003). The species has been documented only once in western Wyoming (Bogan and Cryan 2000). Cerovski and others (2004) show occurrence in 1 latilong in northwestern Wyoming, although no breeding has been documented.

Description

The big free-tailed bat is a large molossid with glossy, light reddish-brown to dark brown dorsal fur and slightly paler ventral fur. Each hair is bicolored, with a nearly white base. The ears are large, extending well beyond the end of the snout when laid forward, and joined at their bases. The upper lip is deeply creased by vertical wrinkles and the muzzle is slender. The tail extends 10 to 15 mm beyond the interfemoral membrane. The wings are long and narrow, especially at the tips. External measurements are as follows: wingspan, 417 to 436 mm; total length, 120 to 139 mm; tail, 40 to 57 mm; hind foot, 7 to 11 mm; ear, 25 to 32 mm; forearm, 58 to 64 mm; and weight, 22 to 30 g (Barbour and Davis 1969; Milner and others 1990). The Brazilian free-tailed bat, the only other free-tailed bat that occurs in Wyoming, is smaller than the big free-tailed bat and its ears are separate at their bases (Barbour and Davis 1969).

Associated Species

Other species that may benefit from management for this species include the California myotis, western small-footed myotis, little brown myotis, fringed myotis, Yuma myotis, big brown bat, spotted bat, and the Brazilian free-tailed bat.

Habitat

The big free-tailed bat primarily inhabits rugged, rocky habitats in arid landscapes, including canyons, desert scrub, floodplains, and woodlands up to 2600 m (8500 ft) (Milner and others 1990; WBWG 1998). It roosts primarily in cracks and crevices in high cliffs, although it has also been known to roost in buildings, caves, and tree cavities (Milner and others 1990; WBWG 1998).

Life History

Little is known about the reproduction of the big free-tailed bat, except that in the Northern Hemisphere females bear a single pup in late spring or early summer (Milner and others 1990).

The big free-tailed bat emerges late in the evening, usually after dark, to begin foraging (NatureServe 2003). It is a swift, powerful flier, and the wings are adapted to rapid, enduring flight in areas where extreme maneuverability is not important (Milner and others 1990). It forages in the open and often ranges up to high altitudes on foraging trips (Altenbach and others 2002). Some individuals may fly more than 80 km (50 mi) 1 way on foraging trips (NatureServe 2003). It feeds almost entirely on large moths (Lepidoptera), although it occasionally takes crickets (Gryllidae), grasshoppers (Tettigoniidae), flying ants (Formicidae), stinkbugs (Pentatomidae), froghoppers (Cercopidae), and leafhoppers (Cicadellidae) (Milner and others 1990).

This species has not been found hibernating and is probably a seasonal migrant throughout much of its range (Milner and others 1990; Altenbach and others 2002).

The big free-tailed bat is colonial. During summer, females form maternity colonies, although groups are probably less than 100 (Milner and others 1990; Altenbach and others 2002).

Females show fidelity to maternity colonies, often occupying the same crevice in successive years. Their return to the roost site involves ritualized behavior, including a general reconnaissance of the site and several landing trials before entry (WBWG 1998).

Status

Although the big free-tailed bat is widely distributed, its range is probably not continuous. It is abundant in some local areas, but its abundance is unpredictable, and it is not found in many places where the habitat seems suitable (Barbour and Davis 1969). In Wyoming, only a single specimen has been documented, and it is considered accidental. Although no viable population is known to exist in the state, additional observations are possible in the future (Luce 1998).

The big free-tailed bat is classified as a nongame species in Wyoming and is protected from take in Section 11, Chapter 52 of the Wyoming Game and Fish Commission Regulations.

Conservation Issues

Potential threats include recreational climbing and other roost disturbances, loss of cliff roosts to blasting or water impoundments, and pesticides and other contaminants.

Survey and Monitoring Issues and Techniques

The recommended survey method is acoustic monitoring. Mist netting records are extremely limited, suggesting serious challenges. The big free-tailed bat is easy to detect acoustically, especially with a low-frequency microphone, and most of its calls are diagnostic. Some of its calls are in the audible range for humans and sound like loud clicks (Wilson and Ruff 1999; WBWG 2003).

Management Recommendations

1. Conduct additional inventory and monitoring surveys in order to determine population status, as the big free-tailed bat is an accidental species in Wyoming and additional information is

necessary to guide management actions. If additional records of the species are documented, determine its habitat requirements in Wyoming.

2. Manage lands where big free-tailed bats are likely to occur and where other associated bat species occur in such a way that provides adequate roosting and foraging habitat to maintain stable populations (that is, secure roosting sites; diverse, native foraging habitat; and uncontaminated water sources).

3. Identify and protect significant roosts of big free-tailed bats in Wyoming, if they exist.

4. Implement Best Management Practices for natural caves (see page 152), abandoned mines (see page 161), buildings (see page 174), and rock shelters (see page 168) in areas where big free-tailed bats roost.

5. Avoid or minimize pesticide use in areas where the big free-tailed bat is likely to occur and other associated bat species occur to avoid direct poisoning and to maintain a food source for bat species and other insectivores.

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PRIORITY HABITATS: INFORMATION, ISSUES, AND RECOMMENDATIONS

Natural Caves

A cave is any naturally-occurring cavity, recess, or system of interconnected passageways beneath the surface of the earth or within a cliff or ledge that is large enough to be traversed by humans (Kerbo 2002). Caves generally provide an overall climate that is less variable than at the surface, with stable temperatures, high humidity levels, low evaporation rates, and an absence of light (WDOW 1994). Although relatively constant, not all cave temperatures are similar, and may be influenced by a number of factors, including the number, size, and position of portals; the size, slope, and contour of passages; the cave's overall volume; the seasonality and dynamics of airflow; and water intrusion (WDOW 1994). Cave habitats may be simple or complex, and often include many smaller tubes, cracks, and fissures (WDOW 1994; Altenbach and others 2002).

Caves are considered a non-renewable resource. They occur in a limited and finite distribution and contain unique animals and communities and fragile habitats (WDOW 1994). Caves are storehouses of information on natural resources, human history, and evolution (Kerbo 2002). Also, because about 25% of the groundwater in the US is located in cave and karst regions, the protection and management of these vital water resources is critical to public health and to sustainable economic development (Kerbo 2002).

Associated Species

Bat species that may benefit from management of this habitat include the western small-footed myotis, long-eared myotis, northern myotis, little brown myotis, fringed myotis, long-legged myotis, Yuma myotis, eastern pipistrelle, big brown bat, spotted bat, Townsend's big-eared bat, pallid bat, Brazilian free-tailed bat, and big free-tailed bat.

Caves in Wyoming

There have been 161 caves documented in Wyoming that could provide bat habitat (Luce 1998). Wyoming's caves are found in widely scattered locations, from 1220 to 3350 m (4000 to 11,000 ft) in elevation. Most have temperatures between -1 and 10 ºC (30 and 50 °F) and high humidity (Hill and others 1976). Although at least 23 different types of caves exist, including lava tubes, tectonic fractures, sea caves, and ice caves (Kerbo 2002), caves in Wyoming are primarily karst and pseudokarst features. Karst describes landforms, such as caves, sinkholes, and underground streams, that are formed by the dissolving, rather than mechanical eroding, of rock, primarily limestone and dolomite (Hill and others 1976; Veni and others 2001). Features similar to those of karst topography but occurring in nonsoluble rocks are classified as pseudokarst. Pseudokarst caves are formed by the process of piping, in which cavities form by the action of certain clays, which swell and contract with the presence or absence of water. Although most caves in Wyoming are karst features, many of Wyoming's basins abound with pseudokarst features (Hill and others 1976).

Caves as Bat Habitat

Caves provide some of the most important roosting sites for bats (Pierson 1998). At least 21 of the 45 bat species in North America use caves regularly, and many of the remaining species use them at least occasionally (Racey and Entwhistle 2003). Bats use caves as winter hibernacula, summer maternity roosts, day roosts, and even night roosts (Sheffield and others 1992; Hinman and Snow 2003). Many caves provide stable microclimatic conditions that are essential for maternity roosts and hibernacula and are available nowhere else; these important roosts are often traditional and are used by successive generations of bats over many years (Sheffield and others 1992; Hinman and Snow 2003). Although caves typically last for long periods of time, they are uncommon in many areas (Kunz 1982b). Caves may serve as refugia for bats in the event of loss or degradation of other roosts in the surrounding landscape, and in some areas, the availability of suitable caves may play a major role in determining the size and distribution of bat populations (Christy and West 1993). Although caves occupy a very small percentage of the total land base, they are disproportionately important as bat habitat, and the preservation of bat roosts in caves is 1 of the most important issues in bat conservation (Sheffield and others 1992).

Characteristics of Caves That Influence Bat Use

Physical characteristics that influence how bats use caves include temperature, humidity, airflow, internal complexity, size of the portal, external habitat, and protection from predators. Variables such as season, species, sex, age, and breeding condition of individuals also play roles in roost selection.

- Temperature is critical in the selection of cave roosts, particularly for hibernation and reproduction, and there may be high metabolic costs for bats that are forced to use caves with suboptimal temperatures (WDOW 1994). Although optimal temperatures vary from species to species, warm environments assist in the growth of embryos and young, while cool (but not freezing) caves reduce metabolic costs during hibernation (Humphrey 1975; Navo 1992). Only a few species are able to use Wyoming's cooler caves for rearing young (Tuttle 2000c).
- High humidity protects bats from desiccation, particularly during hibernation. Some species may require humidity close to 100% (saturation) (Adams 2003).
- Airflow is necessary to replenish the air supply in caves. However, the rate of air movement must be just enough to allow for some circulation and replenishment without destabilizing the cave's microclimate (Adams 2003).
- Large, complex caves with multiple portals and structural and elevational complexity may offer a range of microclimatic conditions, such as cold air or warm air traps, and provide a large selection of roosting opportunities, such as crevices and cavities. This complexity provides habitat for a variety of species and provides opportunities for bats to change roosting locations as their metabolic requirements change over a season (Kunz 1982b; Tigner and Aney 1994; Altenbach and others 2002; Hinman and Snow 2003).
- Caves are especially valuable when they are located near foraging habitat and water, so that the energetic costs of commuting are reduced. Even caves used as hibernacula may be selected in part for their proximity to favorable autumn foraging (Raesly and Gates 1987).

- Some bat species must be able to fly to their roost without having to land and crawl through a portal. For these species, the portal of the cave must be at least the width of a bat's wingspan (Tigner and Aney 1994).
- Bats may select caves that contain features, such as height or crevices, that give them protection from predators (Tigner and Aney 1994).
- Vegetation around the portal affects the climate of the cave, and its presence or absence can be important (WDOW 1993).

Although many of these requirements vary between species, in general, caves increase in value to bats if they provide optimal temperatures for hibernation or reproduction, high humidity, adequate airflow, and protection from predators; are large and complex with a variety of microclimatic conditions; and are in close proximity to foraging habitat and water. Since these requirements can be very specific, suitable caves are at a premium. For many bat populations, there may be only 1 or 2 acceptable roost sites, making these caves absolutely essential to their survival (McCracken 1988).

Conservation Issues

Caves on federal lands are protected through the Federal Cave Resources Protection Act of 1988, which requires federal agencies to inventory and list significant caves on federal lands and to protect such caves from harm, either to the cave or its biota, including bats. This act also states that there can be valid reasons for not disclosing cave locations to the general public, which means that cave locations can be kept confidential and protected from Freedom of Information Act requests (SDBWG 2004). Despite this protection, there are several potential threats to caves, particularly those not on federal lands, including human disturbance, physical alteration or degradation of the cave habitat, and closures that are incompatible with bats.

Human Disturbance

Human disturbance, particularly to hibernation and maternity colonies, is a factor in the decline of many cave-dwelling bat populations (Pierson 1998), and uninformed or misinformed recreationists can present a significant threat to bats and bat habitat. Interest in recreational caving is increasing in the US; membership in the National Speleological Society increased by approximately 28% from 1991 to 1995 and had a membership of more than 11,000 by 1999 (Hickman and others 1999). Also, as the human population has expanded over the past decades, communities and roads have encroached into many areas containing caves, contributing to increased cave visitations. While vandalism and direct aggression toward roosting bats definitely occur and can cause large amounts of damage, other cave visitors may unknowingly cause harm to roosting bats. Even though most active cavers support cave conservation and many even contribute to bat conservation efforts, it is still possible for well-meaning cavers and even biologists collecting survey and monitoring data to cause fatal disturbances to roosting bats (Speakman and others 1991; Pierson and others 1999).

Disturbance during hibernation may cause bats to arouse prematurely and burn stored energy reserves that usually cannot be spared (Sheffield and others 1992). For the little brown myotis, a single arousal can cost 108 mg of fat, or the equivalent of 67 days of torpor (Thomas and others 1990). Although periodic arousals throughout the winter are natural, the additional arousals and increasing energy expenditures provoked by disturbance can reduce survival (Speakman and Thomas 2003). Thomas (1995) found that even brief visits to a cave where no bats were handled resulted in a burst of activity that lasted up to 8.5 hours. Even disturbances as seemingly trivial as light or the body heat of humans may arouse bats (McCracken 1988; Thomas 1995). Noises such as the movement of a nylon jacket, Velcro closures, and even well-intentioned whispering can emit high-frequency sounds that may disturb bats (Tigner and Aney 1994). Also, because bats can require up to an hour or more to arouse from hibernation, they may appear to be undisturbed, but become fully aroused only after humans have left the cave. By flying around and reintegrating into hibernating clusters, active bats arouse others, resulting in a "cascade effect" (Speakman and Thomas 2003). Furthermore, repeated disturbances may force bats to abandon optimal hibernacula and move to alternate locations where less suitable conditions lower their prospects for survival (O'Shea and others 2003).

Disturbance to summer maternity colonies can also be extremely detrimental. Persons entering maternity colonies can cause bats to abandon their young or drop them to the floor where they can die from impact or exposure (Sheffield and others 1992). Disturbance can also cause bats to move to less suitable caves or areas of the same cave, where conditions may reduce growth rates and survival of the young (McCracken 1988). In addition, the handling of pregnant females has been known to cause abortion (Sheffield and others 1992).

Other Potential Threats

Cave-dwelling bats can also be vulnerable to alteration and degradation of the cave habitat. Alteration of vegetation around cave portals can alter the airflow and temperature of roosts (Sheffield and others 1992). Some gates or other closures on caves exist that do not allow access to bats (Oakleaf and others 1996) or that alter the temperature, airflow, and humidity of the cave (Sheffield and others 1992). Caves have also been flooded for water impoundments and have been quarried or mined away (Altenbach and Pierson 1995). Other potential threats to cave-dwelling bats include alteration of the cave microclimate, fires in and around the cave, and pesticides and other environmental and cave contaminants (WDOW 1994).

Best Management Practices for Caves to Benefit Bats in Wyoming

Landowners and land managers can take a variety of simple and inexpensive actions to improve, protect, and preserve habitat for bats. By protecting cave resources for bats, many other unique cave organisms will also benefit. The following Best Management Practices (BMPs) should provide some reasonable guidelines and suggestions for managing caves to benefit bats in Wyoming, although, of course, not all of the BMPs will be appropriate in all situations. See the National Speleological Society's website for additional information on proper caving ethics, conservation, and safety at http://www.caves.org.

1. Protect and maintain caves in Wyoming and avoid practices that degrade or alter them. Unless crucial habitat designation directs otherwise, assume all caves utilized by bats are crucial to the preservation of the bat population (Oakleaf and others 1996) and secure protection for all bat roost sites in caves.

2. Take a landscape level approach to management that incorporates roost sites, foraging habitat, and water sources. All of these components of bat habitat must be in close proximity (within several kilometers) for bats to use them efficiently (Keinath 2004). Avoid the destruction or degradation of bat foraging habitats or water sources near cave roosts.

3. Protect the environment in which caves occur, including soils, surface landforms, natural drainage patterns and hydrologic systems, and cave microclimate and ecosystems (Kerbo 2002).

4. Maintain all vegetation above caves inhabited by bats and near cave portals to avoid altering the internal cave climate and light levels, reducing insect populations, and removing visual barriers to allow increased human disturbance (WDOW 1994). Avoid timber harvest activities and prescribed burning within a 0.4-km (¼-mi) radius of caves inhabited by bats (Stringer and others 1991; Keinath 2004).

5. Avoid building roads within 90 m (300 ft) of caves inhabited by bats, within 0.4 km (¼ mi) where caves will be visible from roads (WDOW 1994), or where they will cause erosion into caves or alter the climate or flow of water in or around caves. Maintain vegetation screening along roads to minimize visibility of caves. Close or apply seasonal restrictions on roads that increase public access to vulnerable bat cave habitat (Oakleaf and others 1996).

6. Avoid mining activities above, inside, or near caves inhabited by bats, or within the watershed of a cave.

7. Keep the locations of caves and bat roosts confidential. Avoid including them on maps, road or trail signs, brochures, or press releases. Direct persons who inquire about local caves to a reputable speleological society.

8. Where recreational cavers may come into conflict with key maternity or hibernation sites, close hibernation sites to visitation from November 1 to April 1 and maternity sites from April 1 to October 1 (Pierson and others 1999). The critical time periods of hibernation and maternity activity may vary regionally and may allow some site-specific flexibility in seasonal closures.

9. At some caves where human disturbance is affecting bat populations, it may be necessary to install bat-friendly closures to allow passage by bats while restricting access to humans, at least during seasons critical to the bats. See “Bat-Friendly Closures” on page 286 for more information.

10. When entering caves inhabited by bats, reduce disturbance by minimizing noise and the number of participants. Limit lights to red lights and those powered by batteries or cold chemicals such as cyalume, and avoid bright flashlights and carbide lamps. Avoid smoking and passing too closely or lingering near roosting bats (Speakman and others 1991; ASM 1992; Sheffield and others 1992).

11. Do not use firearms, fireworks, open fires (including campfires, matches, and candles), camp stoves, or toxicants inside caves that are inhabited by bats, or near cave portals (ASM 1992; Sheffield and others 1992; WDOW 1994).

12. Establish educational programs to inform the public about how activities in caves can threaten bats and how caving can be enjoyed without affecting bats (such as caving in early spring and fall when it is least likely to disturb bats). Use signs and other interpretive media to help people appreciate bats and understand the fragility of cave resources, and enlist professional outfitter/guides and caving organizations as allies.

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Abandoned Mines

Mining excavations range from large open pits to major shafts and adits to small, shallow pits or trenches made for exploration. A single shaft or adit may connect to many miles of underground workings or may extend no more than a few feet into the earth. Commonly, a single underground mine has numerous portals, both shafts and adits, to the surface (Henry 1995). Like natural caves, abandoned mines often provide an overall climate that is less variable than at the surface, with stable temperatures, high humidity levels, low evaporation rates, and an absence of light (WDOW 1994). Although relatively stable, not all microhabitats in abandoned mines are similar, and may be influenced by a number of factors, including the number, size, and position of portals; the size, slope, and contour of passages; the mine's overall volume; the seasonality and dynamics of airflow; and water intrusion (WDOW 1994).

Associated Species

Bat species that may benefit from management of this habitat include the western small-footed myotis, long-eared myotis, northern myotis, little brown myotis, fringed myotis, long-legged myotis, Yuma myotis, eastern pipistrelle, big brown bat, spotted bat, Townsend's big-eared bat, pallid bat, and Brazilian free-tailed bat.

Abandoned Mines in Wyoming

Wyoming, like many western states, has a rich mining history. In 1867, gold was discovered near South Pass at the southern tip of the Wind River Mountains, and Wyoming's first gold rush was on (Hausel 1989). Subsequently, many other minerals and rocks, such as copper, iron, and tungsten, have been mined, which has resulted in many abandoned or inactive mines scattered across the state and has left a pervasive and lasting mark on the landscape.

At this time, approximately 1000 abandoned mines are known to exist across Wyoming. The Wyoming Game and Fish Department (WGFD) has located and surveyed only about 300 of these mines. Nearly 100 of them have been confirmed to be occupied by bats, although WGFD personnel have identified numerous others, following initial site visits and internal surveys, as having significant habitat potential for bats. WGFD personnel have recently confirmed bat occupancy at several abandoned mines that were classified as having significant habitat potential in previous years. Additional surveys to locate the remaining abandoned mines and document use by bats are warranted.

Abandoned Mines as Bat Habitat

Even though they are manmade features, many abandoned mines share characteristics with caves that make them some of the most important roosting sites for bats (Hinman and Snow 2003). Different species of bats use mines for many different purposes, including winter hibernacula, summer maternity roosts, courtship and mating sites, and day roosts (Sheffield and others 1992; Hinman and Snow 2003). Mines also serve as crucial rest stops during spring and fall migration, and are often the only suitable shelters left between summer and winter roosts (Ducummon 2000). Night roosting is also very common at mines, and most mines are likely to be used by night roosting bats at some time or another (Navo and others). In fact, almost any mine could be used for 1 or more of the above purposes at some time of the year (Altenbach and Pierson 1995).

At least 28 of the 45 bat species in North America are known to roost in abandoned mines, and for some of these species, mines represent essential habitat (Altenbach and Pierson 1995; Hinman and Snow 2003). Mines act as refugia in areas where human disturbance of caves, loss of tree cavities, and urban and agricultural development have made natural roosts unsuitable or unavailable, and in some areas mines may be the only remaining viable roosts (Altenbach and Pierson 1995; Tuttle and Taylor 1998; Pierson and others 1999). Even in areas where traditional roosts have not been disturbed or altered, the cave-like microclimates of many abandoned mines attract bats (Tuttle and Taylor 1998). Because mines have been part of the natural landscape for over 100 years, some bat populations have come to depend on them for survival (Navo and others). For example, many abandoned mines provide stable microclimatic conditions that are essential for maternity roosts and hibernacula and are available nowhere else; these important roosts are often traditional and have been used by successive generations of bats over many years (Sheffield and others 1992; Hinman and Snow 2003). In some areas, the availability of suitable mines may play a major role in determining the size and distribution of bat populations (Christy and West 1993). Of the thousands of abandoned mines in the West that have been surveyed, about half show some type of use by bats (Altenbach and Pierson 1995). Moreover, because many abandoned mines have not been surveyed, large populations of bats living in them may still be undiscovered (Tuttle and Taylor 1998). Although abandoned mines occupy a very small percentage of the total land base, they are disproportionately important as bat habitat, and the preservation of bat roosts in abandoned mines is 1 of the most important issues in bat conservation (Sheffield and others 1992).

Characteristics of Abandoned Mines That Influence Bat Use

Physical characteristics that influence how bats use abandoned mines include temperature, humidity, airflow, internal complexity, size of the portal, external habitat, and protection from predators. Variables such as season, species, sex, age, and breeding condition of individuals also play roles in roost selection.

- Temperature is critical in the selection of abandoned mine roosts, particularly for hibernation and reproduction, and there may be high metabolic costs for bats that are forced to use roosts with suboptimal temperatures (WDOW 1994). Although optimal temperatures vary from species to species, warm environments assist in the growth of embryos and young, while cool (but not freezing) roosts reduce metabolic costs during hibernation (Humphrey 1975; Navo 1992).
- High humidity protects bats from desiccation, particularly during hibernation. Some species may require humidity close to 100% (saturation) (Adams 2003).
- Airflow is necessary to replenish the air supply in abandoned mines. However, the rate of air movement must be just enough to allow for some circulation and replenishment without destabilizing the mine’s microclimate (Adams 2003).
- Complex mines with multiple portals and structural and elevational complexity often offer a range of microclimatic conditions, such as cold air or warm air traps; have greater airflow; and provide a large selection of roosting opportunities, such as crevices and cavities. This complexity provides habitat for a greater variety of species and provides opportunities for

bats to change roosting locations as their metabolic requirements change over a season. Nevertheless, many simple, single-portal mines can also provide ideal roosting habitat for bats (Kunz 1982b; Tigner and Aney 1994; Navo and Ingersoll 2000; Altenbach and others 2002; Hinman and Snow 2003).

- Roosts are especially valuable when they are located near foraging habitat and water sources, usually within 0.8 km (½ mi), so that the energetic costs of commuting are reduced (Tuttle and Taylor 1998). Abandoned mines used as hibernacula may be selected in part for their proximity to favorable autumn foraging (Raesly and Gates 1987), such as riparian corridors, water features, and other native habitats that have not been converted or degraded.
- Some bat species must be able to fly to their roost without having to land and crawl through a portal. For these species, the portal of the mine must be at least the width of a bat's wingspan (Tigner and Aney 1994). Portals smaller than 30 x 30 cm (12 x 12 in) are unlikely to be used by bats (Navo 1995).
- Bats may select mines that contain features, such as height or crevices, that give them protection from predators (Tigner and Aney 1994).
- Vegetation around the portal affects the climate of the mine, and its presence or absence can be important (WDOW 1993).
- Physically stable mines usually have a longer life expectancy and provide more reliable bat habitat than unstable mines. Stability of the mine depends on the character and erosion-resistance of the rock; the type, complexity, size, and other characteristics of the mine workings; the quality of support installed during mining; and whether the support was pulled out when the mine closed (Henry 1995).

Although many of these requirements vary between species, in general, abandoned mines increase in value to bats if they provide optimal temperatures for hibernation or reproduction, high humidity, adequate airflow, and protection from predators; are large and complex with a variety of microclimatic conditions; are in close proximity to foraging habitat and water; and are physically stable.

Conservation Issues

Bats that roost in abandoned mines face 3 primary threats from humans: closure of mines, human disturbance, and loss of old mines if mining is renewed (Tuttle and Taylor 1998).

Mine Reclamation and Closure

Abandoned mines can pose serious threats to human safety, so in the interest of hazard and liability abatement, land management agencies, private landowners, mining companies, and mine land reclamation programs have closed and reclaimed many abandoned mines, often without surveying the mines for bat inhabitants (Belwood and Waugh 1991; Altenbach and Pierson 1995). A minimum of about 300, and possibly as many as 400, abandoned mines were closed in Wyoming between inception of the Office of Surface Mining-Abandoned Mine Reclamation Program in 1982, and 1989 when an agreement to conduct pre-reclamation bat inventories was initiated (Oakleaf and others 1996). This represents a significant loss of habitat and possibly the loss of hundreds or thousands of individual bats that were trapped inside the reclaimed mines. Some private and public entities continue to use hard closure techniques, such as bulldozing, backfilling, blasting, sealing with concrete, and foaming, that make mines inaccessible to bats and other wildlife (Navo 1992; Pierson and others 1999; Altenbach and others 2002). Although not all abandoned mines are used by a large number of bats and many may be safely closed, the cumulative effects of closing many small roosts as well as a few large roosts may be devastating to bat populations—even abundant populations (Tuttle and Taylor 1998; Pierson and others 1999; Meier 2000).

Human Disturbance

Disturbance caused by visitors to abandoned mines can present a significant threat to bats and bat habitat. While vandalism and direct aggression toward roosting bats definitely occur and can cause large amounts of damage, even well-meaning mine visitors and biologists collecting survey and monitoring data can unknowingly cause fatal disturbances to roosting bats (Speakman and others 1991; Pierson and others 1999).

Disturbance during hibernation may cause bats to arouse prematurely and burn stored energy reserves that usually cannot be spared (Sheffield and others 1992). For the little brown myotis, a single arousal can cost 108 mg of fat, or the equivalent of 67 days of torpor (Thomas and others 1990). Although periodic arousals throughout the winter are natural, the additional arousals and increasing energy expenditures provoked by disturbance can reduce survival (Speakman and Thomas 2003). Thomas (1995) found that even brief visits to a cave where no bats were handled resulted in a burst of activity that lasted up to 8.5 hours. Even disturbances as seemingly trivial as light or the body heat of humans may arouse bats (McCracken 1988; Thomas 1995). Noises such as the movement of a nylon jacket, Velcro closures, and even well-intentioned whispering can emit high-frequency sounds that may disturb bats (Tigner and Aney 1994). Also, because bats can require up to an hour or more to arouse from hibernation, they may appear to be undisturbed, but become fully aroused only after humans have left the roost. By flying around and reintegrating into hibernating clusters, active bats arouse others, resulting in a “cascade effect” (Speakman and Thomas 2003). Furthermore, repeated disturbances may force bats to abandon optimal hibernacula and move to alternate locations where less suitable conditions lower their prospects for survival (O’Shea and others 2003).

Disturbance of summer maternity colonies can also be extremely detrimental. Persons entering maternity colonies can cause bats to abandon their young or drop them to the floor where they can die from impact or exposure (Sheffield and others 1992). Disturbance can also cause bats to move to less suitable roosts, where conditions may reduce growth rates and survival of the young (McCracken 1988). In addition, the handling of pregnant females has been known to cause abortion (Sheffield and others 1992).

Renewed Mining

Contemporary mining operations often take place in historic mining districts and can threaten bat habitat in abandoned mines. New sampling methods often detect deposits missed by previous miners that are now economical to extract (Brown and others 2000). New mining techniques usually produce open pits, which are unsuitable as bat habitat, and often destroy existing adits and shafts (Brown 1995; Pierson 1998). Even if an existing mine is not directly impacted, nearby blasting can disrupt roosting bats. Even during exploratory drilling, before mining begins, historic mines can be covered as roads are constructed, drills can penetrate and collapse underground workings, and bats can be disturbed by mine personnel entering bat roosts to collect ore samples. Finally, at the completion of mining, any historic mines still open may be sealed without concern for bats as part of reclamation activities (Brown 1995).

Other Potential Threats

Other potential threats to mine-dwelling bats include gates or other temporary closures that do not allow access to some bats (Oakleaf and others 1996); timber harvesting that increases human access to abandoned mines occupied by bats (Oakleaf and others 1996); physically unstable mines, which may collapse and injure bats, block portals, or change the microclimate of the mine (Hinman and Snow 2003); and mines with toxic air or radioactivity (Brown and others 2000).

Best Management Practices for Abandoned Mines to Benefit Bats in Wyoming

Landowners and land managers can take a variety of simple and inexpensive actions to improve, protect, and preserve habitat for bats. The following Best Management Practices (BMPs) should provide some reasonable guidelines and suggestions for managing abandoned mines to benefit bats in Wyoming, although, of course, not all of the BMPs will be appropriate in all situations.

1. Protect and maintain abandoned mines in Wyoming and avoid practices that degrade or alter them. Unless crucial habitat designation directs otherwise, assume all abandoned mines utilized by bats are crucial to the preservation of the bat population (Oakleaf and others 1996) and secure protection for all bat roost sites in mines.

2. Take a landscape level approach to management that incorporates roost sites, foraging habitat, and water sources. All of these components of bat habitat must be in close proximity (within several kilometers) for bats to use them efficiently (Keinath 2004). Avoid the destruction or degradation of bat foraging habitats or water sources near mine roosts (Brown and others 2000).

3. Maintain all vegetation above mines inhabited by bats and near mine portals to avoid altering the internal climate and light levels, reducing insect populations, and removing visual barriers to allow increased human disturbance (WDOW 1994). Avoid timber harvest activities, particularly clearcutting, within a 0.4-km (¼-mi) radius of mines inhabited by bats (Stringer and others 1991; Keinath 2004).

4. Enhance and protect abandoned mines with suitable conditions for bats, even if no bats have been documented there. Some unoccupied mines have later become occupied by bats when they were protected from disturbance or rehabilitated by portal shoring or ventilation (to provide airflow) (Perkins and Schommer; Tuttle and Taylor 1998; Hinman and Snow 2003).

5. Avoid building roads within 90 m (300 ft) of mines inhabited by bats, within 0.4 km (¼ mi) where mines will be visible from roads (WDOW 1994), or where they will cause erosion into mines or alter the climate or flow of water in or around mines. Maintain vegetation screening along roads to minimize visibility of mines. Close or apply seasonal restrictions on roads that increase public access to vulnerable bat mine habitat (Oakleaf and others 1996).

6. Do not use firearms, open fires (including campfires, matches, and candles), camp stoves, or toxicants inside mines that are inhabited by bats, or near mine portals (ASM 1992; Sheffield and others 1992; WDOW 1994).

7. Keep the locations of abandoned mines and bat roosts confidential. Avoid including them on maps, road or trail signs, brochures, or press releases.

8. Establish educational programs to inform the public about how activities in abandoned mines are unsafe for humans and can threaten bats. Use signs and other interpretive media to help people appreciate bats and understand the instability of abandoned mines.

9. Prior to mine closure or renewed mining, evaluate all abandoned mines as bat habitat. Bats can exhibit high temporal and seasonal variation in roost use, and move frequently between roosts. Multiple surveys within and across seasons are essential to determine the significance of mine structures to bats for hibernation, maternity, day roost, night roost, and lek roost activities (Altenbach and others 2002; SDBWG 2004).

10. At mines where human safety is a concern, where adequate surveys cannot be performed, or where human disturbance is affecting bat populations, install bat-friendly closures to allow passage by bats while restricting access to humans, at least during seasons critical to the bats (Luce 1998). See “Bat-Friendly Closures” on page 286 for more information.

11. Where possible, avoid hard closure of mines that are occupied by bats. Hard closure includes activities such as bulldozing, backfilling, blasting, sealing with concrete, and foaming, that make mines inaccessible to bats and other wildlife. According to Altenbach and Pierson (1995), mines that have been closed by backfilling or blasting often subside and create conditions that are more hazardous than the original mine, while properly designed and installed bat-friendly closures have a good safety record.

12. Where possible, avoid renewed mining activities above, inside, or near abandoned mines inhabited by bats.

13. If hard closure of bat-occupied mines or the loss of bat-occupied abandoned mines during renewed mining is unavoidable, safely exclude or remove bats during a non-critical season to avoid mortality (Altenbach and others 2002). Only demolish or exclude bats from the mine during a season when it is not in use, or during early spring or fall if bats use the mine year-round.

14. If hard closure or renewed mining at bat-occupied mines is unavoidable, identify and protect replacement roosting habitat nearby. Mitigate for the loss of occupied roosts either by protecting nearby mines or by reopening ones already closed. Survey mines within about 8 km (5 mi) of the closure site for potential replacement habitat. Mines occupied by the same species or with similar microclimates to the mine that will be lost should be prioritized and protected by gates or fences prior to the exclusion of bats from their current roosts. Avoid locating mitigation sites

within the sphere of potential mine expansion (Tuttle and Taylor 1998; Brown and others 2000; Altenbach and others 2002).

15. After mining is completed, reclaim mine lands with consideration for the unique foraging and roosting needs of bats. Reclaim with native vegetation and appropriate roosting habitat, and protect remaining mine shafts and adits with bat-friendly closures (Bogan 2000).

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Rock Shelters

A rock shelter is any shallow crevice or small cave in a cliff, rock outcrop, or talus slope. Rock shelters are small (less than 5 to 10 m^3 [175 to 350 ft^3]), usually moderately well lighted, and are distinguished from larger caves by a lack of complexity (Bogan and others 2003). Although rock shelters comprise only a small fraction of Wyoming's total land area (Ward and Anderson 1988) and the bats that use them are very difficult to detect (O'Shea and others 2003), these rocky habitats provide very important roosts for several species of bats in Wyoming.

Associated Species

Bat species that may benefit from management of this habitat include the California myotis, western small-footed myotis, long-eared myotis, little brown myotis, fringed myotis, long-legged myotis, Yuma myotis, eastern pipistrelle, spotted bat, Townsend's big-eared bat, pallid bat, Brazilian free-tailed bat, and big free-tailed bat.

Rock Shelters in Wyoming

Cliffs, rock outcrops, and talus slopes are typical features of the mountainous West, including Wyoming; formation of the Rocky Mountains by uplift and volcanism, followed by erosion by glacial and other forces, led to the development of a landscape with high topographic relief. This habitat is found throughout the state in all rock types and is extremely variable. It may appear as cliffs that range from just a few meters to hundreds of meters high, rocky ledges, small rocky outthrusts, stream cutbanks, bluffs, rim rock, or buttes. Talus slopes can be less than a hectare to several hundred hectares in size and are often the result of mass wasting processes associated with cliff habitats. Igneous (basalt and granite), metamorphic (quartzite and migmatites), and sedimentary (limestone and sandstone) deposits are all common throughout Wyoming and provide roosting habitat for bats. Those areas where geological activity is most recent, such as lava flows, glaciation, and faulting, provide some of the more suitable rock shelter habitats for bats (Beidleman 2000; Altenbach and others 2002).

Rock Shelters as Bat Habitat

Roosts in rock shelters are very important for many species of bats (Kurta 2000; O'Shea and others 2003). These sites offer good protection from predators and suitable roosting habitat, usually for smaller colonies and single individuals (Hinman and Snow 2003). Cliffs and large rock features may serve as massive heat sinks, allowing bats roosting in them to minimize their daily use of energy (Vaughan and O'Shea 1976). They are often suitable as maternity and night-roosting habitat during summer, but are generally too exposed to temperature fluctuations to provide significant hibernacula (Altenbach and others 2002; Hinman and Snow 2003). As a result, rock shelters may be important for some species that are generally associated with caves and abandoned mines; that is, some bats may hibernate in caves and abandoned mines during winter but roost in rock shelters during summer (O'Shea and others 2003). In addition, the stability and persistence of cliff and rock habitat may encourage fidelity to specific areas as roosting habitat, which may extend beyond the lifetimes of individual bats (Beidleman 2000).

Cliffs, rock outcrops, and talus slopes are unique habitats that lend topographic diversity to homogeneous areas. As a result, they may also benefit bats indirectly by influencing vegetation structure and diversity and thereby increasing insect diversity and abundance (Ward and Anderson 1988).

Characteristics of Rock Shelters That Influence Bat Use

Bats usually select roosts in rock shelters that provide certain minimum requirements. These requirements include temperature, protection from predators, and proximity to foraging habitat and water.

- Bats are able to minimize their daily use of energy by selecting roosts with moderate, stable temperatures. Temperature may be affected by size and shape of the crevice opening and orientation of the crevice to the sun (Vaughan and O'Shea 1976; Tuttle 2000c; Lausen and Barclay 2002). Also, deep crevices usually have more stable temperatures than shallow crevices (Vaughan and O'Shea 1976).
- Bats often choose roosts in part for the protection they provide from predators (Tuttle and Hensley 1993). Characteristics that may provide protection from predators include height, or distance from level ground, and small openings (Lausen and Barclay 2002). Other bats use the strategy of roosting alone in ground-level cavities that are easily accessible to predators, but each female with her young occupies only 1 in many thousands of openings in extremely rocky landscapes and is difficult for predators to find (Tuttle 2000c).
- Rock shelters are especially valuable when they are located near foraging habitat and water, so that the energetic costs of commuting are reduced.

Conservation Issues

Bat habitat in cliffs, rock outcrops, and talus slopes has probably not decreased greatly in abundance over the last century, especially in comparison to other roost structures such as caves and abandoned mines, and the extent of any such alteration or disturbance in this habitat is undocumented (Keinath 2004). Nevertheless, potential threats to bats that roost in rock shelters include recreation, particularly rock climbing and bouldering; and mining, road and dam construction, and other development (Bogan 2000; Adams 2003; Keinath 2004). During the last few decades, rock climbing and related recreation has become more popular and may cause disturbance to bats roosting and raising young in cliffs and rock crevices. Human disturbance can cause bats to abandon their young or move them to less suitable crevices where conditions may reduce growth rates or survival (McCracken 1988; Sheffield and others 1992). Mining and construction can have negative impacts on roosting bats when they occur at the base or top of cliffs and rock outcrops (Beidleman 2000). In addition, quarrying operations may actually remove buttes and cliffs for a source of rock and disturb or destroy the cracks and crevices where bats roost (Beidleman 2000; Bogan 2000).

Best Management Practices for Rock Shelters to Benefit Bats in Wyoming

Landowners and land managers can take a variety of simple and inexpensive actions to improve, protect, and preserve habitat for bats. The following Best Management Practices (BMPs) should provide some reasonable guidelines and suggestions for managing rock shelters to benefit bats in Wyoming, although, of course, not all of the BMPs will be appropriate in all situations.

1. Protect and maintain cliffs, rock outcrops, and talus slopes in Wyoming; limit their use and development wherever necessary and possible; and avoid practices that degrade or alter them (Ward and Anderson 1988).

2. Take a landscape level approach to management that incorporates roost sites, foraging habitat, and water sources. All of these components of bat habitat must be in close proximity (within several kilometers) for bats to use them efficiently (Keinath 2004). Avoid the destruction or degradation of bat foraging habitats or water sources near roosts in rock shelters. Protect the unique vegetation community that often exists in these areas to maintain insect abundance and diversity (Ward and Anderson 1988). Maintain the microclimate of cliffs and rock outcrops used as roosts by protecting and managing the vegetation up to 240 m (790 ft) from the roost area (Ormsbee 1996).

3. Minimize human disturbances to roost sites in rock shelters. Where recreational climbing or hiking may impact key roost areas, implement use restrictions, and close areas with known maternity colonies to climbing from April 1 to October 1 (Pierson and others 1999).

4. Interact with recreational climbers to maintain confidentiality of cliff and crevice roosts used by bats and encourage support of bat conservation efforts. Maintain roost confidentiality by avoiding revealing exact locations of bat roosts in technical or popular literature (Altenbach and others 2002).

5. Establish educational programs to inform the public about how activities near bat roosts can threaten bats and how climbing and hiking can be enjoyed without affecting bats (such as climbing in early spring and fall when it is least likely to disturb bats). Use signs and other interpretive media to help people appreciate bats and understand the fragility of roosting bats, and enlist professional outfitter/guides and climbing organizations as allies.

6. Alter the timing of rock extraction activities in cliffs, rock outcrops, and talus slopes to avoid disturbing known maternity colonies between April 1 and October 1.

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Buildings

Of the 45 bat species that inhabit the US, over half are known to use buildings as roosts for at least part of the year (Adams 2003; Kunz and Reynolds 2003). One reason bats use manmade structures may be the loss or disturbance of natural roosts in crevices, cavities, and caves as a result of human activities, although many bats probably use buildings according to their availability, in addition to or in preference to their natural roosts (Greenhall 1982; Hickman and others 1999; Adams 2003; Kunz and Reynolds 2003). Throughout history, humans have impacted bat roosting habitat in the process of development, but have simultaneously provided other roosting opportunities in buildings and other structures (Adams 2003). The conservation of these manmade roosts allows them to continue supporting bat colonies.

Associated Species

Bat species that may benefit from management of this habitat include the California myotis, western small-footed myotis, long-eared myotis, northern myotis, little brown myotis, fringed myotis, long-legged myotis, Yuma myotis, eastern pipistrelle, big brown bat, spotted bat, Townsend's big-eared bat, pallid bat, Brazilian free-tailed bat, and big free-tailed bat.

Buildings as Bat Habitat in Wyoming

In Wyoming, the bats that most commonly roost in buildings are the big brown bat and the little brown myotis. Twenty buildings in the state have been identified as major bat roosts and registered with the Wyoming Game and Fish Department (WGFD). The owners of the buildings understand their value to bats and have agreed to preserve the habitat and contact the WGFD before altering it. This is probably a small percentage of the bat roosts in Wyoming's buildings (Luce 1998).

Buildings as Bat Habitat

The widespread use of buildings by bats in temperate regions clearly indicates that these structures are important roosting habitats for bats (Kunz and Reynolds 2003). Buildings offer a range of internal and external habitats for roosting bats, sometimes even more diverse than their natural habitat (Kunz 1982b). Bats are known to roost in a wide variety of buildings, including houses, barns, churches, schools, and commercial buildings (Tatarian 2001; Kunz and Reynolds 2003). The attics and other interior spaces of these buildings, such as beneath floorboards, inside insulation, and between bricks and wood, provide roosts that are analogous to caves, cavities, and crevices. Exterior spaces beneath tile, corrugated roofs, wooden shingles, and clapboard, and crevices between bricks and stones, behind shutters, and between vents all provide roosts similar to natural roosts in crevices and tree bark (Kunz and Reynolds 2003). Several different species commonly roost in abandoned or little-used structures that are unlikely to place them in direct contact with people, but the big brown bat and little brown myotis are also common in buildings that are occupied by people (Adams 2003).

Most bats use buildings on a seasonal basis as maternity roosts, night roosts, bachelor roosts, and transient roosts during migration (Kunz and Reynolds 2003). The use of buildings by bats also varies within each season; bats often use the interior of structures as day roosts, and more exposed locations on either the same or different structures as night roosts (Tatarian 2001). Bats most commonly use buildings as summer roosts, but because of low humidity and low temperatures, they usually do not hibernate in buildings (Tatarian 2001; Adams 2003; Kunz and Reynolds 2003). In the eastern US, the big brown bat will sometimes overwinter in heated buildings that provide roost temperatures above freezing (Whitaker and Gummer 2000; Adams 2003). In the West, however, the humidity is probably too low in buildings for even the big brown bat to hibernate (Adams 2003). Although big brown bats have been known to hibernate in buildings in South Dakota (Tigner 2002), no bats have been found hibernating in buildings in Wyoming.

Characteristics of Buildings That Influence Bat Use

Physical characteristics that influence how bats use buildings include microclimate, the range of temperatures and roost sites available within or on the building, accessibility, light levels, and proximity of the roost to water and foraging habitat. As with most roosts, shelter from the wind and rain and reduced predation risks are important factors that govern the selection of buildings as roosts (Kunz and Reynolds 2003), and variables such as season, species, sex, age, and breeding condition of individuals also play roles in roost selection. However, few studies have been conducted on the preferences of bats roosting in buildings (Kunz and Reynolds 2003; Racey and Entwhistle 2003).

- Temperature is critical in the selection of roosts in buildings, particularly for reproduction. Although optimal temperatures vary from species to species, warm environments allow pregnant bats to maintain a high body temperature at relatively low metabolic cost and assist in the growth and development of young (Humphrey 1975; Williams and Brittingham 1997). Temperature is also a critical factor for hibernation, although at this time bats are not known to hibernate in buildings in Wyoming.
- Buildings are especially valuable to bats if they provide a wide thermal gradient and a range of roosting sites. Taller attics and hollow walls, for example, allow bats, especially non-volant young that can't relocate to other roosts, to behaviorally thermoregulate by moving vertically in the roost (Humphrey 1975; Williams and Brittingham 1997). Buildings with a range of internal and external roosts provide opportunities for bats to change roosting locations as their metabolic requirements change over a season or even a day.
- Buildings must be accessible in order to be usable by bats. Certain construction materials and designs may be more accessible than others; for example, Williams and Brittingham (1997) suggested that tin roofs are more accessible than asphalt shingle roofs. Also, newer building designs and construction practices may not provide as much access to bats as older buildings.
- Light levels may be a factor in the selection of buildings by bats (Kunz and Reynolds 2003). Although Williams and Brittingham (1997) found a wide range of light levels in occupied roosts, occupied roosts were slightly darker than unoccupied roosts, and they suggested that intense illumination in particular may influence roost selection.
- Buildings are especially valuable as bat roosts when they are located near foraging habitat and water, so that the energetic costs of commuting are reduced (Greenhall 1982; Kunz and Reynolds 2003; Racey and Entwhistle 2003).

Although a number of authors have suggested that bats seem to prefer older buildings to newer ones (Schowalter and Gunson 1979; Christy and West 1993; Williams and Brittingham 1997; Hinman and Snow 2003), bats probably do not discriminate between the ages of buildings, but select buildings based on the specific characteristics of the roosts they provide. In fact, many bats do roost in newer buildings (Fenton 2003). However, many older buildings do provide many of the characteristics that bats require in a roost. For example, unlike buildings with modern insulation and heating and cooling systems, many older buildings are more likely to provide a suitable microclimate for bats. Also, buildings constructed in the early 1900s may provide a wider range of roosting sites in attics and hollow walls than newer buildings (Schowalter and Gunson 1979; Christy and West 1993). In addition, older buildings may be less well maintained or well sealed, and may have construction designs or materials that allow better access to bats than newer buildings (Williams and Brittingham 1997; Fenton 2003; Hinman and Snow 2003).

Conservation Issues

Bats that roost in buildings are often in direct conflict with humans (Fenton 2003). Fears and misconceptions about bats and rabies; a dislike for or antipathy toward bats; and noise, odors, and droppings have all prompted humans to deliberately exclude and even exterminate bats roosting in buildings (Pierson 1998; Tatarian 2001; Fenton 2003; Kunz and Reynolds 2003). Bats are often excluded from buildings during repairs, renovations, and historical preservation (Humphrey 1982; Pierson 1998; Tatarian 2001; Kunz and Reynolds 2003), and old buildings that provide roosting habitat are often removed out of concern for human safety (Hickman and others 1999) or to make way for development (Tatarian 2001). Often, the property owners are not aware that bats are roosting in these structures, and their destruction or closure of the roost is unintentional (Pierson 1998; Tatarian 2001). Although exclusion gives bats a better chance at survival than extermination, it nevertheless causes stress among displaced bats. There is some evidence of mortality and reduced reproductive success associated with exclusion (Humphrey 1982; Brittingham and Williams 2000; Racey and Entwhistle 2003), and any loss of roosting habitat has the potential to cause significant loss of bat populations (Hickman and others 1999; Tatarian 2001). (See “Bat-Human Conflicts” on page 266 for more information.)

Other potential threats to bats roosting in buildings include human disturbance, as humans are more likely to enter buildings than most natural roosts (Tatarian 2001; Hinman and Snow 2003); uncovered chimneys and exhaust stacks, which can trap bats (and birds) (Pierson 1998); and the use of chemicals as wood preservatives, treatment of buildings for wood-boring insects, and direct application of toxic chemicals and repellants (Kunz 1982b; Kunz and Reynolds 2003).

Best Management Practices for Buildings to Benefit Bats in Wyoming

Landowners and land managers can take a variety of simple and inexpensive actions to improve, protect, and preserve habitat for bats. The following Best Management Practices (BMPs) should provide some reasonable guidelines and suggestions for managing buildings to benefit bats in Wyoming, although, of course, not all of the BMPs will be appropriate in all situations.

1. Protect and maintain buildings that provide roosting habitat for bats in Wyoming and avoid demolishing or altering them wherever possible. Unless crucial habitat designation directs otherwise, assume all buildings utilized by bats are crucial to the preservation of the bat population (Oakleaf and others 1996).

2. Take a landscape level approach to management that incorporates roost sites, foraging habitat, and water sources. All of these components of bat habitat must be in close proximity (within several kilometers) for bats to use them efficiently. Avoid the destruction or degradation of bat foraging habitat or water sources near roosts in buildings. Avoid prescribed burning or timber harvest activities, particularly clearcutting, within a 0.4-km (¼-mi) radius of buildings inhabited by bats (Keinath 2004).

3. Minimize human disturbances to roost sites in buildings. Where humans may impact key roost areas in unoccupied buildings, implement use restrictions and close maternity areas by installing locks or fences from April 1 to October 1 (Pierson and others 1999; Keinath 2004).

4. Establish educational programs to increase public awareness about the importance of buildings as bat roosts, the risk to bats from building renovation and demolition, and how to safely and responsibly share buildings with bats (Tatarian 2001; Altenbach and others 2002; Keinath 2004).

5. Before demolishing old or abandoned buildings, conduct surveys to determine whether bats use the buildings as roosts (Brown and Berry 1991). If so, consider alternatives to demolition that will conserve the buildings as bat roosts.

6. Where possible, allow bats to remain in occupied buildings. In most cases, especially where bats are roosting on or near the exterior of the building, they can be allowed to remain without endangering the building or the human occupants (Hinman and Snow 2003). (See "Bat-Human Conflicts" on page 266 for more information.)

7. Where the removal of buildings used as bat roosts or the exclusion of bats from buildings is unavoidable, minimize the impacts of the loss of the roost by timing the exclusion or demolition from October 1 to April 1 (Tigner 2002).

8. Keep the locations of bat roosts in buildings confidential. Avoid including them on maps, road or trail signs, brochures, press releases, or other literature.

9. Minimize bat mortality when conducting repairs and renovations on buildings. Where possible, maintain or recreate entrances, crevices, and roosting areas (Entwhistle and others 2001; Tatarian 2001; Richardson 2002).

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Bridges and Culverts

Of the 45 bat species that inhabit the US, over half are known to use bridges and culverts as roosts for at least part of the year (Keeley and Tuttle 1999; Adams 2003). One reason bats use manmade structures may be the loss or disturbance of natural roosts in crevices, cavities, and caves as a result of human activities, although many bats probably use bridges and culverts according to their availability, in addition to or in preference to their natural roosts (Pierson and Erickson 1995; Keeley and Tuttle 1999; Adams 2003). Throughout history, humans have impacted bat roosting habitat in the process of development, but have simultaneously provided other roosting opportunities in bridges, culverts, and other structures (Adams 2003). The conservation of these manmade roosts allows them to continue supporting bat colonies.

Associated Species

Bat species that may benefit from management of this habitat include the California myotis, western small-footed myotis, little brown myotis, fringed myotis, long-legged myotis, Yuma myotis, big brown bat, pallid bat, and Brazilian free-tailed bat.

Bridges and Culverts as Bat Habitat in Wyoming

According to Keeley and Tuttle (1999), the number of bats that use bridges as day roosts drops rapidly above 42° north latitude, which runs through the southern third of Wyoming. During the summer of 1998, Brian Keeley of Bat Conservation International surveyed 121 highway bridges throughout the state. He determined that 86 of those bridges were being used by bats as night roosts, but only 2 were being used as either day or maternity roosts (Priday and Luce 1999). The use of culverts by bats has not been studied or surveyed in Wyoming. Bats have not been documented hibernating in bridges or culverts in Wyoming, as they are usually too exposed for bats to use during winter (Tatarian 2001).

Bridges and Culverts as Bat Habitat

Bridges and culverts with suitable conditions can provide important roost sites for bats (Perlmeter 1996; Pierson and others 1996; Arnett and Hayes 2000; Keeley and Tuttle 2000; Hinman and Snow 2003). Because bridges and culverts often occur in riparian corridors, their proximity to important foraging habitat, water sources, and travel corridors increases their value to bats (Pierson and Erickson 1995; Arnett and Hayes 2000; Entwhistle and others 2001; Sandel and others 2001). Most bats use bridges and culverts on a seasonal basis as night roosts, day roosts, or transient roosts during migration (Tatarian 2001). Bats most commonly use bridges and culverts as night roosts, and Keeley and Tuttle (1999) found that 29% of all structures surveyed had signs of night-roost activity. Night roosts are usually in open areas between bridge support beams that are protected from the wind (Pierson and Erickson 1995; Keeley and Tuttle 1999). Bats less frequently use bridges and culverts as day roosts, which must provide greater protection from weather and predators (Pierson and Erickson 1995; Schmidt 2003h). Day roosts are usually in expansion joints or other crevices (Keeley and Tuttle 1999).

Characteristics of Bridges and Culverts That Influence Bat Use

Characteristics that influence how bats use bridges and culverts include temperature, suitable crevices and cavities, roosting surface, and proximity to water and foraging habitat. As with most roosts, shelter from the wind and rain and reduced predation risks are important factors that govern the selection of bridges and culverts as roosts. Variables such as season, species, sex, age, and breeding condition of individuals also play roles in roost selection.

- Temperature is critical in the selection of both day and night roosts in bridges and culverts. High, stable roost temperatures allow bats to maintain a high body temperature at relatively low metabolic cost, and are especially important in mountainous or arid regions where ambient temperatures fluctuate dramatically on a daily basis (Keeley and Tuttle 1999). Bridges that are exposed to the sun receive the greatest bat use (Keeley and Tuttle 1999). Large, concrete bridges probably provide the most suitable temperature regimes, as they absorb a large amount of heat from solar radiation during the day and retain it through the night (Perlmeter 1996; Pierson and others 1996; Adam and Hayes 2000; Ormsbee and others 2004).
- Bridges and culverts are most useful to bats if they provide crevices or cavities for roosting. Ideal crevices are between 1.2 and 3.2 cm (0.5 and 1.25 in) wide, 30 cm (12 in) or more in depth, and covered at the top (Keeley and Tuttle 1999, 2000). Structures with complex construction often provide suitable crevices or cavities.
- Bridges and culverts with rough textures provide the most suitable roosting surfaces for bats, especially young bats. Older concrete bridges and culverts with irregular surfaces generated by rougher casting forms, weathering, and efflorescence are most likely to provide this feature (Pierson and Erickson 1995; Pierson and others 1996; Keeley and Tuttle 1999).
- Height also offers bats some protection from terrestrial predators. Bats may select bridges that are at least 3 m (10 ft) or more above the ground, and culverts that are between 1.5 and 3 m (5 and 10 ft) tall (Pierson and Erickson 1995; Pierson and others 1996; Keeley and Tuttle 1999).
- Bridges in isolated areas with little ongoing human disturbance beneath the bridges are among the most likely to have bats (Pierson and Erickson 1995; Pierson and others 1996; Keeley and Tuttle 1999).
- Bridges and culverts that are located close to water and foraging areas reduce the energetic costs of commuting (Pierson and Erickson 1995; Adam and Hayes 2000; Arnett and Hayes 2000). Wooden bridges that are coated with creosote may be less likely to be used by bats than those that are not (Adam and Hayes 2000).
- Bridges that are sealed at the top and culverts that are not susceptible to flooding are most suitable for roosting habitat (Pierson and Erickson 1995; Keeley and Tuttle 1999).

Conservation Issues

Because bridges and culverts are manmade structures that are in continuous use by humans, bats that roost in them are often impacted by human activities. Old bridges and culverts that provide roosting habitat are often removed out of concern for human safety or to make way for road and highway improvements (Hickman and others 1999; Tatarian 2001). As these older structures are replaced, the roost is usually lost because modern bridge and culvert designs often do not provide the same roosting potential (Kunz 1982b; Hinman and Snow 2003). Although there are only a few day roosts in Wyoming and the impacts are not known, bats may also be harmed directly during routine road maintenance and repair as tar, water, gravel, or concrete can penetrate through expansion joints or other crevices where they are roosting (Keeley and Tuttle 1999; Entwhistle and others 2001; Hinman and Snow 2003). Because bridges and culverts are usually not surveyed for bats before construction and repair projects begin, transportation personnel may not be aware that bats are roosting in these structures, and their destruction of the roost or the bats themselves is unintentional (Tatarian 2001; SDBWG 2004). However, bats are also vulnerable to intentional vandalism and harassment, especially in bridges that span dry washes or roads that are easily accessible to people (Hinman and Snow 2003).

Best Management Practices for Bridges and Culverts to Benefit Bats in Wyoming

Landowners and land managers can take a variety of simple and inexpensive actions to improve, protect, and preserve habitat for bats. The following Best Management Practices (BMPs) should provide some reasonable guidelines and suggestions for managing bridges and culverts to benefit bats in Wyoming, although, of course, not all of the BMPs will be appropriate in all situations.

1. Protect and maintain bridges and culverts that provide roosting habitat for bats in Wyoming and avoid demolishing or altering them (Oakleaf and others 1996).

2. Take a landscape level approach to management that incorporates roost sites, foraging habitat, and water sources. All of these components of bat habitat must be in close proximity (within several kilometers) for bats to use them efficiently. Avoid the destruction or degradation of bat foraging habitat or water sources near roosts in bridges and culverts.

3. Minimize bat mortality when conducting maintenance, repairs, and renovations on bridges and/or replacing culverts. Before the work begins, conduct surveys to determine whether bats use the structure as a roost (Entwhistle and others 2001). Where possible, time the maintenance activity from October 1 to April 1 and maintain or recreate crevices and roosting areas. Where work must be performed above crevices that are open at the top, covering them with tarps can minimize disturbance (Keeley and Tuttle 1999).

4. Before demolishing or replacing old bridges or culverts, conduct surveys to determine whether bats use them as roosts (Adam and Hayes 2000; SDBWG 2004). If so, consider alternatives to demolition that will conserve them as bat roosts, such as building the new structure nearby and leaving the old one standing (Keeley and Tuttle 1999; Hinman and Snow 2003).

5. Where possible, design and construct new bridges or culverts to enhance the availability of roost sites, particularly new structures that replace older ones that provided bat roosts (Oakleaf and others 1996; Perlmeter 1996; Keeley and Tuttle 1999; Arnett and Hayes 2000). For example, construct bridges with expansion joints or other crevices or cavities that are suitable for bats (Whitaker 1995). Keeley and Tuttle (1999) recommend constructing modified box culverts, called Bat-domed Culverts, to accommodate bat colonies.

6. Provide additional roosting opportunities for bats in existing bridges and culverts with roost potential by retrofitting them with manmade habitats. For example, Arnett and Hayes (2000)

found that boxes installed beneath flat-bottomed bridges can offer additional roosting opportunities to bats, and Keeley and Tuttle (1999) suggest installing habitats such as the Texas Bat-Abode or the Oregon Wedge in existing bridges and concrete culverts.

7. Avoid coating wooden bridges with creosote, which may repel bats (Adam and Hayes 2000).

8. Establish educational programs to increase public awareness about the importance of bridges and culverts as bat roosts, and enlist the Wyoming Department of Transportation and city and county entities responsible for bridge and culvert maintenance and construction as allies in the protection and enhancement of this habitat (Luce 1998; Pierson 1998; Tatarian 2001).

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Forests and Woodlands

Bats are thought to have evolved in association with trees (Racey and Entwhistle 2003), and many bats still depend on forest and woodland habitats for survival. Nearly all of North America's 45 bat species rely on forests to some degree for their roosting or foraging needs (Peters and others 2004; Tuttle and others 2004), and a few species, such as the hoary bat, silver-haired bat, and eastern red bat, are obligate tree-roosting species.

Associated Species

Bat species that may benefit from management of this habitat include the California myotis, western small-footed myotis, long-eared myotis, northern myotis, little brown myotis, fringed myotis, long-legged myotis, Yuma myotis, eastern red bat, hoary bat, silver-haired bat, eastern pipistrelle, big brown bat, spotted bat, Townsend's big-eared bat, pallid bat, Brazilian free-tailed bat, and big free-tailed bat.

Forests and Woodlands in Wyoming

Overall, forests cover about 22% of Wyoming and are found primarily in the mountains, where temperature, moisture, and nutrient conditions enable tree seedling establishment and growth (Knight 1994). The primary types of forests and woodlands in Wyoming include the following.

High Elevation Conifer Forest

High elevation conifer forests occupy some of the coldest and wettest sites in the Rocky Mountains (Green and Conner 1989). The transition between mid and high elevation habitat occurs between 2400 and 2700 m (8000 and 9000 ft), depending on moisture levels and location within the state, and extends up to timberline [at about 3400 m (11,000 ft)] (Green and Conner 1989). High elevation conifer forests are usually dominated by Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), and, to a lesser extent, whitebark pine (*Pinus albicaulis*) (Knight 1994).

Mid Elevation Conifer Forest

Mid elevation conifer forests occur between about 1800 and 3200 m (5900 and 10,500 ft) in northern Wyoming and 2130 to 3500 m (7000 to 11,500 ft) in southern Wyoming (Knight 1994). These forests can be pure or mixed stands including lodgepole pine (*Pinus contorta*), limber pine (*P. flexilis*), Douglas-fir (*Pseudotsuga menziesii*), blue spruce (*Picea pungens*), and/or ponderosa pine (*Pinus ponderosa*). Lodgepole pine is most common and can cover extensive areas; it covers more acres than any other forest type in Wyoming (Green and Conner 1989).

Low Elevation Conifer Forest

At about 1200 to 2500 m (4000 to 8500 ft), the low elevation conifer forests of eastern Wyoming are dominated by ponderosa pine. However, ponderosa pine is absent from the foothill woodlands of western Wyoming, which are dominated by Douglas-fir (Green and Conner 1989; Knight 1994). Limber pine is also common in the low elevation woodlands (Knight 1994).

Juniper Woodland

The 2 major species of juniper in Wyoming are Utah juniper (*Juniperus osteosperma*) and Rocky Mountain juniper (*J. scopulorum*). In eastern Wyoming, Rocky Mountain juniper occurs in ravines or where summer precipitation is higher. Utah juniper occurs in escarpments in the more arid basins of western Wyoming. The elevation range of juniper in Wyoming is 1220 to 3050 m (4000 to 10,000 ft), but it generally occurs below 1830 m (6000 ft) on very dry, sandy, or rocky soils. Juniper woodland in Wyoming is configured in a naturally patchy distribution, and usually exists in a mosaic with sagebrush-grassland habitats. Juniper stands with large, old trees are rare (Green and Conner 1989; Knight 1994; Pavlacky 2000).

Aspen

About 190,000 ha (467,000 ac) of aspen occurs throughout Wyoming's major mountain ranges, from the foothills to the subalpine zone. It typically grows in depressions, ravines, and valley bottoms, or on the lee sides of ridges, where snow accumulates, and where moister and better-developed soils occur. Aspen usually occurs in small groves and scattered stands, although extensive forests can be found in a few areas, such as the west slope of the Sierra Madre (Green and Conner 1989; Knight 1994).

Forests and Woodlands as Bat Habitat

Forests and woodlands provide maternity roosts and other day roosts, hibernacula, night roosts, foraging habitat, and migratory corridors for bats.

Tree Roosts

Although only a few bat species are obligate tree-roosters, many populations within forested landscapes may be dependent on tree roosts. Even those bat species that are most commonly associated with manmade structures, such as big brown bats and little brown myotis, rely heavily on tree roosts in some areas. Tree roosts may also be important for some species that are generally associated with caves, abandoned mines, or other roost structures (Pierson 1998). For example, some bats hibernate in caves during winter but roost in trees during summer (Miller and others 2003).

The major types of tree roosts used by temperate bats include cavities in snags or live trees; crevices behind exfoliating bark, within very rough bark, and in wood; and foliage. Cavity roosts generally provide a relatively stable microclimate and offer protection from predators. Bark roosts provide a more abundant but much less permanent, less secure, and less thermally-stable roosting environment than cavities, and bats that roost in bark often must change roosts more frequently, often daily or weekly. Foliage roosts are the most exposed types of tree roosts, but their abundance makes them easy to find near foraging areas, and might help to reduce commuting distance (Wunder and Carey 1996). Tree-roosting bats usually roost either alone or in small family groups (Kunz and Lumsden 2003).

Foraging Habitat

Forests and woodlands are also important as foraging habitat for bats. Some insect species, including many moths (Lepidoptera), that bats rely on for food reproduce on the shrubs, trees, and flowering plants of the forest environment, making it an important source of insect prey (Grindal and Brigham 1998; Altenbach and others 2002). Bats that feed by gleaning insects from the surfaces of vegetation are particularly dependent on forests and woodlands for foraging (Entwhistle and others 2001). Forests are also more sheltered and often warmer than open environments, giving valuable cover to slow, maneuverable bats that avoid open areas (Entwhistle and others 2001). However, even though many bats are not maneuverable enough to forage directly within the clutter of forest vegetation, most are able to or even prefer to forage in or near the features associated with forest habitat (Grindal 1996). For example, open meadows and water features within the forest, forest edges, and the space above the canopy are important foraging areas for many bats, not just the slow, maneuverable species (Grindal 1996; SDBWG 2004).

Characteristics of Forests and Woodlands That Influence Bat Use

Physical characteristics that influence how bats use forests and woodlands include abundance and suitability of snags; forest age, structure, and composition; elements within the forest such as openings, edges, and water features; and proximity of roosts, foraging habitat, and water. A mosaic of habitat types and elements provides optimal habitat for some bat species and encourages bat use and diversity (Krusic and Neefus 1996; Wunder and Carey 1996).

Each of the following characteristics is applicable only within the context of forest type and all the other characteristics of forests and woodlands that influence bat use. For example, old-growth forests are of great importance to many bats, but providing large amounts of old growth only in high elevation conifer forests, which is of limited importance to bats, is unlikely to benefit a large proportion of the bat population.

Snags and Large Trees

Snags increase bat density and diversity by providing roost sites that are ideal for many species. Many snags contain cavities, crevices, and exfoliating bark that are important features for some maternity colonies and other bat roosts, and may play a vital role in the distribution and abundance of some bat species and populations (Mattson and others 1994). Many live trees also provide these features. Bats probably do not discriminate between tree species, but select trees based on the specific characteristics of the roosts they provide (Kunz and Lumsden 2003). In general, roost trees and snags increase in value to bats if they have the following characteristics:

- Large size, including both diameter and height (Betts 1996; Weller and Zabel 2001). Large trees are more likely to contain cavities, are better insulated and maintain a stable microclimate, may be tall enough to be warmed by the sun, and remain standing longer after death (Betts 1996; Vonhof 1996; Kunz and Lumsden 2003).

- Loose or exfoliating bark (Herder 2000a).
- Early to middle stages of decay (Barclay and Brigham 2001; Racey and Entwhistle 2003).
- Abundant within the stand. Because foliage, bark, and even tree cavities are ephemeral, and because the microhabitat needs of individual bats change over the course of a season, bats often require several suitable roost trees throughout each breeding season (Brigham and Barclay 1996; Kurta 2000). Rather than showing loyalty to a particular tree in the way colonies show fidelity to cave, abandoned mine, and building roosts, tree-roosting bats often move frequently—often daily or weekly—among a number of trees, generally within a relatively small area (Pierson 1998). Therefore, tree-roosting bats require forest stands that contain clumps of suitable snags and trees, and the local abundance and distribution of roosts may be as important as the microhabitat each provides (Pierson 1998). For these reasons, bats often require higher densities of snags than birds, and the traditional estimates of snags required to maintain cavity-nesting birds are probably not sufficient for bats (Crampton and Barclay 1996; Brigham and others 1997; Hinman and Snow 2003; Keinath 2004).
- Surrounded by forested habitat. Since roosts are generally in less-dense microsites in otherwise contiguous mature forest, snags left in clearcuts will not provide habitat for bats as it does for some cavity-nesting birds (Keinath 2004).

Old Growth

Old-growth forests appear to be of great importance to bats, which may be 3 to 10 times more abundant in old growth than in younger forests (Thomas 1988). The natural characteristics of old-growth forests provide many of the features that forest-dwelling bats require without the necessity of additional management or enhancement. These features include abundant, long-standing snags in a variety of decay classes; structural and tree species diversity; large-diameter snags and trees; patchiness and gaps, and thus more edges; and low tree densities and clutter (Thomas 1988; Thomas and others 1988; Crampton and Barclay 1996; Vonhof 1996). Structural characteristics of old live trees, such as cracks and crevices in thick bark, bark pulling away from the trunk, and cavities in the bole where limbs have been shed, offer many potential roosting sites (Christy and West 1993).

Deciduous Trees

For some bat species, deciduous trees may be an important element of the forest. Deciduous trees support a different suite of insects and have a higher density of cavities than conifers. Ober and Hayes (2004) suggest that bat activity increases as the proportion of deciduous vegetation bordering streams increases and that moth abundance and diversity is greater in deciduous woodlands than in coniferous woodlands.

Water Features within the Forest

Some bats that roost in forests require water features within or adjacent to the forest for foraging and/or drinking. Therefore, open water may provide a critical element for bats in many forests (Christy and West 1993). Thomas (1992) found that bats forage 10 times more commonly over streams and ponds than in the forest interior, and that insects are more abundant over water than inside forest stands. Bats may also use linear features such as streams for commuting (Briggs 1998; Racey and Entwhistle 2003).

Small Openings within the Forest

Tree-roosting bats often select roosts that are in microsites that are less dense than the surrounding forest (Keinath 2004) or that are close to small forest openings (Herder 2000a). Such roosts are heated by the sun and benefit reproductive females and juveniles energetically; are more accessible to bats in flight, which reduces the risk of predation; and are conspicuous and easy for bats to find (Vonhof 1996; Weller and Zabel 2001; Kunz and Lumsden 2003). Also, bats that roost in the forest often forage over small openings and meadows within the forest, perhaps because insects are more abundant in these areas and because some bats are unable to maneuver well in very cluttered habitats (Crampton and Barclay 1996; Erickson and West 1996).

Forest Edges

Forest edges are important to many bats, both as foraging and commuting corridors (Brigham and Barclay 1996). Edges are less cluttered than interior forest, making foraging and commuting easier and serving as navigational aids. Also, insect abundance and density may be higher along edges, particularly the lee edge, than in open habitat or in the forest. Even when insect abundance is higher in open areas, some bats choose to forage near edges, perhaps to avoid predation or wind (Crampton and Barclay 1996; Adams 2003). Even bats that do not otherwise use the forest habitat may take advantage of the benefits that forest edges provide.

Proximity of Habitat Elements and Corridors of Habitat

Forests and woodlands are especially valuable when they provide roosts, foraging habitat, and water in close proximity, so that the energetic costs of commuting are reduced (Wunder and Carey 1996). Some bats may also require connecting corridors of forest habitat, such as riparian woodland corridors or hedgerows, between critical resources (Wunder and Carey 1996; Racey and Entwhistle 2003).

Bat Habitat in Wyoming's Forests and Woodlands

Conifer Forest

Because high elevation forests tend toward dense, homogeneous stands and low nighttime temperatures result in low nocturnal insect activity, they are often low in bat diversity. However, this habitat may be important to overwintering bats because many species migrate to higher elevations to find suitable hibernacula. Also, high elevation forests may provide resources for bats that breed near their winter roosts before entering hibernation (Adams 2003).

Mid and low elevation conifer forests are usually more diverse and provide more roost sites than high elevation forests. However, some types of mid elevation stands, especially lodgepole pine, sometimes form pure, dense, "doghair" stands of trees with small diameters and slow rates of growth; stands in this condition probably do not provide ideal bat habitat (Green and Conner 1989).

Juniper Woodland

Juniper woodlands provide unique and valuable foraging and roosting habitat for several bat species. The structural diversity, shrub understory, and other vegetation in most juniper woodlands provides high insect diversity and important foraging habitat for bats. The multi-stemmed juniper growth form produces a large number of natural cavities where the stems meet, and the more tree-like, single-stemmed growth form is a common substrate for woodpeckers to excavate cavities, which are important for cavity-roosting bats. Also, the steep cliffs and canyons that are common in juniper woodlands provide many opportunities for rock- and crevice-roosting bats (Altenbach and others 2002; Adams 2003).

Aspen

The greatest resources that aspen woodlands provide for bats are cavities for roosting. Aspen trees over 40 years of age almost always harbor heart rot while they are alive, and provide excellent conditions for primary cavity excavators (such as woodpeckers) and natural-cavity formation. Consequently, primary cavity excavators exhibit strong preferences for aspen in many areas, and aspen trees likely provide the greatest number of suitable cavities for roosting bats (Vonhof 1996). Under certain conditions, the temperature differences between cavities in live aspen trees and conifer snags may make aspens even more suitable as roosts for bats than snags (Kalcounis and Hecker 1996).

Conservation Issues

Forest management practices that favor even-age monospecific stands; short rotation times; a decreased proportion or altered structure of old growth on the landscape; and selective removal of snags and older, larger trees reduce the availability of roosting habitat and constitute the greatest threat for tree-dwelling bat species (Crampton and Barclay 1996; Pierson 1998; Jung and others 1999; Menzel and others 2000; Kunz and Lumsden 2003). While some snags are usually retained in timber harvest, the numbers are probably too low to accommodate the needs of cavity-dwelling wildlife, and there is often no retention of green trees to serve as future snags (Pierson 1998). Also, many snags are lost to firewood cutting (Luce 1998) and salvage logging. In addition to timber harvest, a number of other activities in forests can affect bats, including livestock grazing, prescribed fire, fire suppression, fuels management, pesticide use, and recreation (Hinman and Snow 2003; Hayes and Loeb 2004).

In high elevation conifer forests, recent increases in the growth and density of trees have been documented throughout western North America. The pattern of communities is becoming more homogeneous; old communities are maintained, while adjacent communities that were once young are now becoming old. These stands have greater vulnerability to insects and stand-replacing fire than the mosaic stand condition. Whitebark pine has been reduced throughout its range by disease epidemics and successional replacement by other conifers. In mid elevation conifer forests, fire suppression has precluded the initiation of new stands and caused a change in the distribution of age classes. In low elevation conifer forests, intense logging has fragmented the mature forest landscapes that were present historically, and extremely dense stands dominated by younger trees have developed.

Although pinyon-juniper woodlands have expanded in many western states over the last century, juniper woodland makes up a mere 2.2% of land area in Wyoming (287,000 ha [709,000 ac]) (Green and Conner 1989), and is a unique community with significant conservation value. Many bat species could be threatened by extensive tree removal, soil erosion, or by cessation of natural juniper stand rejuvenation, primarily through fire suppression (Pavlacky 2000).

Modern fire suppression practices and drought conditions have contributed to a loss of aspen stands and the decline of aspen regeneration in Wyoming and throughout the mountain West. Remaining stands are often decadent and approaching their maximum age. As aspen sprouts become less common, livestock and big game in need of browse concentrate on those that remain, which can lead to their further deterioration (DeByle and Winokur 1985; Knight 1994).

Best Management Practices for Forests and Woodlands to Benefit Bats in Wyoming

Landowners and land managers can take a variety of simple and inexpensive actions to improve, protect, and preserve habitat for bats. The following Best Management Practices (BMPs) should provide some reasonable guidelines and suggestions for managing forests and woodlands to benefit bats in Wyoming, although, of course, not all of the BMPs will be appropriate in all situations.

1. Protect and preserve large tracts of forests and woodlands that provide important roost and foraging resources for bats (Kunz and Lumsden 2003). If possible, leave at least 90% of the existing forest/woodland canopy in every watershed where bats are likely to occur (Altenbach and others 2002). If it is possible to retain only a limited amount of timber from harvest, preserve it in relatively large tracts of late-successional forest, rather than spread out across the landscape (Taylor 1999).

2. Manage for vertical and horizontal heterogeneity, multiple layers of native plants, and variety of age classes in forest and woodland habitats to provide habitat for a diverse insect community and to provide a variety of roosting opportunities for bats (Hutchinson and Lacki 2000; Waldien and others 2000; SDBWG 2004; Tuttle and others 2004). However, avoid fragmenting large tracts of forest or sacrificing old-growth and mature stands (Keinath 2004).

3. Within extensive areas of forest habitat, manage for a patchwork or mosaic of different communities across the landscape. Wet meadows, bare ridges, and other openings; aspen stands; linear elements such as trails, forest roads, and riparian corridors; and interspersed shrub habitats may provide the mosaic of habitats that encourage bat use and diversity (Krusic and Neefus 1996; Entwhistle and others 2001).

4. Protect and maintain water features within forest and woodland habitat to provide a source of water for bats, as well as important foraging habitat and migration and commuting routes (Chung-MacCoubrey 1996a; Krusic and Neefus 1996; Entwhistle and others 2001).

5. Provide small-scale openings in forests and woodlands to improve foraging habitat for bats (Grindal and Brigham 1998). Many bats prefer to forage and commute along forest edges, so any openings should have a high ratio of edge to open area (Crampton and Barclay 1996; Fenton 1997). However, openings should not be too large (7.3 ha [18 ac] or less); the forest should not become fragmented (Krusic and Neefus 1996); and large trees, snags and older forest should be retained (Krusic and others 1996; Perdue and Steventon 1996).

6. Avoid clearcutting in forests and woodlands. Although small-scale openings that contribute to a mosaic of habitats can be beneficial to bats, clearcutting on a larger scale has a negative effect on bats that roost in trees and forage in forest interiors, and on insects that reproduce in forests (Fenton 1997; Vonhof and Barclay 1997; Grindal and Brigham 1998). Even if trees are retained within clearcuts, they often do not provide the thermal characteristics and protection from predators that bats require (Vonhof 1996).

7. Conduct pre-harvest bat inventories to document bat use and habitat inside proposed timber harvest boundaries and firewood-cutting areas, and evaluate the impact of harvest on bat foraging and roosting habitat (Oakleaf and others 1996).

8. Retain trees known to be used by bats for roosts (Briggs 1998). The reuse of trees by bat colonies and the use of some trees more heavily than others suggest that some bats do exhibit long-term fidelity to trees, and emphasize the importance of protecting existing roost trees (Chung-MacCoubrey 2003).

9. Establish a 0.4-km (0.25-mi) radius buffer zone around all bat roosts, within which timber management activities should not occur. Whenever activities must occur within this buffer zone, even when the roost is unoccupied, provide a minimum 150-m (500-ft) radius buffer of intact forest around roosts, to avoid altering airflow and thermal regimes in the roost (Ormsbee 1996; Pierson and others 1999; Keinath 2004).

10. Regardless of the motivation for altering forest habitat, retain all snags, dead-topped trees, and live trees with cavities under any cutting method (Miller and others 2003). In particular, avoid cutting snags that already show evidence of bat use. Because bats often require multiple tree roosts throughout the year and even throughout the breeding season, a substantial number of snags must be preserved. Although we do not yet know the number of sites required to support a population in a given area, traditional estimates of snags required to maintain cavity-nesting birds are probably not sufficient for bats (Crampton and Barclay 1996; Brigham and others 1997; Hinman and Snow 2003). Oakleaf and others (1996) suggest preserving all snags used by bats, all soft snags, and at least 6 hard snags per ha (2.5 per ac). Mattson and others (1994) and the South Dakota Bat Working Group (2004) recommend higher snag densities of at least 21 per ha (8.5 per ac).

11. Manage for the largest snags possible; larger snags remain standing longer, retain bark longer, contain larger cavities and more cavities per snag, and support a greater variety of wildlife. Bats usually prefer to roost in snags that are at least 10 m (33 ft) in height and 35 cm (14 in) in dbh (Mattson and others 1994; Crampton and Barclay 1996). In addition, manage for

snags that are in early and middle stages of decay, that are concentrated in clusters, that are easily accessible to bats, and that have moderate to high levels of exposure to solar radiation (Waldien and others 2000; Kunz and Lumsden 2003)

12. Retain an abundance of live trees of various ages to replace existing snags over time and maintain snag densities in the future (Mattson and others 1994; Waldien and others 2000; Keinath 2004).

13. Where possible, avoid post-fire salvage logging. Salvage and sanitation logging and debris disposal remove snags and snag recruits that provide roosting sites for bats (Chung-MacCoubrey 1996a). Where salvage logging is inevitable, remove trees from 1 area of the burn only, leaving another representative area intact that retains the full complement of snag sizes and densities (SDBWG 2004).

14. Protect snags from firewood cutting (Chung-MacCoubrey 1996a), especially tall, large-diameter snags or those in areas with few snags. To reduce the pressure on snags, make logging slash available to wood gatherers and, if necessary, limit firewood cutting in certain areas, limit cutting to snags less than a minimum dbh (Schmidt 2003), limit cutting to downed material only, and/or implement road closures and obliteration to limit access to snags. In particular, avoid fuelwood harvest in the vicinity of known maternity roosts during the late spring and summer.

15. Maintain all old-growth stands where they exist, and ensure the presence of multiple stages of mature forest on the landscape (Crampton and Barclay 1996; Humes and others 1999; Jung and others 1999; Waldien and others 2000).

16. Provide for the development of future old growth by lengthening rotation cycles and leaving areas unharvested for 100 to 200 years or more (Thomas and others 1988; Jung and others 1999). If forest stands are intensively managed or are on a relatively short rotation cycle, the number of large, older trees that are suitable for roosting will decrease (Vonhof 1996).

17. Retain large trees for bats during forest management activities (Betts 1996). Large live trees are important roosting structures for bats and also provide future replacements for snags (Miller and others 2003; SDBWG 2004). According to Vonhof (1996), bats may roost as readily in second-growth stands in which large trees were retained as in older-aged stands. On the other hand, timber harvest has been associated with a decline in abundance of bats when large roost trees are removed (Campbell and others 1996).

18. Use thinning, defined as the reduction in density of overstory trees through removal of selected trees (Humes and others 1999), to create habitat structure in young stands that bats are able to use more effectively and as an alternative to clear-cutting (Campbell and others 1996; Vonhof 1996; Adams 2003). Thinning can accelerate the development of structural characteristics typically found in old-growth stands (Humes and others 1999; Waldien and others 2000); preserve the largest and most valuable roost trees and snags (Vonhof 1996; Humes and others 1999; Lacki and Schwierjohann 2001); reduce the level of clutter in dense, second-growth stands (Vonhof 1996); and create natural gaps in the canopy to favor bat species that forage in more open habitats (Jung and others 1999; Waldien and others 2000).

19. Use periodic, low-intensity prescribed burns in forests and woodlands to help maintain a more open habitat over time (Vonhof 1996), reproduce the natural disturbance regime of forests (Krusic and Neefus 1996), reduce fuel loads that could lead to catastrophic fires (Hinman and Snow 2003), and increase habitat heterogeneity (Keinath 2004). Ideally, the number of trees killed in each prescribed burn should equal or exceed the number of snags consumed by the fire (Herder 2000a; Keinath 2004).

20. In the vicinity of known maternity colonies, conduct restoration or management activities such as prescribed burning, forest thinning, firewood cutting, livestock grazing, and pesticide application during the non-breeding season (October 1 to April 1). The breeding season is a critical period for the maintenance of bat populations, and some management activities can have serious consequences for maternity colonies by destroying roosts and foraging habitat or causing roost abandonment (Briggs 1998; Pierson and others 1999; Keinath 2004).

21. Maintain, restore, and regenerate aspen stands within coniferous forests. Aspen trees host a different suite of insects and have a higher density of cavities than conifers. In particular, protect large stands of aspen trees, which are strongly preferred by bats and primary cavity excavators (Vonhof 1996).

22. Manage forests and woodlands to conserve or increase diverse insect populations. Small openings, trails, dead wood, road edges with shrubs and grasses, and deciduous trees are some examples of habitats that support diverse insect populations (Vaughan and others 1997).

23. Limit the use of pesticides in forests and woodlands. Where possible, use silvicultural strategies to reduce the amount of susceptible hosts and to reduce the need for pesticides. Use species-specific control measures, such as pheromone confusants and sterile male release, rather than nonspecific measures. Where pesticides are necessary, use them as part of an Integrated Pest Management (IPM) program (Oakleaf and others 1996; Pierson and others 1999).

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Grasslands and Shrub-steppe

Most people do not associate bats with grasslands and shrub-steppe habitats, and little is known about how bats use these habitats. Nevertheless, even though bat diversity is probably limited by the lack of habitat complexity in grasslands and shrub-steppe, these habitats do serve as important foraging and even roosting areas for some bat species (Chung-MacCoubrey 1996b; Adams 2003; Hinman and Snow 2003). Bats that inhabit grassland and shrub-steppe habitats are usually species that are adapted to xeric landscapes, such as the western small-footed myotis, California myotis, and pallid bat (Chung-MacCoubrey 1996b; Adams 2003).

Associated Species

Bat species that may benefit from management of this habitat include the California myotis, western small-footed myotis, long-eared myotis, fringed myotis, Yuma myotis, big brown bat, spotted bat, Townsend's big-eared bat, pallid bat, and Brazilian free-tailed bat.

Grasslands and Shrub-steppe in Wyoming

Grasslands

Most grasslands in Wyoming are classified as mixed-grass or shortgrass prairie. The most extensive grasslands in Wyoming occur east of the Rocky Mountains on the western Great Plains and in several intermountain basins, from a low of 964 m (3160 ft) in the northeast to about 2190 m (7185 ft) in the Shirley and Laramie basins. The grassland environment is characterized by fire, extended periods of drought, the presence of large herbivores, and a short growing season. These factors have led to vegetation composed largely of perennial grasses, a substantial number of sedges (*Carex* spp.) and herbaceous forbs, and often small shrubs (Knight 1994).

Shrub-steppe

The intermountain basins to the west of the Great Plains in Wyoming are characterized by a mosaic of shrublands. Wyoming big sagebrush (*Artemisia tridentata wyomingensis*) is the most widespread shrub, but other common shrubs include greasewood (*Sarcobatus vermiculatus*), saltbush (*Atriplex* spp.), and rabbitbrush (*Chrysothamnus* spp.). Compared to grasslands, the distinguishing features of shrub-steppe ecosystems are the presence of conspicuous shrubs and a larger proportion of the annual precipitation occurring in the winter. Otherwise, grasslands and shrub-steppe are similar—plant growth is limited by water availability and the length of the growing season, and most of the biomass and herbivory is below ground (Knight 1994).

Grasslands and Shrub-steppe as Bat Habitat

Foraging Habitat

Grassland and shrub-steppe habitats often produce a high density and diversity of insects (Entwhistle and others 2001; Adams 2003). Therefore, these habitats can serve as important foraging habitat for bats, even if they are some distance away from suitable roosting habitat.

Their mobility allows bats to utilize habitats and patches of resources that are separated by significant distances (Chung-MacCoubrey 1996b). Open areas provide especially good foraging habitat for those bat species that are less maneuverable in cluttered environments (Hinman and Snow 2003). The edges of these habitats near wooded areas, cliffs, or other features are also important to some of the smaller, more maneuverable bat species.

Roosting Habitat

Even though grassland and shrub-steppe habitats usually contain less vertical structure and complexity than other bat roosting habitats, they often encompass patches of other habitat types that provide diverse and abundant roost sites (Chung-MacCoubrey 1996b). Bat roosts within grasslands and shrub-steppe may include rock outcrops, talus slopes, cliffs, caves, abandoned mines, bridges and other manmade structures, and trees that occur within the habitat (Chung-MacCoubrey 1996b; Adams 2003; Hinman and Snow 2003). Their small size allows bats to exploit even very small and inconspicuous shelters as roosts, such as crevices in and under rocks, and holes in the ground (Chung-MacCoubrey 1996b). In addition, some shrubs may provide night roosts that allow bats to remain close to foraging habitat throughout the night, although shrubs are probably not suitable as day roosts, since they provide little protection from predators, temperature extremes, or wind (Hirshfeld and others 1977).

Characteristics of Grasslands and Shrub-steppe That Influence Bat Use

Grassland and shrub-steppe ecosystems increase in value to bats if they provide abundant and diverse insect resources, if roosts and water are available within or near the habitat, and if they contain linear habitat elements.

- Bats require an abundance and variety of insect species with different hatching cycles to insure a continuous food supply (McCracken 1988). Diverse habitat that has not been converted to monocultures of cropland or nonnative vegetation provides the most ideal insect resources (McCracken 1988; Fenton 1997; Pierson and others 1999; Bogan 2000).
- Grasslands and shrub-steppe ecosystems are especially valuable when roost and water resources are available within the habitat or nearby (Chung-MacCoubrey 1996b; Adams 2003; Hinman and Snow 2003).
- Linear elements such as grassland/woodland edge, riparian corridors, hedgerows, and ditches often support high densities of foraging bats. These habitat elements probably aid in orientation for commuting and foraging bats, attract insects, and provide shelter from wind and/or predators (Entwhistle and others 2001; Hinman and Snow 2003; Racey and Entwhistle 2003).

Conservation Issues

Throughout the West, grassland and shrub-steppe habitats have been greatly altered by nearly 2 centuries of settlement, livestock grazing, agriculture, minerals development, invasion by nonnative vegetation, and changes in wildfire frequency, often resulting in a more homogeneous landscape with lower species diversity (Knight 1994; Chung-MacCoubrey 1996b; Hinman and Snow 2003). In Wyoming, grassland and shrub-steppe habitats have remained largely intact, although many of these activities may pose potential threats to bats. Little research has been conducted to determine how these activities may benefit or adversely affect bats that use grassland and shrub-steppe habitats, so the effects of human activities on bats can only be speculated based on how they affect the known resource requirements of bats (Chung-MacCoubrey 1996b). In Wyoming, natural resource extraction, such as coalbed methane, is a concern, as it may cause changes to the habitat over a large area, such as reduced water quality and habitat fragmentation, but it is not known how these changes may affect bats. In addition, pesticides and other environmental contaminants can reduce the insect resources available to bats and can accumulate to harmful levels in the fatty tissues of bats. On the other hand, human development in grassland and shrub-steppe habitat has provided additional water sources to bats via stock ponds and irrigation ditches and may have balanced the loss of natural roosts or even increased the abundance of roosts by providing buildings, bridges, abandoned mines, planted trees, and so on (Chung-MacCoubrey 1996b; Adams 2003).

Best Management Practices for Grasslands and Shrub-steppe to Benefit Bats in Wyoming

Landowners and land managers can take a variety of simple and inexpensive actions to improve, protect, and preserve habitat for bats. The following Best Management Practices (BMPs) should provide some reasonable guidelines and suggestions for managing grasslands and shrub-steppe to benefit bats in Wyoming, although, of course, not all of the BMPs will be appropriate in all situations.

1. Protect and preserve native grasslands and shrub-steppe habitats that provide important roost and foraging resources for bats. Limit their use and development wherever necessary and possible, and avoid practices that degrade or alter them.

2. Take a landscape level approach to management that incorporates roost sites, foraging habitat, and water sources. All of these components of bat habitat must be in close proximity (within several kilometers) for bats to use them efficiently (Keinath 2004).

3. Manage for diverse grasslands and shrub-steppe habitats with a wide variety of vegetation species and conditions. On a landscape level, use livestock grazing, fire, and mowing together to produce a mosaic of habitat patches (Entwhistle and others 2001; Hinman and Snow 2003). Avoid creating monocultures of nonnative grassland or farmland (McCracken 1988; Fenton 1997).

4. Manage grasslands and shrub-steppe to conserve or increase diverse insect populations (Anonymous 1999).

5. Within extensive areas of grassland and shrub-steppe habitat, protect and maintain a patchwork or mosaic of potential roosts across the landscape. Many bats that forage in grasslands and shrub-steppe utilize roosts within the habitat, such as caves, abandoned mines, rock shelters, trees, buildings, and bridges (Entwhistle and others 2001; Hinman and Snow 2003). Avoid development, vegetation conversion, or other disturbances near known roost sites.

6. Protect and maintain water features within grasslands and shrub-steppe to provide a source of water for bats, as well as insect production and foraging habitat (Chung-MacCoubrey 1996b; Entwhistle and others 2001).

7. Preserve and protect linear features within grassland and shrub-steppe habitat, especially those that occur naturally. Linear features such as grassland/woodland edge, riparian corridors, cliffs, and natural vegetation between cultivated fields can aid in orientation for commuting and foraging bats, provide habitat for insects, and provide shelter from wind and/or predators (Entwhistle and others 2001; Everette and others 2001; Racey and Entwhistle 2003).

8. Limit the use of pesticides in grasslands and shrub-steppe. If pest control is necessary, use the principles of Integrated Pest Management (IPM) to target specific insect pests, avoid the loss of non-target insects that are food for bats, and minimize exposure of bats to harmful chemicals (Oakleaf and others 1996; Pierson and others 1999; Entwhistle and others 2001).

9. Where grassland or shrub-steppe habitat has been converted to cultivated farmland, improve the habitat for bats by leaving grassy strips and natural areas between fields, expanding field margins, retaining crop residue, and enhancing farmland diversity (Entwhistle and others 2001; Hinman and Snow 2003; Nicholoff 2003).

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<u>Riparian Corridors</u>

Riparian corridors provide some of the most important habitat for bats (Hayes and Adam 1996; Wunder and Carey 1996; Grindal and others 1999; Adams 2003). Grindal and others (1999) found that bat activity is about 40 times greater in riparian habitat than in upland areas. Riparian landscapes often provide hospitable habitat corridors through otherwise open and exposed terrain, particularly in the plains and basins of Wyoming (Knight 1994; Adams 2003). These habitats provide water for drinking, roosting habitat, foraging habitat, and travel corridors for bats. Even bats that primarily use other habitats for roosting, such as coniferous forests or caves, often rely on riparian corridors for foraging and drinking (Altenbach and others 2002).

Associated Species

Bat species that may benefit from management of this habitat include the California myotis, long-eared myotis, northern myotis, little brown myotis, fringed myotis, long-legged myotis, Yuma myotis, eastern red bat, hoary bat, silver-haired bat, eastern pipistrelle, big brown bat, spotted bat, Townsend's big-eared bat, pallid bat, and Brazilian free-tailed bat.

Riparian Corridors in Wyoming

Riparian corridors occur adjacent to rivers, streams, and large irrigation channels and are often characterized by tree-dominated woodlands at both high and low elevations. The greatest vegetation diversity is found in the riparian systems of the plains and basins of Wyoming, where plains cottonwood (*Populus deltoides*), the most abundant riparian tree, occurs with green ash (*Fraxinus pennsylvanica*), boxelder (*Acer negundo*), lanceleaf cottonwood (*Populus acuminate*), willow (*Salix* spp.), elderberry (*Sambucus* spp.), buffaloberry (*Shepherdia* spp.), introduced Russian olive (*Elaeagnus angustifolia*), American elm (*Ulmus americana*), snowberry (*Symphoricarpos* spp.), chokecherry (*Prunus virginiana*), and Virginia creeper (*Parthenocissus vitacea*). At higher elevations, narrowleaf cottonwood (*Populus angustifolia*), Engelmann spruce (*Picea engelmannii*), lodgepole pine (*Pinus contorta*), aspen (*Populus tremuloides*), willow, alder (*Alnus* spp.), dogwood (*Cornus* spp.), mountain maple (*Acer glabrum*), and water birch (*Betula occidentalis*) dominate the riparian zones (Green and Conner 1989; Knight 1994; Nicholoff 2003).

Riparian Corridors as Bat Habitat

In general, habitats increase in value to bats when they provide roosts, foraging habitat, and water in close proximity, so that the energetic costs of commuting are reduced. Many riparian corridors provide all 3 of these habitat components, as well as travel corridors for commuting and migrating, making them extremely valuable habitats for bats.

Water Sources

A major benefit that riparian areas provide for bats is the availability of drinking water. Bats require an adequate amount of water daily for survival and most species must have access to open water surfaces where they can drink in flight (Tuttle 1996a). Depending on accessibility, size, surrounding vegetation, and whether they are ephemeral or perennial, rivers and streams provide a large proportion of the drinking water for bats (Altenbach and others 2002; Hinman and Snow 2003).

Foraging Habitat

Riparian corridors also provide important foraging habitat for many bats. Many insect species breed in and emerge from the water, and bats such as the little brown myotis and the Yuma myotis feed directly over the water's surface on these aquatic insects (Pierson 1998; Grindal and others 1999). Also, high quality riparian habitat supports a much richer insect fauna than surrounding upland areas and provides valuable cover for foraging bats (Wunder and Carey 1996; Vaughan and others 1997; Seidman and Zabel 2001). Many bat species, such as the Townsend's big-eared bat and the pallid bat, will follow stream corridors and forage within the broad riparian zone, and some species, such as the long-eared myotis, forage primarily within riparian habitats (Pierson 1998).

Roosting Habitat

Riparian corridors provide potential roosting habitat for a variety of bat species. The riparian zone is often characterized by tree-dominated woodlands that contain abundant snags, mature trees with loose bark, and deciduous trees that provide shelter for tree-roosting bats (Wunder and Carey 1996; Martin and Kiser 2004). Riparian corridors also often contain rock crevices, eroded stream banks, and cliffs that provide roosts (Wunder and Carey 1996; Hinman and Snow 2003). In addition, some bat species will preferentially select roosts in riparian corridors because of their proximity to water (Entwhistle and others 2001).

Travel Corridors

Bats frequently use riparian corridors as both daily commuting and seasonal migratory routes, even when streambeds are dry (Wunder and Carey 1996; Hinman and Snow 2003). The linear habitat probably aids bats in orientation and provides shelter from wind and/or predators (Racey and Entwhistle 2003).

Characteristics of Riparian Corridors That Influence Bat Use

Physical characteristics that influence how bats use riparian corridors include structure and composition of the vegetation, abundance and suitability of snags and other roosts, availability of water, and water quality. A mosaic of habitat types and elements provides optimal habitat for some bat species and encourages bat use and diversity (Krusic and Neefus 1996; Wunder and Carey 1996).

- The structure and composition of the vegetation in the riparian zone is an important component of bat habitat. A diverse, productive riparian zone provides abundant insect prey, roosts, and protection from predators; and improves foraging conditions by blocking wind (Vaughan and others 1997; Hinman and Snow 2003). Deciduous trees, old growth, and vertical vegetation structure are all habitat components that benefit bats (Thomas 1988; Tuttle 1996a; Ober and Hayes 2004).

- Large-diameter, tall snags and old live trees with thick, exfoliating bark and cavities increase bat density and diversity by providing roost sites that are ideal for many species (Christy and West 1993; Betts 1996; Brigham and Barclay 1996; Vonhof 1996; Pierson 1998; Barclay and Brigham 2001; Weller and Zabel 2001). Riparian corridors that also contain rock crevices, eroded stream banks, and cliffs provide roosts for a variety of bats (Wunder and Carey 1996; Hinman and Snow 2003).
- Because bats drink while in flight, streams must be uncluttered and large enough for bats to approach and skim the surface in order to be available as water sources (Christy and West 1993; Tuttle 1996a; Seidman and Zabel 2001).
- Water quality is also critical; bats may be killed directly by ingesting water contaminated with pesticides or other toxic chemicals, or indirectly by a reduction in the number or diversity of insects that are available (Kurta 2000).

Conservation Issues

Riparian corridors have been altered more extensively than any other habitat in Wyoming. Prior to European settlement, riparian habitat was more diverse, with a variety of vegetation ages and structures, more beaver ponds, and more braided river channels with oxbows and gravel bars (Knight 1994). Streamflow regulation, fire suppression, farming, irrigation, livestock grazing, timber harvesting, mining, construction, and other human activities have created a riparian habitat that is quite different from that of presettlement times (Finley and others 1983; Knight 1994; Vaughan and others 1997; Bogan 2000; Hinman and Snow 2003; SDBWG 2004). These activities may have impacted the suitability of riparian corridors for bats by reducing the water quality, the number of available roost trees and other vegetation, and the abundance and diversity of insects (Chung-MacCoubrey 1996b; Vaughan and others 1997; Pierson and others 1999; Adams 2003)

Best Management Practices for Riparian Corridors to Benefit Bats in Wyoming

Landowners and land managers can take a variety of simple and inexpensive actions to improve, protect, and preserve habitat for bats. By maintaining and restoring riparian corridors for bats, many other wildlife species will also benefit. The following Best Management Practices (BMPs) should provide some reasonable guidelines and suggestions for managing riparian corridors to benefit bats in Wyoming, although, of course, not all of the BMPs will be appropriate in all situations.

1. Maintain or improve the condition of vegetation in riparian corridors to represent diverse, healthy plant communities. Manage for a patchwork or mosaic of different species of native aquatic and riparian vegetation, vertical diversity (from submerged and emergent aquatic vegetation to riparian woodland), horizontal diversity, and shoreline conditions across the landscape (Pierson and others 1999; Hutchinson and Lacki 2000; Waldien and others 2000; Entwhistle and others 2001; SDBWG 2004; Tuttle and others 2004).

2. Retain and protect snags, large trees, and other potential roosts. Manage for an abundance of tall, large-diameter snags and old live trees with thick, exfoliating bark and cavities (Christy and West 1993; Betts 1996; Brigham and Barclay 1996; Vonhof 1996; Pierson 1998; Barclay and

Brigham 2001; Weller and Zabel 2001). Although we do not yet know the number of sites required to support a population in a given area, traditional estimates of snags required to maintain cavity-nesting birds are probably not sufficient for bats (Crampton and Barclay 1996; Brigham and others 1997; Hinman and Snow 2003; Keinath 2004).

3. Retain a buffer zone in riparian corridors where no timber harvesting, firewood cutting, or other conversion or development is allowed. Besides providing essential habitat for bats, especially those that depend on mature trees, and their insect prey, buffer strips also improve water quality by trapping contaminants before they reach the water's edge, preventing soil erosion, and reducing sedimentation (Pierson and others 1999; Entwhistle and others 2001).

4. When planting trees, select native species and avoid Russian olive and tamarisk (salt cedar) (*Tamarix chinensis*). These exotic woody plants are vigorous species that can be established easily in many areas, but they out-compete native plants and host relatively few insect species.

5. Retain and restore the natural features of rivers and streams, such as meanders, oxbows, gravel bars, calm pools, and riffles, and avoid channelizing streams, increasing river flow, or infilling meanders and ponds (Vaughan and others 1997; Altenbach and others 2002).

6. Manage streams and springs for stable, year-round flows, particularly during critical time periods for bats, such as during the maternity season (April 1 through October 1), and possibly winter for some species.

7. Reduce and control point and non-point sources of pollution to attain good water quality necessary to support living resources. Bats may be killed directly by drinking contaminated water, or indirectly by a reduction in the number or diversity of insects that are available.

8. Strictly limit pesticide application in and near riparian corridors to activities that improve or maintain vegetation (such as elimination of competitive noxious weeds). Where pesticides are necessary, use them as part of an Integrated Pest Management (IPM) program (Oakleaf and others 1996; Pierson and others 1999; Nicholoff 2003).

9. Reduce land use activities that increase soil erosion and sedimentation. Some actions that can reduce soil erosion and sedimentation include using contouring and minimum tillage; maintaining winter cover; protecting ditch banks and stream banks from burning; maintaining buffer zones of vegetation between riparian areas and activities such as timber harvest, farming, and mining; and avoiding skid trails, fire incident bases, camps, and other centers of activity immediately adjacent to streams.

10. Manage grazing intensity, stocking rates, and livestock distribution at levels that will maintain the composition, density, and vigor of desired plants and will not damage shorelines or water quality.

11. Avoid placing mines, oil and gas drill sites, sand or gravel pits, geothermal sites, and roads immediately adjacent to riparian areas.

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Water Features

Clean, available water and productive, diverse riparian areas are essential components of bat habitat (Grindal and others 1999; Pierson and others 1999; Seidman and Zabel 2001; Hinman and Snow 2003). Water is not only important to bats for drinking. It also provides important foraging habitat for bats, abundant insect prey, increased vegetation and structural diversity, and corridors for daily travel and migration (Hinman and Snow 2003). In the arid West there is a significant relationship between bat species richness and abundance and types and availability of water—water can play an important role in determining the distribution of some bat populations and species (Chung-MacCoubrey 1996b; Altenbach and others 2002; Adams 2003).

Water Features in Wyoming

Wyoming is an arid state and water is a critical and limited resource for both wildlife and humans. Because water is so important to humans, and because actions on the land ultimately affect the condition of the waterways, the status of water resources has been substantially influenced by settlement. Prior to European settlement, riparian habitat was more diverse, with a variety of vegetation ages and structures, more beaver ponds, and more braided river channels with oxbows and gravel bars. Streamflow regulation, fire suppression, agriculture, irrigation, livestock grazing, and other human activities have created a riparian habitat that is quite different from that of presettlement times (Knight 1994). Although montane wetland communities were probably in much the same condition as they are today, the wetlands of the plains/basin regions were probably much more widespread and had a much greater supply of higher quality water. About 38% of the state's wetlands have been lost to hayfields, croplands, mining, urban development, and other land uses (WDC 1995). Prior to settlement, lakes and ponds were abundant in the montane areas of Wyoming, but were almost non-existent in the plains/basin regions. Since the 1930s, thousands of ponds have been dug in Wyoming to provide water for livestock, and along with reservoirs and irrigation systems, they have dramatically increased the amount of open water in the state (USFWS 1990). In some arid areas, artificial sources of water may be the only ones within miles (Kurta 2000), and they may have allowed some bat species to inhabit dry but otherwise suitable habitat (Chung-MacCoubrey 1996b). Unfortunately, many artificial water sources do not support diverse, productive vegetation communities and typically do not provide as high quality habitat for robust insect communities as natural and historical riparian and wetland habitats (Finley and others 1983; USFWS 1990). It is possible that these changes have affected the distribution and abundance of some bat populations, but the lack of historical data on population trends or status make this impossible to confirm.

Water Features as Bat Habitat

Water Sources

Bats require an adequate amount of water daily for survival and most species must have access to open water surfaces where they can drink in flight (Tuttle 1996a). Because of their high-protein diet, insectivorous bats must have water to excrete toxic nitrogenous waste products (Chung-MacCoubrey 1996b). Daily water loss in bats is high in comparison to other mammals because of their small size, the respiratory demands imposed by flight, and the large evaporative surfaces of their wing membranes (Adams 2003; Keinath 2004). In most of Wyoming, water loss is exacerbated by the arid environment. Bats are particularly challenged to maintain water balance during key times of the year. For example, energy and water demands are quadrupled during late pregnancy and lactation, and maternity roosts of most species need to be in close proximity to a reliable water source (Christy and West 1993; Altenbach and others 2002; Hinman and Snow 2003). Water is also an important factor during hibernation, especially during periodic arousal, when metabolic activity and cellular waste production increase (Ruffner and others 1979). For this reason, most bats select hibernacula with high relative humidity (Ruffner and others 1979), and springs that remain unfrozen through the winter may be important resources for some species (Altenbach and others 2002). Bat species that are adapted to live in the most arid environments, such as the California myotis and pallid bat, produce highly concentrated urine and are more efficient at conserving water (Chung-MacCoubrey 1996b).

Foraging Habitat

Water features and their associated riparian vegetation also provide important foraging habitat for many bat species. Many insect species breed and emerge from the surface of water bodies, and species such as the little brown myotis and the Yuma myotis feed directly over the water surface on these aquatic insects (Pierson 1998; Grindal and others 1999). Also, high quality riparian habitat supports a much richer insect fauna than surrounding upland areas and provides valuable cover for foraging bats (Entwhistle and others 2001; Seidman and Zabel 2001; Altenbach and others 2002). Many bat species, such as the Townsend's big-eared bat and the pallid bat, will follow stream corridors and forage within the broad riparian zone, and some species, such as the long-eared myotis, forage primarily within riparian habitats (Pierson 1998).

Mineral Sources

Some bats also visit water sources to obtain nutrients such as calcium and sodium, which may otherwise be limiting resources, especially during pregnancy and lactation (Kunz and Lumsden 2003). Studies in Colorado showed that females and juveniles tend to preferentially visit water holes with the highest concentrations of dissolved calcium, whereas adult males show no such preference (Adams 2003). Additional research is needed to understand water features as potential mineral sources, and the importance for conservation may be profound.

Characteristics of Water Features That Influence Bat Use

Bats use many kinds of water resources, including both natural features (such as streams, rivers, lakes, ponds, springs, and wetlands) and artificial features (such as reservoirs, irrigation ditches, stock ponds, and troughs). Physical characteristics that influence how bats use water resources include size of the water body, extent of open water, surrounding and emergent vegetation, turbulence of the water, proximity to roosts, and water quality. Because bats drink while in flight, they require water sources large and uncluttered enough for them to approach and skim the surface. Small, maneuverable *Myotis* species may be able maneuver through vegetative clutter and drink from pools as small as a few centimeters in diameter, whereas larger, less maneuverable species, such as the hoary and big brown bat, need larger, uncluttered surfaces and the big free-tailed bat may require surfaces up to 30 m (100 ft) long (Christy and West 1993;

Tuttle 1996a; Seidman and Zabel 2001). Although tall vegetation and other features surrounding small bodies of water may reduce accessibility for some bats, the presence of some vegetation around water is nevertheless an important component of bat habitat. A diverse, productive riparian zone provides abundant insect prey, provides protection from predators, and improves foraging conditions by blocking wind (Vaughan and others 1997; Hinman and Snow 2003). In addition, water resources are especially valuable when they are located near roosting habitat, so that the energetic costs of commuting are reduced (Kunz and Lumsden 2003). Also, species that forage low over water, such as the little brown myotis, often concentrate their activity over calm areas (ponds and stream pools) and avoid turbulent water. Turbulent water creates a high level of background noise that could interfere with echolocation and, although bats may not be restricted to calm areas, they probably select these areas to improve their foraging efficiency (Fenton and others 1983; Mackey and Barclay 1989). Calm water may also be a safer setting for drinking (Fenton and others 1983). Finally, water quality is critical; bats may be killed directly by ingesting water contaminated with pesticides or other toxic chemicals, or indirectly by a reduction in the number or diversity of insects that are available (Kurta 2000). In general, water features increase in value to bats if they are large, calm, and uncluttered; are in close proximity to roosts; have a diverse and productive riparian zone; support a diverse insect community; and are free of pesticides and other contaminants.

Conservation Issues

Although reservoirs and agricultural programs such as irrigation and stock ponds have increased the quantity of water features across the state, runoff associated with human activities in watersheds often affects the quality of the water. Urban areas, mining, livestock grazing, farming, timber-related activities, construction, road building, and other development are all potential sources of contaminants, excessive nutrients, and/or sediment in water. Loss or degradation of water sources or riparian habitat as a result of any of these activities can affect insect populations, drinking water, and the suitability of bat foraging areas.

Best Management Practices for Water Features to Benefit Bats in Wyoming

Landowners and land managers can take a variety of simple and inexpensive actions to improve, protect, and preserve habitat for bats. By maintaining and restoring water resources for bats, many other wildlife species will also benefit. Some management activities that improve the health of aquatic and riparian habitats may also improve fisheries and watersheds. The following Best Management Practices (BMPs) should provide some reasonable guidelines and suggestions for managing water resources to benefit bats in Wyoming, although, of course, not all of the BMPs will be appropriate in all situations.

1. Take a landscape level approach to management that incorporates roost sites, foraging habitat, and water sources. All of these components of bat habitat must be in close proximity (within several kilometers) for bats to use them efficiently (Keinath 2004). Remember that bats often roost in upland habitats, so riparian protection alone may not guarantee protection of adequate bat habitat (Seidman and Zabel 2001).

2. Maintain habitat diversity. Within extensive areas of aquatic and wetland habitat, manage for a patchwork or mosaic of types and conditions across the landscape. Ideally, a variety of sizes, depths, shoreline conditions, and vegetation structures and compositions should be available. Manage for a mosaic of different species of native aquatic and riparian vegetation, with vertical diversity (from submerged and emergent aquatic vegetation to riparian woodland), as well as horizontal diversity.

3. Maintain or restore a buffer strip of native vegetation surrounding water resources that is free from conversion or development. Besides providing important habitat for bats and their insect prey, buffer strips also improve water quality by trapping contaminants before they reach the water's edge, preventing soil erosion, and reducing sedimentation.

4. When planting trees, select native species and avoid Russian olive and tamarisk (salt cedar). These exotic woody plants are vigorous species that can be established easily in many areas, but they out-compete native plants and host relatively few insect species.

5. Retain and restore the natural features of rivers and streams. A variety of features such as natural meanders, oxbows, gravel bars, calm pools, and riffles promotes high insect diversity and enhances foraging for bats. In particular, calm pools within turbulent streams provide areas where bats can echolocate without background noise. Avoid channelizing streams, increasing river flow, or infilling meanders and ponds (Vaughan and others 1997).

6. Maintain accessibility of water to bats, which drink while in flight, by eliminating, modifying, or reducing obstructions such as fencing. When springs are developed into stock tanks, avoid using covers, latticework, or similar structures that can make them unavailable to bats.

7. Manage streams and springs for stable, year-round flows, particularly during critical time periods for bats, such as parturition, lactation, and possibly winter for some species.

8. Create large artificial ponds, particularly near occupied bat habitat such as woodlands, caves, or abandoned mines. Include as many natural features as possible, such as varied depths and diverse vegetation.

9. Maintain good water quality. Reduce and control point and non-point sources of pollution to attain the water quality necessary to support living resources. Bats may be killed directly by drinking contaminated water, or indirectly by a reduction in the number or diversity of insects that are available.

10. Strictly limit pesticide application in and near water features to activities that improve or maintain vegetation (such as elimination of competitive noxious weeds). Where pesticides are needed, use them as part of an Integrated Pest Management (IPM) program, and use only those pesticides that are approved by the US Environmental Protection Agency specifically for use in and adjacent to aquatic areas.

11. Avoid using foggers for mosquito control near water resources.

12. Carefully plan aerial application of herbicides to prevent drift of chemicals into water resources and employ drift retardants. Depending on the wind speed, provide a buffer zone of 1.6 to 6.4 km (1 to 4 mi) downwind of the aircraft, and 75 m to 1.6 km (250 ft to 1 m) upwind. Avoid spraying herbicides in winds exceeding 16 kph (10 mph), or during calm weather when temperature inversions may prevent sprays from reaching the ground. Pellet herbicides are less prone to wind drift and are preferred when applying near aquatic areas.

13. Consider other alternatives for vegetation management, besides herbicides, before any is chosen. These include regulation of muskrat populations, water level manipulation, livestock grazing, prescribed burning, mowing, disking, crushing, and excavating. Whatever management scheme is selected should mimic natural processes as closely as possible.

14. Reduce land use activities that increase soil erosion and sedimentation in aquatic habitats and manage riparian areas for stable, non-eroding banks and stabilizing vegetation. While siltation is a natural physical process and a certain amount of sediment from natural erosion is normal, accelerated sediment runoff caused by human activities can cause severe negative impacts to aquatic life. Also, sediment input and runoff can carry with it contaminants from the surrounding watershed that can remain trapped in sediments indefinitely. Some actions that can reduce soil erosion and sedimentation include using contouring and minimum tillage; maintaining winter cover; protecting ditch banks and streambanks from burning; maintaining buffer zones of vegetation between water features and activities such as timber harvest, farming, and mining; and avoiding skid trails, fire incident bases, camps, and other centers of activity immediately adjacent to water features.

15. Maintain proper stocking rates and livestock distribution to protect water features. Incompatible grazing can have harmful long-term effects on survival and regeneration of plant seedlings; can negatively influence the species, structure, and health of vegetation; and can cause soil compaction, trampling of the shoreline, altered local hydrological conditions, and degraded water quality from waste materials and excessive soil in the water. Manage grazing intensity at a level that will maintain the composition, density, and vigor of desired plants and will not damage shorelines or water quality.

16. Where appropriate, fence livestock away from sensitive water resources to avoid destroying vegetation, increasing water turbidity, and polluting the system. Livestock can also destroy vegetation covering earthen retaining walls and dams, eventually leading to washout of these structures. If livestock is dependent on the water source, a pipeline may be constructed from the pond to a stock tank. If this option is not feasible, a “water gap” can be constructed. This involves constructing a fence into a small portion of the pond so livestock can use this restricted area for watering.

17. Where necessary, use livestock grazing to maintain an open vegetation structure around small water bodies to allow access to bats, particularly in areas where other water may be unavailable.

18. Repair old stock ponds rather than replacing them with stock tanks. Stock tanks lack aquatic and riparian vegetation, and provide only a small surface area of water, which may be

inaccessible to larger, less maneuverable bat species. Where possible, maintain and encourage vegetation in and around stock ponds to improve habitat for insects, bats, and other wildlife.

19. Ensure that ponds containing mining wastes are netted to exclude bats and birds, and fenced off to exclude other wildlife that may be attracted to water. Flagging, reflectors, and strobes are not effective because animals become habituated to these deterrents. It is necessary to employ a technique, such as complete covering with metal or polypropylene mesh or eliminating ponds, that will reduce or eliminate the possibility of wildlife entering disposal pits (Clark 1991; Esmoil and Anderson 1995).

20. Avoid placing mines, oil and gas drill sites, sand or gravel pits, geothermal sites, and roads immediately adjacent to water features.

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SURVEY GUIDELINES FOR BATS IN WYOMING

Effective management of bat populations in Wyoming is impossible unless the best available methods for inventory and monitoring are practiced in a consistent and standardized manner throughout the state. With that in mind, the Wyoming Bat Working Group (WYBWG) has reviewed the existing available information and developed these bat survey guidelines for Wyoming. These guidelines are intended to be a reference tool providing general applications of methodologies and information specific to Wyoming that may not be available elsewhere. Training of personnel is beyond the scope of this document and these guidelines are not intended to replace formal training or hands-on experience. These guidelines should also be used in conjunction with the recommendations in other sections of this Bat Plan (such as the species and habitat accounts) to ensure the success of surveys and avoid harming bat populations. Because inventory and monitoring surveys often address very different objectives, the following survey guidelines are presented in 2 separate sections on “Bat Inventories” and “Monitoring Bats” in order to facilitate project planning.

General Survey Information

An awareness of bat activity patterns, including when and where they roost and forage, is vitally important to the success of bat surveys. It is also important to keep in mind that a multitude of variables, such as timing, weather, and location can affect survey success. Because any one of these variables can result in drastically different bat activity patterns between survey nights or even on a single survey night, surveys should be conducted more than once at each site in order to maximize detection of all species present.

Timing (Daily)

Although bats are primarily nocturnal, individual bats and certain species may emerge as early as ½ hr before sunset. On the other hand, some bat species are considered “late fliers” and typically emerge well after sunset. Although there is no single best time to capture bats and the most suitable time is dictated by the survey objectives, in most cases surveys should be initiated a minimum of ½ hr before sunset and continue for a minimum of 3 hrs after sunset to maximize the detection of all species present.

Timing and Weather (Seasonal)

Mid October to mid April: Bat activity is low during this period as most bat species in Wyoming either hibernate or migrate to warmer climates. Mist net and acoustic surveys will likely be unproductive. Hibernacula surveys conducted by trained personnel can be an effective method of sampling bats at known roost sites.

Mid April to mid May: As the temperature increases during this period, bats begin to emerge from hibernation or migrate back to Wyoming. Most

	survey techniques are applicable and effective, but results are highly dependent on weather.
Mid May to mid August:	Females are pregnant and forming maternity colonies during this period, while males roost individually or in small bachelor colonies. Most survey techniques are effective, except hibernacula surveys. However, capture surveys are at great risk of disturbing maternity colonies and pregnant or lactating females and should be conducted with caution.
Mid August to mid October:	Bat activity peaks in early August as young become volant and decreases through mid October as bats begin to migrate or move to hibernacula. Most survey techniques, except hibernacula surveys, are effective through mid September. Results for all survey techniques are highly variable in October.

Weather (Daily)

Generally, bat activity is directly correlated with increases in temperature (that is, as temperature increases so does bat activity), and inversely correlated with increasing wind speed and moisture (such as rain). Although bat activity does not actually vary with phases of the moon, some bats may be more difficult to capture on nights when there is a large moon around sunset, which could bias surveys on such nights. Also, bats often emerge earlier on overcast evenings, presumably because light levels decrease sooner. Although there is no single best night to capture bats and the most suitable night will be dictated by survey objectives, in most cases surveys will be most successful during calm, warm, dry, dark nights.

Location

Bats may be and often are detected in a variety of settings, although concentrating survey efforts near bat roosts, foraging areas, and travel corridors will greatly increase survey success. Foraging areas vary by species and often relate as much to insect emergence as habitat features. For example, some species forage in cluttered vegetation, while others require open spaces, some species forage over water features, while others forage over the forest canopy—see the species accounts in this Bat Plan for information about where each species usually forages. When survey objectives are to document a specific bat species, it will probably be beneficial to focus survey efforts near appropriate roost habitat for that species, such as near cliffs for spotted bats. Again, see the species accounts in this Bat Plan for information about where each species usually roosts.

When survey objectives are to document bat diversity, select locations that concentrate large numbers of bats of different species, usually water bodies where bats come to forage and drink, or travel corridors, such as forest edges and riparian corridors, where bats commute between roosts and foraging areas. When selecting a water feature to survey, try to choose a water body in an area where not much other water is available—the “perfect” pond amid dozens of others will be less productive than a small pond in a large dry valley, simply because the latter concentrates the bats. Water features to do not need to be large to attract bats—suitable survey sites can include stock ponds, watering tanks, and even puddles in two-track roads.

When mist netting, avoid bodies of water that are too large to be adequately covered by the mist nets—a large lake does not concentrate the bats enough to funnel them into the nets. Also, choose ponds that are shallow enough to wade into and still reach the upper pocket of the net. When netting over streams, choose streams with slow-moving water and/or large pools. Try to select sites with vegetation or a landscape that will naturally funnel the bats into a small area.

Always survey a variety of sites within the entire area of interest. Bats often have specific or traditional foraging areas or roosts, so avoid concluding that bats are not using an area just because they were not detected at a single site within that area—they may be concentrated elsewhere nearby.

BAT INVENTORIES

The WYBWG has developed a survey matrix that summarizes survey methods for each bat species in Wyoming (see page 241). The Wyoming survey matrix was developed from the existing Western Bat Working Group survey matrix (WBWG 2003) by revising rankings and methodologies according to their applicability and effectiveness in Wyoming.

Although there is no single best time to survey for bats and the most suitable time is dictated by the survey objectives, unless otherwise noted, all surveys should be initiated a minimum of ½ hr before sunset and continue for a minimum of 2 hrs after sunset, preferably longer, to maximize detection of all species present.

I. Acoustic Surveys

Acoustic surveys are used to document the presence of bats at specific locations (such as travel corridors, streams, and ponds), and to identify roost sites (such as abandoned mines, buildings, caves, and rock crevices). They can also be used to identify productive mist netting sites. Visual surveys are often conducted simultaneously with acoustic surveys to increase their effectiveness. The more advanced ultrasonic survey systems (such as AnaBat® and Petterson models) can be used to identify species and determine the species composition of the community. Although the Petterson models offer some advantages over AnaBat® systems, the cost of these units is generally prohibitive. A "pass" is defined as a discrete event when a bat is heard and/or seen within the vicinity of the observer. Under most conditions it is impossible for observers to differentiate between 1 bat that makes multiple passes and several bats that each make only 1 pass. A comparison of each acoustic survey method is presented in Table 3 on page 227.

A. Audible Surveys

1. Rationale – This type of survey is a low-cost and effective method for documenting the presence of spotted bats in Wyoming.

2. Equipment – No specialized equipment is required for this type of survey, although observers should have good high-frequency hearing. Inexperienced observers should have formal training and/or be accompanied by an experienced observer before conducting solo surveys.

3. Application – Observers that are unfamiliar with spotted bat ecology should review the species account on page 94 prior to planning surveys. Avoid surveying in areas with high noise pollution (such as highways), which can inhibit the observer's ability to detect bats. If multiple calls are detected simultaneously during a pass, record only the number of unique individuals.

4. Analysis of Data – For each pass, record the time, location, and habitat. For stationary counts, report data as the total number of passes and passes per unit time

(passes/survey length). For transect counts, report data as the total number of passes only.

5. Datasheet – See the Acoustic Survey Form on page 248.

B. Heterodyne "Minibat" Detector Surveys

1. Rationale – This type of survey is used to document the presence or absence of bats at a given location. It is a valuable and cost effective method for identifying productive bat capture sites. This type of survey is also used to document the presence of bats at potential roost sites.

2. Equipment – A variety of manufacturers produce a wide-range of minibat detectors. Although all minibat detectors operate similarly, they vary greatly in price (from under $100 up to several hundred dollars) and features (such as digital displays and frequency scanning). All minibat detectors are handheld units and are relatively easy to use. They are readily available online and most are shipped within few days of purchase. Detectors with a tunable frequency dial or digital scanner are preferable.

3. Application - Detectors with tunable frequencies should be set between 20 and 40 kHz, as most bats in Wyoming echolocate within this frequency range. Some detectors allow the observer to tune the detector to a specific frequency and these may be used to document the presence of a specific species; however, species identification is generally difficult with minibat detectors because several bat species (such as *Myotis* spp.) overlap in frequencies. Generally, the survey is conducted at a single location (such as near a water source or roost portal). However, it is also possible to survey by walking systematically through a sample unit. Survey intensity should ensure adequate coverage of the sample unit.

4. Analysis of Data – See Section I.A.4 on page 223.

5. Datasheet – See the Acoustic Survey Form on page 248.

C. AnaBat® Surveys (Zero-Crossing)

1. Rationale – This type of survey is used to document presence/absence and species composition of bat communities. Although AnaBat® will detect vocalization frequencies of all bat species in Wyoming simultaneously, species identification is time-consuming and can be difficult for some species (such as *Myotis* spp.). Other species (such as Townsend's big-eared bats) can be difficult to detect with standard equipment because their calls are so quiet that they must be quite near the detector for a clean call to be recorded.

2. Equipment – A variety of AnaBat® systems are available from Titley Electronics at http://www.titley.com.au. AnaBat® uses a zero-crossing continuous recording interface. Generally, complete AnaBat® systems include an AnaBat® II Detector and

an AnaBat® ZCAIM interface unit (for use with laptops) or an AnaBat® CF Storage ZCAIM (for use with compact flash cards). The AnaBat® CF Storage ZCAIM eliminates the need for a laptop and large battery, making the system more portable. The compact flash cards can be removed from the unit and the data can be downloaded to a desktop or laptop computer for analysis after the survey is complete. Although the AnaBat® ZCAIM requires a laptop, it allows the observer to analyze data in the field.

3. Application – During setup, record the location and habitat into the header to ensure that all call sequences are stamped with the relevant information. AnaBat® surveys can be conducted either actively or passively. Active surveys allow the observer to make field notes to assist with data analysis (such as noting that a bat was small-bodied and foraging over the surface of a pond). Active surveys also allow the observer to track bats in flight with the microphone to obtain more complete recordings and fewer fragmentary call sequences. This type of survey should follow the general timing guidelines of surveys. Passive surveys are conducted without an observer present beyond the initial setup, and allow the observer to set up multiple units within a given area or survey multiple areas simultaneously. Both active and passive surveys can be conducted in conjunction with other capture surveys (see Section III on page 232). This can greatly enhance the observer's ability to detect species that are not easily captured, as well provide species information for subsequent data analysis. Passive surveys also allow the observer to simultaneously conduct capture surveys. Passive surveys not associated with capture surveys should be conducted for the entire night whenever possible. If calls are being used for species identification, AnaBat® detectors should be set at least 50 m (20 ft) from known roosts to ensure that foraging calls are recorded.

4. Analysis of Data – It is beyond the scope of this document to discuss call file analysis specifics; however, typical minimum frequencies for bats in Wyoming have been compiled to assist surveyors with call identification (see Table 4 on page 249). Data can be analyzed either quantitatively or qualitatively. Although a quantitative approach can remove observer biases and may save time during analysis, the approach requires a large call library for each species in order to accurately identify species. The qualitative approach is generally preferred in Wyoming because a large call library for Wyoming species does not exist. Complete species identification is preferable whenever possible, but should only be made when recorded passes are clear. When passes cannot be identified to species, they should at least be identified to species group (40-kHz bats, 50-kHz bats, and so on). See Table 5 on page 250 for call file analysis recommendations. Also, please keep in mind the following points.
   a. Bat calls are highly variable and species identification can be both time-consuming and difficult. Consultation with those experienced in AnaBat® file analysis should be obtained whenever a question arises.
   b. Call analysis assumes that standard navigational calls are being recorded in a clear environment, so the placement of AnaBat® units and the activity of bats being recorded are critical. Call pattern, frequency, and rate can change as a result of a variety of factors, such as when bats are flying near vegetation, when bats are

flying in an enclosed area, when bats are flying near other bats (particularly of the same species), or when bats detect a prey item (feeding buzzes). Analysis using other calls, such as those recorded at or near roosts, usually cannot be properly differentiated, even by experts. If in doubt, get advice from an expert on recording and identifying calls.

c. Data analysis can be simplified by counting the number of detections in each frequency category. This simplified analysis provides an index of the relative composition of species groups. For example, one might record 6 call sequences of 40-kHz bats and 2 call sequences of 20-kHz bats.

5. Datasheet – Datasheets may vary according to project needs, but the AnaBat® Survey Form on page 251 presents the basic information that should be recorded. It can be used directly, or as a template.

D. Petterson "SonoBat" Surveys (Time-Expansion)

1. Rationale – Although no one in Wyoming is currently using Petterson bat detectors, those planning to work with species that are acoustically difficult to differentiate, such 40-kHz *Myotis* species, may find this system beneficial. See Section I.C. on page 224 for additional information on species identification and acoustic surveys. Time-expansion (Petterson) bat detectors offer enhanced species identification over zero-crossing (AnaBat®) detectors by creating a high-resolution call diagram by utilizing additional call parameters not recorded by zero-crossing detectors, such as harmonics and amplitude. However, time-expansion detectors may result in missed calls due to the time-delay of the playback feature. Also, when combined with the special software required to analyze calls, they are much more expensive than AnaBat® detection systems.

2. Equipment – A variety of Petterson detectors are available from Petterson Electronik AB at http://www.batsound.com. Generally, time-expansion detectors are available in either the D200 series or D900 series. Petterson detectors can either be linked directly to a laptop or to a tape recorder for downloading to a laptop. Petterson offers call analysis software on their website, although most North American researchers are using SonoBat software developed by Joe Szewczak, which is available at http://www.sonobat.com.

3. Application – See Section I.C.3 on page 225.

4. Analysis of Data – See Section I.C.4 on page 225.

5. Datasheet – See the AnaBat® Survey Form on page 251.

Table 3. Comparison of acoustic survey techniques.

SURVEY TYPE	EQUIPMENT NEEDED	COST/ UNIT	PRESENCE /ABSENCE	SPECIES ID	PASSIVE SURVEYS	ACTIVE SURVEYS	DATA ANALYSIS	TARGET SPECIES	SUGGESTED USE
Audible	Good, high-frequency hearing	$0	Y	Limited	N	Y	Easy and simple	Spotted bat	Surveys targeting only spotted bats.
Heterodyne “Minibat” Detectors	Portable bat detector	$50 and up	Y	Limited	N	Y	Easy and simple	Variable – depends on the setting	Active surveys to detect bat activity where species identification is not necessary.
AnaBat® Systems	AnaBat® II Detector, AnaBat® ZCAIM, and associated software	~$1500	Y	Yes	Y	Y	Difficult and time-consuming	Variable – records all frequencies	Surveys when general species composition and/or abundance are important.
Petterson Bat Detectors	Petterson D200 or D900 Series and SonoBat software	$1500 to $3500, plus soft-ware	Y	Yes	Y	Y	Moderately difficult and time-consuming	Variable – records all frequencies	Projects where positive species identification of each pass is very important and budget is not prohibitive.

II. Handling, Holding, and Processing Bats

Handling bats allows researchers to collect data on a wide variety of parameters, such as age, sex, weight, and reproductive status, that cannot be collected during acoustic surveys. Bat population parameters can then be derived from the additional information collected on individual bats, providing land and resource managers with additional data to conserve bat populations.

Researchers should practice extreme care and caution when handling bats to avoid harming themselves and/or the bats. Bats are delicate animals and can easily suffer broken limbs, torn wing membranes, abortion, or other physical injury when not handled properly. At the same time, bats may bite humans during handling which exposes the handler to injury and/or disease. Those planning to handle bats should review the "Public Health" section on page 271.

Anyone planning to or currently handling bats is considered at risk of contracting rabies and should have a rabies prophylaxis immunization (CDC 2004) prior to handling bats. See the Center for Disease Control's (CDC) website on human rabies prevention (http://www.cdc.gov/mmwr/preview/mmwrhtml/00056176.htm) for vaccination schedules, minimum titer levels, and post-exposure treatments.

Researchers should be familiar with and have experience with capture techniques, such as mist nets and harp traps, before deploying these devices in the field in order to minimize injury to bats. Handlers should also be familiar with bat anatomy (see Figure 18 on page 252).

A. Handling Bats

1. Rationale – This section outlines important information to consider when handling bats to help minimize the risk of injury to bats and humans. It is important to remove bats from the mist net or harp trap as quickly as possible to prevent injury to the bats or damage to the equipment.

2. Application – Removal from Capture Devices – The bones and wing membranes of bats are extremely delicate, making it necessary to take special care when removing these appendages from capture devices. Occasionally allowing a "chewy" bat to bite on a capture bag or the loose part of a glove can facilitate its removal from the capture device. Wherever possible, avoid cutting bats free from the capture device. On the occasion that a bat becomes extremely entangled and it becomes necessary to cut it free, use nail or fishing line clippers to carefully clip constraints. Avoid using sharp pointed instruments, such as scissors or knives, as they can easily result in injury to either the researcher or the bat. After removing bats from the capture device, quickly transfer them to a proper holding container, taking special care to ensure that bats are removed and transferred without injury. Even when not injured, most bats become stressed when handled, so they should be handled as little as possible (see Section II.B on page 229).

3. Equipment – Handlers should wear soft, pliable, and form-fitting leather gloves to provide protection from bites while maintaining dexterity. Many researchers prefer leather batting gloves or golf gloves. Avoid gloves with any nylon mesh, as the teeth and claws of bats can become stuck in such fabric. Tweezers or small crochet hooks are often handy when trying to remove bats that are tangled in nets. Nail or fishing line clippers are also important when bats become so entangled that it is necessary to cut the net in order to safely remove them (although this should always be a last resort).

B. Holding Bats Prior to Processing

1. Rationale – While waiting for processing, store bats temporarily in proper holding containers to help reduce stress and injury.

2. Application – Nighttime temperatures in Wyoming can vary drastically and are usually significantly cooler than daytime temperatures. After placing a bat in a bag, carefully fold it over and tie it to prevent escape. Place the bag in a warm, dry environment to prevent the bat from becoming torpid. On cold, moist nights where temperatures approach 4.5 ºC (40 ºF), bats may be kept warm by holding them in their bags under the jacket of a handler against the body. Take care not to smash the bats and never place bags containing bats on the ground. Bat energy budgets are tight and any lost foraging time is potentially detrimental to their health, so bats should be released as soon as possible after capture. Bats may be held up to 30 minutes, but never longer than 45 minutes, prior to processing to ensure that the bat has had an opportunity to defecate and urinate and avoid biasing weight measurements (see Section II.D on page 230). In most situations, each bat should be stored in its own bag, although on occasion similar species of smaller bats (weighing less than 10 g [0.35 oz]) may be stored together. Always store larger bats individually. Female bats captured in May and early June may be pregnant and should be processed and released immediately if possible to avoid the stress of storage and extra handling. Wash bags after every outing to minimize potential parasite and disease transmission between bats.

3. Equipment – A wide variety of cotton bags are commercially available from retailers of capture devices. Cotton bags are the best holding containers in most situations because they are breathable and warmer than mesh bags. Bags should be approximately 30 cm (12 in) by 45 cm (18 in) and close with a drawstring rather than Velcro. Seams and loose edges should be on the outside of the bag to prevent bats from becoming entangled in frayed fabric. Avoid synthetic bags or materials with chemical coatings, such as urethane waterproofing.

C. Species Identification

1. Rationale – This section will assist researchers with the proper identification of bat species in Wyoming.

2. Application – Most of Wyoming's bat species are diagnostic and easy to identify with the assistance of the dichotomous key to the bats of Wyoming (see page 254). However, several *Myotis* species can be difficult to distinguish even when in hand by experienced researchers, in particular the little brown myotis and Yuma myotis, the western small-footed myotis and California myotis, and the long-eared myotis and northern myotis. Besides the dichotomous key, researchers should review the sections on weighing bats (see Section II.D on page 230), measuring bats (see Section II.E on page 230), and the relevant species accounts in this Bat Plan prior to surveying.

3. Equipment – Fine-scale metric rulers or calipers are also handy for taking body measurements, and a small spring-loaded scale with a range of 1 to 100 g is necessary for taking weights. Handlers may find specialized fly-tying glasses to be helpful for species identification.

D. Weighing Bats

1. Rationale – Recording the weights of bats in a consistent and standardized manner can facilitate species identification.

2. Application – Where possible, store bats in a proper holding container for approximately 30 minutes to give them the opportunity to defecate and urinate prior to weighing (see Section II.B on page 229). Transfer the bat to a clean, dry cotton bag and weigh it with either an electronic scale or a 20-g spring scale. Record the gross weight (GW) to the nearest degree of precision provided by the scale (such as tenths of a gram for spring scales). Remove the bat from the bag, weigh the empty bag, and record it as the bag weight (BW). Finally, calculate the net bat weight (NW) by subtracting the BW from the GW. NW = GW – BW.

E. Measuring Bats

1. Rationale – Recording the measurements of bats in a consistent and standardized manner can facilitate species identification.

2. Application I – Forearm Length – Measure forearm length by carefully folding a wing back into its roosting position and inserting the forearm into a caliper. Carefully slide the jaws of the caliper closed until it just touches the wrist and elbow. The length of the forearm is the total length between the wrist and elbow. Take special care not to damage the wing membrane or break any bones. The process usually works best if a second handler holds the calipers steady while the forearm is aligned with the jaws of the caliper. Forearm length should be recorded in millimeters.

3. Equipment – Digital calipers are easier to read and use than other types of calipers.

4. Application II – Ear Length, Wing Span, and Body Measurements – Ear length is generally difficult to measure and is only recommended for distinguishing confusing species, such as the long-eared myotis and northern myotis. Use a plastic metric ruler with millimeter increments. Carefully place the ruler in front of the ear, move it to the base of the ear, and measure from the base to the tip of the ear. Take special care not to damage the ear or poke the bat with a corner of the ruler. Also take wingspan and other body measurements with a plastic ruler.

5. Equipment – 1 small plastic metric ruler and 1 large plastic ruler.

F. Sexing Bats

1. Rationale – This section will help researchers properly identify the sex of captured bats.

2. Application – The sex of adult bats is easily identified when in hand. Males are characterized by a visible and noticeable pendulous penis, whereas females lack this appendage.

G. Determining Reproductive Status

1. Rationale – Identification of the reproductive status of adult bats is necessary to distinguish between individuals that are breeding in Wyoming and those that are not. Take special care when handling potentially pregnant females during May and early June.

2. Application – Documenting reproduction in male bats is difficult because it is nearly impossible to determine whether a male has successfully bred in the field (although one can tell whether the bat is in reproductive condition, as the testicles will be noticeably enlarged posterior to the penis). Therefore, the only viable way to assess the reproductive status of bat populations is by documenting reproduction in females. Although it is possible to assess female reproductive status during pregnancy (May and June), pregnant females may be hypersensitive to stress associated with captures and abort pregnancies. Therefore, females captured during this period should be given special care and released as soon as possible without assessing reproductive status. Reproductive status of females captured between mid June and mid September can easily be assessed in the field. Females with pups have enlarged nipples showing signs of lactation (such as keratinized skin). Lactating females will express milk from their nipples with slight pressure, while post-lactating females have nipples that look withered and will not express milk. Most female bats in Wyoming have a single nipple located just under the armpit on either side of the body cavity. Nipples can be located by gently blowing on the fur along the body cavity. Document females with enlarged nipples as lactating, and females for which no nipples can be located as not reproductive. Reproductive status cannot be assessed with confidence after mid September.

H. Aging Bats

1. Rationale – Aging bats can provide additional information on the reproductive status of bat populations in Wyoming. It can also help determine which bats should be checked for signs of lactation. Bats captured before mid July will nearly always be adults, making age determination unnecessary.

2. Application – Although several methods exist (such as tooth wear and length of forearm) for distinguishing adult bats from young of the year, the following method for examining the phalanges is best for general field application in Wyoming. Carefully stretch out the wing to expose the phalanges and hold the outstretched wing over a white light. Juveniles will display a distinct growth plate in the 1st and 2nd phalanges that looks like a clear bulbous section of the phalange. Adults will lack this bulbous growth plate and phalanges will be uniformly dark (see Figure 19 on page 253).

I. Marking Bats

1. Rationale – Marking bats has been employed to assess population demographics, such as survivorship.

2. Application – Because of their small body size, even the lightest available markers (such as bands and chains) can significantly impact the ability of bats to fly and forage effectively. Therefore, marking bats using these techniques is not considered safe and ethical at this time by the WYBWG. A preferred alternative is hair dye.

J. Radio Telemetry

1. Rationale – Radio telemetry can be a useful tool for locating bat roosts.

2. Application – Like markers, radio transmitters can significantly impact the ability of bats to fly and forage effectively. Generally, the weight of a radio transmitter should not exceed 5% of the bat's total weight. For example, a 10-g bat should never carry a transmitter weighing more than 0.5 g. As a result, the majority of bat species in Wyoming are too small to be safely fitted with radio transmitters, and the resulting small transmitters have a life-expectancy of only a few days. Therefore, researchers should carefully weigh their research needs before deciding to use radio transmitters on bats. Currently, it is recommended that only individuals weighing at least 10 g be selected for telemetry studies in Wyoming.

III. General Capture Surveys

A Chapter 33 Scientific/Educational Permit must be obtained from the Wyoming Game and Fish Department prior to capturing and handling bats.

A wide variety of techniques have been developed to capture bats, ranging from simple techniques that require little equipment, such as hand capture, to more complex techniques that require highly specialized equipment, such as harp traps. Capture methodology varies depending on the target species, accessibility, and survey objectives. However, because most simple techniques have only specialized applications and are not widely utilized, only mist nets and harp traps are discussed in this section.

Not all bat species have the same capture probabilities and some may go undetected even though they are present at the survey site. For example, high-flying bats, such as hoary and silver-haired bats, are more difficult to capture than lower-flying bats and may go undetected during a single sample period. Also, some less abundant species may successfully avoid capture during a single sample period. See the Wyoming Bat Survey Matrix on page 241 for additional information on surveying for individual bat species. To effectively detect the full suite of species present at a given site, it will probably be necessary to survey for multiple nights and/or utilize an AnaBat® Ultrasonic Bat Detector in conjunction with mist nets (see Section I.C on page 224). However, if bats are to be captured at a site during multiple nights, avoid trapping on consecutive nights and/or change net locations and configurations because capture success typically declines as bats learn to avoid nets set in the same locations (Kunz and Brock 1975).

A. Mist Netting

1. Rationale – Mist nets may be used to assess the presence or absence of bat species, determine the species composition of bat communities, and/or determine the relative abundance of bat species. Because mist nets are lightweight, compact, relatively inexpensive, and easily transported and erected in the field, they are the most commonly used devices for capturing bats (Kunz 1988).

2. Equipment – Mist nets are generally constructed of 36 or 38 mm (1.4 to 1.5 in) black nylon mesh, have 4 or 5 shelves, are 2 to 3 m (7 to 10 ft) high, and vary in length from 2.6 to 20 m (8.6 to 66.7 ft). Nets longer than 12 m (39 ft) may be difficult to handle. Also, avoid using lighter mist nets, such as those used to capture small songbirds, as bats may chew through these nets. Mist net suppliers include Avinet (http://www.avinet.com) and Manonet (http://www.afonet.org). Retailers will require a banding permit number or a copy of the Chapter 33 Scientific Collection permit. Most mist netting supplies, such as net poles, may also be purchased through these retailers. Net poles are available in a wide variety of materials (including bamboo and aluminum), prices, and lengths (usually 3 m [10 ft] or less). Homemade poles constructed of ½- or ¾-inch electrical conduit are the least expensive option.

3. Application – See Section II on page 228 prior to initiating surveys. Mist nets can be deployed successfully in almost any location where bats are expected to fly, and are highly effective for capturing bats at ground, sub-canopy, and canopy levels. Identify productive sites by conducting acoustic surveys in advance (see Section I.B on page 224). Capture success is usually highest near water sources; foraging sites; and flyways, such as forest gaps, trails, and mountain ridges. Mist nets may be deployed

near roosts, although special care should be taken to avoid harming young bats and causing roost abandonment (see Section IV on page 236). When deploying nets over water, set the lowest shelf cord close enough to the water surface so that bats do not fly under the net; however, keep the net pocket high enough to ensure that captured bats do not hang in the water.

Bats will often maneuver around 1 net and fly into another, so multiple net sets may be advantageous, especially in open areas. The number of nets that will be most successful is often correlated to the size of the area being sampled. Larger areas will require more net sets. Nets can be deployed in many different patterns, including H, T, V, W, X, Y, and Z configurations. For example, nets can be set in an H pattern to funnel bats into 1 main capture net or harp trap (see Section III.B on page 235). Properly set mist nets have distinct pockets formed by the netting and shelf cords. Avoid sagging nets and stabilize net poles by anchoring guy ropes to other objects such as stakes, tree limbs, or large rocks. Record the number of nets and their configuration on data sheets for future reference.

Nets may be installed anytime during the day, but should be kept closed until ½ hour prior to sundown to ensure that birds and other non-target species are not accidentally captured. Once nets are open, monitor them continuously for a minimum of 2.5 hours and remove bats as soon as possible after capture. At the end of the survey period, close all nets before dismantling the sets.

Survey sites should be sampled at least twice each year during 2 different seasons. The first sampling period should be during early summer to assess the adult bat community. The second sampling period should be during August, after the young are volant, to assess reproduction.

Upon capture, bats usually drop into the pocket of the mist net. From there, they are usually easy to remove and seldom need to be cut free. Although there is no single best method for removing bats from mist nets, always begin by determining which side of the net the bat entered. Next, determine which part of the bat last entered the net and carefully begin moving the net away from that part of the bat (see Section II.A on page 228). Always remove bats from the net as soon as possible after capture. The time and difficulty required to remove a bat from a mist net usually increases with the length of time the bat has spent in the net. See Section II on page 228 for information on handling bats after capture and species identification.

4. Analysis of Data – Report data as the total number of captures, total captures by species, total survey time, and location. Capture per unit effort, such as number of captures per total survey time, should also be reported.

5. Data Sheet – See the General Capture Form on page 256.

B. Harp Traps

1. Rationale – Harp traps are used to assess the presence or absence of bat species, determine the species composition of bat communities, and determine the relative abundance of bat species. Some harp traps are collapsible and easy to erect in the field, which increases their portability (Tidemann and Woodside). Although harp traps are considerably more expensive than other capture devices, they offer several advantages; for example, they do not need to be continuously monitored and captured bats are relatively protected from exposure.

2. Equipment – Harp traps are usually constructed of 2 rectangular frames supported by 4 tubular leg extensions. A bank of fin wires spaced approximately 2.5 cm (1 in) apart is strung vertically between each frame. A poly-lined canvas bag is supported beneath the trap to hold captured bats. Harp trap suppliers include Bat Conservation and Management (http://batmanagement.com) and Alana Ecology (http://alanaecology.com). Harp traps vary in size from 1 to 4 m^2 (4 to 45 ft^2). Multiple traps can be linked together with specialized hardware to increase the capture area.

3. Application – See Section II on page 228 prior to initiating surveys. Harp traps can be deployed successfully in almost any location where bats are expected to fly and are highly effective for capturing bats at ground and sub-canopy levels. Identify productive sites by conducting acoustic surveys in advance (see Section I.B on page 224). Set harp traps in locations similar to mist nets for the greatest capture success (see Section III.A.3 on page 233). Take special care when capturing bats near roosts to avoid harming young bats and causing roost abandonment (see Section IV on page 236).

   Harp traps can be deployed in many different situations, including suspending the trap. Because of the relatively small capture area of harp traps, mist nets may be used to funnel bats into the trap. Record the number of harp traps, mist nets, and their configuration on data sheets for future reference.

   Harp traps may be set anytime during the day up to ½ hour prior to sundown. Once installed, harp traps may be monitored continuously or periodically, such as every 15 minutes, for a minimum of 2.5 hours. Captured bats should be removed during regular monitoring intervals. See Section II on page 228 for information on handling bats after capture and species identification.

   Survey sites should be sampled at least twice each year during 2 different seasons. The first sampling period should be during early summer to assess the adult bat community. The second sampling period should be during August, after the young are volant, to assess reproduction.

4. Analysis of Data – See Section III.A.4 on page 234.

5. Data Sheet – See the General Capture Form on page 256.

IV. Roost Surveys

Surveying for bats at known or suspected roost locations can be a very effective method for identifying roost occupancy, species presence, and seasonal use of the roost. However, roost surveys conducted by well intentioned but poorly-trained surveyors may negatively impact the roost, individual bats, and populations, and may place the surveyor at great risk of injury or death. A wide variety of techniques are available for surveying roosts, but they are not all appropriate for all situations. In many cases, a great deal of data can be collected about the roost and the bats that potentially occupy the roost without ever entering the roost. On the other hand, bat use of roosts in some seasons, such as winter, may be nearly impossible to detect and quantify without entering the roost. This section is intended to guide land managers in planning for and requesting trained surveyors to collect data at roosts and minimize impacts to bats.

Because of the risk of harm to both surveyors and bats in and around roosts, only trained personnel should conduct roost surveys. Hazards exist on the surface, around openings, and inside roosts and potential roosts. Several excellent sources and protocols have been developed that provide specific guidelines for conducting surveys under these conditions, including Altenbach and others (1999; 2002a; 2002b) and Sherwin and others (2002). The WGFD maintains a roost database of all known and potential roosts in Wyoming. All personnel planning to conduct roost surveys should contact the WGFD Nongame Mammal Biologist (260 Buena Vista, Lander, WY 82520, 307-332-2688) for assistance in conducting surveys, copies of protocols, and additional information on roosts in Wyoming.

A. Diurnal External Roost Surveys

1. Rationale – Primarily used to document cave and abandoned mine locations and physical features, data collected during diurnal external roost surveys are useful for determining the potential for sites to serve as bat roosts. It is usually not possible to determine with certainty whether bats are currently using the roost. The data collected during these surveys are used to prioritize other surveys.

2. Equipment – GPS, compass, spotlight or flashlight, and 7.6-m (25-ft) measuring tape.

3. Application – Surveys can be conducted year-round but are preferable in seasons where snow cover is absent to ensure that potential hazards are easily identifiable by the surveyor. It may not be possible to gather all required data in all situations.

4. Analysis of Data – Record the date and time of survey; substrate; potential hazards; habitat type; actual or approximate size of the portal or shaft; bearing of the opening;

slope aspect; GPS location, including UTM easting, UTM northing, zone, and datum; and whether a dark zone exists. For shafts, record whether a horizontal drift exists.

5. Data Sheet – See the External Roost Survey Form on page 258.

B. Nocturnal External Acoustic Surveys

1. Rationale – Nocturnal external acoustic surveys are useful for documenting summer use and presence of bats at potential roost sites. These surveys are most effective with heterodyne bat detectors. It is usually not possible to distinguish bat species using this survey technique.

2. Equipment – GPS, tally counter, and heterodyne bat detector.

3. Application – See Section I.B on page 224 for additional information on heterodyne bat detectors. Surveys should be conducted June through September. Initiate surveys ½ hour before sunset and monitor the roost entrance for a minimum of 2.5 hours. Locate survey stations a safe distance from the roost entrance to minimize risk to the surveyor. Visual observations of bats can be enhanced at twilight by backlighting the bats against the sky. Where possible, repeat surveys at least twice during a season.

4. Analysis of Data – Record the date and time of survey, habitat type, distance to roost, number of total passes, time of first pass, time of last pass, and any bats observed entering or exiting the roost.

5. Data Sheet – See the Acoustic Survey Form on page 248.

C. Nocturnal External Exit Roost Surveys

1. Rationale – Nocturnal external exit roost surveys are useful for identifying the number of bats occupying day or maternity roosts. These surveys cause minimal impacts to the bats and require no special training, although it is not possible to distinguish bat species.

2. Equipment – GPS and tally counter.

3. Application – See Section IV.B.3 on page 237 for application. Also, complete an External Roost Survey Form (see page 258) if this is the first visit to the roost. Conduct surveys during the summer season—June through September. Terminate surveys 1 hour after sunset or when bats are no longer exiting the roost.

4. Analysis of Data – Record the date and duration of survey, habitat type, number of bats observed exiting the roost, time of the first observed exit, and duration of exit.

5. Data Sheet – See the Exit Count Survey Form on page 259.

D. Nocturnal Portal Capture Surveys

1. Rationale – Nocturnal portal capture surveys are commonly used to identify the species and sex of bats using a roost or to determine whether the roost is being used by bats. Prior to conducting capture surveys, either a nocturnal external acoustic or exit survey should be performed to minimize impacts to maternity colonies or other large concentrations of bats.

2. Equipment – See Section III (General Capture Surveys) on page 232.

3. Application – See Section II on page 228 for information about handling, holding, and processing bats. The size of the capture device will vary with the size of the opening. Capture devices may be installed anytime during the day, but should be kept closed until ½ hour prior to sundown to ensure that birds and other non-target species are not accidentally captured. Once capture devices are open, monitor them continuously for a minimum of 2.5 hours and remove bats as soon as possible after capture. Plastic polysheeting can be used to seal off portions of the portal that are not covered by the capture device and prevent bats from flying around the capture device. The capture device should be placed a few feet in front of the portal to ensure that the surveyor has access to both sides to remove both incoming and outgoing bats.

4. Analysis of Data – Record the date and time of survey; substrate; potential hazards; habitat type; actual or approximate size of the portal or shaft; bearing of the opening; slope aspect; GPS location, including UTM easting, UTM northing, zone, and datum; and whether a dark zone exists. For shafts, record whether a horizontal drift exists.

5. Data Sheet – See the Roost Capture Form on page 260.

E. Internal Roost Surveys

1. Rationale – Internal roost surveys are commonly used to assess the potential of a site to serve as a bat roost, determine whether the site is currently being used by bats and which species are present, and determine seasonality of roost use.

2. Equipment – A minimum of 2 light sources, digital thermometer, GPS, 4-gas detector, and respirator. All flashlights and spotlights should be covered with red lenses.

3. Application – Surveys should be conducted at least once during each the cold and warm seasons. Conduct surveys of roosts known to be occupied by bats only once every 3 years during the season of occupancy, and avoid entering known maternity roosts before August to minimize impacts to the bat residents. Conduct hibernacula surveys between November and April. Because this type of survey poses significant risks to both surveyor and bats, surveys should be performed by properly trained personnel only.

4. Analysis of Data – Record date of survey, dimensions of the entrance, location and number of bats, signs of bat use (such as guano and insect remains), any additional openings, and noticeable airflow. Also provide a map of the interior of the site with interior dimensions, length of passages and chambers, and ambient temperatures and humidity for each room and passage.

5. Data Sheet – See the Internal Roost Survey Form on page 262.

MONITORING BATS

Bats are inherently difficult to monitor because of their small size, secretive nature, and low capture probability. Efforts are currently underway by several groups, such as the WBWG and the North American Bat Conservation Partnership, to develop monitoring protocols for most western bat species. These invaluable efforts are being closely watched by the WYBWG, which will review these documents carefully as they become available. The best approach for Wyoming will determined by the WYBWG to ensure that the monitoring strategies developed or adopted will be most beneficial for Wyoming's bat fauna.

Wyoming Bat Survey Matrix
Revised June 2005

The following Wyoming Bat Survey Matrix was developed by revising the Western Bat Working Group's survey matrix for western bat species. Use the following key to determine which survey techniques are most effective for individual bat species in Wyoming.

KEY
1 = Highly Effective
2 = Effective in Most Habitats or Situations
3 = Effective in Some Habitats or Situations
4 = Presents Serious Challenges
5 = Generally Not Effective
U = Unknown

Bat Species		Survey Type				Comments
Scientific Name	Common Name	Netting	Roost	Acoustic (passive)	Acoustic + Visual (active)	Survey Information
Antrozous pallidus	Pallid Bat	3	3	2	1	**Netting**- Capture: Flies low to ground and readily captured in nets (often in upland habitats). ID: Morphologically distinct. **Roost**- Location: Colonies easy to detect in man-made roosts; difficult in most natural roosts (trees and rock crevices). Frequently uses man-made roosts (mines, bridges, buildings) in parts of its range. Often found in night roosts, especially mines and bridges. ID: Roost conspicuous, easy to ID. Guano with characteristic culled insect parts (particularly Jerusalem crickets and scorpions) often distinctive. **Passive Acoustic**- Detection: Easy to detect acoustically. ID: Subset of calls diagnostic, particularly if it gives a "directive" call. **Active Acoustic**- Visually distinctive.
Corynorhinus townsendii	Townsend's Big-eared Bat	2	2	4	4	**Netting**- Capture: May avoid mist nets, netting most effective at night roosts. ID: Morphologically distinct. **Roost**- Location: Easiest to find by searching for colonial roosts in mines and caves. Roosts in buildings occasionally. ID: Easy to locate and ID in roost. **Passive Acoustic**- Detection: Difficult to detect acoustically--low intensity calls ("whispering bat"). ID: Calls, when detected, are diagnostic. **Active Acoustic**- Visually distinctive in most settings.
Eptesicus fuscus	Big Brown Bat	2	3	3	1	**Netting**- Capture: Readily captured in mist nets, but problematic in open areas, especially where water is abundant. ID: Morphologically distinct. **Roost-** Location: Easy to locate man-made roosts; difficult in most natural roosts (trees and rock crevices). Natural roosts dominate throughout much of range. Night roost surveys often effective. ID: Colonies often conspicuous, species easy to ID. **Passive Acoustic**- Detection: Easy. ID: subset of sequences diagnostic; acoustic overlap with *L. noctivagans* and *T. brasiliensis*. **Active Acoustic**- Visually distinctive in flight.

Bat Species		Survey Type				Comments
Scientific Name	Common Name	Netting	Roost	Acoustic (passive)	Acoustic + Visual (active)	Scientific Name
Euderma maculatum	Spotted Bat	4	5	2	1	**Netting**- Capture: Can be effective where water is a limiting factor in xeric conditions, although netting is not effective in many portions of range. ID: Morphologically distinct. **Roost**- Location: Non-colonial, cliff-roosting; very difficult to locate and generally inaccessible. ID: Unknown; no roosts have been visually inspected. **Passive Acoustic**- Detection: Easy to detect acoustically (with microphones sensitive to audible frequencies). Calls are audible to human ear. ID: Sequences diagnostic. **Active Acoustic**- Distinctive in flight.
Lasionycteris noctivagans	Silver-haired Bat	2	5	2	1	**Netting**- Capture: Vulnerability to net capture varies with habitat, but generally quite susceptible to capture. Captured over water sources (large and small). ID: Morphologically distinct. **Roost**- Location: Very difficult to locate in natural roosts (trees and snags). ID: Unlikely to locate via roost search but can be distinguished visually in flight upon exit. **Passive Acoustic**- Detection: Easy to detect acoustically. ID: Some calls distinctive, but overlap with *T. brasiliensis* and *E. fuscus*. In areas without *T. brasiliensis*, many sequences are diagnostic. **Active Acoustic**- With experience can be distinguished visually in flight.
Lasiurus cinereus	Hoary Bat	3	5	1	1	**Netting**- Capture: Flies high; often under-represented in net captures. Often forages in areas that cannot be feasibly netted. ID: Morphologically distinct. **Roost**- Location: Non-colonial. Very difficult to locate tree roosts. ID: Difficult to locate bats in foliage but easy to distinguish from other species. **Passive Acoustic**- Detection: Easy to detect acoustically. ID: Many calls diagnostic in Wyoming. **Active Acoustic**- Distinctive in flight

Bat Species		Survey Type				Comments
Scientific Name	**Common Name**	**Netting**	**Roost**	**Acoustic (passive)**	**Acoustic + Visual (active)**	**Scientific Name**
Myotis ciliolabrum	Western Small-footed Myotis	2	3	4	3	**Netting**- Capture: Readily captured in nets in Wyoming but varies throughout range. ID: Morphologically similar to *M. californicus*. Can be reliably identified using combination of morphological and acoustic data. **Roost**- Location: Predominantly non-colonial. Frequently in mines, natural roosts likely dominate, and difficult to find. Sometimes found in night roosts. ID: Roosts in small groups. Requires handling for positive identification. **Passive Acoustic**- Detection: Easy to detect acoustically. ID: Overlap with other 40-kHz *Myotis,* making ID difficult. **Active Acoustic**- Can sometimes be distinguished when observed in flight, but requires experience.
Myotis evotis	Long-eared Myotis	1	3	2	1	**Netting**- Capture: Readily captured in mist nets at both aquatic and terrestrial sites. ID: Morphologically distinct except in areas of overlap with *M. septentrionalis*. Also similar to *M. thysanodes* in some regions. **Roost**- Location: Can be detected in man-made roosts, but often cryptic; difficult in most natural roosts (trees and rock crevices). Natural roosts dominate. Sometimes in night roosts, particularly mines and bridges. ID: Small colonies. Generally crevice roosting. Often requires handling for positive identification. **Passive Acoustic**- Detection: Intermediate intensity calls ~35 kHz. ID: Calls diagnostic.
Myotis lucifugus	Little Brown Myotis	1	3	2	2	**Netting**- Capture: Usually readily netted in Wyoming, but may vary. ID: Morphologically similar to *M. yumanensis*. Can be reliably identified using combination of morphological and acoustic data. **Roost**- Location: Frequently in man-made roosts (mines, bridges, buildings). Difficult to find in most natural roosts (trees and rock crevices). Sometimes found in night roosts. ID: Highly colonial and easy to detect in man-made roosts. Often requires handling for positive identification. **Passive Acoustic**- Detection: Easy to detect acoustically. ID: Some calls/sequences diagnostic, though can be difficult to distinguish from other 40-kHz *Myotis*. **Active Acoustic**- Flight behavior sometimes distinctive, particularly over water.

Bat Species		Survey Type				Comments
Scientific Name	**Common Name**	**Netting**	**Roost**	**Acoustic (passive)**	**Acoustic + Visual (active)**	**Scientific Name**
Myotis septentrionalis	Northern Myotis	3	3	2	2	**Netting**- Capture: More successful in interior forest than over water in eastern deciduous forest; harp traps set in gaps between trees effective in South Dakota and Wyoming. Occasionally captured over water. ID: Easy except where range overlaps with *M. evotis*. **Roost**- Location: Surveys for night roosts and hibernacula can be effective; day roosts under bark. ID: Very cryptic in day roosts. Requires handling for positive identification. **Passive Acoustic**- Detection: Intermediate intensity calls ID: Many sequences diagnostic, but overlap with other 40-kHz *Myotis*, particularly *M. lucifugus*. Also potential for confusion with *M. evotis*. **Active Acoustic**- May be helpful in distinguishing it from other small-eared *Myotis*. Often flies in cluttered settings where ID can be difficult.
Myotis thysanodes	Fringed Myotis	1	3	2	1	**Netting**- Capture: Readily captured in mist nets. ID: Generally easy, but morphologically similar to *M. evotis* in some areas. **Roosts**- Location: Can be detected in man-made roosts, but difficult in most natural roosts (trees and rock crevices). Natural roosts dominate. Sometimes found in night roosts. ID: Small colonies, often roosts in crevices. Requires handling for positive identification. **Passive Acoustic**- Detection: Intermediate intensity calls. ID: Many sequences/calls diagnostic. Possible confusion with *A. pallidus*. **Active Acoustic**- Flight behavior, in combination with call morphology, sometimes helpful.
Myotis volans	Long-legged Myotis	1	2	4	3	**Netting**- Capture: Effective in Wyoming. ID: Morphologically distinct. **Roost**- Location: Can be found in man-made roosts; difficult in most natural roosts. Natural roosts dominate. Often found in night roosts. ID: Requires handling for positive identification. **Passive Acoustic**- Detection: Easy to detect acoustically. ID: Issues currently unresolved with other 40-kHz *Myotis*. **Active Acoustic**- Flight behavior can be distinctive.

Bat Species		Survey Type				Comments
Scientific Name	**Common Name**	**Netting**	**Roost**	**Acoustic (passive)**	**Acoustic + Visual (active)**	**Scientific Name**
Lasiurus borealis	Eastern Red Bat	2	5	1	1	**Netting**- Capture: Readily captured over water and in side channels in eastern US. ID: Morphologically distinct. Roost- Location: Difficult to locate tree roosts. ID: Difficult to locate bats in foliage, easy to ID. **Passive Acoustic**- Detection: Easy to detect acoustically. ID: Most sequences diagnostic. **Active Acoustic**- Distinctive in flight.
Myotis californicus	California Myotis	1	4	2	1	**Netting**- Capture: Readily captured in mist nets. ID: Morphologically similar to *M. ciliolabrum*. Can be distinguished from *M. ciliolabrum* by combination of capture and recording of hand-release echolocation call. **Roost**- Location: Can be found in man-made roosts, but generally non-colonial and crevice-roosting; most roosts not man-made and difficult to find. Sometimes found in night roosts. ID: Requires handling for positive identification. **Passive Acoustic**- Detection: Easy. ID: Difficult to distinguish from *M. yumanensis* (50-kHz *Myotis*) but ranges do not overlap in Wyoming. **Active Acoustic**: Flight behavior distinctive.
Myotis yumanensis	Yuma Myotis	1	2	2	2	**Netting**- Capture: Water-skimming foraging style makes this species highly vulnerable to capture in mist nets set over still water. ID: Morphologically similar to *M. lucifugus*. Can be distinguished from *M. lucifugus* by combination of capture and recording of hand-release echolocation call. **Roost**- Location: Commonly in man-made roosts. Forms large aggregations in night roosts (particularly bridges). Difficult to locate most natural roosts. ID: Highly colonial and easy to detect in man-made roosts. Requires handling for positive identification. **Passive Acoustic**- Detection: Easy to detect acoustically. ID: Difficult to distinguish from *M. californicus* (50-kHz *Myotis*).

Bat Species		Survey Type				Comments
Scientific Name	**Common Name**	**Netting**	**Roost**	**Acoustic (passive)**	**Acoustic + Visual (active)**	**Scientific Name**
Tadarida brasiliensis	Mexican Free-tailed Bat	3	3	3	1	**Netting**- Capture: While sometimes captured in mist nets, this species flies high and is generally more abundant than net captures would suggest. ID: Generally distinctive. **Roost**- Location: Highly colonial and easy to detect in man-made roosts; difficult in most natural roosts. ID: Easy to locate and ID in most roosts. Guano and odor distinctive. **Passive Acoustic**- Detection: Easy to detect acoustically. ID: Some calls overlap with other species (*L. noctivagans, E. fuscus, L. cinereus*), but many are diagnostic. In most settings this is the easiest way to detect the species. **Active Acoustic**- Visually distinctive.
Nyctinomops macrotis	Big Free-tailed Bat	3	5	1	1	**Netting**- Capture: Records extremely limited, suggesting serious challenges. ID: Morphologically distinct. **Roost**- Location: Generally cliffs and rock crevices; often inaccessible. Also known to use building and tree roosts. ID: Generally requires monitoring at emergence. **Passive Acoustic**- Detection: Easy to detect acoustically (best with low-frequency microphone); calls in audible range for some people. ID: Most calls diagnostic. Species poorly known. **Active Acoustic**- Distinctive in flight.
Pipistrellus subflavus	Eastern Pipistrelle	U	3	1	1	**Netting**- Capture: Unknown. ID: Morphologically distinct. **Roost**- Location: Natural roosts dominate. Generally non-colonial and crevice-roosting; most roosts are difficult to find. However, the only record for Wyoming was in winter roost. **Passive Acoustic**- Detection: Easy. ID: Most call sequences distinct. **Active Acoustic**: Flight behavior distinctive.

ACOUSTIC SURVEY FORM

SITE INFORMATION

Date (mm/dd/yy):		
Site # / WP#:	**Locality (place name, drainage):**	
Picture # (if applicable):	**Elevation(m):**	**Observers (full name; circle recorder)**
Property Owner:	**Phone #:**	
UTM Zone/GPS Datum:	**GPS EPE (m):**	
GPS Location of Reference Waypoint (UTM): Easting __________________; Northing ____________________		
Route from known location:____ _____________		

WEATHER DATA

Beginning Temperature (^{o}C): _______________	**Beginning Temperature (^{o}C):** _______________
Beginning Baro. Pressure (mmHg): ______________	**Ending Baro. Pressure** (mmHg): ________________
Beginning Wind (mph): _______________	**Ending Wind (mph):** _______________
Beginning Relative Humidity (%): _______________	**Ending Relative Humidity** (%): _________________

AUDIBLE SURVEYS (EUMA)

Observer:	**Time of civil sunset** (24hr):	**Phase of Moon:**
Start Time (24hr):	**End Time** (24hr):	
# of Passes (24hr):	**Time of First Pass** (24hr):	**Time of Last Pass** (24hr):
Comments:		

GENERAL SURVEYS - HETERODYNE (MINI-BAT DETECTOR)

Observer:	**Time of civil sunset** (24hr):	**Phase of Moon**:
Make/Model:	**Frequency Setting** (khz):	
Start Time (24hr):	**End Time** (24hr):	
Total # of Passes:	**Time of First Pass** (24hr):	**Time of Last Pass** (24hr):
Habitat Type:		
Comments:		

ROOST SURVEYS - HETERODYNE (MINI-BAT DETECTOR)

Roost Type (Cave, Abandoned Mine, other):		**Distance to Roost**:
Observer:	**Time of civil sunset** (24hr):	**Phase of Moon**:
Make/Model:	**Frequency Setting** (khz):	
Start Time (24hr):	**End Time** (24hr):	
Total # of Passes:	**Time of First Pass** (24hr):	**Time of Last Pass** (24hr):
# of Bats Observed Entering Roost:	**# of Bats Observed Exiting Roost**:	
Habitat Type:		
Comments:		

Table 4. Typical minimum call frequency of foraging bats in Wyoming.

Common Name	**Scientific Name**	**Typical Minimum Frequency**
Spotted bat	*Euderma maculatum*	< 10 kHz
Hoary bat	*Lasiurus cinereus*	< 20 kHz
Big free-tailed bat	*Nyctinomops macrotis*	< 20 kHz
Big brown bat	*Eptesicus fuscus*	20 – 30 kHz
Silver-haired bat	*Lasionycteris noctivagans*	20 – 30 kHz
Brazilian free-tailed bat	*Tadarida brasiliensis*	20 – 30 kHz
Pallid bat	*Antrozous pallidus*	30 – 40 kHz
Townsend's big-eared bat	*Corynorhinus townsendii*	30 – 40 kHz
Long-eared myotis	*Myotis evotis*	30 – 40 kHz
Fringed myotis	*Myotis thysanodes*	30 – 40 kHz
Eastern red bat	*Lasiurus borealis*	40- 50 kHz
Western small-footed myotis	*Myotis ciliolabrum*	40- 50 kHz
Little brown myotis	*Myotis lucifugus*	40- 50 kHz
Northern myotis	*Myotis septentrionalis*	40- 50 kHz
Long-legged myotis	*Myotis volans*	40- 50 kHz
Eastern pipistrelle	*Pipistrellus subflavus*	40- 50 kHz
California myotis	*Myotis californicus*	50- 60 kHz
Yuma myotis	*Myotis yumanensis*	50- 60 kHz

Table 5. Recommended AnaBat® call file analysis abbreviations.

SP (species code): If there are multiple designations, separate each with a comma *without using spaces* (e.g., aMYLU,aB25k).

Code	Definition	Notes
aXXXX?	Species XXXX identification is questionable (based on analysis of the AnaBat® call file).	
aM40k	Species only identifiable as a 40-kHz myotis (e.g., MYLU, MYVO, MYCI).	
aM50k	Species only identifiable as a 50-kHz myotis (e.g., MYCA, MYYU).	
aB25k	Species only identifiable as a bat with an Fmin in the 25-kHz range, based on analysis of the AnaBat® call file (generally includes EPFU, LANO, and TABR).	
aB30k	Species only identifiable as a species with steep calls ending roughly in the 30-kHz range (e.g., MYTH, MYEV, ANPA, sometimes COTO).	
aXXXX, aYYYY	Calls of both species XXXX and YYYY occur in the same file (based on analysis of the AnaBat® call file).	
vXXXX	Species XXXX positively identified by visual observation.	
rXXXX	Species XXXX recorded during hand release	
tXXXX	Species XXXX recorded during hand release with a tether.	
Q	Questionable call identification--requires further analysis.	
b	Call file is identifiable as a bat, but cannot be assigned a species.	

Table 6. Four-letter species codes (XXXX)

ANPA	MYCA	MYTH	LABO	TABR
COTO	MYCI	MYVO	LACI	PIHE
EPFU	MYEV	MYYU	LANO	PISU
EUMA	MYLU	MYSE	NYMA	

ANABAT® SURVEY FORM

SITE INFORMATION

Site # / WP#:		**Locality** (place name, drainage):	
Landowner:	**Elevation**(m):		**Observers** (full name; circle recorder)
Picture # (if applicable**):**			
UTM Zone/GPS Datum:		**GPS EPE** (m):	
GPS Location of Reference Waypoint (UTM): Easting _________________; Northing __________________________			
CF Unit and Card Number Used:			

SESSION INFORMATION

Date (dd/mm/yy):		**Time of civil sunset** (24hr):	**Phase of Moon:**
Time activated (24hr):		**Time deactivated** (24hr):	
Division Ratio:	**Sensitivity:**	**Height above Ground:**	
Orientation:			

AnaBat® Configuration: Sketch (grid cell size: ________m)

Notes

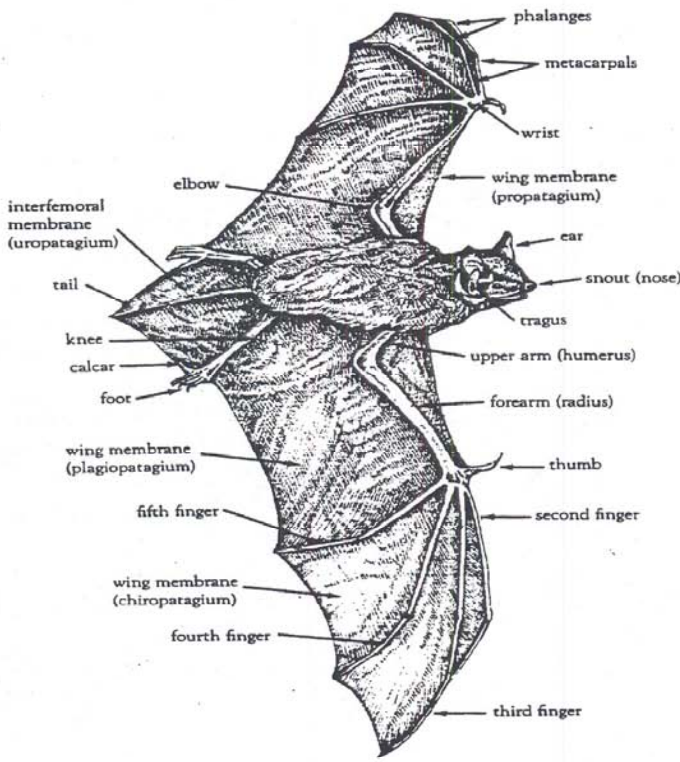
WEATHER DATA

Beginning Temperature (°C): _______________	**Beginning Temperature (°C):** _______________
Beginning Baro. Pressure (mmHg): ______________	**Ending Baro. Pressure** (mmHg): ________________
Beginning Wind (mph): _______________	**Ending Wind (mph):** _______________
Beginning Relative Humidity (%): _______________	**Ending Relative Humidity** (%): _________________

CALL ANALYSIS (call file# = representative call file)

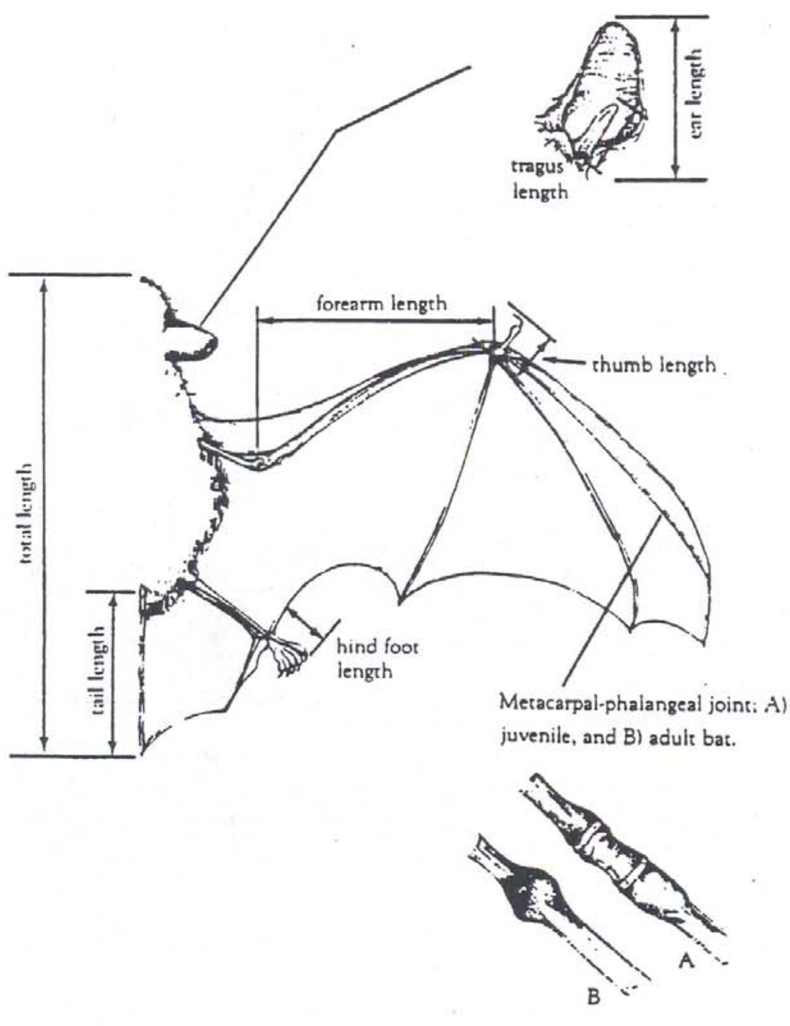
Species 1 (call file#):	**# of calls:**	**(call file#):**	**# of calls:**
Species 2 (call file#):	**# of calls:**	**(call file#):**	**# of calls:**
Species 3 (call file#):	**# of calls:**	**Comments:**	
Species 4 (call file#):	**# of calls:**		

THE ANATOMY OF A BAT



Source: "The bats of Texas" by David J. Schmidly, drawing by Christine Stetter

Measurements used in Species Identification Keys



DICHOTOMOUS KEY TO THE BATS OF WYOMING

Revised June 2005

The criteria listed only apply to adult animals in which the metacarpal-phalangeal joint on the right second finger is not bulbous and appears solid with no open spaces when viewed against a bright light.

1a. Tail fully within the interfemoral membrane or extending a few millimeters beyond the edge of the interfemoral membrane (FAMILY VESPERTILIONIDAE)	2
1b. Approximately 50% of the tail extends beyond the trailing edge of the interfemoral membrane (FAMILY MOLLOSSIDAE)	17

FAMILY VESPERTILIONIDAE

2a. Black dorsal fur; conspicuous white spot on each shoulder, one white spot on rump; ears 45 to 50 mm	Spotted Bat (*Euderma maculatum*)
2b. Lacks white spots on rump and shoulders	3

3a. At least the anterior half of the dorsal surface of the interfemoral membrane is well-furred	4
3b. Dorsal surface of the interfemoral membrane naked or sparsely-furred	6

4a. Uniform black dorsal fur with silver tips; black face	Silver-haired Bat (*Lasionycteris noctivagans*)
4b. Dorsal fur color variable but not uniformly black; face not black	5

5a. Dorsal fur dark gray and tipped with band of white (hoary appearance); forearm length 46 to 58 mm; light-colored ears distinctively edged in black	Hoary Bat (*Lasiurus cinereus*)
5b. Dorsal fur bright reddish-orange to yellow	Red Bat (*Lasiurus borealis*)

6a. Ear length 25 mm or more; ear color translucent or paler than pelage	7
6b. Ear length 25 mm or less; ear color variable, ranging from same as pelage to black	8

7a. Pale yellow-brown dorsal fur, lighter at base than tip; blunt snout; light-colored translucent ears 25 to 33 mm long; forearm 50 to 55 mm long	Pallid Bat (*Antrozous pallidus*)
7b. Slate gray or brown fur; prominent fleshy lumps above nose; ears 30 to 39 mm long	Townsend's Big-eared Bat (*Corynorhinus townsendii*)

8a. Tri-colored dorsal hairs, brown at tip and base, yellow between; forearm length 30 to 35 mm; pink forearm	Eastern Pipistrelle (*Pipistrellus subflavus*)
8b. Dorsal fur uniformly medium brown to pale brown	9

9a. Keel on calcar visible to the naked eye	10
9b. Keel on calcar absent	13

10a. Wingspan 325 to 350 mm; tragus round; forearm length > 42 mm
Big Brown Bat (*Eptesicus fuscus*)

10b. Wingspan < 300 mm; forearm length < 42 mm — 11

11a. Underside of wing furred from side of body to the elbow; wingspan 250 to 270 mm; forearm length 35 to 41 mm — Long-legged Myotis (*Myotis volans*)

11b. Underside of wing not furred from side of body to the elbow — 12

12a. Tail extends slightly beyond the interfemoral membrane; black mask visible; no distinct rise in the braincase profile; length of bare snout approx. 1.5 times the width across nostrils; forearm length 30 to 36 mm
Western Small-footed Myotis (*Myotis ciliolabrum*)

12b. Tail does not extend beyond the interfemoral membrane; black mask absent; distinct rise in the braincase profile; length of bare snout approx. equal to the width across nostrils; forearm length 32 to 35 mm
California Myotis (*Myotis californicus*)

13a. Distinct fringe of hair on trailing edge of interfemoral membrane visible to naked eye; ears 16 to 20 mm; forearm length 39 to 46 mm — Fringed Myotis (*Myotis thysanodes*)

13b. Some hairs may be present but lacks distinct fringe on trailing edge — 14

14a. Ears 19 to 25 mm long; ears extend up to 7 mm beyond nose when laid forward; tragus long and thinLong-eared Myotis (*Myotis evotis*)

14b. Ears < 19 mm long — 15

15a. Ears 17 to 19 mm; ears extend < 2 mm beyond nose when laid forward; tragus long, thin, pointed, and > 50% of ear height
Northern Long-eared Myotis (*Myotis septentrionalis*)

15a. Ears < 16 mm — 16

16a. Ears generally darker than dorsal fur; forearm length 36 to 41 mm; usually 1 upper premolar; foot hairs usually extend past toes; pelage dark brown with silky sheen
Little Brown Bat (*Myotis lucifugus*)

16b. Ears pale and nearly same color as dorsal fur; forearm length 32 to 38 mm; always 2 upper premolars; foot hairs do not extend past toes; pelage lacks silky sheen
Yuma Myotis (*Myotis yumanensis*)

FAMILY MOLLOSSIDAE

17a. Ears connected and joined at base before reaching top of nose; forearm length 44 to 50 mm
Big Free-tailed Bat (*Nyctinomops macrotis*)

17b. Ears not connected, although occasionally meeting before reaching top of nose; forearm length 36 to 46 mm — Brazilian Free-tailed Bat (*Tadarida brasiliensis*)

GENERAL CAPTURE FORM

SITE INFORMATION

Site # / WP#:	**Locality** (e.g., Drainage):	
Property Owner:	**Elevation**(m):	**Observers** (full name; circle recorder)
Roost Survey (Yes/No):	**Roost Type** (Cave, Mine, Other):	
UTM Zone/GPS Datum:	**GPS EPE** (m):	
GPS Location of Reference Waypoint (UTM): Easting ________________________; Northing ___________________________		

SESSION INFORMATION

Date (dd/mm/yy):	**Time of civil sunset** (24hr):	**Phase of Moon:**
Time Nets Open (24hr):	**Time Nets Closed** (24hr):	

Net Configuration: Sketch (grid cell size: ________m)

Notes

No. of Nets Set

 # 6m: __________

 # 9m: __________

 # 12m: _________

 # 18m: _________

Harp Trap _____

WEATHER DATA

Beginning Temperature (^{o}C): _______________	**Ending Temperature (^{o}C): _______________**
Beginning Baro. Pressure (mmHg): ___________	**Ending Baro. Pressure** (mmHg): _____________
Beginning Wind (mph): _______________	**Ending Wind (mph): _______________**
Beginning Relative Humidity (%): ____________	**Ending Relative Humidity** (%): _______________

CAPTURE TOTALS

	M/F		M/F		M/F		
ANPA	________	**MYCA**	_______	**MYTH**	_______	**Total Bats**	______
COTO	________	**MYCI**	_______	**MYVO**	_______	**Total Species**	______
EPFU	________	**MYEV**	_______	**MYYU**	_______	**Total Adult**	______
EUMA	________	**MYLU**	_______	**PIHE**	_______	**Total Juvenile**	______
LABO	________	**MYSE**	_______	**NYMA**	_______	**Total Males**	______
LACI	________	**LANO**	_______	**TABR**	_______	**Total Females**	______

CAPTURE DATA

SPECIES (4 letter code)	**TOC** (24hr)	**Sex** (M/F)	**Age** (J/A/?)	**Repro** *	**FA** (mm)	**Th.** (mm)	**E** (mm)	**Wt** (g)	**V#**	**Notes** (inc. AnaBat® rec. time)

* Repro = Males: **N** (Non-reproductive), **D** (descended); Females: **N** (non-reproductive), **P** (pregnant), **L** (lactating), **PL** (post-lactating)
TOC = Time of Capture, FA = Forearm Length, Th. = thumb length, E = ear length, V# = voucher number, if collected.

EXTERNAL ROOST SURVEY FORM

SITE INFORMATION

Date (mm/dd/yy):				
Site # / WP#:			**Locality (place name, drainage):**	
Picture # (if applicable):		**Elevation(m):**		**Observers (full name; circle recorder)**
Property Owner:	**Phone #:**			
UTM Zone/GPS Datum:	**GPS EPE (m):**			
GPS Location of Reference Waypoint (UTM): Easting __________________; Northing ______________________				
Route from known location:____				

ROOST TYPE

Mine Adit (Horizontal Opening):__________________

Mine Shaft (Vertical Opening):________________

Cave:______________

Other:______________________

Gate Present (Yes/No)?_______________

Describe Gate:______________________________________

____

____

PHYSICAL FEATURES INFORMATION

Surrounding Habitat Description:____
Slope:_______________ Aspect:_________________ Substrate of Opening:_________________________
Dark Zone Present (Yes/No)?:__________ Approximate Depth to Dark Zone:______________________
Opening Width (m or in):_______________________ Opening Height (m or in):_______________________
Approximate length or depth of opening:____
(> "x" feet or meters OK)

HAZARDS

Physical Hazards Present (Yes/No):_________ Describe:____

____

Additional Comments:____

____

EXIT COUNT SURVEY FORM

SITE INFORMATION

Date (mm/dd/yy):			
Site # / WP#:		**Locality (place name, drainage):**	
Picture # (if applicable):	**Elevation(m):**		**Observers (full name; circle recorder)**
Property Owner:	**Phone #:**		
UTM Zone/GPS Datum:	**GPS EPE (m):**		
GPS Location of Reference Waypoint (UTM): Easting ________________; Northing ____________________			
Route from known location:____ **____________**			

ROOST TYPE

Mine Adit (Horizontal Opening):___________ **Gate Present (Yes/No)?______________**

Mine Shaft (Vertical Opening):______________ **Describe Gate:___________________________________**

Cave:_____________ **____**

Other:_____________________ **____**

Opening Width (m or in):__________________ **Opening Height (m or in):_______________________**

SURVEY INFORMATION

Observer:	**Time of civil sunset** (24hr):	**Phase of Moon**:
Survey Start Time (24hr):	**Survey End Time** (24hr):	
# of Bats Observed Exiting Roost:	**Distance to Roost**:	
Time of 1st Exit:	**Time of Last Exit:**	**Duration of Exit:**
Habitat Description:		
Comments:		

ROOST CAPTURE FORM

SITE INFORMATION

Site # / WP#:		**Locality** (e.g., Drainage):	
Property Owner:	**Elevation**(m):		**Observers** (full name; circle recorder)
Roost Survey (Yes/No):	**Roost Type** (Cave, Mine, Other):		
UTM Zone/GPS Datum:	**GPS EPE** (m):		
GPS Location of Reference WayPoint (UTM): Easting _______________________; Northing ___________________________			

ROOST TYPE

Mine Adit (Horizontal Opening):______________

Mine Shaft (Vertical Opening):________________

Cave:______________

Other:_____________________

Opening Width (m or in):____________________

Gate Present (Yes/No)?_______________

Describe Gate:_______________________________________

____

____

Opening Height (m or in):______________________

SESSION INFORMATION

Date (dd/mm/yy):	**Time of civil sunset** (24hr):	**Phase of Moon:**
Time Nets Open (24hr):	**Time Nets Closed** (24hr):	
Describe Location of Net:		

WEATHER DATA

Beginning Temperature (^{o}C): ________________	**Ending Temperature (^{o}C): ________________**
Beginning Baro. Pressure (mmHg): ____________	**Ending Baro. Pressure** (mmHg): ______________
Beginning Wind (mph): ________________	**Ending Wind (mph): ________________**
Beginning Relative Humidity (%): _____________	**Ending Relative Humidity** (%): ________________

CAPTURE TOTALS

	M/F		M/F		M/F		
ANPA	________	**MYCA**	_______	**MYTH**	_______	**Total Bats**	______
COTO	________	**MYCI**	_______	**MYVO**	_______	**Total Species**	______
EPFU	________	**MYEV**	_______	**MYYU**	_______	**Total Adult**	______
EUMA	________	**MYLU**	_______	**PIHE**	_______	**Total Juvenile**	______
LABO	________	**MYSE**	_______	**NYMA**	_______	**Total Males**	______
LACI	________	**LANO**	_______	**TABR**	_______	**Total Females**	______

ROOST CAPTURE DATA

SPECIES (4 letter code)	**TOC** (24hr)	**Flying** (In / Out)	**Sex** (M/F)	**Age** (J/A/?)	**Repro***	**FA** (mm)	**Th.** (mm)	**E** (mm)	**Wt** (g)	**V#**	**Notes** (inc. AnaBat® rec. time)

* Repro = Males: **N** (Non-reproductive), **D** (descended); Females: **N** (non-reproductive), **P** (pregnant), **L** (lactating), **PL** (post-lactating)
TOC = Time of Capture, FA = Forearm Length, Th. = thumb length, E = ear length, V# = voucher number, if collected.

INTERNAL ROOST SURVEY FORM

SITE INFORMATION

Date (mm/dd/yy):			
Site # / WP#:		**Locality (place name, drainage):**	
Picture # (if applicable):	**Elevation(m):**		**Observers (full name; circle recorder)**
Property Owner:	**Phone #:**		
UTM Zone/GPS Datum:	**GPS EPE (m):**		
GPS Location of Reference Waypoint (UTM): Easting ________________; Northing __________________			
Route from known location:____			

EXTERNAL ROOST INFORMATION

Mine Adit (Horizontal Opening):_______________ **Gate Present** (Yes/No)?____________

Mine Shaft (Vertical Opening):_____________ **Describe Gate:**______________________________

Cave:___________ ______________________________________

Other:_________________ ______________________________________

Surrounding Habitat Description:____

Slope:____________ **Aspect:**______________ **Substrate of Opening:**___________________

Dark Zone Present (Yes/No)?:_________ **Approximate Depth to Dark Zone:**_________________

Opening Width (m or in):___________________ **Opening Height (m or in):**_________________

Airflow Present (Yes/No)?:_____ **Airflow Direction**(In/Out):_____ **Approx. Airflow Speed:**_______

Hazards and Obstructions at Portal:____

INTERIOR ROOST INFORMATION

Width (m or ft):	**Height** (m or ft):	**Substrate**:
Depth or Length (m or ft):	**Dark Zone** (Yes/No):	**If Yes, Depth Start** (m or ft):
Timbered Adit (Yes/No)?:	**Condition of Timbers**:	
Water Present (Yes/No)?:	**Location and Depth** (m or ft):	
Number of Entrances:	**Previously Mapped** (Yes/No)?:	**Map Location:**
Hazards and Obstruction:		

OBSERVED BATS

BAT SIGN PRESENT (Yes/No):___________

ANPA	________	**MYCA**	_______	**MYTH**	_______
COTO	________	**MYCI**	_______	**MYVO**	_______
EPFU	________	**MYEV**	_______	**MYYU**	_______
EUMA	________	**MYLU**	_______	**PIHE**	_______
LABO	________	**MYSE**	_______	**NYMA**	_______
LACI	________	**LANO**	_______	**TABR**	_______

TYPE (guano, wrappings, other):_______________

If no bat sign or bats are observed, evaluate suitability for bats based on habitat characteristics:
(HIGH LOW NIL)

OBSERVED BATS DATA

SPECIES (4 letter code)	**QTY**	**STATUS***	**LOCATION** (room or corridor)	**DEPTH** (m)	**HEIGHT** (m)	**Temp** (°C)	**Humidity**	**Notes**

* Status = **T** (Torpid), **F** (Flying), **R** (Roosting and Alert)

INTERIOR MAP (Draw if not mapped and plot following locations for: bats, sign, hazards, temperature, and humidity)

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Bat-Human Conflicts

Over half of the bat species in the US are known to roost in or on buildings at least some of the time (Adams 2003; Kunz and Reynolds 2003). Unfortunately, this sometimes places them in direct conflict with humans (Fenton 2003). Fears and misconceptions about bats and rabies; a dislike for or antipathy toward bats; and noise, odors, and droppings have all prompted humans to deliberately exclude, repel, and even exterminate bats roosting in buildings (Barclay and others 1980; Greenhall 1982; Humphrey 1982; Olson 1991; Pierson 1998).

However, in many cases, owners are not bothered by or even aware of the bats roosting in or on their houses and buildings (Olson 1991). Unlike rodents, bats do not make holes in buildings, chew wiring, or build nests (Tigner 2002). Although large concentrations of bats can cause odors and accumulations of guano, many roosts are small and do not cause problems except to deposit droppings on the porch or sidewalk (Brown and Berry 1991; Luce 1998; Tigner 2002). Bats avoid humans wherever possible and reports of unprovoked attacks by bats are usually the result of a disoriented bat landing on the nearest available object (Humphrey 1982). Although people are sometimes concerned about the transmission of rabies and other diseases, bats roosting in areas that are outside the living space of humans, such as attics or the exterior of buildings, pose little risk. Nevertheless, care should be taken to avoid direct contact with bats and any bites should be treated as potential rabies transmission cases. (See “Public Health” on page 271 for more details.)

Many bats are loyal to specific roosts, and studies have shown that bats that are excluded from their roosts in buildings often do not survive (Humphrey 1982; Neilson and Fenton 1994; Brittingham and Williams 2000). Because the vast majority of bat colonies occupying buildings do not cause problems, they should be allowed to remain in place wherever possible (Luce 1998). Many people choose to coexist with bats in or on their buildings and enjoy the benefits of a ready supply of fertilizer for their garden and the contribution that bats make to a healthy ecosystem as the primary predators of nocturnal insects (Humphrey 1982; Brown and Berry 1991; Tigner 2002).

Resolving Conflicts between Humans and Bats

Contact between Bats and Humans

- To remove a bat that has wandered into the living quarters of a house, the simplest method is to open a window or door to the outside, close the doors to other rooms, and give the bat time to fly out (Humphrey 1982; Luce 1998). If it is still present by nightfall, turn off all the lights inside the house, as light will cause the bat to hide rather than seek out the open door or window (Olson 1991).

- Avoid handling bats wherever possible, take precautions against being bitten, and teach children not to pick up bats or other mammals. Bats found on the ground should be handled only with extreme care while transporting to a veterinarian or public official for rabies testing (Humphrey 1982; Luce 1998).

- If the bat is in a state of torpor and has not found its way out of the house, it may be possible to capture it and release it outside (Humphrey 1982; Olson 1991; Luce 1998). Wearing gloves, use a piece of cardboard as a scraper to gently slide the bat from its roosting surface into a small box or coffee can. Keep the container in a cool place until dark, then place the bat in the crook of a tree or other safe location outside to release it. Be sure to release it on the same day it is captured so it can eat and drink on its normal cycle (Luce 1998).

- In situations where bats are roosting in a building and there is concern about their gaining access to the living space of the building, consider isolating the area preferred by the bats from the rest of the building, instead of excluding them from the building entirely (WDOW 1993; Tigner and Aney 1994). For example, Kennedy (1996d) suggests walling off a section of the attic for bats, keeping part of the attic available for storage. Consider installing a vapor barrier, such as polysheeting, during renovations to ensure that urine and guano odor does not contaminate the living area.

Excluding Bats from Buildings

- Bats cannot be lured out of a preferred roost by simply placing a bat shelter nearby (Luce 1998; Brittingham and Williams 2000). If it is absolutely necessary to discourage bats from roosting in a building, exclusion—sealing bats out of the structure—is the most effective and permanent method, and allows bats at least the opportunity to seek alternative roosts (Barclay and others 1980; Greenhall 1982; Humphrey 1982; Olson 1991). All possible entrances to the roost, as small as 1 cm (3/8 in), must be completely sealed for exclusion to be effective (Luce 1998; Olson 1991). Bats are often very loyal to specific roosts and are surprisingly adept at finding alternate ways into buildings, especially those that they have occupied in the past.

- Avoid bat-proofing buildings while the bats are present—the best time is during winter while they are roosting in other locations and not present (October 1 through April 1) (Brown and Berry 1991; Luce 1998; Tigner 2002). If entrances to the roost are sealed while bats are present, they may be trapped and killed, or they may seek alternate exits and inadvertently enter the building's living space (Constantine 1982; Luce 1998; Tigner 2002). Furthermore, young bats that are not yet able to fly are at particular risk from exclusions that are performed during the maternity period, as they may be sealed inside the roost while the adults are out foraging (Constantine 1982; Tigner 2002).

- Exclusion techniques are site-specific, can be frustrating, and have potential to harm bats. Therefore, **please contact the Wyoming Game and Fish Department's (WGFD) Nongame Mammal Biologist** for advice before attempting to exclude bats from your building.

Harassment of Bats

- Do not kill bats. All of Wyoming's bats are protected from intentional take by Wyoming Game and Fish Commission regulation. Killing bats intentionally is illegal (Luce 1998), and it is also a poor solution to problem bats in buildings. In general, killing bats is a waste of time because unless the building is made inaccessible by sealing the entrances, it will usually be recolonized by new bats (Constantine 1982; Greenhall 1982).

- Do not use toxic chemicals or pesticides to control bats. Toxic chemicals and pesticides used on bats may be persistent in the building and dangerous to humans, pets, and bats for years, and sick and dying bats often scatter and fall to the ground where they are more likely to come into contact with children and pets (Barclay and others 1980; Tuttle and Kern 1981; Constantine 1982; Humphrey 1982). Furthermore, whether or not rabies has occurred in the colony, the stress imposed by pesticide toxicity may activate latent viral infections, thus increasing the incidence of rabies (Barclay and others 1980; Tuttle and Kern 1981).

- Avoid relying on repellants and other control measures, such as broadcasting loud or ultrasonic noises, illuminating roosts, or chemical or sticky repellants, to discourage bats from roosting in a building. Although these methods are usually not lethal, they do not make the roost inaccessible to bats and are generally ineffective in deterring bats (Humphrey 1982; Williams and Brittingham 1997; Luce 1998).

Contact Information

The WGFD uses information about where bats are roosting to learn more about bat populations in Wyoming. Personnel can also help you with ways to share your building with bats, or, if necessary, techniques for excluding bats from the building. **If there are bats roosting in your home or other building, please contact the Nongame Mammal Biologist at the Wyoming Game and Fish Department, at (307) 332-7723 or (800) 654-7862.**

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Public Health

Although bats are known to host a variety of diseases, in reality, they are no more or less likely to have diseases than other animals, and disease transmission to humans is rare (Tuttle and Kern 1981). Only 2 diseases, rabies and histoplasmosis, are known to have been transmitted from bats to humans, and exposure risks are easy to avoid (Keeley and Tuttle 1999). A third disease, West Nile virus, is still poorly understood, and has not yet been well studied in bats.

Rabies

Rabies is a viral infection that affects the central nervous system of mammals, including humans. It is most often reported in wild animals, particularly raccoons, skunks, foxes, coyotes, and bats, while domestic animals, including cats, dogs, and livestock, account for about 7% of rabid animals reported in the US (CDC 2004a). Bats can contract and transmit rabies, and the disease has been found at one time or another in many North American species of bats. However, media coverage of rabies in bats is often sensationalized and exaggerated, and folklore depictions of bats often perpetuate irrational fears (Tuttle and Kern 1981; Brown and Berry 1991; Fenton 2003). There is often a biased view of the incidence of rabies in bat populations because bats that are submitted for testing are most likely to be individuals that are sick and easily caught or already dead (Pierson and others 1999; Messenger and others 2003). In reality, bats do not rank very high among mortality threats to humans, and, statistically, pets, bees, playground equipment, and sports are far more dangerous to humans than bats. In North America, the incidence of rabies in bats is very low, usually less than 0.5% (Tuttle and Kern 1981; Messenger and others 2003; Racey and Entwhistle 2003), and rabies from bats accounts for only about 1 human death per year in the US (BCI 2003; Fenton 2003; CDC 2004a). In Wyoming, not one person has contracted rabies in nearly 30 years, although a few people have been exposed and sought treatment to prevent contracting the disease (Luce 1998). Only 3 of the 18 bat species in Wyoming are known to have tested positive for rabies—the little brown myotis, the big brown bat, and the silver-haired bat.

Rabies is nearly always transmitted by a bite from an infected animal, although non-bite exposures can result from contact between saliva or nervous tissues of an infected animal and open wounds or the mucous membranes of the eyes, nose, or mouth (BCI 2003). Most human exposures to infected bats result from careless handling of sick, grounded individuals (Tuttle and Kern 1981; BCI 2003). Although rabid dogs, cats, and other carnivores often become aggressive and try to attack humans and other animals, bats normally bite only in self-defense and are rarely aggressive, even when rabid (Tuttle and Kern 1981; Brown and Berry 1991).

Bats have often been cited as major carriers of rabies because of misinformation spread in the 1960s that they were asymptomatic reservoirs of the disease and would not die from it. More recent research has not supported this. Bats either survive exposure to rabies without spreading it or they succumb like other animals, usually within 3 to 5 days (Trimarchi 1978; Tuttle and Kern 1981; Messenger and others 2003). Also, researchers find no credible support for the hypothesis that undetected bites by bats are a significant factor in transmitting rabies to humans, as humans usually feel and recognize any bites they receive (BCI 2003; Messenger and others 2003). Furthermore, rabies cannot be transmitted by bat blood, urine, feces, or fur, and there is no evidence of airborne transmission in buildings. Although 2 cases of airborne transmission were reported in the 1950s in Texas caves that support very unusual environments, no similar cases have occurred since, despite the fact that many thousands of people enter bat caves each year, and no such transmission has occurred in buildings (BCI 2003; Fenton 2003; Messenger and others 2003).

How to Avoid Exposure

Although rabies from bats does not rank very high among mortality threats to humans, prudence and the following simple precautions can help reduce the risk of exposure.

- Avoid handling bats wherever possible and teach children never to handle any unfamiliar animal. If it is necessary handle a bat to transport it for rabies testing or to remove it from a building, wear gloves and use a piece of cardboard as a scraper to gently slide the bat from its roosting surface into a small box or coffee can (Tuttle and Kern 1981; Greenhall 1982; Luce 1998; BCI 2003; CDC 2004a).

- Bats roosting in areas of buildings that are outside the living space of humans, such as attics or building exteriors, pose little risk. Nevertheless, care should be taken to exclude bats from the living quarters or occupied spaces of homes or other buildings (Tuttle and Kern 1981; CDC 2004a). (See "Bat-Human Conflicts" on page 266 for more information.)

- Do not poison bats. All of Wyoming's bats are protected from intentional take by Wyoming Game and Fish Commission regulation, so killing bats intentionally is illegal (Luce 1998). Also, poisoned and sick bats often scatter and fall to the ground where they are more likely to come into contact with children and pets, and toxic chemicals and pesticides used on bats may be persistent in the area and dangerous to humans, pets, and bats for years (Barclay and others 1980; Tuttle and Kern 1981; Constantine 1982; Humphrey 1982; BCI 2003). Furthermore, whether or not rabies has occurred in the colony, the stress imposed by pesticide toxicity may activate latent viral infections, thus increasing the incidence of rabies (Barclay and others 1980; Tuttle and Kern 1981).

- Keep rabies vaccinations current for all domestic dogs, cats, and ferrets (BCI 2003; CDC 2004a).

- People who are at high risk of exposure, such as field biologists, rabies researchers, veterinarians, and wildlife rehabilitators, should receive pre-exposure rabies immunization (Tuttle and Kern 1981; BCI 2003; Messenger and others 2003).

- In the case of a bite from a bat, wash the wound thoroughly with soap and water and seek medical attention immediately. A safe and effective post-exposure vaccine is available for humans and may be appropriate unless laboratory tests show the bat to be negative for rabies (Trimarchi 1978; Tuttle and Kern 1981; Brown and Berry 1991; BCI 2003; Fenton 2003; CDC 2004a).

- Any bat that bites a human should be safely captured and tested for rabies as soon as possible (Trimarchi 1978; BCI 2003; Fenton 2003). If the bat is dead, avoid destroying its head, place it in a plastic bag, and keep it refrigerated (Greenhall 1982; Olson 1991). The bat may be given to a veterinarian, animal control officer, Wyoming Game and Fish Department representative, or public health official. Bats suspected of having rabies are sent to the Wyoming State Veterinary Laboratory in Laramie for testing (Olson 1991; Luce 1998).

Histoplasmosis

Histoplasmosis is a respiratory disease caused by a fungus called *Histoplasma capsulatum* that lives in soil enriched by the droppings of animals such as birds or bats. Humans risk infection only when they inhale the spores of the fungus—when soil or guano containing the fungus is disturbed, the spores become airborne and may be inhaled (Tuttle and Kern 1981; Greenhall 1982; Keeley and Tuttle 1999). The disease usually is asymptomatic or causes minor flu-like symptoms, although it can result in serious illness if a large number of spores are inhaled (Greenhall 1982; Humphrey 1982; BCI 2003). In the US, histoplasmosis is most common in the Ohio and Mississippi river valleys and other areas where high temperatures and humidity favor it (Luce 1998; BCI 2003). It is rare in the northern latitudes and the dry western states, although it is possible for it to develop in environments such as warm, moist caves. It is rare in Wyoming and has only been documented in 1 cave (Luce 1998).

How to Avoid Exposure

The best way to avoid exposure to histoplasmosis is to avoid inhaling dust from animal droppings (Tuttle and Kern 1981; BCI 2003). Ways to accomplish this include the following:

- Wear a respirator capable of filtering particles as small as 2 μ in diameter or use a self-contained breathing apparatus when cleaning or entering areas with bird or bat droppings (Tuttle and Kern 1981; Greenhall 1982; Keeley and Tuttle 1999).
- Dampen dry guano with water before removal (Greenhall 1982; Olson 1991).
- Or use a vacuum cleaner to remove dry bat guano (Tuttle and Kern 1981).

West Nile Virus

West Nile virus is a mosquito-borne virus that was first detected in the US in 1999 in New York. It quickly spread westward and was discovered in Wyoming in 2002 (Cornish and others 2003). Birds act as reservoirs for the virus, infecting mosquitoes that then may transmit the virus back to more birds or on to other hosts. West Nile virus has been confirmed in a small number of bats in the US (Gruver and Keinath forthcoming). Bats, like other mammals such as humans and horses, are probably “dead-end” hosts that can contract the virus but do not transmit it back to mosquitoes as birds do, but this has not been well studied (BCI 2003; Cornish and others 2003; SDBWG 2004). The degree to which bats are exposed to the virus and its population-level effects are also currently unknown (Gruver and Keinath forthcoming).

How to Avoid Exposure

Although bats cannot transmit West Nile virus to humans, here are some suggestions for avoiding exposure to the disease:

- Avoid mosquito bites by staying indoors during peak mosquito-biting times (dawn, dusk, and at night); wearing light-colored long-sleeved shirts and long pants; and applying mosquito repellant, especially with DEET (CDC 2004b; NAS 2004).

- Reduce the number of mosquitoes around human habitation by eliminating any standing water that is not ecologically important. For example:
  - Get rid of unwanted containers such as old tires and tin cans.
  - Empty or change water in flowerpots, barrels, pet dishes, and birdbaths weekly.
  - Drill drainage holes in the bottoms of containers that are left outside.
  - Clean roof gutters regularly.
  - Turn over wheelbarrows and plastic wading pools when not in use.
  - Aerate ornamental pools or stock them with mosquito-eating fish.
  - Thoroughly clean livestock-watering troughs monthly (CDC 2004b; NAS 2004).

- A balanced perspective on mosquito control for West Nile virus should reflect the important ecological role of non-target insects as natural mosquito predators, pollinators, and important food resources for bats. Massive spraying to kill adult mosquitoes is the least effective method of controlling West Nile virus, and the risks to human and wildlife health usually outweigh the benefits. Larviciding, however, which kills mosquitoes when they are in the aquatic, larval stage, may be effective in reducing populations of mosquitoes that come into contact with humans. Larviciding should only be undertaken in disturbed or manmade bodies of water near human habitation that are less important ecologically (ABC 2000).

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Bat Houses

Bat houses are becoming increasingly popular as more people become interested in watching bats and attracting them to their neighborhoods. Well designed, well placed, and maintained bat houses can provide watchable wildlife opportunities for the public and a visible reminder that can enhance public awareness of bats (Brown and Berry 1991; Tuttle 1996a). They can also be used as part of an integrated pest management plan (Tuttle 1996a; Altenbach and others 2002).

However, it is important to avoid unrealistic expectations about the value of bat houses as bat habitat or as mitigation for the loss of roosting habitat (Brown and Berry 1991; Tatarian 2001). Although many bat houses provide roosts for bats, many others remain vacant (Brown and Berry 1991), and bat houses are not always successful in providing shelter for displaced colonies (Brittingham and Williams 2000). Bat houses are sometimes poorly designed and/or placed, and often do not provide suitable microclimates for roosting bats (Brittingham and Williams 2000). In some cases, good houses may go unoccupied in an area where bats are abundant because ideal natural roosts are readily available. And in places where few bats remain, it may simply take a long time for them to find the houses (Bell 1995).

Bat houses are most commonly used by species that are relatively abundant and general in their roosting and foraging requirements (Anonymous 1999). Bat houses are usually occupied by crevice-roosting bats and are unlikely to benefit those species at greatest risk that occupy large cavities (Brown and Berry 1991; Pierson 1998). Therefore, bat houses should not be viewed as adequate substitutes for the conservation of bat habitat, particularly for the most sensitive species (Anonymous 1999). They should only be used as mitigation for the loss of roosting habitat when the loss of that habitat is absolutely unavoidable and when they can be designed, placed, and maintained with great care.

Bat houses provide day roosting and night roosting habitat for bats and can also attract maternity colonies if they maintain a high enough temperature (Luce 1998; Anonymous 1999). They are not likely to be occupied by bats in winter (Anonymous 1999). In Wyoming, the little brown myotis is the species most likely to occupy bat houses, followed by the big brown bat, pallid bat, and long-eared myotis (Luce 1998).

Temperature is one of the most important factors in determining whether a bat house will be occupied (Fenton 1985; Kiser and Kiser 2000). Many bat house owners worry that their bat houses will get too warm, but research suggests the opposite (Kennedy 1996a). Bat houses that are not specifically designed and placed to maximize temperatures are seldom warm enough and are rarely used (Brittingham and Williams 2000). High temperatures are important, especially for maternity roosts, because they minimize energy expenditure and allow fat storage for winter, shorten gestation length, and promote the growth and development of juveniles. However, the temperature requirements of bats vary according to sex, age, season, and weather extremes (BCI 1993; Brittingham and Williams 2000). The ideal bat house offers at least a 10 to 15 ºF range of internal temperatures that are generally higher than the ambient temperature, mainly between 27 and 38 ºC (80 and 100 ºF) (BCI 1993; Williams and Brittingham 1997; Brittingham and Williams 2000; Tuttle and Hensley 2003). For these reasons, many of the following recommendations for bat houses address ways to provide high daily temperatures and wide temperature gradients.

Design

There are many bat house design plans available and many different kinds of bat houses available for purchase. However, not all plans and houses that are available are suitable for providing roosts for bats. Although bat houses do not all need to be exactly the same, they should all provide a few basic requirements for bats. Whether you decide to build your own bat houses or purchase them already built, use the following guidelines to choose the best design.

- Large size is a consistent factor in the success of bat houses (Bell 1995). Large structures provide the most stable high temperatures, while tall houses provide temperature gradients, allowing bats to move vertically to find suitable temperatures (Fenton 1985; Brittingham and Williams 2000). All bat houses should be at least 0.6 m (2 ft) tall and 36 cm (14 in) wide. Widths of up to 0.6 m (2 ft) or more are likely to be preferred by many bats (Tuttle and Hensley 2003).

- Bat houses should provide chambers, or crevices, for bats to roost in. In general, bats prefer long, vertical crevices. Most bats that roost in bat houses prefer 19- to 25-mm (¾- to 1-in) wide crevices, with crevice heights of 64 cm (25 in) or greater (Kiser and Kiser 1999; Tuttle and Hensley 2003). Although the number of roosting chambers is not critical, houses with 3 or more chambers are more likely to provide a range of temperatures and accommodate larger numbers of bats (Tuttle and Hensley 2003).

- Bats can have difficulty landing on bat houses they wish to enter. Therefore, all bat houses should have an 8- to 15-cm (3- to 6-in) vertical landing area extending below the entrance (Hensley 1993b; Tuttle 1996b; Tuttle and Hensley 2003).

- Interior walls and landing areas of bat houses should be roughened to give bats a good surface from which to hang (Kennedy 1995a). Wood surfaces can be scratched or grooved horizontally at approximately 13-mm (½-in) intervals, or covered with durable UV-resistant plastic screening (1/8- or ¼-in mesh) (Tuttle and Hensley 2003). Avoid metal screen, which can cause injury to bats, and “fiberglass” or nylon screen, which deteriorates quickly (Kiser 1998b). Mesh must be securely stapled down and trimmed along all exposed edges and should not cover ventilation slots (Kiser 1998b; Tuttle and Hensley 2003). Staples used to attach plastic mesh should not protrude from the far sides of panels and will last longer if they are exterior grade or galvanized (Tuttle and Hensley 2003).

- Ventilation slots in the lower 1/3 of the house are important to prevent overheating and provide a wide range of temperatures, especially in areas of the state where the average high temperatures in July are 29 ºC (85 ºF) or above. A vent on the front of the house should extend from side to side about 15 cm (6 in) above the bottom and as long as the house is wide. Vertical vents about 15 cm (6 in) long should be included on the sides of the house at the ends of the rear chamber. All vents should be 13 mm (½ in) wide to reduce entry of light and other animals, such as birds (Brittingham and Williams 2000; Tuttle and Hensley 2003).

- Although houses with open bottoms have fewer problems with birds, mice, squirrels, parasites, and guano (Tuttle and Hensley 2003), houses with partially closed bottoms can help retain heat and may be especially beneficial to bats in the colder areas of Wyoming (Kiser and Kiser 2000). Occupancy rates for little brown myotis at Ft. Laramie National Park increased in bat houses with partially closed bottoms (T. Benson, National Park Service, personal communication).

Construction

- Bat houses can be constructed of most types of wood, although outdoor grade plywood is best (Kiser 1997; Anonymous 1999). Avoid using pressure-treated lumber, as it contains chemicals that may be toxic to bats (Fenton 1985; Tuttle and Hensley 2003). Also avoid using rough-cut lumber because it is heavy and uneven, making it difficult to work with and difficult to seal (Kennedy 1995a; Kiser 1997).

- Half-inch plywood is ideal for fronts, backs, and roofs, while the sides can be made from any 1-inch boards, such as cedar, pine, oak, or poplar (Kiser 1997; Tuttle and Hensley 2003). Roosting partitions can be made from 3/8-inch plywood to reduce the weight of the house and leave more space for roosting (Tuttle and Hensley 2003).

- The tops and sides of bat houses should be tight-fitting to reduce heat loss (Fenton 1985), and all seams should be caulked, especially around the roof (Kennedy 1995b; Tuttle and Hensley 2003). Insulating the upper portions of both front and back chambers and the ceiling helps to stabilize temperatures (BCI 1993).

Paint

- Paint all outer surfaces, landing, and entry areas of bat houses with 1 coat of primer followed by 2 coats of flat exterior, water-based paint or stain to protect against moisture, air leaks, and wood deterioration. Also apply 2 coats of dark paint or stain to interior surfaces prior to assembly to extend the lifespan of the bat house and provide a darker interior (Tuttle and Hensley 2003). Avoid oil-based paint products.

- Darker colors help bat houses absorb more heat from less sun. In areas of the state where the average high temperatures in July are 29 ºC (85 ºF) or less, paint bat houses black. In areas where the average high temperatures in July are between 29 and 35 ºC (85 and 95 ºF), paint houses a dark color, such as dark brown, gray, or green (Kennedy 1996a; Brittingham and Williams 2000; Tuttle and Hensley 2003). Average high temperatures are available from local weather bureaus or from The Weather Channel's website at www.weather.com.

Placement

- Exposure to the sun is an important consideration in the placement of bat houses—too little sun exposure is the major reason that many bat houses remain vacant (Hensley 1993a; Tuttle and Hensley 2003). In areas where the average high temperatures in July are 27 ºC (80 ºF) or less, bat houses should receive at least 10 hours of sun each day, and more hours may be better. In the remainder of the state, where average high temperatures in July are less than 38 ºC (100 ºF), houses should receive at least 6 hours of direct sun each day (Kennedy 1996a; Tuttle and Hensley 2003). Houses that are mounted on poles should face east and west to maximize their exposure to the sun (Hensley 1993a).

- The best mounting sites for bat houses are buildings, chimneys, and other heat-retaining structures, such as dams, silos, and bridges (Pierson 1998; Kiser and Kiser 2002). Wood or stone structures with sufficient sun exposure are ideal, and locations under eaves have often been successful. However, bat houses on metal siding are not usually successful (Kennedy 1995b; Tuttle and Hensley 2003).

- Although pole-mounting is more popular than mounting on buildings and other heat-retaining structures, success is slightly lower, especially in Wyoming, where the lower relative humidity allows temperatures to drop dramatically after sundown (Kiser and Kiser 2002). Nevertheless, pole-mounting does offer several advantages, including height, back-to-back pairing, and the ability to face houses in any direction in full sunlight (BCI 1993;

Kiser 2000). Pole-mounted houses should be installed back-to-back on sturdy poles or 10- x 10-cm (4- x 4-in) posts. The 2 houses should be spaced 2 cm (¾ in) apart to provide a variety of temperatures and allow bats to move between the houses (Luce 1998). A 60-watt bulb may be installed as a heat source, although special care must be taken to isolate the roosting chamber and ensure that bats do not come in contact with the bulb (T. Benson, National Park Service, personal communication).

- Bat houses that are mounted on trees are generally less successful than houses that are mounted on either buildings or poles, probably because they usually receive less sun, are too close to obstructions, and are more vulnerable to predators (Kennedy 1995b; Kennedy 1996c; Luce 1998; Kiser and Kiser 1999; Kiser and Kiser 2002; Tuttle and Hensley 2003). However, mounting houses on standing dead trees that receive ample sunlight may be a viable option in some cases (Anonymous 1999; Adams 2003).

- Bat houses should be mounted so that the bottom of the house is 3.6 to 6 m (12 to 20 ft) above ground to provide a clear flight path and discourage predators, although 3 to 3.6 m (10 to 12 ft) may suffice in some cases (Kennedy 1995b; Anonymous 1999; Tuttle and Hensley 2003).

- Houses mounted at least 6 to 7.6 m (20 to 25 ft) from the nearest tree on the sides of buildings or high up on poles provide the best protection from predators. In some cases, it may be necessary to place roof flashing 0.6 m (2 ft) wide around each pole that supports the bat house to protect against predators (Luce 1998; Tuttle and Hensley 2003).

- Bat houses located within 400 m (¼ mi) of permanent fresh water, such as a lake, pond, river, stream, or open marsh, are most likely to attract bats (Fenton 1985; Tuttle and Hensley 1993; Anonymous 1999; Kiser and Kiser 1999; Tuttle and Hensley 2003). Large streams and lakes at least 1.2 ha (3 ac) in size are particularly valuable (Tuttle and Hensley 1993).

- Bat houses are most successful in areas of diverse habitat, such as a mix of agricultural areas, shelterbelts or tree and shrub stands, native grass meadows, and riparian areas. In addition to open water and suitable habitat, caves, abandoned mines, cliff faces, or buildings, which in combination provide year-round habitat in the immediate vicinity of the bat house, will greatly improve the chances of bat occupancy. Placing the bat house in a natural bat flyway near a stream corridor or in a forest opening will also increase the chance of bats finding and using the bat house (Luce 1998; Kiser and Kiser 1999; Tuttle and Hensley 2003).

- The most successful bat houses are mounted in groups of 3 or more with slight differences in color, exposure, insulation, or ventilation, so that bats can move from house to house at different times of the season to take advantage of optimum temperatures (Tuttle and Hensley 1993; Anonymous 1999).

Timing

- Bat houses can be installed at any time of the year, but are more likely to be used their first summer if installed before the bats return in spring (Kennedy 1996b; Tuttle and Hensley 2003).

- When using bat houses in conjunction with excluding bats from a building, install the bat houses at least 2 to 6 weeks before exclusion (Kennedy 1996b; Brittingham and Williams 2000; Tuttle and Hensley 2003).

Patience and Experimentation

- Be patient for at least 2 seasons. An estimated 30% of bat house occupancy does not occur until the second season or later and 1 determinant of bat house success is the amount of time it has been in place, so bat house locations or treatments should not be changed until at least 2 seasons have passed without use, unless there are obvious deficiencies (Bell 1995; Luce 1998; Kiser and Kiser 1999).

- If a bat house remains unoccupied for at least 2 seasons, begin experimenting with locations or treatments. Many unoccupied houses could quickly become successful if they were moved only a few feet to receive more or less sun, stained or painted to absorb or reflect heat, recaulked, or mounted higher (Tuttle and Hensley 1993; Anonymous 1999).

- When installing new houses, mount 2 or more side by side with only 1 variable between them, such as color, design, insulation, or ventilation. Or place identical houses on opposite sides of a building at the same height or in locations where they receive more or less sun (Bell 1995).

- It is best to start with a few pairings of bat houses, testing for local needs, and expanding in numbers only after some have attracted bats (Anonymous 1999; Tuttle and Hensley 2003). However, successfully attracting bats should be viewed as only the first step and an opportunity to begin testing preferences, 1 variable at a time (Bell 1995).

Maintenance

- Although maintenance may not be necessary for the first few years if houses have been carefully sealed and painted, eventual recaulking and painting will be necessary, as bats may abandon drafty houses if they are not repaired. Houses should be checked annually for maintenance needs, and repairs should be made during the off-season when bats are not present (Anonymous 1999; Tatarian 2001; Tuttle and Hensley 2003).

- If wasp nests accumulate, they should be removed in late winter or early spring before either wasps or bats return (Tuttle and Hensley 2003).

- It is not necessary to clean bat houses with open bottoms.

Monitoring

Careful observation of bat occupancy can provide vital knowledge about which bat houses are successful and which may be candidates for relocation. Also, monitoring the bats' position inside the bat house, their movement between bat houses, and recording the times of day and the seasons in which movement occurs can help provide a greater understanding of bats' thermal needs and aids in the success of bat house programs (Anonymous 1999).

- One way to monitor day use of bat houses is to shine a strong flashlight or sunlight reflected from a mirror up into the house and count the bats. Bats hit with the light may scurry toward the top of the shelter and bunch up, so count quickly. Make observations as brief as possible at first and do not repeat more than once per week or the bats may abandon the house. Once a colony is well established, the bats often become tolerant of the disturbance as long as you do not touch the mounting pole or house and do not shine bright lights for more than 10 seconds (Anonymous 1999; Tuttle and Hensley 2003).

- If there are only a few bats it may be relatively easy to count them by simply looking inside, but when larger colonies become established the only reasonably accurate method is to count them emerging at dusk (Tuttle and Hensley 2003). Plan to be in place by about ½ hour before sunset and remain for about 1½ hours. It may be helpful to have more than 1 monitor and to compare counts (Anonymous 1999).

- From about June 15 to August 1, be alert for the presence of juvenile bats. The best way to check for them is to shine a light into the house after the adults have emerged at dusk, usually about 45 minutes after sundown (Anonymous 1999; Tuttle and Hensley 2003).

- To document night roosting, first arrive in the vicinity of the bat house about 8:30 pm to observe bats that are flying and feeding in the area and attempt a rough count of flying bats. Then, after the bats have fed and gone to their night roost, usually from about 10:30 pm until early morning, use a strong flashlight to look up into the house and count the bats.

Sources

The following sources provide design plans for bat houses:

- "The Bat House Builder's Handbook" is the bible for anyone interested in installing bat houses in their area. It is available from Bat Conservation International (BCI) at http://www.batcon.org.
- NRCS Wildlife Habitat Management Institute's leaflet on bats at http://www.whmi.nrcs.usda.gov/technical/leaflet.htm#A.
- USGS Northern Prairie Wildlife Research Center's plans for the Johnson Bat House at http://www.npwrc.usgs.gov/resource/tools/ndblinds/johnbat.htm.

If you prefer to purchase a bat house, be sure to visit BCI's list of companies that have been approved by the Bat House Certification Program at http://www.batcon.org/bhra/models.html. BCI also has certified houses available for sale on its online catalog.

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BAT-FRIENDLY CLOSURES

Caves and abandoned mines can pose threats to human safety, so in the interest of hazard and liability abatement, land management agencies, private landowners, mining companies, and mine land reclamation programs have used a variety of methods to close these valuable bat roosts (Belwood and Waugh 1991; Altenbach and Pierson 1995). Also, at some caves and abandoned mines where human disturbance is impacting significant bat roosts, it is sometimes necessary to install gates or other closures to allow passage by bats while restricting access to humans, at least during seasons critical to the bats (Pierson and others 1991). (See “Natural Caves” on page 149 and “Abandoned Mines” on page 157 for more information about these issues.)

Traditionally across the West, abandoned mines have been reclaimed by hard closure techniques, such as bulldozing, backfilling, blasting, sealing with concrete, and foaming (Belwood and Waugh 1991; Navo 1992; Herder 2000b; Altenbach and others 2002). Hard closure techniques are usually effective and permanent. However, they not only result in the destruction of roosting habitat, but also can cause direct and indirect mortality of bats (Dalton and Dalton 1995; Herder 2000b).

Soft, or non-entrance-blocking, closures, such as fencing and warning signs, may be appropriate in some cases where trespass and vandalism are not chronic problems and the bats are less tolerant of gates. However, fencing and signing are often not the best long-term solutions because they are easily vandalized and they leave the roost vulnerable to human disturbance (Dalton and Dalton 1995; Oakleaf and others 1996; Altenbach and others 2002). In most cases, the most effective closure for a cave or abandoned mine that permits continued access by bats is a properly designed and installed metal gate (Dalton and Dalton 1995). Bat-friendly closures (BFCs) allow bats to pass through openings too small for most humans, thereby providing security for bat populations during critical seasons and addressing human safety issues (Belwood and Waugh 1991; Pierson 1998; Herder 2000b; Altenbach and others 2002). Modern BFC designs are also difficult for vandals to breach and are often less expensive than hard closure methods (Tuttle and Taylor 1998). Also, BFCs may be constructed with a lockable opening to provide access for authorized surveys or for recreation during seasons that are not critical for bats.

While BFCs are valuable tools for the management of caves and abandoned mines and the protection of bats, they are not necessarily a panacea for all management needs and in some cases can cause bats to abandon the cave or mine (Hathorn and Thornton; Tuttle 1977; Kennedy 2002; Kerbo 2002; Adams 2003). For example, poorly designed BFCs may restrict airflow and alter the cave microclimate (Pierson and others 1991; Dalton and Dalton 1995; Pierson 1998; Currie 2000; Kerbo 2002); may require bats to decrease flight speed and increase their chances of being taken by predators (Pierson and others 1991; Herder 2000b); or may not allow access for bats, especially maternity colonies or some species that are sensitive to gates (Tuttle 1977; Pierson and others 1991; Oakleaf and others 1996; Pierson 1998; Currie 2000; Kennedy 2002; Kerbo 2002). As a result of these risks, careful planning and design is critical, and BFCs should be used to protect caves and abandoned mines only where they are essential and a truly bat-friendly closure can be constructed (Pierson 1998; Kennedy 2002; Kerbo 2002).

Identifying Closure Projects

Since BFCs are permanent structures, may impact the roost environment, and require expenditures of resources, they should only be installed after careful planning and assessment (Kennedy 2002; Kerbo 2002). Biological surveys to assess the cave or abandoned mine for bat use should be completed prior to installation (Kennedy 2002; Hinman and Snow 2003). Surveys should be designed to determine the seasonal presence or absence of bats, the relative numbers of bats present, the type of colony present, the type and number of species present, and the potential for bat use if no bats are currently documented (Henry 2002). Surveys should be conducted in all 4 seasons, since bat use may vary considerably throughout the year (Henry 2002; Hinman and Snow 2003). Also, a final survey should be conducted immediately prior to closure, since bats can move into a previously unoccupied site if previous surveys were conducted in other years or seasons (Hinman and Snow 2003). If the minimum surveys cannot be performed, hard closures should be avoided and all closures should be bat-friendly.

Because a lack of funding and the potential risks of gating usually preclude the installation of a gate at every cave or abandoned mine that contains bats, and because every cave or abandoned mine roost has unique features, it can be a challenge to prioritize potential closure projects (Olson 2002). If surveys reveal actual or potential bat use, use the following considerations to help determine whether a BFC is warranted. Also keep in mind that other protective methods, such as administrative closures, signs, fencing, redirecting trails, and public education, can be effective in some cases and are usually less expensive than gating (Kennedy 2002).

- Is bat use of the roost significant? Significant roosts in Wyoming include maternity roosts of any species; hibernacula of any species; and roosts that are used by 15 or more bats during any season. However, if only a small number of bats use the roost or it is a bachelor roost, the priority for installing a BFC may be lower (Altenbach; Anonymous; Henry 2002).
- Is the cave or abandoned mine good potential habitat? Even if surveys do not reveal current bat use, a BFC may be justified, especially if it is a complex feature with the potential for many temperature regimes to satisfy different bat species at different seasons (Anonymous; Henry 2002; Kennedy 2002). Several caves and abandoned mines that were initially documented by the WGFD in the 1990s as being good potential habitat now have significant bat use (M. Grenier, WGFD, personal communication).
- How feasible is gating? Significance of the cave or abandoned mine as a roost must be weighed against the cost and feasibility of installing a BFC (Altenbach).
- Is human safety an issue? Human health, safety, and access should be given priority when considering closure of a cave or abandoned mine.
- Is the roost at risk? Caves that are heavily utilized by humans during periods of bat activity and those that display signs of over-utilization, such as litter and vandalism, should be given priority.
- Is the roost easily accessible or visible? A mine that is more accessible to people may be a higher priority for gating than a remote site that is difficult to reach (Henry 2002; Olson 2002).

BFCs are site-specific and unique, can be complicated and frustrating, and have potential to harm bats. Therefore, **please contact the Wyoming Game and Fish Department's (WGFD) Nongame Mammal Biologist at (307) 332-7723 or (800) 654-7862** for advice early in the planning stages of any closure project.

Funding

Cultivating potential project funders can be an ongoing, time-consuming process, but critical in today's budget consciousness. Federal, state, or private assistance is often available to provide partial or full funding for BFCs. Obtaining the financial resources required to properly construct BFCs often involves coordination between individuals, foundations, corporations, and government agencies (Tuttle and Taylor 1998; Kath 2002). The WGFD has dedicated equipment available to assist in the development and maintenance of BFC projects, and also has a program to match funds allocated by the land management agency for maintenance of bat gates with in-kind labor.

Design and Construction

There are many types and designs of closures that incorporate bat-friendly features. Every cave, abandoned mine, and closure project is unique—and the bat species present, the seasons they use the roost, and the size and angle of the portal may all dictate innovative adaptations of the "standard" designs (Kennedy 2002). Nevertheless, all successful BFCs should be vandal-resistant and effective in controlling human access, should not interfere with the natural flow of air or water, and should not alter or only minimally alter the flight of bats (Dalton and Dalton 1995; Currie 2000; Kennedy 2002). Use the following guidelines to help meet these objectives and choose the best design.

Gates

The most common and often most effective BFC is the horizontal bar gate. These gates are made of welded angle iron or steel bars placed horizontally across the entrance or passage of a cave or abandoned mine. They are generally installed at horizontal or sloping portals and are anchored into solid rock or concrete footers (Tuttle and Taylor 1998; Meier 2000; Dalton 2002).

Design

- One of the most crucial factors in gate design is the spacing of horizontal and vertical bars to provide bats with the greatest possible flight space and allow maximum airflow, while still preventing human entry. Space horizontal bars no less than 14.6 cm (5¾ in) apart to avoid restricting bat movement and reduce predation, and no greater than 15.2 cm (6 in) apart to keep children from squeezing through. Space vertical bars as widely as possible, limited only by the strength of the material used and the construction design—no less than 0.6 m (2 ft) apart to accommodate the wingspan of bats, and up to 1.2 m (4 ft) or more apart with strong materials such as angle iron (Hathorn and Thornton; Tuttle 1977; Navo 1992; Dalton and Dalton 1995; Tuttle and Taylor 1998; Currie 2000; Kennedy 2002). Where possible, stagger the vertical bars to add strength and allow them to be spaced more widely (Tuttle 1977).

- Near heavily populated areas where the gate will be accessible to small, unsupervised children, it may be appropriate to decrease the spacing between the horizontal bars to 8.9 to 10.1 cm (3½ to 4 in) in the bottom half or third of the gate, as bats usually fly through the upper portion of a gate (Tuttle and Taylor 1998; Currie 2000).

- Even at sites with multiple entrances, avoid using solid doors or incorporating plate steel, concrete, or stone walls into gates (Dalton and Dalton 1995; Currie 2000).

- To allow authorized access, use a removable horizontal crossbar, rather than a hinged door. The advantages to removable bars are ease of construction, disguising the obvious entry point, and reduction of moving parts (Tuttle and Taylor 1998; Kretzmann 2000; Kennedy 2002).

- Secure removable bars with locks that are protected from hacksaws, torches, and hammers as much as possible. Locks are often the most vulnerable portion of the gate, so protect them with lock guards, place them under the bar rather than on the outside face of the crossbar, and/or use security bolts similar to automotive locking lug nuts, such as McGuard bolts (Currie 2000; Kretzmann 2000; Kennedy 2002).

Materials

A variety of materials have been used in the construction of bat gates. Considerations in the selection of material are its resistance to the anticipated level of vandalism at the site, its availability and cost, cost of installation and maintenance, restriction to bat access, and its potential to modify the microclimate of the roosting area (Dalton 2002; Vittetoe 2002).

Angle Iron

The most commonly used and recommended material for bat gates is 4- x 4-inch angle iron (Tuttle and Taylor 1998; Currie 2000). Angle iron is a very strong material, which allows it to be used in wide spans and large construction, although it is best suited to horizontal entrances or inclines of less than 45º (Tuttle and Taylor 1998; Pierson and others 1999; Currie 2000; Powers 2002). It is moderately resistant to abrasive cutting and can be made resistant to abrasive cutting if T-bar and rod inserts are used, so it is often used in areas that are vulnerable to vandalism (Navo 1992; Pierson and others 1999; Dalton 2002). When it is angled properly in the cave or mine passage, angle iron has very little effect on airflow (Tuttle and Taylor 1998; Powers 2002). However, although angle iron is readily available, it is relatively expensive, and its high mass and handling difficulties make it expensive to install (Navo 1992; Dalton 2002).

Round Bar

The earliest bat gates were constructed of 2.5-cm (1-in) round steel bars (Navo 1992; Currie 2000). Round bar gates have a minimal effect on airflow and if proper spacing is maintained between the bars they have a minimal effect on bat movements. Their greatest disadvantage is that they are easy for vandals to cut through, especially mild steel or rebar. Round bar gates constructed of alloyed steels are much more resistant to vandalism (Currie 2000).

Manganal Steel

Bat gates constructed of 2.5-cm (1-in) round bar of Manganal steel, although vulnerable to gas cutting, are highly resistant to abrasive cutting. Manganal steel is also easy to handle and install. Although it is more expensive than other materials and not readily available, if the site is remote and anticipated vandalism would be from abrasive cutting, such as hacksaws, its increased cost could be offset by its resistance to vandalism and ease of handling (Amodt 2002; Dalton 2002).

Rectangular Tube

Five- to 7.6-cm (2- to 3-in) rectangular tube is readily available, low in cost, and easy to install because of its cutting and welding characteristics. However, it is vulnerable to all kinds of cutting, so it should be used only where the risk of vandalism is very low. It is also possible to hard face and fill rectangular tube with reinforced concrete to create a composite bar that is highly resistant to vandalism (Dalton 2002; Vittetoe 2002).

Placement

- Gates are often built into the entrance of the cave or abandoned mine, usually recessed a foot or so from the surface. Building the gate into the entrance, rather than bolting it to the outside, stabilizes the entrance area and creates a much more vandal-resistant structure (Dalton and Dalton 1995).

- Gates also may be placed inside the cave or abandoned mine, usually just within the dark zone. This may reduce predation on bats, but also makes the gate more difficult to inspect and monitor (Tuttle 1977; Tuttle and Taylor 1998; Kennedy 2002; Nieland 2002).

- Avoid placing gates in small or constricted areas of the passage or entrance. Gates placed in large cross-sectional areas allow maximum airflow and allow more bats to pass through a larger area with less risk of predation (Tuttle 1977; Dalton and Dalton 1995; Tuttle and Taylor 1998; Kennedy 2002; Nieland 2002).

- Avoid placing gates at the bottom of an entrance slope to reduce debris, which can pile up against the gate (Kennedy 2002).

Construction

- Wherever possible, schedule gate construction during the time of year when bats are not using the roost to avoid disturbance (Tuttle and Taylor 1998; Kennedy 2002; Nieland 2002). In particular, avoid construction while maternity colonies are present (Anonymous).

- If construction must take place while bats are present in the cave or abandoned mine, avoid working within 2 hours of dusk or dawn (Tuttle and Taylor 1998).

- Avoid allowing welding fumes or smoke to be drawn into areas where bats are roosting. Consider installing temporary plastic sheeting across the passage to keep smoke and fumes from being drawn into the cave or mine. At the end of the work day the curtain can be dropped to allow normal bat passage for the evening (Tuttle and Taylor 1998; Kennedy 2002; Nieland 2002).

- Install gates with secure foundations and anchors to avoid vandalism and unauthorized entry. The first choice is to anchor the base of the gate directly into bedrock. A second choice is to build a steel or angle iron barrier or sill plate to form the base of the gate or extending along the ground in front it and cover the barrier with concrete or rocks. A third choice is to use expanded metal sheeting or fabricated steel grid under the foundation. It may also be possible to drive 2.5-cm (1-in) steel bars into the ground every 15 to 20 cm (6 to 8 in) along the base of the gate and weld these to the back of the gate. Also, secure the horizontal and vertical bars of the gate to the walls and ceiling with 2.5-cm (1-in) steel anchor pins. Drive the anchor pins into holes drilled 20 to 30 cm (8 to 12 in) deep, depending on the strength of the rock, and weld them to 15-cm (6-in) flat steel wall plates (Dalton and Dalton 1995; Currie 2000).

Collars

In some cases, where abandoned mine portals are too unstable or unsafe to install a traditional gate, or where it is likely that the portal will collapse within a few years, it may be appropriate to install a gated culvert pipe, or collar (Tuttle and Taylor 1998; Meier 2000; Langdon 2002). A culvert can be a habitat improvement over the existing condition where the portal is blocked or will collapse in the near future without stabilization (Langdon 2002).

- Corrugated steel is the most common material, and is generally least expensive for culverts over 60 cm (24 in) in diameter, although culvert materials also include smooth stainless steel, corrugated aluminum, plastic (both corrugated and smooth), and concrete. Some biologists believe bats prefer smooth wall culverts to corrugated walls. Because aluminum and plastic are lighter than steel, they may be preferable when the culverts must be moved by hand (Langdon 2002).

- Closure devices may be installed internally within the culvert, underground beyond the culvert end, or externally outside the culvert. However, Langdon (2002) suggests installing internal gates with round bars through precut holes in the culvert, and Tuttle and Taylor (1998) suggest that attaching the gate to the inner end of the culvert can help bats avoid predation.

- The length of the culvert depends on how the backfill is placed, the type of backfill material, the steepness of the slope above the site, and how well the culvert fits into the opening (a tight fitting culvert can be shorter). A rule of thumb for minimum length is twice the diameter plus 0.9 m (3 ft), although there is some evidence of reduced bat use for culverts longer than 3 m (10 ft) (Langdon 2002).

- The diameter of the culvert should be as large as possible and still fit within the opening—no less than 96 cm (36 in). Match the existing portal size and location as closely as possible to reduce the chance of changing the airflow and internal temperatures (Langdon 2002). In large openings, several smaller 96-cm (36-in) culverts may be nested together to maintain maximum airflow while decreasing the risk of vandalism.

Cupolas

Vertical mine shafts require 3-dimensional cupolas, or cage-type closures, since horizontal gates over shaft entrances can force bats to slow down or land, increasing the chances of predation, and can become blocked by debris (Tuttle and Taylor 1998; Kennedy 2002; Kretzmann 2002). Horizontal adits that are 0.9 m (3 ft) or less in diameter may also require a cupola-style closure to avoid increased predation (Tuttle 1996a). Cupolas are not usually practical for large openings over about 6 m (20 ft) in diameter (Kennedy 2002; Sasse 2002). For vertical entrances with very short drops, a standard vertical gate may be installed deeper within the cave or mine where the passage begins to be more horizontal, as long as the vertical entrance itself is not a liability concern (Kennedy 2002).

- As with standard bat gates, cupolas can be constructed of angle iron, steel tubing, or other bar stock (Dalton and Dalton 1995; Kretzmann 2000; Meier 2000).

- Cupolas should be high and wide enough to provide adequate flight space (at least 0.5 to 0.9 m^2 [6 to 10 ft^2]) for bats to maneuver safely through the bars without being caught by predators (Tuttle and Taylor 1998; Kretzmann 2002). In general, the longer and narrower the opening, the larger and taller the structure should be (Kennedy 2002).

- At vertical and steeply inclined openings, it is important to provide a secure and permanent foundation for the cupola structure. Where strong, unfractured bedrock exists, use a cast-in-place reinforced concrete footing. In less competent rock, options include riser pipes set on bedrock, polyurethane foam or concrete plugs with riser pipes, concrete "hollow-core" plugs, and concrete slabs (Kretzmann 2000, 2002).

- Possible shapes for the cupola structure include rectangular boxes, hexagonal shapes, and those with sloping tops. Sloping tops and sides can be used to place the structure below sight lines along a highway, shed falling or thrown rocks, discourage people from climbing the structure, and lower the weight of the structure without reducing its height at sites with difficult construction access (Kretzmann 2002).

Soft Closures

Soft closure methods, such as perimeter fencing and/or signs, are sometimes viable alternatives where access is extremely difficult and where funding is inadequate for other closure methods. Soft closures may also be less intrusive to maternity colonies and bat species that do not adapt well to gates. However, soft closures are not as vandal-resistant as most gates, and in some cases may actually attract more attention to roost sites, so it is important to evaluate the variables of each site on an individual basis, including its accessibility, vulnerability, topography, and type and species of the bat colony.

Perimeter Fencing

In addition to the advantages and disadvantages described above, perimeter fencing can be an appropriate closure at caves and abandoned mines with very large vertical openings, where cupola closures are not practical (Kennedy 2002). Fences also keep people farther away from the roost site than gates erected at the entrance of the cave or mine (Adams 2003), and can be built during any season, since they are not constructed in the actual passage used by bats (Buecher and Buecher 2002).

- Fences may be constructed of 4 strands of barbed-wire (Driesner 1995; Altenbach and others 2002), chain-link (Tuttle 1977; Kretzmann 2000; Sasse 2002), or vertical steel bar (Sasse 2002). Although more expensive, vertical steel bar fences are the sturdiest and require the least maintenance (Sasse 2002). Barbed-wire fencing, while effective against accidental entry by humans, may be the least resistant to intentional entry.

- Vertical steel bar fences should be constructed of 2.5-cm (1-in) diameter steel bars spaced 15 cm (6 in) apart, extending 3.2 m (10½ ft) above the ground, and with the top 56 cm (22 in) bent outward at a 45º angle (Sasse 2002). Chain link fences should be at least 2.4 to 3.7 m (8 to 12 ft) in height, coated with black PVC to reduce visibility, and fitted with an outward-facing barbed-wire outrigger on top to increase effectiveness against unauthorized entry (Tuttle 1977; WDOW 1994; Kretzmann 2000; Buecher and Buecher 2002; Sasse 2002). Barbed-wire fences should be 1.2 m (4 ft) high to the top wire, with 0.3 m (1 ft) between wires; have 1.8-m (6-ft) T-posts planted solidly, with a 2.4-m (8-ft) maximum between T-posts without fence stays and a 3-m (12-ft) maximum with fence stays; and have anchored corners as needed (Driesner 1995).

- Secure the bottom of the fence to prevent people from crawling or digging underneath by installing a concrete footing and setting posts in concrete and/or bedrock. However, avoid setting the entire base of the fence in concrete, as this could make repairs difficult (Tuttle 1977; Buecher and Buecher 2002; Sasse 2002).

- Set the fence well back from the cave or abandoned mine entrance to avoid interfering with the flight path of bats. This distance may vary according to the topography and the flight path of the bats—Driesner (1995) suggests setting the fence at least 1.2 m (4 ft) from the portal, Altenbach and others (2002) suggest 10 m (33 ft), and Sasse (2002) suggests a distance equal to at least twice the height of the fence. Therefore, observations should be made prior to construction to determine the flight path used by bats and avoid obstructing them (Sasse 2002). Where the slope of the land allows, locate the fence so that its top is at the same elevation as the bottom of the cave or mine entrance to eliminate any hindrance of the flight of bats (Buecher and Buecher 2002).

- Where possible, eliminate evidence of access for fence construction, or block access, to avoid attracting additional human activity (Tuttle and Taylor 1998). Also, use the natural topography and vegetation as a screen, and paint the fence to blend in with the site or coat it with black PVC (Kretzmann 2000; Sasse 2002).

- Use signs in conjunction with fences to increase their effectiveness against unauthorized entry (Tuttle 1977; WDOW 1994; Driesner 1995).

Signs

Warning and interpretive signs should always accompany other closure methods, such as gates or fences. In some cases, signs may be adequate soft closure methods by themselves to prevent disturbance of the roost. As closure methods, they are the easiest to install and the least expensive, but they are easily ignored and removed, and are therefore not usually the best long-term solutions by themselves (Dalton and Dalton 1995; Buecher and Buecher 2002; Nieland 2002; Hinman and Snow 2003).

- Locate signs so that they are readable and obvious (WDOW 1994; Tuttle and Taylor 1998; Nieland 2002). Signs that are used in conjunction with other closure methods should be placed inside the closure where they can be read but are inaccessible to vandals and will not attract attention to the roost (Kennedy 2002; Nieland 2002). Avoid placing signs on the gate or anywhere that they might impede airflow or the movement of bats (WDOW 1994; Tuttle and Taylor 1998; Nieland 2002).

- Signs should be durable and vandal-resistant (WDOW 1994; Nieland 2002). Metal and plastic signs are much more resistant to weather, decomposition, and gnawing rodents than paper or wooden signs (Kennedy 2002).

- Signs should include educational information about the reasons for the closure, the dates that visitation is allowed (if applicable), and contacts for more information. Signs should also include the legal consequences of unauthorized entry, although this should not be the focus of the sign as it may be taken as a dare by would-be vandals (WDOW 1994; Buecher and Buecher 2002; Kennedy 2002; Nieland 2002).

Monitoring and Maintenance

- Conduct pre-closure surveys before gate construction begins to establish baseline bat population and use data (Tuttle and Taylor 1998; Pierson 1998; Herder 2002; Kennedy 2002). Pre-closure surveys should be conducted during all 4 seasons (Herder 2002) and should include the times that emergence begins and ends and the location of flight paths through the entrance (Tuttle and Taylor 1998). (See “Identifying Closure Projects” on page 287 for more information.)

- Monitor the roost regularly after closure to ensure that the bat use is uninterrupted and to identify any adverse effects to bats resulting from gate installation (Pierson 1998; Tuttle and

Taylor 1998; Pierson 1998; Currie 2000; Herder 2002; Kennedy 2002). Tuttle and Taylor (1998) suggest repeating the pre-closure observations immediately after construction is completed, throughout the first season of use, and once again a year later.

- If the gate is having negative impacts on the bat population, modify or remove it as quickly as possible (Tuttle and Taylor 1998; Kennedy 2002).

- Inspect the closure regularly to detect any damage, deterioration, or breaching attempts by humans (Tuttle and Taylor 1998; Currie 2000; Kennedy 2002; Nieland 2002). Examine the condition of the gate, the lock, and the attachment to the surrounding bedrock, and confirm that the gate is still functioning to keep people out of the cave or mine while allowing free access to bats (Bucknam 2002).

- If a gate or other closure is damaged, repair and reinforce it promptly to reduce the time that the roost is exposed (Kretzmann 2000; Kennedy 2002; Nieland 2002). Prompt repair also may frustrate the vandals and, over time, lead to less vandalism (Kretzmann 2000).

- Establish a schedule of routine maintenance to repaint, remove debris from the gate, and change locks before they stop working (Kennedy 2002).

- Use the information gained through security and biological monitoring to modify future gate designs, select the most appropriate closure method at similar sites, predict bat response to gates, and develop an index of bat population trends (Tuttle 1977; Tuttle and Taylor 1998; Currie 2000; Herder 2002).

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OTHER ISSUES AND THREATS

Wind Turbines

Wind has become the world's fastest growing power source, with over half of the states in the US possessing developed wind resource areas, and increasing about 30% annually since 1996 (Kunz 2004). Wind energy is generally considered environmentally friendly technology because it is a renewable resource and produces electricity without air and water pollution, mercury emissions, or greenhouse gas emissions (USFWS 2003; Schwartz 2004). However, aside from these indirect benefits to bats, birds, and many other plant and animal species, wind energy production can impact both bats and birds directly when they collide with rotors, towers, or guy wires (Schwartz 2004).

Initially, attention to the biological effects of wind energy facilities focused on birds. However, studies of avian mortality also found dead bats around wind turbines, and subsequent studies have revealed that bat collision mortality at wind plants is a widespread phenomenon (Johnson and others 2000; Keeley and others 2001; Johnson 2004). According to Johnson (2004), the overall average bat fatality rate for US wind projects is 3.4 fatalities per turbine per year. As more facilities with larger turbines are built, the cumulative effects of this rapidly growing industry may contribute to the decline of some bat populations. The potential harm to these populations from an additional source of mortality or adverse habitat impacts makes careful evaluation of proposed facilities essential (USFWS 2003).

How and Why Wind Turbines Impact Bats

A major step toward reducing bat fatalities at wind energy facilities is to identify and understand the causal factors of the fatalities. This is a difficult task because collisions with wind turbines are rarely observed directly, and therefore inferences must be drawn from patterns discernible from carcasses found near turbines (Schwartz 2004).

About 90% of bat mortality at wind energy facilities involves migratory species such as hoary, silver-haired, and eastern red bats, and hoary bats account for nearly half of all bat fatalities (Gruver 2001; Keeley and others 2001; Erickson and others 2002; Johnson 2004; Kunz 2004). In addition, nearly 90% of bat fatalities occur in late summer and early fall, during the peak of fall migration (Keeley and others 2001; Erickson and others 2002; Johnson 2004). Although the sensory cues migrating bats use at night are poorly known (Kunz 2004), evidence suggests that migrating and commuting bats may depend on vision rather than echolocation, which would make them vulnerable to rotating turbine blades in the same way as birds (Keeley and others 2001; Erickson and others 2002; Kunz 2004). Also, migrating and commuting bats often follow linear features in the landscape, and may be drawn to ridges where wind energy facilities are located or the right-of-ways for wind turbine construction and maintenance (Erickson and others 2002; Kunz 2004). For these reasons, many researchers believe that most of the bat mortality at wind energy facilities involves migrating, commuting, or dispersing bats (Gruver 2001; Erickson and others 2002).

Studies of bat activity also suggest that fatalities at US wind facilities do not usually involve foraging bats. Bat collision mortality during the breeding season is nearly non-existent, despite the fact that relatively large populations of some bat species have been documented in close proximity to wind plants (Erickson and others 2002). It seems unlikely that foraging bats using echolocation to locate prey would be unable to detect turbines, since it is known that bats are able to navigate through clutter zones of fine strands of wires spaced only 1 m (3 ft) apart and to detect large background features as far away as 100 m (328 ft) (Erickson and others 2002; Johnson 2004). Studies have also shown that bats can avoid colliding with moving objects more successfully than stationary ones, presumably because their foraging habits program them to detect moving objects (Erickson and others 2002; Johnson 2004). Finally, bats generally do not forage above 25 m (82 ft), which is the lowest height of the blade on most wind turbines (Keeley and others 2001; Erickson and others 2002).

Another key question regarding bat mortality at wind plants is whether turbines actually attract bats. Several studies have shown high foraging activity by bats around artificial lights. This suggests that lights on turbines may attract moths and other nocturnal insects, in turn attracting foraging bats. However, other studies seem to indicate that bats are not attracted specifically to lit turbines (Johnson 2004; Kunz 2004). Other hypotheses suggest that wind turbines emit high-frequency sounds that may attract bats, that bats may be attracted to turbines during migration because they are perceived as roost trees, or that bats may be killed as they encounter the turbulence associated with rotating blades (Kunz 2004; Williams 2004).

Recommendations to Minimize Bat Mortality at Wind Energy Facilities

Although some bat mortality is expected at most wind energy facilities, impacts can be minimized in most cases by good project assessment, design, and management practices (WDFW 2003).

- Evaluate prospective wind energy facilities to determine how bats use the area, potential impacts on bats and other wildlife, and the best way to reduce the level of risk for bats. Numerous factors influence the potential for bat mortality at wind plants, including bat abundance, migration corridors, geographic area, topography, prey abundance, weather, turbine placement, rotor design, and rotor speed. New wind plant facilities should take all of these factors into account to limit bat fatalities (Nicholoff 2003; USFWS 2003; Kunz 2004). Because numbers of bats in an area will vary seasonally, within a season, and according to weather conditions, monitor prospective wind plant sites numerous times during spring, summer, and fall (Keeley and others 2001). Be aware that most ultrasonic detectors have a range of less than 30 m (98 ft), so they should be positioned high enough above the ground to detect bats that are likely to encounter towers and rotors (Kunz 2004).

- Avoid placing wind turbines in or near known migration corridors or in flight paths between colonies and feeding areas (USFWS 2003; WDFW 2003).

- Where possible, locate new wind energy facilities on lands that are already developed, cultivated, or disturbed, and place linear facilities, such as transmission lines and access roads, in or adjacent to existing disturbed corridors to minimize habitat fragmentation and degradation (WDFW 2003).

- Minimize the use of lights on wind turbines wherever possible to avoid attracting insects and bats to the area. Use the minimum number and minimum intensity of lights and the minimum number of flashes per minute allowable by the Federal Aviation Administration (USFWS 2003; WDFW 2003).

- Where possible, shut down wind turbines during periods when bats are highly concentrated in the area, such as during migration, primarily in August and September (Keeley and others 2001; Erickson and others 2002; USFWS 2003; Kunz 2004).

- Implement post-construction monitoring programs at wind energy facilities to continue to determine the impacts of wind plants on bats and factors important for the placement of wind turbines (USFWS 2003). In addition to monitoring methods such as acoustic recordings, post-construction assessments should also incorporate fatality searches and scavenger/decomposition assessment (WDFW 2003; Kunz 2004).

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Environmental Contaminants

The primary threats to bat colonies are habitat loss, human disturbance, and the direct destruction of bats and their roosts. However, environmental contaminants, such as pesticide residues and heavy metals, probably have been involved in some declines of bat populations (Clark 1988a; McCracken 1988). Impacts of environmental contaminants on individual bats can be either direct exposure, or indirect as a result of an altered food supply, physical habitat, availability and quality of water, or other factors (O'Shea and others 2000).

Pesticides

The use of chemical pesticides in agriculture and forestry may have an impact on some bat populations (Brown and Berry 1991; Pierson 1998). Three characteristics of bats increase the likelihood of their being harmed by pesticides.

- Many bat species concentrate in small areas to roost, making incidental exposure of large groups more likely. Bats that roost in buildings may also be exposed to chemicals that are used in timber treatments, some of which have been shown to be toxic to bats (Clark 1981; Clark 1988b; Keinath 2004).
- Bats forage on insects most heavily in twilight hours, which is when pesticides are often applied to avoid drift, so bats may be more likely to encounter pesticides directly (Clark 1981; Clark 1988b; Keinath 2004).
- The long lifespans of bats allow more time for contact and internal accumulation of pesticides, and their low reproductive rates slow the recovery of impacted populations (Clark 1981; Clark 1988b; Keinath 2004).

Although the precise effects of any of these characteristics on bat-pesticide interactions are not known, collectively they suggest that insectivorous, temperate-region bats are vulnerable to pollutants (Clark 1981). Subtle but equally devastating impacts are also possible from exposure to pesticides well below lethal levels. Sublethal poisoning may affect the reproduction, acoustic behavior, and energy metabolism of bats and possibly causes a loss of coordination that prevents flight (Clark 1981; Keinath 2004).

In particular, organochlorine pesticides (DDT, dieldrin, endrin, and heptachlor) and their residues probably have contributed to local or regional declines of bat populations because of their long residence time in the environment and bioaccumulation in the food chain (Clark 1981; Gruver and Keinath forthcoming). Organochlorines are fat-soluble and are readily stored in fat, so they are able to accumulate in the tissues of surviving insects, then become concentrated in bat tissues once they are consumed (Geluso and Altenbach 1976; Clark 1981; Keinath 2004). Bats often accumulate very high concentrations of organochlorines in their tissues, which are often many times above those of other wildlife, such as birds (Keinath 2004). Probable reasons for this elevated bioaccumulation in bats include their high metabolic demands, pronounced fat cycles, and lactation.

- High metabolic rates of bats, associated with their small size and flight, demand greater rates of food intake, which increases the intake and potential accumulation of chemicals (Clark 1981; Clark 1988b; Keinath 2004).
- Because organochlorines are stored in fat, bats are at most risk from poisoning during times when they rely on their stores of fat, especially during migration and/or hibernation (Geluso and Altenbach 1976; Clark 1981; Geluso and others 1981; Clark 1988b).
- Organochlorines often concentrate in the fat of milk, exposing young bats to high doses while nursing (Clark 1981; Geluso and others 1981; Clark 1988b; Keinath 2004).

Most organochlorine pesticides have been banned or reduced in the US, so many wildlife-related problems have improved (Clark 1988a). However, bat species that migrate south of the US have a greater likelihood of exposure (Brown and Berry 1991; Adams 2003).

In the US, organochlorine pesticides have largely been replaced by organophosphates (such as Acephate, diazinon, and methyl parathion) and carbamates (such as Aldicarb, carbaryl, and carbofuran) (Clark 1988a; Clark 1988b). These chemicals are relatively short-lived and generally do not accumulate in food chains (Clark 1988a). Bats are primarily exposed when they forage over agricultural fields that are being or have just been sprayed and receive the chemical through their skin and lungs, or when they eat insects that have just been sprayed but are still alive (Clark 1988a). The effects of organophosphates and carbamates on bats have not been studied, even though their use has increased markedly in replacing organochlorines and they have been documented to impact birds (Clark 1981; Pierson 1998; Schmidt 2003d).

Pesticides may also impact bats indirectly by reducing the abundance and diversity of insects available to them. Even the application of pesticides with very low toxicity to vertebrates (such as Bt [*Bacillus thuringiensis*]) can still reduce the prey base for bat populations and suppress bat reproduction (Pierson 1998; Pierson and others 1999). Each year thousands of acres are treated with pesticides in agricultural, urban, and forested areas, so the impacts to bats could be significant in target spray areas where large amounts of the prey base are removed (Brown and Berry 1991; Oakleaf and others 1996; Pierson and others 1999).

Recommendations

- Limit pesticide application to activities that improve or maintain the habitat (such as elimination of nonnative species). In particular, eliminate the use of those pesticides that are known to be detrimental to bats (Keinath 2004).

- Where pesticides are necessary, use them as part of an Integrated Pest Management (IPM) program. IPM involves closely monitoring pest populations of plants, animals, and insects, and using chemicals only when and where pests are likely to cause economically or ecologically important damage.

- Where available, use biological control for specific noxious species, such as selective viral and fungal pathogens, pheromone confusants, mass trapping, sterile male release, or parasite/predator release, rather than chemical control (Oakleaf and others 1996; Pierson and others 1999; Nicholoff 2003; Schmidt 2003).

- Reduce reliance on pesticides that are detrimental to bats by incorporating these strategies: applying pesticides by hand to target pests as specifically as possible, using silviculture strategies to reduce pests, using suitable crop and grazing practices, using pest-resistant crop strains, using less toxic or persistent forms of pesticides, and eliminating standing water that is not ecologically important (Pierson and others 1999; Tuttle 2000a; Nicholoff 2003).

- Establish buffer zones around riparian and wetland areas and around known bat roost sites in rock shelters, caves, and abandoned mines where no pesticide spraying is allowed. Oakleaf and others (1996) suggest ½-mile (0.8-km) buffer zones, while Pierson and others (1999) suggest a 2-mile (3.2-km) radius buffer zone around Townsend's big-eared bat roost sites. In determining buffer zones, give consideration to the application method and the potential for spray drift (WDOW 1993; Pierson and others 1999).

- Avoid applying pesticides in bat foraging areas from March to May and September to October, as these are important foraging periods between breeding season and hibernation (WDOW 1993).

- Monitor short- and long-term impacts of large-scale insect control projects. Survey potential roosts and foraging areas to establish baseline data before beginning a project to control insects, and continue surveying to determine the impacts of the project (Oakleaf and others 1996; Pierson and others 1999).

Heavy Metals

Bats that roost and forage near mining and industrial point sources are also at risk from heavy metals in the environment (Clark 1988a; Adams 2003; Bennett and others 2004). Like organochlorine pesticides, heavy metals tend to bioaccumulate in the food chain and in the tissues of bats (Clark 1988a; O'Shea and others 2000). Bats are especially at risk when they drink water that is polluted by heavy metals, and because the nymph stage of many insects is aquatic, heavy metals in water may be ingested disproportionately by bat species that forage mostly over water (Adams 2003). The presence of arsenic, cadmium, chromium, copper, lead, mercury, methyl mercury, nickel, and zinc in bat carcasses verifies that they do ingest these toxins (Adams 2003; Bennett and others 2004), which can result in a variety of pathological conditions and death in mammals (O'Shea and others 2000). However, heavy metals in the environment are often overlooked in conservation efforts for bats and little is known about their impacts on individual health and populations of bats (O'Shea and others 2000; Adams 2003; Bennett and others 2004). Bennett and others (2004) recommend conducting regular monitoring of heavy metal contaminants in bats.

Toxic Material Impoundments

Mining companies often construct facilities to clean and refine mined commodities (Meier 2000). However, these impoundments often contain toxic materials, such as cyanide or oil. Because artificial ponds and reservoirs often provide important water sources for bats, especially in arid areas, these toxic material impoundments can pose serious threats to foraging bats (Esmoil and Anderson 1995; Pierson and others 1999; Adams 2003; Keinath 2004).

Oil Waste Pits

Oil-field waste pits are constructed by the oil and gas industry to dispose of water extracted during oil production. Inefficient treating or separating systems may result in some oil being discharged with the water into the pits. Once in the pit, small particles of oil float to the surface, forming a film that can be hazardous to wildlife (USFWS; Esmoil and Anderson 1995; Ramirez 1999). Oil waste pits are also used to contain oil spills or to catch oil drips (Ramirez 1999).

Besides the 2 million migratory birds that die in oil reserve pits each year, bats are also at risk (Adams 2003). Bats and their carcasses have been found in oil waste pits in many areas, including Wyoming (Esmoil and Anderson 1995; Pierson and others 1999; Ramirez 1999). However, the numbers of bats killed in oil waste pits is not known because surveys have not been conducted as rigorously for bats as they have been for birds (Ramirez 1999; Adams 2003). Also, as with all carcasses, dead bats often sink below the surface and go undetected, so the numbers of fatalities may be much higher than is currently documented (USFWS; Pierson and others 1999; Ramirez 1999, 2000; Adams 2003).

The problem is that bats probably are unable to distinguish clean, valuable sources of water from those covered with oil (USFWS; Esmoil and Anderson 1995; Ramirez 1999, 2000). Besides being attracted to oil waste pits as sources of water, bats may also be attracted to insects that become trapped in the oil and struggle to escape. Bats attracted to oil-covered ponds can suffer death by becoming entrapped in the oil and drowning, by ingesting toxic quantities of oil when they drink the water or lick their fur, or by cold stress if oil damages the insulation provided by their fur (Ramirez 1999, 2000). Even if bats are not killed immediately, if they absorb or ingest oil in less than toxic amounts they may suffer a variety of systemic effects and may become more susceptible to disease and predation (Ramirez 2000).

Cyanide Ponds

Modern gold mining operations often use cyanide solution to extract gold from ore. The solution, usually with 100 to 300 ppm of cyanide, is then channeled into ponds (Clark 1991). Vat leaching ponds can be very large, sometimes 80 ha (200 ac) or more, while heap leach pools are relatively small and transitory, but are even more difficult to isolate from wildlife (Clark 1991; Pierson 1998; O’Shea and others 2000).

Surveys have shown that bats are the most common group of mammals found dead near cyanide ponds, most likely poisoned as a result of drinking water containing cyanide (Meier 2000; O’Shea and others 2000; Gruver and Keinath forthcoming). Bat deaths have been reported at ponds containing cyanide at less than 20 ppm, a concentration that is considered very low (Clark 1991). Data also suggest that bat mortality at cyanide ponds is concentrated in late summer and fall, suggesting that bats are most susceptible during migration (Clark 1991; O’Shea and others 2000). Unfortunately, most cyanide ponds are in historic mining districts that are being reworked because of the efficiency of modern methods, which is where bats often concentrate in abandoned mine roosts (Pierson and others 1999; O’Shea and others 2000).

The numbers of bats killed by cyanide poisoning and the real effects on bat populations are unknown because no studies have rigorously quantified deaths (Clark 1991; Pierson and others 1999; Adams 2003). In most operations, cyanide ponds are surveyed for carcasses only depending on the degree of concern or availability of mining personnel (Clark 1991). Also, it is likely that some bats die after they leave the area, so their carcasses are unlikely to be found (O’Shea and others 2000; Adams 2003).

Recommendations

- Use effective and proven exclusionary devices to prevent bats and other wildlife from visiting toxic material impoundments (USFWS; Ramirez 1999). Metal or polypropylene netting appears to be the most effective method of excluding bats from oil waste pits and cyanide ponds (USFWS; Clark 1991; Esmoil and Anderson 1995; Ramirez 1999; O'Shea and others 2000). Netting should be suspended a minimum of 1.2 to 1.5 m (4 to 5 ft) from the surface of the pond to prevent it from sagging and exposing the surface during heavy snow loads (USFWS; Ramirez 2000).

- Avoid relying on deterrents such as flagging, reflectors, strobes, or noisemakers. Animals often habituate to these deterrents and their use has proven ineffective (USFWS; Clark 1991; Esmoil and Anderson 1995; Ramirez 1999).

- Where possible, redesign contamination systems to either eliminate open pits altogether or keep surface oil off open pits (USFWS; Ramirez 1999, 2000; Adams 2003).

- Where possible, use closed containment systems to collect oil field produced water. Closed containment systems require little or no maintenance, can be moved from site to site as necessary, eliminate soil contamination and remediation expense, do not attract wildlife, and isolate oil from the environment (USFWS; Ramirez 1999, 2000).

- Decrease or eliminate cyanide concentrations in water before releasing it into open ponds (Clark 1991; Pierson and others 1999; O'Shea and others 2000; Adams 2003).

- Use covered drip systems for gold extraction rather than sprinklers to reduce puddling (O'Shea and others 2000).

- Provide clean water alternatives for bats and other wildlife adjacent to areas where toxic materials are impounded (Pierson and others 1999).

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APPENDICES

Appendix I—Glossary

Adit – A horizontal mine passage driven from the surface for the working or de-watering of a mine.

Bat detector – An electronic device sensitive to ultrasonic and audible sounds produced by bats.

Calcar – The spur of cartilage and bone that projects inward from the ankle and helps to support the trailing edge of the interfemoral membrane in bats.

Chiroptera – A taxonomic order of mammals that categorizes bats. Latin for "hand wing".

Dorsal – Referring to the back of a bat or other animal.

Echolocation – Locating objects by listening for the echo of emitted sounds.

Eutrophication – The process of nutrient enrichment of water that can cause excessive growth of plant material and a reduction in the oxygen level in the water.

Heterothermic – Refers to animals, such as bats, whose body temperatures vary with the environment to save energy consumption.

Hibernaculum – A roost used by bats for hibernation in winter; plural is *hibernacula*.

Hibernation – A state of greatly reduced core body temperature for prolonged periods of time during winter by a heterothermic animal.

Integrated Pest Management (IPM) – Involves closely monitoring pest populations of both plants and animals, and using chemicals only when and where pests are likely to cause economically or ecologically important damage. This reduces exposure of wildlife to harmful chemicals and reduces the destruction of non-target insects and plants.

Interfemoral membrane – The membrane extending between the tail and hind legs in bats.

Karst – Landforms, such as caves, sinkholes, and underground streams, that are formed by the dissolving, rather than mechanical eroding, of rock, primarily limestone and dolomite.

Kilohertz (kHz) – A measure of sound frequency in units of 1000 cycles per second.

Maternity colony – An aggregation of female bats during pregnancy and lactation.

Maternity roost – A warm roost that maximizes the growth rate of young bats while providing protection from predation and weather.

Mesic – Refers to a relatively wet habitat.

Microchiroptera – One of 2 suborders of bats, including 17 families of mostly insectivorous and frugivorous bats. Latin for "small bats".

Mist net – A fine net stretched between two poles and used for catching bats.

Molossidae – Free-tailed bats.

Night roost – A roost used by bats at night for various activities, such as resting, consuming and digesting prey, and social interactions, usually located under an open-air overhang made by a rock or human-made structure such as a porch.

Pelage – Body fur.

Portal – An entrance or opening to a cave or abandoned mine.

Primary cavity nester – Animals, such as woodpeckers, that nest in cavities that they formed themselves. Secondary cavity nesters, such as bats, are dependent on the cavities formed by primary cavity nesters, or excavators.

Pseudokarst – Landforms, such as caves and fissures, that are formed by the process of piping, in which cavities form by the action of certain clays, which swell and contract with the presence or absence of water.

Riparian – Lands adjacent to streams, rivers, ponds, and lakes where the vegetation is strongly influenced by the presence of water.

Riparian corridors – Lands adjacent to corridors of water, such as streams and rivers, where the vegetation is strongly influenced by the presence of water

Roost – The place where bats shelter, rest, and/or breed.

Shaft – A vertical mine opening from the surface into a mine.

Snag – A standing dead tree.

Torpor – A voluntary physiological state in which a heterothermic animal's body temperature is depressed, resulting in a lowered metabolic rate and an inability to perform normal behaviors, such as locomotion. Usually at a higher body temperature than hibernation.

Tragus – A projection of flesh and cartilage that stands up inside the front of the ear in bats; plural is *tragi*.

Ultrasonic – Sound frequencies above the audible range of human hearing, usually frequencies above 20 kHz.

Uropatagium – see *interfemoral membrane*.

Ventral – The underside of an animal.

Volant – Having the power of flight.

Wing loading – The ratio of body mass (g) divided by wing area (cm^2).

Xeric – Refers to an extremely dry habitat.