WESTERN BATS AND MINING

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Abstract

In North America north of Mexico, there are 45 species of bats and 32 of these species occur west of approximately 100° W longitude. At least 22 of the western species are known to use abandoned mines to some extent and all 32 species could be affected by mine-related activities. Two species are listed as Federally Endangered and another 11 taxa are species of concern. As a group, bats have a low reproductive potential and disturbance to colonies or loss of roosting or foraging habitat can depress population levels. Aspects of their natural history, roosting habitat, and foraging habitat are discussed herein and related to potential impacts of mining.

Introduction

There are about 4200 different kinds or species of mammals and bats (Order Chiroptera) are the second largest group, after rodents, comprising about 1000 species. Globally, only primates (including humans) are more widely distributed, as bats occur on all continents except Antarctica, from tree line to tree line, as well as on many remote oceanic islands. The majority of bats, about 88 percent of all species, are tropical in distribution with fewer species in the temperate zones (Table 1). Among bats in temperate regions (e.g., North America) most belong to the family Vespertilionidae (vespertilionid or evening bats), primarily in the genera *Myotis*, *Pipistrellus*, and *Eptesicus* (Findley, 1993).

One of the clearest geographic patterns that bats exhibit is that of increasing species diversity towards the equator. In the New World for example, bats demonstrate a clear latitudinal gradient. At the Equator, there are about 100 species; at 15° N latitude, 70 species; at 20° N, 50 species; at 30°N, 20 species; above 35° N latitude, 10 species; and above 55° N latitude, only a handful (Findley, 1993). Exact reasons for this decline in diversity towards the poles are unknown but probably include absence of suitable roosting sites, extreme seasonality of food (primarily insects), and extreme weather conditions.

In North America north of Mexico, there are 45 species of bats representing 19 genera and 4 families. West of approximately 100° W longitude in the United States there are about 32 species of bats (Table 2). Of this number, roughly 26 species are exclusively western in distribution with an additional 6 species occurring more or less continent-wide. In contrast, the East has only about 12 species that occur there exclusively (Pierson, 1998). Humphrey (1975) demonstrated that increasing bat species diversity in the West is due in part to increasing topographic relief, which in turn translates into greater availability of roosting sites.

Of the 32 species occurring in the West, at least 22 species are known to use mines to some extent (Table 3; Altenbach and Pierson, 1995), and all 32 species could be affected in some way by mine-related activities. Two of the 22 species are Endangered nectar-feeding bats of the genus *Leptonycteris* and are discussed by Currie (this volume). An additional 11 species (including *Myotis lucifugus occultus*) are former U.S. Fish and Wildlife Service Category 2 Candidate Species, now usually referred to as species of concern. These 11 species, and others, are frequently listed by various states as "at-risk" species.

Although we have some understanding of regional and global patterns of species diversity and life history, we have very little rigorous data on population numbers of most species and almost no data on population trends. For some species of colonial bats in the eastern United States we do have data that document population declines and, in a few cases, recovery of populations. However, for most western bats we have almost no satisfying population data (O'Shea and Bogan, 2000). What is clear is that there are many instances of large numbers of bats disappearing from known roosts. Such disappearances are often linked with known events such as frequent disturbance, vandalism, alteration of caves or mines that make them unsuitable for bats, or various types of land-use change.

Life History Features of Western Bats

There are several unifying features of the life history of bats in western North America. Most are insectivorous and pursue their insect prey in a variety of ways; three are nectar-feeders and occur only seasonally in the United States. All the species have low reproductive rates for a small mammal of this body size, typically having only one young per female per year (Findley, 1993). In North America, bats of the genus *Lasiurus* may have up to five young in a litter although the average is lower. Gestation is usually two to three months long and following birth in early summer there is an extended period of maternal care of up to 1.5 months before the young are able to forage on their own. Juvenile mortality is high but once an individual survives its first year, there is a good probability of a relatively long life. Maximum known age of a North American bat is over 30 years (Findley, 1993) and the average is probably 4 to 7 years or so, depending upon the species. Although there are a variety of predators on bats, the assumption by most biologists has been that predation risks are low for most bats.

Once the young are independent in late summer, both they and the females have a narrow window of time during which they must obtain energy in the form of insect prey to last them through the rigors of winter. Most western species probably travel relatively short distances to winter quarters where they hibernate. However, some species are known or believed to escape winter by migrating longer distances to areas where temperatures and insect populations remain high enough for continued activity (Findley, 1993). In the spring, bats typically return to their natal areas where young are born and grow to maturity. Mating in most species occurs in the fall, just before hibernation, and sperm are "stored" in the uterus of the female over the winter. In spring, the female ovulates, the egg is fertilized, and development of the young bat ensues.

Western bats occur in a wide variety of ecological situations and, based on their life histories and distributions, some species appear to be rather general in their requirements whereas others appear to have more specific requirements. Generally, bats need two kinds of habitat to survive:

roosting habitat and foraging habitat. Roosting habitat is critical to long-term survival of bat populations and may be limiting to North American bats (e.g., Humphrey, 1975). Equally important however, and not always equally considered, (but see Pierson, 1998) is the importance of areas where bats can forage and drink.

Roosts used by Western Bats

Western bats use a variety of roosts and differences are correlated with gender, reproductive condition, time of the year, and feeding strategy. During summer, females of most species aggregate in colonies within which the young are born and nursed; colony sizes range from scores to thousands of mothers and young (Barbour and Davis, 1969). At this time, males are usually dispersed across the landscape, often in different areas or even regions of the country (e.g., Findley and Jones, 1964), and frequently roost alone. One reason for this is that males and females have different thermoenergetic strategies during the summer. Males forage nightly and then typically seek a roosting site during the day that allows them to lower their body temperature to conserve energy. Females, however, appear to seek roosting sites that are somewhat cooler than ambient temperatures during the day and warmer than ambient at night. Development of the embryo and growth of young is dependent on maintaining a more or less constant body temperature; generally, torpor is uncommon in pregnant or lactating females and growing young (Racey, 1982). Maternity roosts also appear to be chosen to provide security from predators and disturbance.

Once the young are independent, all individuals begin to pursue the “male” strategy of obtaining as much energy at night as possible and then conserving energy during the day. Thus maternity colonies begin to break up and individuals seek roosts that allow torpor (lowering of body temperature) to occur. As fall progresses, and depending on the species of bat, individuals may move among a network of roosts, where mating may occur. Subsequently, they move to the winter roost where hibernation occurs; such roosts are called hibernacula. In the western U.S., some species (e.g., California myotis, western pipistrelle, pallid bat) may not enter hibernation or may hibernate only short periods of time. Individuals of these species may be observed on winter evenings and nights (O’Farrell et al., 1967). In the case of migratory species, once sufficient energy has been obtained and stored as fat, they begin their flights to areas to the south (Cockrum, 1969).

Thus, over the course of a year, most species will use several different kinds of roosts. As noted above, summer roosts used during daylight hours tend to be gender specific with females typically aggregated in a few, historically-used roosts and males often using sites that are more abundant on the landscape; both types of sites must meet certain thermal requirements. However, at night between foraging bouts both sexes may use the same kind of roost. Night roosts are usually occupied only for short periods of time, are frequently common across the landscape, and may be relatively open, allowing bats to arrive and depart freely. Although night roosts may just be sites for rest and digestion of food, they also may serve a social function as well. During the day, night roosts are unoccupied and can be recognized by the presence of stains and guano. We know little about the extent to which western bats use temporary night roosts in the spring and fall. In the eastern U.S. swarming of bats occurs at temporary roosts in the fall; this is thought to be important for reproduction and as a precursor to entering hibernation. It seems likely that such roosts are important in the West as well.

Lewis (1995) has suggested that fidelity of bats to their roosts is related to the type of roost that is occupied. In particular, high fidelity appears to be directly related to roost permanency and inversely related to roost availability. Bats, that occupy spatially abundant but less permanent roosts, are more likely to change roosts frequently. Conversely, bats appear to show high site fidelity to roosting sites that are uncommon and permanent within an area.

Overall, two kinds of roosts are of particular importance: maternity roosts and hibernacula. Mines are known to provide both kinds for some species. Maternity roosts, where young are born and develop, are critically important, especially given the relatively low reproductive potential of most species of bats. When such roosts are destroyed or made uninhabitable, bat populations may be locally depressed due to failure of reproduction. This may be especially true if the roosts do not occur commonly across the landscape. Disturbance to bats while they are in either maternity roosts or hibernacula can be devastating to local populations. Disturbance at maternity roosts may cause females to drop and abandon their young; if the young are unable to forage on their own they will die.

Hibernating sites where bats can escape the rigors of winter and food scarcity are equally important and appear to be chosen based on strict temperature, humidity, airflow, and security requirements. Hibernacula are usually uncommon across the landscape and some species are known to be completely dependent upon only a very few sites for hibernation. Closing or alteration of such hibernacula is known to have caused population declines in some species. Often, relatively slight changes in temperature or airflow are sufficient to cause bats to abandon a roost. Disturbance in hibernacula causes bats to arouse, a process that results in expenditure of limited energy stores. It is generally believed that most bats enter hibernation with only a narrow safety margin in terms of stored energy (Humphrey and Kunz, 1976). If disturbances occur frequently, bats may be forced out of the hibernaculum to feed at a time when insects may not be available.

Actual natural sites used by western bats over the course of a year include cavities and cracks in trees, under the bark of trees, foliage of trees (including palms and yuccas), caves (both complex and simple), cracks and crevices in sheer cliffs, under rocks and boulders, and cracks in boulders. These sites, and similar ones, provide security and meet the physiological requirements of roosting bats. With settlement and development of the West, bats have lost some natural roosts but now also roost in structures such as houses, garages, barns, silos, warehouses, hangars, bridges, as well as abandoned mines. Tuttle and Taylor (1998) note that of 8,000 mines that were surveyed for bats nationwide, 30 to 80 percent showed some signs of use by bats and 10 percent contained important colonies. Factors that contribute to making a mine desirable to bats include location, proximity to foraging and drinking areas, internal structure, volume, temperature and temperature stability, airflow, ventilation, presence of other species, and absence of predation. Mines, especially those at high latitudes or altitudes, may be too cool for reproductive females in the summer but may be very desirable for hibernation. Alternatively, warmer mines, such as those in the southern U.S., may not be good for hibernation but may be used by reproductive females. A good discussion of how attributes of mines affect bat use can be found in Tuttle and Taylor (1998).

Foraging Habitat

Although North American bats are mostly insectivorous, they display an impressive array of feeding types (Table 4). Aerial insectivory, the capture of flying insects, is the "classic" form of feeding by bats but some scientists now distinguish between two different types of this feeding mode. Some bats capture flying insects in open space that is unfettered by obstacles, such as above a forest canopy, whereas others forage for flying insects in or near vegetation, such as in forests. Two other foraging modes are the capture or "gleaning" of insects directly from vegetation or trees and the capture of insects off the surface of the water or directly above it. Finally, among North American bats, three species specialize on the pollen and nectar of selected species of flowering plants (e.g., columnar cacti and agaves).

The extent to which bats are "specialists" in any of several areas, including diet, is a subject of some discussion among bat biologists (e.g., Fenton, 1982). Nonetheless, an awareness of the basic ways that bats forage (Table 4), coupled with the understanding that in most bat communities there will be multiple species using different modes, suggests that the concept of foraging areas or habitat for bats is likely to be complex. Additionally, it seems likely that just as bats show fidelity to some types of roosts (Lewis, 1995), they also continue to use productive foraging sites over time (Pierson, 1998). In terms of how western bats and mining may interact, it is fairly intuitive that closure or modifications of an abandoned mine may have direct effects on bats in the vicinity. However, foraging habitat for bats is neither obvious nor intuitive and this may obscure the effects of mining on potential foraging areas. Negative effects may be direct or indirect. If water sources are contaminated or drained bats may be affected directly, due to poisoning or loss of a place where they can drink. More subtly and indirectly, if land use causes changes in vegetation, there also may be changes in the insect community upon which the bats depend. For example, bats are known to forego foraging in lush non-native vegetation and instead travel some distance to forage in more natural vegetation (e.g., Brown et al., 1994).

Most western bat communities probably consist of six to twelve species (or more). Depending on the region, the community may include species that forage for insects over water surfaces (e.g., stock ponds, settling pools, or rivers), ground foragers that actually alight on the ground to feed, aerial insectivores feeding in open spaces above the vegetation, and finally species that pursue insects in and near vegetation. Usually, nearly all bat species in a community are dependent on nearby sources of water. Habitat change or loss of water sources due to land management, mining, or other activities have the potential to affect insect populations that bats depend upon as well as preferred foraging areas. To fully assess the effects of land-use practices on bats we need information on the habitat associations of insect prey (Pierson, 1998). Unfortunately, this information is not available for most bats. It seems likely that conversion of formerly diverse plant communities to various monocultures (e.g., agriculture, urbanization) has impacted bat communities to some degree. Invasion by, or reclamation with, non-native plants may also affect foraging opportunities for bats.

Loss of Habitat from Mining

Historically, most early mining in the West was directed at high-grade veins of precious metals that were most efficiently mined through underground workings. Although underground mining probably had some direct effects on bats (e.g., tailings, road-building, contaminants), it may have been more benign than some modern practices. Most mining today is focused on more disseminated, lower-grade, deposits that are most efficiently mined by surface or open-pit mines. This type of mining has a greater potential to modify large areas and consequently impact foraging habitat for bats.

Henry (1995) discussed environmental issues associated with mining and noted three general topics: impacts on surface and ground water, effect on wildlife habitat, and visual-aesthetic values. He notes that the greatest negative impact of mining has been on surface and ground water. Contaminated water sources are certainly a concern for bats, especially in arid areas, but there are other issues as well. O'Shea et al. (this volume) discussed the effects of mining-related contaminants on bats and their foraging habitat.

The negative effects of mining and reclamation (or lack thereof) on habitat are issues for wildlife in general (Henry, 1995). In the case of bats, habitat loss can occur in multiple ways. Initial mining efforts, including road building, site clearing, blasting, excavation, and disposal of waste rock may disturb bats roosting in the vicinity and will probably have negative effects on bat roosting and foraging habitat. Quarrying operations may disturb or destroy cracks and crevices in cliffs where bats roost. Open pit mining may have significant impacts on foraging habitat through destruction of native vegetation and loss of the native insect communities; water sources may be destroyed or polluted. Renewed mining in historic underground workings may displace bats that have found roosts in abandoned mines and have negative consequences for foraging areas as well. Other than the use of abandoned mines as roosts, I suspect that few reclamation specialists ever consider bat habitat needs during reclamation of abandoned mines. Nonetheless, the often sterile, monocultural aspect of many reclaimed areas is probably a barren wasteland for most bats. This may be especially true if non-native vegetation has been used in the reclamation.

Conclusions

Although we lack conclusive evidence of actual population declines in many western bat species, scientists and managers are in general agreement that such declines have occurred, both locally and regionally. Furthermore, most authorities believe that such declines are continuing. It seems obvious that with settlement of the West bats have lost both roosting and foraging habitat and have been subjected to disturbance and destruction in many areas. Although many bats have proven to be adaptable and have moved into anthropogenic structures we have no way of knowing the extent to which this has compensated for loss of natural habitat. Certainly, abandoned mines have become important to many species, vitally so for a few (e.g., *Macrotus californicus*). It is imperative that as abandoned mine closures are contemplated, adequate surveys for roosting bats are conducted prior to closure and alternative gating methods are considered (Altenbach et al.; Currie; Sherwin et al.; this volume).

If abandoned mines, properly gated and secured for use by bats, are the good news, then the bad news, arguably, is that existing mines and mining practices have the potential to alter or destroy both roosting and foraging habitat for bats in the West. Although research is badly needed on the interactions between bats and mining (e.g., impact of loss of natural vegetation on insect prey of bats), much can be done to alleviate potential negative impacts. We know enough about bat foraging and roosting habits to be able to develop some understanding of the potential effects in a given area and to implement mitigation measures in many cases. Pre-project surveys for bats, roosts, and foraging areas should be conducted, especially for species of concern. Hopefully, areas of importance, especially roosts, can be protected during actual mining. During the mining project, if roosts or important foraging areas have been found, monitoring of these resources should be continued. Where bat roosts conflict with mining plans, appropriate times and techniques for exclusion of bats should be used (Sherwin, personal communication). If possible, alternative roost structures should be provided. Finally, reclamation of abandoned mine lands should consider the unique needs of bats, both for foraging and roosting, and use native vegetation and appropriate real or artificial roosting habitat.

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Table 1. Summary of numbers of families, genera, and species of bats in the major geographic divisions of the world (after Altringham, 1996).

Taxon	North America	South America	Europe and Asia	Ethiopan Region	Oriental Region	Australian Region
Families	4	9	8	8	9	6
Genera	19	67	23	44	57	48
Species	45	230	90	190	270	166

Table 2. Species of bats occurring in the western United States.

Family Mormoopidae (Mormoopid or ghost-faced bats)
Mormoops megalophylla (Ghost-faced bat)

Family Phyllostomidae (Phyllostomid or leaf-nosed bats)
Macrotus californicus (California leaf-nosed bat) C2
Choeronycteris mexicana (Mexican long-tongued bat) C2
Leptonycteris curasoae (Southern long-nosed bat) E
L. nivalis (Mexican long-nosed bat) E

Family Vespertilionidae (Vespertilionid or evening bats)
Myotis auriculus (Southwestern myotis)
M. californicus (California myotis)
M. ciliolabrum (Western small-footed myotis) C2
M. evotis (Long-eared myotis) C2
M. keenii (Keen's myotis)
M. lucifugus (incl. *M. occultus*; Little brown myotis) C2
M. septentrionalis (Northern myotis)
M. thysanodes (Fringed myotis) C2
M. velifer (Cave myotis) C2
M. volans (Long-legged myotis) C2
M. yumanensis (Yuma myotis) C2
Lasionycteris noctivagans (Silver-haired bat)
Lasiurus blossevillii (Western red bat)
L. borealis (Eastern red bat)
L. cinereus (Hoary bat)
L. xanthinus (Western yellow bat)
Pipistrellus hesperus (Western pipistrelle)
Eptesicus fuscus (Big brown bat)
Euderma maculatum (Spotted bat) C2
Corynorhinus townsendii (= *Plecotus townsendii*; Townsend's big-eared bat) C2
Idionycteris phyllotis (Allen's big-eared bat) C2
Antrozous pallidus (Pallid bat)

Family Molossidae (Molossid or free-tailed bats)
Tadarida brasiliensis (Brazilian free-tailed bat)
Nyctinomops femorosaccus (Pocketed free-tailed bat)
N. macrotis (Big free-tailed bat) C2
Eumops perotis (Western mastiff bat) C2
E. underwoodi (Underwood's mastiff bat) C2

E = Federally Endangered
C2 = Former Category 2 Candidate Species (now Species of Concern)

Table 3. Species of western bats known to use mines (after Altenbach and Pierson, 1995). Common names of species especially dependent on mines are in bold-faced type.

Family	Species	Common Name
Mormoopidae		
	Mormoops megalophylla	Ghost-faced bat
Phyllostomidae		
	Choeronycteris mexicana*	Mexican long-tongued bat
	Leptonycteris curasoae E	**Lesser long-nosed bat**
	Leptonycteris nivalis E	Greater long-nosed bat
	Macrotus californicus*	**California leaf-nosed bat**
Vespertilionidae		
	Antrozous pallidus	Pallid bat
	Conrynorhinus townsendii*	**Townsend's big-eared bat**
	Eptesicus fuscus	Big brown bat
	Idionycteris phyllotis*	Allen's big-eared bat
	Lasionycteris noctivagans	Silver-haired bat
	Myotis auriculus	Southwestern myotis
	M. californicus	California myotis
	M. ciliolabrum*	Western small-footed myotis
	M. evotis*	Long-eared myotis
	M. lucifugus (occultus*)	Little brown myotis
	M. septentrionalis	Northern myotis
	M. thysanodes*	Fringed myotis
	M. velifer*	**Cave myotis**
	M. volans*	Long-legged myotis
	M. yumanensis*	Yuma myotis
	Pipistrellus hesperus	Western pipistrelle
Molossidae		
	Tadarida brasiliensis	Brazilian free-tailed bat

E = Species listed as Endangered under Endangered Species Act
* = Former U.S. Fish and Wildlife Service Category 2 Candidate Species

Table 4. Foraging strategies of some western bats (after Findley, 1993).

Forest/Clearing aerial insectivores

Eptesicus fuscus
Lasionycteris noctivagans
Mormoops megalophylla
Myotis californicus
M. ciliolabrum
M.volans
Pipistrellus hesperus

Open-air aerial insectivores

Eumops perotis
E. underwoodi
Lasiurus blossevillii
L. borealis
L. cinereus
L. xanthinus ?
Nyctinomops femorosacca
N. macrotis
Tadarida brasiliensis

Gleaning insectivores

Antrozous pallidus
Euderma maculatum
Idionycteris phyllotis
Corynorhinus townsendii
Macrotus californicus
Myotis auriculus
M. evotis
M. septentrionalis
M. thysanodes

Water-surface foragers

Myotis lucifugus
M. velifer
M. yumanensis

Nectarivores

Leptonycteris curasoae
L. nivalis
Choeronycteris mexicana