Mammals
Taxidea taxus  
(American Badger)

Order: Carnivora  
Order Description: Carnivores  
Family: Mustelidae  
Family Description: Weasels, Skunks and Others

Description:
The badger's fur is grayish and grizzled with black. It has a "badge-like" black marking on its face, which is accentuated by white that extends from the face rearward. The badger body is well suited for digging; it is short and stout and somewhat flattened. Its ears are rather short and its snout appears slightly upturned. Its legs are short and stout, black colored and well suited for digging. The foreclaws are long and curved and its hind claws are shovel-like. Badgers always adopt a low profile, seeming to hug the ground. Total length is 24 to 30 inches (600-750 mm), their tail is about 4 to 6 inches (105-150 mm) and they weigh up to 26 pounds (12 kg).

Range:
Badgers range from the Great Lakes states west to Pacific Coast, and from Canadian Prairie Provinces, south to Mexican Plateau.

Habitat:
Prefers open areas with enough soil to dig in, but can be found from high alpine country to low valleys. They may also frequent brushlands with little groundcover. They seem especially common in large grass and sagebrush meadows and valleys. In Idaho, this species occurs in shrub steppe, in agricultural areas, and in open woodland forests.

Diet:
They feed primarily on small rodents such as ground squirrels, pocket gophers, kangaroo rats, prairie dogs, and mice, most of which they capture by digging into the burrows of these small mammals. But, they will also eat scorpions, insects, snakes (even rattlesnakes), lizards, and birds, especially when rodent population is low. An Idaho study reported that individuals preyed on Townsend's ground squirrels, lagomorphs, deer mice, kangaroo rats, and various arthropods.

Ecology:
They are usually active day and night, but primarily nocturnal activity has been reported. They remain underground in burrows when inactive. They use permanent dens in the winter, but during the summer they often dig a new den each day. In one Idaho study, individuals rarely stayed underground for more than 24 hours except in the winter. One female emerged from her winter den only once during a 72 day period. A southwestern Idaho study reported winter underground stays from several days to several weeks. Their population density averages 1 badger per 2.6 km2 in prime open country, although a southeastern Idaho study reported 5 badgers per km2 that were associated with ground squirrel populations in areas of sparse vegetation. One Idaho study reported a home range of less than 4 km2, while another in-state study found that adult home range averaged 2.4 km2 Most young-of-year badgers dispersed during their first summer (up to 110 km). Home ranges of badgers tend to overlap, but individuals are basically solitary. Since badgers dig burrows frequently, both in search of prey and for shelter, their burrows are common in badger habitat. Elliptical in shape, about 8 to 12 inches high and 12 to 18 inches wide, their burrows are important ecologically for other species. Various small mammals, such as ground squirrels and rabbits use their burrows for shelter, as do snakes and other vertebrates. Badgers have been maligned by humans because their burrows can be injurious to livestock, but rodent control and the cover their burrows provide for other wildlife probably offset the few leg injuries to livestock. Badgers are considered to be solitary, but recently there have been reports and sightings of badgers and coyotes hunting together. Coyotes take advantage of rodents escaping from burrows being

http://imnh.isu.edu/digitalatlas/bio/mammal/Carn/muste/amba/badger.htm

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excavated by badgers, and badgers take advantage of rodents escaping from coyote foraging by scurrying into burrows. This seems like an example of _predator mutualism_. Badgers have earned a reputation for their ferocity. When cornered they use what seems to be their main lines of defense: either burrowing out of sight or hissing loudly and feigning charges.

**Reproduction:**
Mating occurs mid- to late summer and even into early fall. _implantation_ is delayed until December to February. Females produce 1 litter averaging 3 (2 to 5) young, born from March to early April (Idaho study found 1.4 young). The young are _altricial_, being blind and only partially furred. Females nurse their young through June and young leave their family groups in early fall. The male will occasionally stay close to the female when young are in the nest burrow. An Idaho study reported 30% of young-of-year females bred, and males reached sexual maturity as yearlings.

**Conservation:**

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**Important State References:**

Information written by Donald Streubel,© 2000
Map image provided by Stephen Burton,© 2000
American Badger

Distribution, Abundance, and Seasonality

Uncommon, permanent resident found throughout most of the state, except in the northern North Coast area (Grinnell et al. 1937). Most abundant in drier open stages of most shrub, forest, and herbaceous habitats, with friable soils.

Specific Habitat Requirements

Feeding: Badgers are carnivorous. They eat fossorial rodents: rats, mice, chipmunks, and especially ground squirrels and pocket gophers. Also eat some reptiles, insects, earthworms, eggs, birds, and carrion. Diet shifts seasonally and yearly in response to availability of prey.
Cover: Badgers dig burrows in friable soil for cover. Frequently reuse old burrows, although some may dig a new den each night, especially in summer (Messick and Hornocker 1981).

Reproduction: Young are born in burrows dug in relatively dry, often sandy, soil, usually in areas with sparse overstory cover.

Water: No data found.

Pattern: Suitable habitat for badgers is characterized by herbaceous, shrub, and open stages of most habitats with dry, friable soils.

Species Life History


Seasonal Movements / Migration: Non-migratory. Area used during winter smaller than at other seasons.

Home Range: Home range estimates vary geographically and seasonally. In Utah, Lindzey (1978) found fall and winter home ranges of 5 females varied from 137-304 ha (338-751 ac). Those of 2 males varied from 537-627 ha (1327-1549 ac). In Idaho, Messick and Hornocker (1981) found that home ranges of 7 adult females and 3 males averaged 160 ha (400 ac) and 240 ha (600 ac), respectively.

Territory: Little information available. Family members may share the territory of a female (Seton 1929). However, males generally are solitary, except in the breeding season (Messick and Hornocker 1981).


Niche: Badgers are highly specialized fossorial mustelids that help control small mammal populations. Somewhat tolerant of human activities, however predator control using indiscriminate trapping and persistent poisons causes extensive losses.

Sources & References

California Department of Fish and Game, 1999.
California's Wildlife, Sacramento, CA.
Written by: G. Ahlborn, reviewed by: M. White, edited by: M. White, G. Ahlborn

American Badger - *Taxidea taxus*

### Characteristics

The American badger has a flat body with short legs and a triangular face with a long, pointed, tipped-up nose. It has long brown or black fur with white stripes on its cheeks and one stripe running from its nose to the back of its head. It has small ears on the side of its head and long, sharp front claws.

### Range

In the United States, the American badger can be found from the west coast to Texas, Oklahoma, Missouri, Illinois, Ohio, Michigan and Indiana. It is also found in southern Canada in British Columbia, Manitoba, Alberta and Saskatchewan.

### Habitat

The American Badger lives in open areas like plains and prairies, farmland and the edges of woods.

### Diet

Small burrowing mammals like ground squirrels, rats, gophers and mice make up most of the badger’s diet. It digs its prey out of the ground with its strong, sharp claws. The badger will sometimes dig into the burrow of an animal and wait for it to return. Coyotes often will stand by while a badger is burrowing and catch animals that come out of a tunnel trying to escape the badger. The badger also eats snakes, birds and reptiles. It will sometimes bury extra food to eat later.

### Life Cycle

The American Badger mates between July and August, but the embryos don’t really start to grow until December or February. The female gives birth in March. She will have between one to five babies. The babies will be weaned by June.

### Behavior

Dens and burrows are a very important part of the badger’s life. A badger usually has lots of different dens and burrows. It uses them for sleeping, hunting, storing food and giving birth. A badger may change dens every day, except when it has babies. Badger dens have one entrance with a pile of dirt next to it. When a badger is threatened, it will often back into a burrow and bare its teeth and claws. It may then plug up the burrow’s entrance.

The badger is well-protected from predators. Its muscular neck and thick, loose fur protect it when it is captured by a predator. This gives the badger time to turn on the predator and bite and claw it. When a badger is attacked, it also uses vocalizations. It hisses, growls, squeals and snarls. It also releases an unpleasant musk that may drive a predator away.

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Description: *Nyctinomops macrotis*, like all molossids, has a free tail tip which extends beyond the edge of the interfemoral membrane. It can be distinguished from the other three molossids which occur in California based on its size or forearm length. This species, with a forearm length of 58-64 mm, is larger than *Nyctinomops femorosaccus* (forearm 45-49 mm) or *Tadarida brasiliensis* (forearm 36-46 mm), and smaller than *Eumops perotis* (forearm 75-83 mm) (Barbour and Davis 1969, Milner et al. 1990). It has large, broad ears which are joined at the midline of the forehead, and extend beyond the tip of the nose when laid forward (Schmidly 1991). It weighs 22-30 g (Schmidly 1991).

Taxonomic Remarks: *N. macrotis* is in the family Molossidae. *N. macrotis* was first described from a specimen found in a tree hollow in Cuba (Gray 1839). The California form was described by Allen (1893). Although in the past it has been called *Tadarida macrotis* or *Tadarida molossa*, the currently accepted nomenclature is *Nyctinomops macrotis* (Freeman 1981, Koopman 1993). It is a monotypic species.

Distribution: *N. macrotis* is distributed from Uruguay and northern Argentina, northward through South America, mostly east of the Andes, through central America and Mexico into the southwestern United States, with records also from the Greater Antilles (Milner et al. 1990). In temperate North America, there are also individual records from eastern Kansas, Iowa, South Carolina and British Columbia (Hall 1981, Di Salvo et al. 1992, Nagorsen and Brigham 1993). Records are more common for Texas, Arizona, New Mexico, and Utah than for California.

There are very few records for this species in California. The type specimen for a form originally described as *Nyctinomops macrotis nevadensis* was most likely collected in California, although the exact locality is not known (Allen 1893, Allen 1894). There are several records from San Diego County (Huey 1932, 1954, August and Dingman 1973), one from Alameda County (Museum of Vertebrate Zoology, UC Berkeley, 1916), and a number from scattered locations in California, with a concentration in southern California (D. Constantine pers. comm.).

Surveys conducted in 1993-1995 (Pierson and Rainey 1996b, c) identified two possible localities for this species. A moribund specimen was found below a cliff face in San Diego County in April, 1991 (P. Brown pers. comm.). Acoustic and visual observations in November 1994 and May 1995 suggested that other individuals of *N. macrotis* were roosting at this locality (Pierson and Rainey 1996b, c). Recordings of echolocation calls possibly attributable to *N. macrotis* were also made at Barker Dam in Joshua Tree National Park on August 30, 1992 (Pierson and Rainey 1996b, c).

Recent records collected by the California Department of Health Services, although all of isolated and dead individuals, suggest that, though this species is rare, it has a scattered distribution throughout much of the state, and could be expected almost anywhere (D. Constantine pers. comm.).

Life History: Available information on the population biology of this species, although limited, suggests that adult females form nursery colonies, and give birth to a single young in June or July, with lactating females having been taken as late as mid-September (Barbour and Davis 1969, Constantine 1961).

Very little is known about the foraging ecology of *N. macrotis*. Ross (1967) found only macrolepidoperans (probably hawk moths) in the stomach of one individual. Easterla and Whitaker
(1972) examined 60 stomachs, and found that the most important food was large moths. Also occasionally included in the diet were crickets (Gryllidae), grasshoppers (Tettigoniidae), and flying ants (Formicidae).

Habitat: In the southwestern U.S., *N. macrotis* is primarily associated with arid, high relief landscapes, i.e., Big Bend National Monument in Texas or the canyonlands of southern Utah (Barbour and Davis 1969, Easterla 1973, Milner et al. 1990, D. Rogers pers. comm.). Easterla (1973) documented it in four plant communities -- arroyo, shrub desert, woodland, and moist Chisos woodland -- although the majority of animals were in the floodplain-arroyo association. Although it has been found at about 2,440 m elevation in New Mexico (Jones 1965), it is more typically detected below 1,800 m (Milner et al. 1990).

Relatively few roosts of *N. macrotis* are known. A colony of about 130 was discovered by Borell (1939) in the Chisos Mountains of Texas. The animals were in a horizontal rock crevice (ca. 15 cm wide and 6 m long), located about 12 m above a talus slope in a narrow, rocky canyon. Although animals have been detected in buildings and caves (Milner et al. 1990) -- two specimens from San Diego County were in buildings (Huey 1932, 1954b) -- the few colonies of this species that have been located in the southwestern U.S. have been in rock crevices in canyon settings (Milner et al. 1990). In Cuba, the species appears to roost in small groups and has been found in tree hollows (Silva Taboada 1979).

**Status:** Class II. Acoustic surveys were conducted from 1993-1995 at a number of localities throughout California (Pierson and Rainey 1996b, c). These yielded possible records of *N. macrotis* at one site in San Diego County and at Joshua Tree National Park, Riverside County. Thus, although this species may occur almost anywhere in the state, it is likely very rare. Also, since no reproductive females or juveniles have been identified in any of the published records, it still is not known whether this species breeds in California.

Alterations or disturbance of cliff habitat (i.e., water impoundment projects, highway projects, and recreational climbing) could potentially affect this species. Not enough is known regarding the habitat requirements of this species to identify other potential threats.

**Management Recommendations:** Additional surveys for this species (which could be conducted in the context of surveys for other species) are urgently needed, especially in the canyon areas of southern California (San Diego, Imperial, and Riverside counties). Acoustic sampling may be the most efficient and effective method detecting the presence of this species in an area. While molossids are generally readily detectable acoustically, they also display a large variability in their echolocation calls (Simmons et al. 1978). This interpretation of acoustic data should be undertaken with caution until the range of variation within potentially similar species is adequately characterized.
BIG FREE-TAILED BAT
*Nyctinomops macrotis*

Locations verified by authors
(captures, observations, museum records)

- ▲ Constantine 1998
- □ CNDDB 1979-1998
- ○ 1978 and before
- ▼ CNDDB 1978 and before

Terrestrial Mammal Species of Special Concern in California, Brylski et al. 1998

1:4,880,000

Wildlife Branch: KFien12109
Big Free-tailed Bat (*Nyctinomops macrotis*)

**PROTECTION STATUS NOTES**
The big free-tailed bat was proposed as a federal candidate species in 1994. This species is currently on the BLM's special status species list for Utah and Colorado. It is considered a Species of Special Concern by the states of California and Utah. In Texas, it is not considered Endangered or Threatened, but little is known about population trends.

**DESCRIPTION**
*Nyctinomops macrotis* can be distinguished from other molossids (= free-tailed bats) based on size. With an adult forearm of 58–64 mm it is larger than *T. brasiliensis* or *N. femorosacca*, and smaller than *Eumops perotis*. Also, it has vertical grooves or wrinkles on the upper lip, which are lacking in *Eumops*.

**LIFE HISTORY**
This species is a seasonal migrant, and a powerful flyer. The species forms maternity colonies, and females bear one young in late spring or early summer. Lactating females have been taken in July, August and September, and volant juveniles recorded on 8 and 27 August. Maternity roosts have been documented in rock crevices, with evidence of long term use. It appears that the return to the roost site by this bat involves ritualized behavior, including a general reconnaissance of the site and several landing trials before entry. Owls are the only documented predators of this species. *N. macrotis* has an audible echolocation call, which is characterized as loud and with a frequency range of 17–30 kHz. Surveys based on echolocation calls for this species may be possible, as captures appear to be uncommon (outside of Big Bend National Park, where the most animals in North America have been documented). Easterla, however, reports that the populations at the Park fluctuate greatly from year to year. Little is known about the species population dynamics and ecology.

Big free-tailed bats roost mainly in crevices and rocks in cliff situations, although there is some documentation of roosts in buildings, caves, and tree cavities.

*N. macrotis* forages almost entirely on large moths, but some data exist to document occasional foraging on other insects, including grasshoppers, beetles, crickets, leafhoppers and flying ants.

**DISTRIBUTION**
*N. macrotis* ranges from most of South America northward to include Mexico, Arizona, New Mexico, southern and western Texas, southern California and southeastern Nevada, southern Utah, and north to central Colorado. The species is migratory, and there are some extralimital records from British Columbia, Iowa, Kansas, and South Carolina. The known elevational range is from near sea level to about 8,500 ft. *N. macrotis* appears to be mainly an inhabitant of rugged, rocky habitats in arid landscapes. It has been found in a variety of plant associations, including desert shrub, woodlands, and evergreen forests. It appears to be associated with lowlands, but has been documented at around 8,000 ft in New Mexico.

**THREATS AND REASONS FOR DECLINE**
No known threats to the species have been identified to date. However, some of the general threats to bats...
could apply to *N. macrotis*. These could include impacts to foraging areas from grazing, riparian management, the use of pesticides, and in some places disturbance to the roost site (e.g. blasting of cliffs or water impoundments).

**ONGOING RECOVERY**

Although big free-tailed bats are locally abundant, they are often absent from seemingly appropriate habitat. Since these fast flyers are rarely netted over any but the largest and most obstacle-free ponds, it is quite possible that they are limited by suitable drinking sites, which are known to have decreased in number during historic times.

**OTHER**

Information is needed on *N. macrotis* regarding roosting ecology, seasonal movement patterns, and breeding colony distribution. Current evidence suggests that the species breeds farther north than previously thought, including southern Utah and Colorado. Vocalization recordings are needed to train researchers and managers that may attempt to survey for the species based on audible calls. Reference calls need to be established and geographically verified, and made available at a depository, and/or establish a site where recordings can be sent for verification. It will be important for bat biologists to be able to distinguish between the different audible bats in the southwest.

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**For more information**

Additional details can be found in the online version of *The Mammals of Texas* for the Big Free-tailed Bat.
Fringed myotis, *Myotis thysanodes*
Elizabeth D. Pierson & William E. Rainey

**Description:** *Myotis thysanodes* is one of the larger *Myotis* species, with a forearm length of 40-47 mm, and an adult weight of 5.3-7.6 g. It can be distinguished from all other California bat species by a well-developed fringe of hair on the posterior edge of the tail membrane. It has relatively large ears, and can most readily be confused with the long-eared myotis, *Myotis evotis*. *M. evotis* is smaller (forearm = 36-41 mm), with longer ears (22-25 mm in *M. evotis* vs. 16-20 mm in *M. thysanodes*). Although *M. evotis* sometimes has a scant fringe of hairs on its tail membrane, it is never as distinct as that in *M. thysanodes*. *M. thysanodes* varies in color from yellowish brown to a cinnamon brown, with more northern populations tending to have darker coloration.

**Taxonomic Remarks:** *M. thysanodes* is in the Family Vespertilionidae. The type locality for *M. thysanodes* is Old Fort Tejon (at Tejon Pass) in the Tehachapi Mountains, Kern County, California (Miller 1897). Four subspecies are recognized (Hall 1981, Manning and Jones 1988), *M. t. aztecus*, *M. t. thysanodes*, *M. t. pahasapensis*, and *M. t. vespertinus*. Most *M. thysanodes* in California are referable to *M. t. thysanodes*; populations in the northwestern part of the state (Humboldt, Siskiyou and Shasta counties) have recently been placed in the new subspecies, *M. t. vespertinus* (Manning and Jones 1988), although relatively few specimens have been examined and the boundary between subspecies has not been clearly delineated. Recent investigation of evolutionary affinities among long-eared *Myotis* of the southwestern U.S. (Reduker et al. 1983) suggest they form a monophyletic clade, and that *M. thysanodes* shared a common ancestor with *M. evotis*, after the divergence of *Myotis auriculus* (a species not currently known from California).

**Distribution:** *M. thysanodes* is widely distributed across the western third of the United States, is found in most of Mexico, and reaches into southern British Columbia. Three subspecies have very limited distributions, *M. t. pahasapensis* in western South Dakota, western Nebraska and eastern Wyoming, *M. t. aztecus* in southern Mexico (Hall 1981), and *M. t. vespertinus* in southwestern Washington, western Oregon, and northwestern California (Manning and Jones 1988). *M. t. thysanodes*, the primary subspecies found in California, ranges from 51°54' N. lat. in southern British Columbia (Rasheed et al. 1995) to Michoacán in southern Mexico (Hall 1981).

In California, the species is found the length of the state, from the coast (including Santa Cruz Island) to >1,800 m in the Sierra Nevada. Records exist for the high desert and east of the Sierra Nevada (e.g., lactating females were captured in 1997 by P. Brown near Coleville on the eastern slope of the Sierra Nevada). However, the majority of known localities are on the west side of the Sierra Nevada.

**Life History:** *M. thysanodes* is a colonial species. Although Barbour and Davis (1969) state that nursery colonies of several hundred are not uncommon, and the colony studied by O’Farrell and Studier (1975) contained 1,000-2,000 individuals, colonies observed in California in recent years more typically contain 10-20 adults (E. Pierson and W. Rainey unpubl. data), although one colony of > 200 was known from the San Bernardino Mountains (P. Brown pers. comm.).

The reproductive cycle in *M. thysanodes* has been most thoroughly investigated at a colony in northeastern New Mexico by O’Farrell and Studier (1973). Like other North American vespertilionids, *M. thysanodes* appears to mate in the fall after the maternity colony has disbanded. Ovulation, fertilization and implantation occur in the spring and are followed by a pregnancy of 50-60 days. Females give birth to a single young per year. In the New Mexico colony, parturition occurred between 25 June and 7 July. Available evidence suggests that births take place much earlier.
in California. In Napa County, females in late stage pregnancy have been observed in early May, and young 10-14 days old by the third week in May (Pierson and Rainey unpubl. data). Farther north, in Shasta County, females in late pregnancy or with newly born young were observed in late May and early June for three consecutive years from 1992-1994 (Rainey and Pierson unpubl. data).

Prenatal and postnatal growth has been described by O’Farrell and Studier (1973). Young are born unfurred, with their eyes open, at about 22% adult weight. They are capable of limited flight by 16.5 days of age, and full flight at 20.5 days.

Only limited information is available on diet in *M. thysanodes*. In a study conducted in New Mexico, Black (1974) concluded the species appeared to be a beetle strategist. In western Oregon (Whitaker et al. 1977), the dominant prey item in the diet of three out of four animals examined was lepidopterans (moths). The diet also included phalangids (harvestmen), gryllids (crickets), tipulids (crane flies), and araneids (spiders). The feces of one individual captured on the upper Sacramento River in California contained predominantly coleopterans (beetles) and hemipterans (bugs) (Rainey and Pierson 1996). Relatively heavy tooth wear on animals examined in a five year study on the Sacramento River would suggest that in this area the species feeds primarily on heavy bodied insects, such as coleopterans and hemipterans. The presence of non-flying taxa in the diet of the Oregon animals suggests a foraging style which relies at least partially on gleaning.

Winter behavior is even more poorly understood than summer behavior. Scattered winter records suggest, however, that the species is not migratory, and like many species in the more temperate parts of California, may be intermittently active throughout the winter. The species has been found hibernating in buildings and mine tunnels along the coast in the San Francisco Bay area and in the coast range north of San Francisco.

**Habitat:** *M. thysanodes* occurs in a wide range of habitats, from desert scrub to high elevation conifer forest (O’Farrell and Studier 1980). Barbour and Davis (1969) found it to be one of the more common species in oak forest at 1,500-1,800 m elevation in the Chiricahua Mountains. In a study in the Mogollon Mountains of New Mexico and Arizona, Jones (1965) found *M. thysanodes* occurred almost exclusively in evergreen forest (>2,000 m elevation), and was the fourth most common species in this habitat. In a long-term study in western New Mexico (Jones and Suttkus 1972), *M. thysanodes* was found predominantly at the highest elevation sampled (2,600 m), and was the ninth most common bat species in this habitat.

A paucity of records makes it difficult to assess habitat preferences for this species in California. The earliest records for the state (Grinnell 1933) are all between 360 and 900 m elevation. Orr (1956) in reviewing specimens held at the California Academy of Sciences, notes two localities from the coastal region (Carmel in Monterey County and Woodside in San Mateo County). P. Brown (pers. comm.) reports finding a colony in 1991 at Big Bear in the San Bernardino Mountains. More recently, records have accumulated from the upper Sacramento River (Rainey and Pierson 1996), and the Sierra Nevada (Pierson and Rainey unpubl. data). Although nowhere common, the species occurs as one of the rarer taxa in netting records from the central coast to at least 1,950 m in the Sierra Nevada. It has been found in mixed deciduous/coniferous forest and in both redwood and giant sequoia habitat (Pierson and Rainey unpubl. data).

Most known roosts for *M. thysanodes* are in caves, buildings, or mines (O’Farrell and Studier 1980). Although outside of California maternity colonies have been found in caves (e.g. Baker 1962, Easterla 1966, Judd 1967), the only cave in California for which there are multiple records is Clough Cave in Sequoia National Park. The majority of roost sites documented in California have been
found in buildings (e.g., Orr 1956), including the type locality at Old Fort Tejon (Miller 1897). Although mines are mentioned as roost sites by several authors (Cahalane 1939, Cockrum and Musgrove 1964, Barbour and Davis 1969), there are no published records of maternity roosts in mines. Since 1987, we have located two small maternity roosts in mines (ca. 10 adult females each) in the coast range north of San Francisco. P. Brown (pers. comm.) in 1992 also located a maternity colony of ca. 50 in a mine in the southern Sierra foothills, and in 1991 captured lactating females entering a mine in the Castle Mountains, in the eastern Mojave Desert. Five roosts in the Laguna Mountains, San Diego County, located by radiotelemetry in the summer of 1996, were in rock crevices on cliff faces (Miner et al. 1996). Research within the past few years in Oregon and Arizona has also documented that *M. thysanodes* roosts in tree hollows, particularly in large conifer snags (Cross and Clayton 1995, Chung-MacCoubrey 1996). In California, a small colony was also located in a hollow redwood tree in the Carmel Valley (Pierson and Rainey unpubl. obs.). Tree-roosting behavior is consistent with an observed association between *M. thysanodes* and heavily forested environments in the northern part of its range (M. Brigham pers. comm., Cross et al. 1976, E. Pierson and W. Rainey pers. obs.).

One issue needing further investigation for this species is its preferred roost temperature. Work by Studier and O’Farrell (1972) on a colony in New Mexico suggested that *M. thysanodes* could fly at lower ambient temperature than many species, and sought cooler roosting conditions than did *M. lucifugus* with which it shared an attic roost. The two mine roosts which were identified recently in California were both relatively cool and damp (one mine had standing water). In contrast, a mine used as a nursery roost in the southern Sierra Nevada is dry and moderately warm (P. Brown pers. comm.). Barbour and Davis (1969) noted that this species was readily captured at the entrances to night roosts in buildings, mines and caves. In a five year study on the upper Sacramento River, we observed that *M. thysanodes*, though one of the least commonly encountered bats, was more readily detected at bridge night roosts than in netting surveys conducted over water (Pierson et al. 1996).

**Status:** Class II. The status of this species has not been systematically investigated. Museum records suggest that while *M. thysanodes* is widely distributed in California, it is everywhere rare. Our personal experience is that although this species occurs in netting and night roost surveys in a number of localities, it is always one of the rarest taxa (Pierson et al. 1996).

Available museum records offer documentation for only six maternity sites: two in Kern County (including the type locality at Old Fort Tejon), and one each in Marin, Napa, Tuolumne, and Tulare counties. Investigation of four of these sites since 1990 has shown that while the roosts are still available this species is no longer present at any of these sites.

The limited data available suggest serious population declines. Maternity colonies identified between 1891 (Old Fort Tejon) and the early 1970s (Point Reyes National Seashore, Marin County) were likely considerably larger than any colonies known today. Forty-two animals were collected at the Fort Tejon site (five different collections between 1891 and 1945), 58 at Point Reyes National Seashore between 1973 and 1974, 40 in one year from a site in Napa County, 20 from a Tuolumne County site, and 14 from a Kern County site. Although, in the context of surveys not targeting this species, we have identified six new maternity sites in northern California, none of these contains more than 10-30 females. One site in Napa County was described by Dalquest (1947) as having about 50 animals in July 1945. Forty animals were collected at that time. In June 1987 the site contained 10-15 animals, and in August 1988, none. The grounds around this building had been considerably modified in 1988 for a new winery installation, and the building which housed the bats...
was experiencing more human activity and scheduled for renovation. P. Brown (pers. comm.) observed two somewhat larger colonies (40-50 animals) in southern California, although one was in a house from which it has since been excluded. This species appears to be extremely sensitive to disturbance at roost sites and to human handling. While some species of Myotis, like *Myotis yumanensis*, seem tolerant of human incursions into their roosting space, *M. thysanodes* is not.

A cave in Sequoia National Park was documented in 1951 as being a *M. thysanodes* maternity site. Sixteen animals were collected at that time. Additionally, this cave has experienced very heavy recreational use for many years. Repeated attempts by the Park Service to gate the cave have been thwarted by vandalism. Although *M. thysanodes* has been mist-netted in the vicinity of this cave, it has not apparently been observed roosting there recently.

A comparison of historic and current records indicates limited recolonization at sites from which it has been extirpated. What may have been the largest documented colony in California occupied a barn at Point Reyes National Seashore. Fifty-eight animals were collected from this site in 1973 and 1974. Monitoring of this site since 1979 showed annual reoccupation by a *Myotis yumanensis* maternity colony, but *M. thysanodes* was not detected until 1996. The site has been protected by the Park Service for at least ten years, with no known human incursions into the roosting space. This suggests that the distribution of *M. thysanodes* is patchy and its dispersal capabilities limited.

Closure of old mines for hazard abatement and renewed mining in historic districts both pose considerable risks to this and other cavern dwelling bat species (Belwood and Waugh 1991, Brown and Berry 1991, Altenbach and Pierson 1995, Riddle 1995). One of the two *M. thysanodes* mine nursery sites we (E. Pierson and W. Rainey) have found since 1987 was destroyed by renewed mining. The colony persists by default, now occupying the lower level of a mine gated as a mitigation site for *Corynorhinus townsendii* (Pierson et al. 1991).

Restoration of historic buildings may also pose a threat to this species. One historic roost site (Old Fort Tejon) and two current roost sites are located in historic buildings owned by the California Department of Parks and Recreation. Another is located in a utility building on a State wildlife refuge. The tendency for bats to occupy historic buildings creates potential conflicts between the goals of historic preservation, access for public education, and wildlife protection. Although these conflicts are generally resolvable, and bat populations can almost always be accommodated in buildings without damaging historic values, this is frequently not appreciated.

In some forested settings, *M. thysanodes* appears to rely heavily on tree cavities as roost sites, and may be threatened by current timber harvest practices. For example, Chung-MacCoubrey (1996) in Arizona found that this species prefers large diameter (45-65 cm DBH) conifer snags, the size tree which is preferentially harvested under “shelterwood removal” regimes.

Although the species is protected from over-collection under current Department permitting practices, there is no doubt that scientific collection contributed to or accounted for the extirpation of the colony at Point Reyes National Seashore, and possibly the colony at Old Fort Tejon. While these museum records are invaluable in providing the only historic data we have, historic collecting practices appear to have harmed some populations.

**Management Recommendations:** Distributional surveys are needed, particularly in the Sierra Nevada and Coast Range. These mountain ranges offer the opportunity to evaluate distribution in relationship to latitude, altitude, and habitat type. It is particularly important to investigate the association between this species and late successional forest. This can be accomplished partly by
netting and night roost (e.g., mine, building, and bridge) surveys. Identification of tree roosts would, however, require radiotracking. Given the apparent sensitivity of this species to disturbance, radiotracking studies should be undertaken with the greatest caution. Until the tolerance of the species for radiotracking can be evaluated, studies should be limited to males and post-lactating females. Also, studies should be conducted in a setting which offers the opportunity to recapture the animals to assess transmitter impacts and remove the transmitter package. To minimize disturbance of day roosting sites, and maximize chances of recapture, animals selected for radiotracking should be captured only at night roosting sites.

Although extensive mine surveys have been conducted by P. Brown and others in the desert regions of southern California in the past 20 years, only limited surveys have been conducted in the Sierra Nevada foothills and other areas of central and northern California. Since mine use by bats appears to vary regionally, more extensive mine surveys need to be conducted in northern and eastern California.

Two of the currently known roost sites occupy historic buildings in state parks. Park personnel in these two parks have been very responsive to protecting the bats, and have been able to accommodate them within the historic structures. Although there is no inherent conflict between wildlife protection and historic preservation, local management is not consistently supportive of wildlife protection goals. Thus, policies need to be changed within appropriate agencies at both the Federal and State level to recognize the potential importance of anthropogenic features to bats and other wildlife.

The extent to which *M. thysanodes* uses caves is not well documented in California. Since it is known to use caves quite extensively elsewhere in its range, and has been considered a cave-dwelling bat (Barbour and Davis 1969), it should be considered along with other bat species in cave management plans. The reluctance of land management agencies to manage caves for wildlife rather than for human recreation poses one of the most significant threats to bat populations in California. Revised management practices which restrict human access to bat caves would make a significant difference for a number of bat species, likely including *M. thysanodes*. 
**Fringed Myotis**

*Myotis thysanodes*

**Recognition**: The fringed myotis is distinguished by its relatively long ears and a conspicuous fringe of stiff hairs on the trailing edge of the uropatagium. The pelage varies in color from pale to rich brownish, individual hairs being lead-gray at their bases. The membranes are dark. Total length of five individuals from northwestern Colorado averaged 86.8 mm; length of forearm averaged 40.1 mm; and weight averaged 7.5 g. The wingspan is 265-300 mm. The only other medium-sized myotis with long ears is the long-eared myotis, a species in which the ears are 21-24 mm long (by contrast with ears 17-20 mm long on the fringed myotis).

**Distribution**: This is a western species, ranging from the Isthmus of Tehuantepec in Mexico north to British Columbia, Montana and Wyoming. The animals apparently occur as scattered populations at moderate elevations on the Western Slope, along the foothills of the Front Range and the mesas of southeastern Colorado. Maximum elevation is 7,500 feet.

**Habitat and Habits**: The fringed myotis is a species of coniferous forest and woodland at moderate elevations in Colorado. Records of occurrence are few, and the species isn't common in the state, but perhaps it is simply widely distributed. Typical vegetation of the habitat includes ponderosa pine, pi-on, juniper, greasewood, saltbush and scrub oak. The animals roost in rock crevices, caves, mines, buildings and trees. They are known to hibernate in caves and buildings. Where this species has been studied well, migration seems not to be extensive.

**Breeding**: Breeding takes place in fall; ovulation, fertilization, implantation and gestation occur in spring, as sperm are stored over the winter in the female’s uterus. Up to several hundred females congregate in nursery colonies. Males are solitary while the young are reared. In a typical season, all mature females breed. The single young is produced after a gestation of 50 to 60 days. Newborn young are hairless and pinkish, and their eyes are closed. Growth is rapid, however, and they can fly by 20 days old. Maximum known longevity is 11 years. Although some individuals may live even longer, the average lifespan is much shorter than that.

**Food**: The fringed myotis feeds on such arthropods as moths, daddy longlegs and beetles. They forage along water, above shrubs and woodlands or low over meadows (apparently in more open areas than the long-eared myotis), emerging to feed about two hours after sunset. Flight speeds average about 9 miles per hour.

_Last Updated: 10/15/2008_
Species Accounts - Mammals
Riparian brush rabbit  *Sylvilagus bachmani riparius*

**State:**  Endangered  1994  
**Federal:**  Endangered  2000

**General Habitat:**
Riparian brush rabbits are only found in native riparian areas with large clumps of dense shrubs, low growing vines, and some tall shrubs and scrubby trees in the San Joaquin Valley. Grasses are the most important food, and riparian brush rabbits rarely venture more than one to two yards from dense cover. Its range is quite narrow. It is found in the 261-acre Caswell Memorial State Park in southern San Joaquin County, and near a railroad right of way in the Paradise Cut area south of Stockton.

**Description:**
The riparian brush rabbit is one of eight subspecies of the brush rabbit, an animal generally widespread in California. The riparian brush rabbit can be distinguished from other brush rabbit subspecies by its isolated location and its skull characteristics. This subspecies is slightly larger, has larger eyes and ears, is more grayish and yellowish in coloration, and has a very conspicuous tail. The animals are most active in the early morning and evening hours. The breeding season is typically from January to May, with peak activity between mid-January and mid-April. Gestation is about 27 days, and females may breed again shortly after giving birth. About three to four litters per female may be produced during the breeding season, with three to four young per litter.

**Status:**
Flooding, wildfires, predation, and disease remain the greatest threats to the riparian brush rabbit. The last documented estimate of population size was 200 to 300 individuals in 1993. During the mid-1970s, the population had dipped to an extreme low of 15 to 20 individuals due to severe flooding. The floods of 1996 may also have caused extensive mortality. Initial attempts to live-capture rabbits during a study that began in 1997 were of limited success, indicating an extremely low estimated population. In 1997, USFWS proposed endangered status...
In 1998, USFWS finalized the *Recovery Plan for Upland Species of the San Joaquin Valley, California*. The Recovery Plan addresses the research, management, and recovery needs for the riparian brush rabbit, including restoring habitat and establishing additional populations within the historic range. In 2000, the riparian brush rabbit was listed as a federal endangered species. A brush rabbit working group has met periodically since 1997 to help guide conservation efforts for the subspecies. In 1998 live capture success was very low but improved slightly in 1999; a new population was discovered in the Paradise Cut area of San Joaquin County on Union Pacific Rail Road right of way lands. An agreement developed between the DFG and the rail road company allowed the rabbits within the right of way to be live captured and removed to a captive breeding facility, consisting of three large fenced and secured enclosed pens built in 2001-2002 on Department of Water Resources land in San Joaquin County.

Captive breeding facilities were stocked with wild caught rabbits in equal sex ratios. Genetic studies are ongoing to ensure the suitability of rabbits from different wild populations for captive breeding and translocation purposes. An additional wild population of rabbits was discovered on private land near the city of Stockton in 2003. Releases of radio-tagged rabbits began in 2002. To date, well over 100 rabbits have been produced in the three captive breeding pens and over 70 have been released to the wild to establish a new wild population on the San Joaquin River National Wildlife Refuge. Successful breeding within the new population has already been documented, and further releases are scheduled for 2003. Due to the ever accelerating nature of captive breeding a species such as a rabbit, the foregoing numbers must be considered a bare minimum of the total potential of the project. Mortality of the released rabbits is deemed moderate due to natural predation.

The goal of the recovery strategy is to continue to breed and release captive reared rabbits and establish at least three new wild populations in suitable habitat on secure public lands. Each such newly established population may ultimately consist of several hundred to thousands of individual riparian brush rabbits. With suitable areas provided, the populations are expected to reach the carrying capacity of the available habitats, which could lead to the ultimate recovery of the species. Augmentation of the Caswell Memorial State Park population with captive reared rabbits to near the carrying capacity of the available habitat is also proposed. The search continues for additional wild populations to protect and secure, as well as to serve as a source of breeders for the captive breeding facility.

The status in 2003 of the riparian brush rabbit: *Stable to Increasing.*
San Joaquin antelope squirrel  
Ammospermophilus nelsoni

State: Threatened  1980
Federal:

General Habitat:
Habitats of antelope squirrels consist of grasslands with moderate shrub cover which includes such species as salt bush, ephedra, bladder pod, goldenbush, snakeweed, and others. Populations now exist primarily in marginal habitats of the low foothills and mountains of the western edge of the valley. Currently, populations of significant size exist only in western Kern County at Elk Hills and on portions of the Carrizo and Elkhorn plains.

Description:
The San Joaquin antelope squirrel is one of five species of antelope squirrels. The species is omnivorous with a diet consisting primarily of grass and forb seeds and insects. Antelope squirrels use burrows that they or other animals have dug. The general active period during spring and summer months coincides with air temperatures of 68°F to 86°F.

Status:
Historically, San Joaquin antelope squirrels ranged from western Merced County to the southern end of western San Joaquin Valley. They occupied the valley floor in Kern County and along the eastern edge northward to Tipton, Tulare County. Conversion of native habitat to intensive forms of agricultural development is the greatest threat to the population. Recovery options for this species are addressed in the USFWS 1998 Recovery Plan for Upland Species of the San Joaquin Valley, California.

Researchers have gathered data on the interrelationships between antelope squirrels and the State and federally listed giant kangaroo rat. Translocation of giant kangaroo rats from one locality to another has been successful on the Carrizo Plain National Monument during 1989-92 and may have application to recovery efforts for antelope squirrels since the habitat requirements of the two species are quite similar. A study on the Lokern Area Preserve in Kern County, initiated in 1997, is addressing the issue of grazing as a management tool for several species including the antelope squirrel. San Joaquin antelope squirrels have steadily increased in number since 1998, due in large part to the below-average rainfall experienced since 1999. Numbers of antelope squirrels are now high across the Lokern Study Area. In 1999 and 2000, more squirrels were caught on the grazed plots compared to the ungrazed plots, but the lack of grass in both controls and treatments in recent years has masked any benefit we found from grazing. Rainfall levels that are higher than the average are needed in coming years in order to return the ungrazed sites to dense grass cover. Once the control plots are grassy, it should be possible to quantify the effect of cattle grazing on populations of San Joaquin antelope squirrels.

The DFG is involved in several conservation efforts for the San Joaquin antelope squirrel, including the
Metropolitan Bakersfield HCP, the California Department of Corrections Electric Fence HCP, the Coles Levee area 2081 Agreement, and the Arco Western Energy HCP.

The status in 2003 of the San Joaquin antelope squirrel is Stable to Declining.
Mohave ground squirrel  
*Spermophilus mohavensis*

**State:** Threatened 1971  
**Federal:** None

**General Habitat:**  
The Mohave ground squirrel occurs only in California. It is resident in the various desert scrub communities and Joshua Tree Woodland of the western Mojave Desert in southwestern Inyo, eastern Kern, northwestern San Bernardino, and extreme northeastern Los Angeles counties. The Mohave ground squirrel inhabits flat to moderate terrain and is not generally found in steep contours although juveniles apparently traverse steep terrain during dispersal. The species has been found most frequently in sandy, alluvial soils, but is also found in gravelly and occasionally rocky soils. Habitat features center on availability of food resources and soils with appropriate composition for burrow construction.

**Description:**  
The squirrel is cinnamon-gray in color with white underparts. Juveniles are cinnamon-colored and molt to grayer pelage as they mature. The species lives in underground burrows, in which it spends at least seven consecutive months (usually from July or August through February) at a low metabolic rate, living on body fat alone, to avoid the seasons of the year in which food is least available.

**Status:**  
The Mohave ground squirrel is threatened by loss and degradation of its habitat due to agriculture, urban, suburban, and rural development, energy development, military activities, livestock grazing, and OHV use. Agriculture affects the species through conversion of habitat, exposure to pesticides, herbicides, and rodenticides. Agricultural development has resulted in the loss of occupied and potential habitat in the area between Antelope Valley, Lucerne Valley, and the Mojave River Basin. Although the species likely occupied the Antelope Valley historically, widespread conversion of native habitats has apparently resulted in the extirpation of the species from west of Palmdale and Lancaster.

Urbanization has resulted in the loss of native habitats, particularly surrounding the cities of Palmdale/Lancaster and Victorville/Adelanto/Hesperia/Apple Valley. Urban development has accelerated in recent years in these and other areas, such as Mojave, California City, and Ridgecrest. Impacts associated with urban and rural development include the direct mortality of individuals due to increased vehicle use and increased numbers of domestic and feral cats and dogs. Energy development, including geothermal and solar energy development, has resulted in habitat loss for Mohave ground squirrels, and several such projects are now under consideration. For
example, the BLM has identified sites for potential renewable energy resources, such as wind, solar, and photovoltaics, in the Mojave Desert.

The Mohave ground squirrel is not absent from all urban areas. In 2002, a Mohave ground squirrel was observed south of Highway 138, near Pinyon Hills, and a second observation occurred near an aerospace industrial complex located adjacent to Palmdale. In the first case, the site and adjacent areas are comprised of extensive tracts of undeveloped lands and those with relatively light rural development. At the second site, there are about five to six contiguous square miles of relatively undeveloped land, but the entire area is surrounded by urban and agricultural development. The ground squirrel has also been observed in residential backyards in Inyokern and may be seen foraging on the golf course at China Lake. One squirrel was recently trapped at the proposed Hyundai facility south of California City, where the consultant had identified habitat as being marginal. In these latter cases, the sightings are adjacent to extensive areas of undeveloped lands. Given these observations, the only certain areas of extirpation within the range of the species are those that have been physically developed. Such areas include, but are not limited to, paved roads and parking lots; residential, commercial, and industrial sites occupied by buildings, graded areas, and other areas where vegetation has been mechanically removed; solar facilities at Kramer Junction and Harper Lake; and large mined areas such as at U.S. Borax, Rand Mining Company facilities, and in portions of the Shadow Mountains east of Edwards AFB.

Four major, active military installations occur within the West Mojave and comprise a total of 4,165 square miles: the Naval Air Weapons Station at China Lake, the Fort Irwin National Training Center, Edwards Air Force Base, and Marine Corp Air Ground Combat Center near Twentynine Palms. A 250-square-mile expansion of Fort Irwin has been proposed. Military maneuvers result in mortality to ground squirrels, damage to vegetation, soil compaction, a change in soil texture, and creation of fugitive dust. The results are largely denuded habitat; altered vegetation composition, abundance, and distribution; and a change to finer grained soils. In studies of the desert tortoise, military activities had the greatest adverse impact in valley bottoms, areas that also provide habitat for the Mohave ground squirrel. Changes in soil texture, from a coarser to finer texture, has been documented in agricultural areas and areas of military maneuvers. Finer textured soils do not provide a suitable substrate for ground squirrel burrow construction.

Grazing by livestock may affect Mohave ground squirrels through changes in soil and vegetative structure, accelerated erosion, and collapsing of burrows. Sheep are generally grazed in the desert between late February and the middle of June, which coincides with Mohave ground squirrel emergence from hibernation in February and its entire activity period, particularly during very dry years when the squirrel may enter hibernation in June. These times are critical for both adult and juvenile squirrels to attain sufficient fat reserves to enter into and successfully emerge from hibernation. The severity of grazing impacts may range from marginal in lightly-used areas to extreme at cattle troughs and sheep bedding areas. Research conducted at the Coso study area demonstrated that forage consumed by Mohave ground squirrels is also consumed by both sheep and cattle. Competition for winterfat, hopsage, and saltbush, all important ground squirrel food plants, could be exacerbated during times of drought because alternative sources of food are not available. Although the Mohave ground squirrel is adapted to drought and arid conditions, prolonged drought reduces productivity of forage plants and reproduction in the ground squirrel. Shrub cover required by the Mohave ground squirrel for thermoregulation and protection from predators can be reduced by grazing pressure.

Persistent grazing pressure has resulted in the replacement of native perennial grasses by non-native annual grasses throughout much of the western Mojave Desert. Human development in the desert has also resulted in the proliferation of non-native grasses, such as red brome, cheatgrass, and Mediterranean grass. Grazing, OHV use, and other types of ground disturbance facilitate the spread of these grasses, which are adapted to disturbance and outcompete the native species that constitute food plants of the Mohave ground squirrel. The increase in grass cover between desert shrubs has been linked to increased fire frequency and fire intensity in the desert. Fires cause direct mortality when ground squirrels are burned or inhale lethal amounts of smoke, which can occur both in and out of burrows. Fire changes the composition of vegetation by facilitating the
establishment of non-native grasses and removing forage plants. Fires also fragment habitat by creating patches
of unsuitable habitat.

Habitat fragmentation results in the isolation of populations and potential loss of genetic variation. Small isolated
populations may experience a reduced ability to adapt to environmental change, and a decrease in reproductive
success, growth, and survivorship. Such populations face a greater probability of extirpation. During extended
droughts, for example, lower quality habitat may not be capable of supporting the species, and result in local
extirpation. Recolonization of these areas may occur when conditions favoring reproduction resume.

In 2003, the BLM released the draft environmental documents for the West Mojave Plan (Plan). If adopted by
the BLM, the Plan amends the California Desert Conservation Plan of 1980. It presents a strategy to conserve
and protect the Mohave ground squirrel, desert tortoise, and nearly 100 other sensitive plant and animal species,
while providing a streamlined program for complying with the requirements of the California and federal
Endangered Species Acts. Seven alternative conservation strategies, representing different approaches to
achieving biological goals and objectives for the covered species, are provided. These strategies are intended to
mitigate for the future incidental take of the proposed “covered species” from urban development and land
management activities. Goals of the Plan include protecting Mohave ground squirrel habitat throughout its range
and ensuring long-term viability of the species. The entire known range of the Mohave ground squirrel occurs
within the West Mojave; all but a small part of that, which is located northeast of Searles Dry Lake, occurs
within the planning area, west and north of the Mojave River.

The preferred alternative for the West Mojave Plan proposes ecosystem-scale conservation with the
establishment of four very large Desert Wildlife Management Areas (DWMA) and additional lands for the
Mohave Ground Squirrel Conservation Area. The desert tortoise and Mohave ground squirrel are “umbrella
species”, a term used to describe protection of many other species under the “umbrella” of conservation for
important wide-ranging species. A conservation area would be established for the long-term survival and
protection of the Mohave ground squirrel. This Conservation Area would include portions of the Fremont-Kramer
and Superior-Cronese Tortoise DWMAs, and additional, essential habitats located west and north of the two
tortoise DWMAs.

The West Mojave Plan would adopt provisions of the Los Angeles County Significant Ecological Area ordinance.
Los Angeles County has identified a Significant Ecological Area (SEA) for northeastern Los Angeles County that
should prove beneficial to protection of the Mohave ground squirrel. Within SEAs, the County performs a
heightened environmental review for new projects, and has proposed zoning the area for a minimum lot size of 10
acres. The West Mojave Plan would focus on ground squirrel habitat on eastern side of the Sierra Nevada. This
narrow band of habitat provides an important linkage corridor from north to south along Highways 178, 14, and
395. Projects in this area would also receive special review to ensure that habitat is not fragmented. Impact
avoidance measures applicable to the desert tortoise would also be applied to the Mohave ground squirrel. These
measures include restrictions on commercial activities, construction activities, and hunting and shooting.

The ultimate preserve design for the Mohave ground squirrel will need to conserve a substantial portion of its
known range to allow for natural fluctuations in local and regional populations in response to climatic factors,
rainfall. The size and location of preserve areas should be based on biological, demographic, and genetic
considerations and core preserve areas must be large enough to support sufficient numbers of individuals to
account for natural fluctuations in abundance. Further, it is critical that core reserves are situated in high quality
habitats in which the species can persist during drought conditions. These "drought refugia" provide sources from
which populations may expand under better conditions.

In contributing to the conservation strategy for the squirrel, the DFG expressed concern that no strategy would
be successful without the participation of the military bases in the western Mojave Desert. Because the Mohave
ground squirrel is not federally listed, the military departments are not required to develop policies to conserve
the species. The DFG and USFWS concurred that those wildlands on military bases not needed for current missions should be managed for the greatest biodiversity of wildlife species and that those local areas on bases be managed for listed species such as the desert tortoise and Mohave ground squirrel. Special protective measures would need to be implemented if the Fort Irwin National Training Center expands into the Superior Valley region, as has been proposed. In December 2000, legislation authorizing expansion of Fort Irwin into critical habitat for the desert tortoise in the Superior Valley region was passed and signed into law by President Clinton. The proposed expansion is currently undergoing extensive environmental review; the release date of the documents is not known at this time (late 2004).

Determining the status of the Mohave ground squirrel is difficult due to behavioral and demographic aspects of the species. The species is inactive throughout much of the year, and abundance as well as the period of surface activity varies from year to year. Live-trapping studies must be scheduled carefully and even then cannot necessarily establish the absence of the species from a site. These points were underscored in a recent study conducted by the USGS. USGS scientists reviewed existing Mohave ground squirrel trapping records to facilitate future habitat modeling and population trend predictions. The scientists found that the trapping records could not be used to develop models because of differences in sampling methodology and types of data reported. The researchers found, however, that trapping success declined significantly between 1980 and 2000 across most of the range of the species, raising concerns that Mohave ground squirrel numbers are decreasing across its geographic range. The exception was in the Coso geothermal region where numbers of animals increased between 1984 and 1998. Population numbers did not correlate with winter rainfall. Due to the lack of quantitative data, additional research is needed to accurately determine the status and trend of the Mohave ground squirrel.
Morro Bay kangaroo rat

*Dipodomys heermannii morroensis*

**State:** Endangered 1971
Fully Protected

**Federal:** Endangered 1970

**General Habitat:**
The Morro Bay kangaroo rat primarily inhabits low, sparse coastal dune scrub vegetation associated with stabilized sand dunes in the Morro Bay area. Its habitat is highly localized in the vicinity of Los Osos in San Luis Obispo County. Plant species in its habitat include bush lupine, dune lupine, mock heather, coyote bush, California sagebrush, croton, buckwheat, phlox, and deerweed. Plant roots provide support for burrows.

**Description:**
This kangaroo rat, like all species of kangaroo rats, has long hind legs, small front legs and feet, brown upper parts, and a white belly. It is smaller and darker than any other subspecies of Heermann's kangaroo rat. The average adult weight is approximately 2.3 ounces, and the average length is about 11 inches. The lack of a complete hip stripe also distinguishes this animal from other kangaroo rats.

**Status:**
The Morro Bay kangaroo rat is threatened by loss and degradation of its habitat due to development, invasion of non-native plant species, disruption of natural disturbance patterns, and OHV use. The kangaroo rat is also threatened by predation by cats. The historic known distribution of this species was approximately 200 acres. If it still exists, it is believed to occur only on one small, privately-owned parcel of native vegetation. The most recent observations of the kangaroo rat date from the mid-1980s. A revised Draft Recovery Plan for the Morro Bay kangaroo rat was released in 2000 by the USFWS. The recovery plan was revised to allow captive breeding of the species if individuals are found.

The Morro Bay kangaroo rat is geographically isolated from other subspecies of the Heermann's kangaroo rat. A mitochondrial DNA study of museum specimens conducted at San Francisco State University suggests recent origin of the Morro Bay kangaroo rat and that the historic population underwent at least one genetic bottleneck. Researchers also found that historical populations of the Morro Bay kangaroo rat exhibited low genetic diversity even prior to a population bottleneck that endangered the subspecies. A genetic bottleneck refers to a drastic reduction in the size of the original population, usually due to a catastrophic event, which reduces the gene pool of the species.

In 2002, San Luis Obispo County received a grant from the USFWS under the Service's Habitat Conservation
Planning Assistance and Land Acquisition Section 6 grant program. This grant will help initiate the development of an HCP which will cover 43,500 acres in the Estero area, the central coastal part of the county. Development of an HCP in this area will provide for a conservation strategy for covered species to address recovery needs and to allow for more flexible planning and implementation. This HCP will benefit several listed species including the Morro shoulderband snail and the Morro Bay kangaroo rat. Additional federal funding has been granted to conduct a two year field survey for the Morro Bay kangaroo rat and to estimate the genetic relatedness between the Morro Bay and Lompoc kangaroo rats. The Lompoc kangaroo rat has been used as a surrogate for the Morro Bay kangaroo rat to develop captive breeding protocols.

The DFG considered the Morro Bay kangaroo rat to be Possibly Extirpated.
**Giant kangaroo rat** *Dipodomys ingens*

**State:** Endangered 1980  
**Federal:** Endangered 1987  

**General Habitat:**  
Giant kangaroo rats require annual grassland and shrubland habitats with sparse vegetative cover and soils that are well drained, fine sandy loams with slope generally less than 10 percent. Areas of low annual precipitation and infrequent flooding are preferred by this species for establishment of permanent colonies. The historical range extended from Merced County south to Kern County and west to eastern San Luis Obispo and northern Santa Barbara counties.

**Description:**  
Giant kangaroo rats are small mammals with elongated hind limbs for hopping and external cheek pouches for carrying food to their burrows. The giant kangaroo rat is the largest of all kangaroo rats and weighs from 4.6 to 6.4 ounces. The total length is 12 to 13 inches, including a tail that is six to eight inches. Giant kangaroo rats subsist almost entirely on the seeds of annual plants such as brome grasses and filaree. The animals harvest, stack, and dry caches of grasses and forbs near the entrance of their burrows. Giant kangaroo rats inhabit a territory, known as a precinct that averages 20 feet in diameter where a shallow burrow system, about 12 inches deep, is constructed. Each kangaroo rat maintains and defends an individual territory in a colony that may consist of from two to thousands of precincts.

**Status:**  
The historical range of the giant kangaroo rat extended from Merced County south to Kern County and west to eastern San Luis Obispo and northern Santa Barbara counties. Populations were most numerous in areas with sparse vegetative cover and low annual precipitation. Today very little undisturbed suitable habitat remains. The loss of original habitat to agricultural conversion may be as much as 98 percent. Five relatively small areas totaling 12-square miles remain that support population densities typical of those existing prior to 1950.

In 1997, several population assessment studies confirmed that the giant kangaroo rat population had dramatically declined along with that of many other kangaroo rats in the southern San Joaquin Valley. At other locales such as the Elkhorn Plain in eastern San Luis Obispo County the declines were not as severe. In 1998 and 1999 giant kangaroo rat numbers began to increase at the Elkhorn Plain study area. Genetics studies, initiated in 1993, continue on this and other kangaroo rat species, and are yielding valuable information that can be applied to
recovery strategies for all endangered kangaroo rats.

In 1997, an additional research effort began at the Lokern Area in western Kern County to further investigate the role of livestock grazing on species and habitats on the floor of the San Joaquin Valley. However, few giant kangaroo rats have been caught on plots in the Lokern Study Area since the beginning of the study. Researchers did, however, capture the most individuals in any year of the study in 2002 when they caught three in each of two treatment plots (out of four). In addition, a colony of about 20 individuals was seen near one of these treatment plots. Although numbers have remained fairly low throughout the study, giant kangaroo rats have only been caught in plots grazed by cattle, never in any of the four ungrazed plots. In a separate study initiated by BLM in 1993 at a location about 3 km north of the Lokern Study Site, researchers have captured giant kangaroo rats twice a year since 1993. Population numbers were as high as 110 individuals caught in a six-night census when the study began, decreased to 0 for both sessions in 1998 (dense grass year), and has steadily increased back up to about 45-70 individuals caught in 2002/2003. Trends in population size seem correlated with the amount of grass cover: the less grass, the greater the number of giant kangaroo rats caught.

The conversion of native habitat to agricultural uses remains the greatest threat to the species. Ongoing studies, initiated in 1987 at the Elkhorn Plain, an area that is now included in the Carrizo Plain National Monument, which was established in 2000, indicate a healthy population that is reproducing well during years with adequate rainfall. Researchers from the Endangered Species Recovery Program conduct giant kangaroo rat population censuses twice a year at the Elkhorn Plain study area.

The recovery options for the giant kangaroo rat are addressed, along with those for 33 other species of plants and animals, in the USFWS 1998 Recovery Plan for Upland Species of the San Joaquin Valley, California. The DFG is involved in several conservation efforts for the giant kangaroo rat. Some of the efforts include the Metropolitan Bakersfield HCP, the California Department of Corrections Electric Fence HCP, the Coles Levee area 2081 Agreement, and the Arco Western Energy HCP. Despite these conservation efforts, habitat loss remains the primary obstacle to recovery with only populations on established preserve lands secure for the foreseeable future.

The status in 2003 of the giant kangaroo rat: Stable to Declining.
Stephen's kangaroo rat  
*Dipodomys stephensi*

**State:** Threatened 1971  
**Federal:** Endangered 1988

**General Habitat:**  
The Stephen's kangaroo rat inhabits annual grassland with sparse perennial vegetation in the San Jacinto Valley and adjacent areas of western Riverside and northwestern San Diego County. Occupied habitats consist of sparse, slightly disturbed coastal sage scrub, dominated by California sagebrush or California buckwheat, or annual grassland. The populations with the highest densities have been found in areas where the herbaceous layer still contains California native annuals, and where perennial plant cover is less than 30 percent. Stephens' kangaroo rat occurs on level or low rolling terrain with slopes of less that 30 percent where gravel is a common component of the soil. It is not found on extremely hard or sandy soils. In general, the highest abundances of Stephens' kangaroo rats occur on gentle slopes less than 15 percent.

**Description:**  
Stephens' kangaroo rat physically resembles all other kangaroo rat species in having long hind legs, small front legs and feet, brown upper parts, a white belly, and a long, tufted tail. There are five toes on the hind foot and the tail is 1.45 times the length of the head and body. Stephens' kangaroo rat is distinguished from the sympatric agile kangaroo rat (*Dipodomys agilis*) by a lateral white tail band that is one half or less (rather than one half or more) times the width of the dorsal tail stripe, dusky (rather than dark) soles on the hind feet, a comparatively grizzled appearance to the dorsal tail stripe due to many white hairs, a darker tail tuft due to few white hairs, a smaller ear, and a relatively broad head. The average adult Stephens' kangaroo rat is 11 to 12 inches in length and weighs 23 ounces.

**Status:**  
Stephens' kangaroo rat is threatened by destruction, fragmentation, and degradation of its habitat through human and human-induced activities. Adverse impacts to kangaroo rat habitat result from clearing of land for urban and suburban development and for agriculture, water projects, military activities, wildland or prescribed fires, OHVs, livestock use, and invasion of non-native plant species. The Stephens' kangaroo rat is restricted to Riverside County and adjacent northern-central San Diego County.

The USFWS released its draft recovery plan for the kangaroo rat in mid-1997. The document proposes that USFWS consider the kangaroo rat for reclassification to threatened status when four reserves totaling at least 15,000 acres of habitat occupied by the kangaroo rat in western Riverside County and one habitat reserve in San Diego County are "permanently protected, funded, and managed." The USFWS would consider delisting the kangaroo rat when at least five habitat reserves in western Riverside County, totaling at least 16,500 acres of occupied habitat and two additional reserves in San Diego County are "permanently protected, funded, and
Stephens' kangaroo rat populations at several reserves in Riverside County are being monitored through burrow counts and live-trapping. The kangaroo rat is the sole species addressed in the 1996 Habitat Conservation Plan for the Stephens' Kangaroo Rat in Western Riverside County (SKR HCP), prepared by the Riverside County Habitat Conservation Agency. The HCP provides Take Authorization for the species within its boundaries. The West Riverside Multiple Species Habitat Conservation Plan (MSHCP) provides Take Authorization for the kangaroo rat outside the boundaries of the Stephen's Kangaroo Rat HCP, but within the MSHCP boundaries. The core reserves established by the NCCP will be managed as part of the MSHCP Conservation Area consistent with the NCCP. Under the MSHCP, species conservation objectives include maintaining occupied habitat within the NCCP boundary; maintaining occupied habitat within the MSHCP Plan Area but outside of the HCP boundary; and maintaining a specified population density.

Approximately 22,400 acres of occupied sites and suitable habitat will be conserved in the MSHCP Conservation Area, 3,200 acres more than acreage conserved under the SKR HCP. The Conservation Area will conserve adequate representations of the older and younger populations with three of the core reserves containing the older populations and at least four of the core reserves containing the younger populations. In general, the largest and key populations of the Stephens' kangaroo rats are centered within the larger core reserves in western Riverside County: 1) the San Jacinto Wildlife Area/Lake Perris-Badlands-Potrero Valley complex; 2) the Lake Mathews/Estelle Mountain-Steele Peak-Kabian Park-Sedco Hills complex; and 3) the Lake Skinner/Domenigoni Valley-Sage-Wilson Valley-Vail Lake-Aguanga-Anza Valley complex. Other important locations in the MSHCP Plan Area not in the existing Stephens' kangaroo rat reserve include the Potrero Valley, Anza and Cahuilla valleys, and the Sage/Aguanga area.

Preserve configuration and connectivity within and between populations are essential to the long-term conservation of the species. Research has shown that the Stephen's kangaroo rat is more sedentary than other species of kangaroo rat and that genetic exchange between populations of the species is restricted in fragmented habitat. Maintaining connectors between core areas is, therefore, critical to maintaining genetic exchange in the species. Because the kangaroo rat is relatively sedentary, these connectors should include functional habitat that can be permanently colonized. The preserve design envisioned under the MSHCP would include the three large core reserves in western Riverside County. Culverts under Highway 79 and Highway 60 in the first area allow kangaroo rat movement to habitat bisected by these highways. Culverts could be installed under Highway 74, a potential barrier to movement in the Lake Matthews habitat complex.

In northern San Diego County, Stephens' kangaroo rat occurs at Camp Pendleton, Fallbrook Naval Weapons Annex, Lake Henshaw, Santa Maria Valley (Ramona), and Guejito Ranch. Occurrences in grasslands adjacent to Guajome Lake and Pilgrim Creek and Ramona that the species could be more widespread in grasslands of San Diego County than was previously thought, but suitable habitat is mostly north and east of the MHCP plan area. Available habitat in San Diego County has been greatly reduced and fragmented through urban and agricultural development. Periodic disturbances that reduce shrub cover and increase cover by annual plants may improve habitat for this species. Only about 31% of the remaining grasslands in the MHCP area are expected to be conserved, and much if this occurs on clay soils unsuitable for burrow construction and in isolated areas that are too small to support viable populations of kangaroo rat. Nevertheless, Stephens' kangaroo rat could potentially
colonize grasslands or agricultural fields in Oceanside, in the vicinity of occupied habitat on Camp Pendleton and Fallbrook Navel Weapons Annex. The 2003 wildfires burned large areas of San Diego County, including approximately 19,000 acres (25%) of habitat suitable for the Stephens' kangaroo rat. Because Stephens' kangaroo rats prefer low, sparse vegetation, compared to denser grassland or coastal sage scrub, the long-term effects of fire may be beneficial to the species.

Recent mitochondrial DNA (mtDNA) analysis found that the different geographic regions within the species' range (northern, central and southern) differ genetically, with the central area having the greatest diversity of genetic lineages. The data indicate that genetic flow has been restricted among the different geographic regions of the species' range. A notable finding was that genetic diversity of sample sites in the southern part of species' range (Fallbrook, Camp Pendleton, Lancaster Valley, and Guejito) was much lower than the northern and central sample sites. This low diversity may indicate a possible population bottleneck that occurred during a recent range expansion in the southern region. The genetic characteristics of the Anza and Cahuilla valleys population are unknown.

Other conservation efforts involving this species include the Lake Mathews MSHCP, Pacific Gateway Homes HCP, and Ridge at Cresta Verde HCP. A previously unknown population of the kangaroo rat was discovered in the Ramona Valley, San Diego County in October 1997. It is not known if this species still inhabits extreme southwestern San Bernardino County.

At the end of 2002, the DFG considered the trend and status for the Stephens' kangaroo rat to be Unknown.
**Tipton kangaroo rat**  
*Dipodomys nitratoides nitratoides*

**State:** Endangered 1989  
**Federal:** Endangered 1988

**General Habitat:**
Tipton kangaroo rats are limited to arid land communities of the valley floor in the Tulare Basin, in level to nearly level terrain at an elevation of 200 to 300 feet. Woody shrubs such as spiny saltbush, iodine bush, and mesquite are sparsely scattered over the terrain with scant to moderate ground cover of grasses and forbs. Soils are typically fine-textured and alkaline.

**Description:**
The Tipton kangaroo rat is one of three subspecies of the San Joaquin kangaroo rat (*Dipodomys nitratoides*). Tipton kangaroo rats are visually similar to other kangaroo rats; they have a tawny yellow head and back with a white belly and a white stripe on the elongated hind legs that continue down the sides of the otherwise black tail. Other characteristics include: a large head, compared to other rodents, with large eyes and small rounded ears; small forelegs with strong claws; and a long, tufted tail. Adult Tipton kangaroo rats weigh about one to 1.3 ounces.

**Status:**
This subspecies originally occupied a range that included the Tulare Lake Basin in portions of Fresno, Kings, Tulare, and Kern counties. This geographic range encompassed about 1.7 million acres. An estimate of historic population based on today’s density data and the estimated extent of former range is about 17.2 million individuals. Currently, approximately 190,200 individuals, or about 1 percent, remain. The conversion of native habitat to agricultural, residential, and commercial developments and flooding remain the principal threats to this species.

The recovery options for the Tipton kangaroo rat are addressed in the USFWS *Recovery Plan for Upland Species of the San Joaquin Valley, California*, completed in 1998. Proposed actions include establishment of habitat preserves and captive breeding and translocation of populations. Severe declines, beginning in 1994, affected all kangaroo rat populations, including Tipton, in the southern San Joaquin Valley. In 1998 and 1999 populations slowly returned to previous population levels of the early 1990s. As of 2003, the population levels of Tipton kangaroo rats are largely unknown but presumed to be still fairly low and vulnerable to further declines. Dense vegetation due to above average rainfall has had a negative impact on this and other kangaroo rat species. During wet years, kangaroo rat species may suffer from diseases precipitated by low food stores and seeds that are moldy.
The closely related short-nosed kangaroo rat (*D. n. brevinasus*) occurs at the Lokern grazing study area. Findings by researchers regarding the affects of cattle grazing on the short-nosed kangaroo rat may have application to the Tipton kangaroo rat. Short-nosed kangaroo rats have steadily increased in number since 1998, due in large part to the below-average rainfall experienced since 1999. Numbers of the species are now high across most of the Lokern Study Area. In 1999 and 2000 more short-nosed kangaroo rats were caught on the grazed plots compared to the ungrazed plots, but the lack of grass in both controls and treatments in recent years has masked any benefit we found from grazing. Higher than average level of rainfall is needed in future years to return the control sites to high grass cover. Once the control plots are grassy, researchers should be able to quantify the effect of cattle grazing on populations of short-nosed kangaroo rats.

The DFG is involved in several conservation efforts for Tipton kangaroo rat including the Kern County Valley Floor and Waste Facilities HCPs, Kern Water Bank HCP, Metropolitan Bakersfield HCP, and the PG&E San Joaquin Valley HCP. Despite these conservation efforts, the species is in severe decline; extinction could occur if current levels of habitat loss continue into the future.

The status in 2003 of the Tipton kangaroo rat: *Declining.*
**General Habitat:**
The Fresno kangaroo rat occupies chenopod scrub and grassland in the San Joaquin Valley. The historic range of the Fresno kangaroo rat extended from north central Merced County, south through southwestern Madera and central Fresno counties. Typical plants within the species habitat include seep weed, iodine bush, saltbush, peppergrass, filaree, wild oats, and foxtail fescue.

**Description:**
The Fresno kangaroo rat is one of three subspecies of the San Joaquin kangaroo rat. The Fresno kangaroo rat is the smallest of the San Joaquin kangaroo rats with a total length of nine inches, including a five-inch tail. Adults weigh about one ounce. Their fur is dark yellowish-buff on the back and white on the stomach. A white stripe extends along the flanks and on the sides of the tufted tail.

**Status:**
The current population distribution and population size are unknown. The species is critically threatened by loss of habitat and fragmentation throughout its range. Surviving populations are isolated and are likely small. The species is also threatened by flooding and the use of rodenticides within its range.

Demographic studies, initiated in 1993, are continuing to locate any extant populations of Fresno kangaroo rats. Beginning in 1995 and continuing to 2003, fire management has been applied to the habitat supporting a small population of kangaroo rats on a small patch of habitat at the Lemoore Naval Air Station, Fresno County. Additional study and management is planned; discussions are ongoing between land managers and researchers concerning the future management of larger tracts of land that may constitute suitable habitats at Lemoore NAS and at other locations within the range of the species in the San Joaquin Valley. Populations of Fresno kangaroo rats are suspected on certain private lands, but access to conduct the necessary surveys has not been granted.

The recovery options for the Fresno kangaroo rat have been addressed in the USFWS Recovery Plan for Upland Species of the San Joaquin Valley, California, completed in 1998. The recovery plan calls for establishment of additional habitat preserves and the possible captive breeding and translocation of populations of this species onto those secure refuges. The Fresno kangaroo rat may well be one of the most severely endangered mammal species in the State and drastic measures may be needed to save it from extinction in the next decade. One option that could be a step toward recovery of the species would involve the rehabilitation of deteriorated...
kangaroo rat habitat at the DFG Alkali Sink Ecological Reserve where the species was last reported in 1992. The ecological reserve once supported a moderate population of the species. With suitable habitat established, the area could be re-populated with captive-reared Fresno kangaroo rats. Similar recovery actions could be attempted at other locations within the range of this species.

The status in 2003 of the Fresno kangaroo rat: Declining.
Salt-marsh harvest mouse  *Reithrodontomys raviventris*

State:  Endangered  1971
        Fully Protected

Federal:  Endangered  1970

**General Habitat:**
The salt-marsh harvest mouse is found only in California, inhabiting tidal and nontidal salt marshes of Suisun, San Pablo, and central and south San Francisco Bays. Its preferred habitat is dominated by pickleweed although this species can occur in the upper marsh zone dominated by other salt-tolerant plants.

**Description:**
The salt-marsh harvest mouse has rich brown fur on its back, underparts of cinnamon to buffy white, and a unicolored tail. It is very similar in appearance to the western harvest mouse, a closely-related species, which complicates identification of the salt-marsh form in field studies. The salt-marsh harvest mouse can tolerate quite salty food and water.

**Status:**
The salt-marsh harvest mouse is threatened by loss and degradation of its habitat through human and human-induced activities. Of the 193,800 acres of tidal marsh that bordered San Francisco Bay in 1850, only about 30,000 remain. Parts of the East Bay shoreline are eroding. About 600 acres of former salt marsh along Coyote Creek, Alviso Slough, and Guadalupe Slough have been converted to fresh- and brackish-water vegetation due to freshwater discharge from South Bay wastewater facilities. This area may no longer support the salt-marsh harvest mouse. Adverse impacts to harvest mouse habitat have also resulted from filling of marshes to allow development, invasion of non-native cordgrass and other non-native species, and pollution from urban run-off, industrial discharges, and sewage effluent. The salt-marsh harvest mouse is likely subject to predation by the non-native red fox and non-native feral cat.

The USFWS is preparing a recovery plan for tidal-marsh species in the San Francisco Bay, including the salt-marsh harvest mouse. Determining the distribution and abundance of the mouse is one of the management goals of the San Francisco Estuary Wetlands Regional Monitoring Program (WRMP) Plan, the first version of which was released in June 2002. The mission of the WRMP, which is a product of the San Francisco Estuary Institute and wetland managers representing a variety of agencies including the DFG, “is to provide the scientific understanding necessary to protect, create, restore, and enhance wetlands of the San Francisco Bay Region, through objective...”
and cost-effective monitoring, research, and communication.” Although the initial focus of the WRMP is on the tidal bay lands of the San Francisco estuary, the geographic scope of the WRMP is the entire estuary plus the watersheds that drain to the estuary within the nine-county San Francisco Bay Area.

At the end of 2002, the DFG considered the population trend and status for the salt-marsh harvest mouse to be Unknown.
Amargosa vole *Microtus californicus scirpensis*

**State:** Endangered 1980  
**Federal:** Endangered 1984

**General Habitat:**  
Habitat for the Amargosa vole consists of a discontinuous, narrow band of small, permanent fresh-water marshes along the Amargosa River of Inyo County. Bulrush is the dominant overstory species. Associated wetland species include cattail, saltgrass, and willow. The vole may occur downstream in adjacent San Bernardino County. The flooding of potential or inhabited vole habitat during late summer thunderstorms and extended periods of winter rainfall probably allow permanent vole occupation only in marshes on the margins of the river’s floodplain.

**Description:**  
This small mammal is pallid, neutral gray above, smoky gray below, has a tail which is brown above and grayish below, and has feet of brownish gray. The comparatively short tail, small rounded ears, short legs, and compact, almost-cylindrical body shape distinguish voles from other mouse-like rodents. It differs from most other subspecies of California vole by its brighter coloration. As with other voles in the genus *Microtus*, the Amargosa vole probably is active year round.

**Status:**  
The Amargosa vole is threatened by loss and degradation of its habitat through human and human-induced activities. Adverse impacts to vole habitat include groundwater pumping and water diversion, OHV use, cattle grazing, invasion by tamarisk and other non-native plants, and severe or prolonged flooding. Construction of the Tidewater-Tonopah Railroad and the Old Spanish Trail in the early 1900s, and development of springs in Shoshone and Tecopa, are believed to have fragmented or eliminated habitat that existed at that time. The vole is also subject to predation by the domestic cat from nearby human-occupied areas. The alien house mouse, found in marshes inhabited by this vole, may compete with the vole for food.

The USFWS prepared a Recovery Plan for this species in 1997. The Recovery Plan indicated that protection of extant wetland habitat and the water sources need to perpetuate these wetlands are critical to the survival and
recovery of the Amargosa vole. Delisting criteria and species-specific management options were not proposed due to the lack of detailed biological information for the species.

An analysis of effect of habitat fragmentation and genetics of the Amargosa vole revealed a significant level of differentiation between populations from different marshes. Because the marshes occupied by the Amargosa vole are fragmented within the surrounding desert habitat, dispersal by the voles, and consequently genetic exchange between populations, is limited. The data obtained in this study suggested a relatively recent divergence of the Amargosa vole from closely related species, and that it is persisting along an independently evolving lineage. Such data can be used to guide conservation activities by identifying individual marshes that are critical to preserving the genetic diversity of the species.

The vole is a featured species in the planning effort for the Northern and Eastern Mojave Desert Management Plan developed by the BLM, with considerable contribution by the USFWS and NPS. The BLM's July 2002 proposed plan included the elements of the Recovery Plan, including preservation and management of its remaining habitat. The final plan was approved by the BLM in December 2002, as an amendment to the California Desert Conservation Plan of 1980. Although the planning team had considered an alternative plan that would have emphasized managing lands for recovery of the vole, desert tortoise, and other species, the team recommended a plan allowing less land devoted to such recovery. For the Amargosa vole, the final plan maintains the emphasis of the alternative in protecting the watershed of the Amargosa River. Both versions of the plan propose establishing an Amargosa River Area of Critical Environmental Concern (ACEC). The final plan identifies five areas along the river for potential implementation of a conservation strategy for the vole. Two of the areas are Areas of Critical Ecological Concern: the Grimshaw Lake Natural Area and the Amargosa Canyon Natural Area. The final plan proposes identifying potential segments of the Amargosa River for addition to the National Wild and Scenic River system. The BLM anticipates purchasing approximately 2,600 acres of privately-held land containing currently-suitable and/or potentially-restorable habitat for the vole.

The DFG considers the population trend and status for the Amargosa vole to be Unknown.
**Sierra Nevada red fox**  
*Vulpes vulpes necator*

State: Threatened 1980  
Federal: None

**General Habitat:**
The Sierra Nevada red fox is known to inhabit types of vegetation similar to those used by the marten and wolverine. Sightings of the subspecies have been reported from the 5,000 to 7,000 foot elevation range with extremes placed at 3,900 feet in Yosemite Valley and 11,900 feet at Lake South America in the southern Sierra Nevada. The range is described as the southern Cascade Range in northern California, southeastward to the northern Sierra Nevada, and then south along the Sierra Nevada crest to Tulare County. Preferred habitat for the Sierra Nevada red fox appears to be red fir and lodgepole pine forests in the sub-alpine, and in the alpine of the Sierra Nevada.

**Description:**
The Sierra Nevada red fox, California’s only indigenous subspecies, is one of 10 recognized North American subspecies of *Vulpes*. The Sierra Nevada red fox is distinguished from members of the introduced lowland population of red foxes by its slightly smaller size and darker colored fur.

**Status:**
The Sierra Nevada red fox inhabits remote areas of the State where chance encounters with humans are uncommon. It occurs at low densities throughout Sierra Nevada and Cascade Range of California. Threats to the Sierra Nevada red fox are unknown.

The existence of the Sierra Nevada red fox in the Lassen Peak region has provided an opportunity to conduct research to assist in the recovery of this threatened species and to increase our information base on the ecology of the subspecies. Fox populations have been confirmed in two proposed wilderness areas: Wild Cattle Mountain on the southern boundary of Lassen Volcanic National Park and in Heart Lake on the southwestern boundary of the park below Brokeoff Mountain.

Since 1997, the University of California at Berkeley, Lassen Volcanic National Park, Lassen National Forest, and the DFG has been conducting research on the Sierra Nevada red fox in Lassen Volcanic National Park. Research has included home range size and composition, habitat use for foraging and reproduction, seasonal movements between federal and private lands, diet, local density and spatial interactions with other sympatric carnivores.
such as coyotes (*Canis latrans*) and bobcats (*Lynx rufus*). Pilot studies were conducted in the summers of 1998 and 1999 and full-time research commenced in March 2000. In March 2000, researchers began a 30-month investigation of the basic ecology of the Sierra Nevada red fox in the Lassen Peak region. Radio-collared animals were tracked using ground and aerial telemetry, and non-collared animals were detected by systematic photostation surveys. Of particular interest were data on seasonal and elevational movements of red foxes and relationship to prey availability and the presence of other carnivore species in the Park.

As of July 2001, five red foxes (one male and four females) had been radio-collared and tracked by telemetry. Summer home ranges, primarily between June and October, averaged 2300 acres and had little overlap, suggesting territoriality. In winter, the foxes moved up to nine miles southward to lower elevations, returning to higher elevations once spring returned. The locations and characteristics of red fox rest sites and dens were recorded, and scats were collected for diet analysis. Photostations detected red foxes most often between 2100 and 0500 hrs.

The ongoing research is a spin-off of a study of the wolverine (*Gulo gulo*), initiated in 1990, using remote, automatic cameras for the first time in a large scale field investigation of a furbearer. That earlier study incidentally yielded the first documented photographs of the Sierra Nevada red fox in the Lassen Park area. Since then, additional remote-camera photographs of Sierra Nevada red foxes have been taken at that location in conjunction with the ongoing research of the subspecies. The techniques used in the wolverine study (i.e., baited stations with remote cameras) have shown promise for application to the study of several other carnivores including the Sierra Nevada red fox. Genetic samples taken from red foxes captured during this study are currently under analysis.

The current status of the Sierra Nevada red fox is unknown.
San Joaquin kit fox  *Vulpes macrotis mutica*

State: Threatened 1971  
Federal: Endangered 1967

**General Habitat:**
Kit foxes occur in the remaining native valley and foothill grasslands and chenopod scrub communities of the valley floor and surrounding foothills from southern Kern County north to Los Baños, Merced County. In addition, smaller, less dense populations are thought to exist further north and in the narrow corridor between Interstate 5 and the Interior Coast Range from Los Baños to Alameda and Contra Costa Counties. Portions of Monterey, Santa Clara, San Benito, San Luis Obispo, and Santa Barbara counties are also included in the range of the San Joaquin kit fox.

**Description:**
The kit fox (*Vulpes macrotis*) is the smallest canid species in North America. San Joaquin kit foxes have an average body length of 20 inches, an average tail length of 12 inches and stand about nine to 12 inches at the shoulder. These slender-billed mammals are characterized by relatively long legs and large, conspicuous ears. Adult males weigh about five pounds, and adult females weigh about 4.6 pounds.

**Status:**
Currently, kit foxes occur in the remaining native valley and foothill grasslands and chenopod scrub communities of the valley floor and surrounding foothills from southern Kern County north to Los Baños, Merced County. Distribution is spotty within this broad range. In addition, smaller, less dense populations are thought to exist further north and in the narrow corridor between Interstate 5 and the Interior Coast Range from Los Baños to Contra Costa County. Portions of Monterey, Santa Clara, San Benito, San Luis Obispo, and Santa Barbara counties are also included in the range of the San Joaquin kit fox. Studies and information from various sources indicate that a density of one kit fox per square mile in suitable habitat is a reasonable figure to use to estimate...
populations based on known acreage of habitat, although densities can range from less than one to over six foxes per square mile.

Loss of native habitat to various kinds of agriculture (e.g., cotton fields and vineyards), and residential and commercial developments remain the principal threats to this species. Several research projects funded by the DFG and studies by cooperators, begun in the mid-1990s and continuing to the present, are yielding more information about the habitat needs and biology of the kit fox. The recovery actions recommended for the kit fox are contained in the USFWS Recovery Plan for Upland Species of the San Joaquin Valley, California, which was completed in 1998. The kit fox is described as a keystone species (i.e., a species essential to the health of the natural community), and efforts to save habitat for this species will result in benefits to other endangered plant and animal populations.

Long-term ecological studies at the Elk Hills Naval Petroleum Reserve in western Kern County terminated several years ago following the sale of the Reserve to private interests in the late 1990’s. However, the landmark research that was conducted over a period of more than a decade is currently being published in a number of journal articles and will make valuable contributions to our understanding of the biology, ecology, and management of the species and its recovery. Considerable research activity has been initiated or continued for the kit fox in recent years. One study, started in 1997, examines the special case of the kit fox in the urban environment. Kit foxes have been captured, radio-collared and their movements monitored within the city of Bakersfield, Kern County. This field phases of this investigation of the demography and ecology of San Joaquin kit foxes in urban environments will continue through June 2004, and then data analyses and report and manuscript preparation will be conducted. Preliminary results have indicated that urban kit fox populations exhibit favorable demographic patterns, and that conservation of these populations could contribute to overall recovery efforts. The DFG has contributed funding, derived from federal sources, and support for this project.

Other studies on the San Joaquin kit fox include:

- An investigation of the effects of two-lane highways on San Joaquin kit foxes was initiated in 2001 and data collection will continue through June 2004. Results from this investigation will be used to develop strategies to mitigate road effects on kit foxes. Kit foxes are impacted by highways through direct road killing mortalities as well as indirectly through habitat loss and fragmentation effects.

- A study of the effects of livestock grazing and agricultural burning, as well as other farmland and ranchland activities on competitive interactions between San Joaquin kit foxes and coyotes was initiated in January 2003 and data collection will continue through June 2004. Results from this investigation will assist in developing habitat management strategies that may benefit kit foxes on these private lands.

- Research on the use of artificial den structures by San Joaquin kit foxes was initiated in May 2001 and data collection will continue through June 2004. Results from this investigation will be used to develop strategies to mitigate den loss and also to enhance den availability in areas where natural dens are a limiting factor for kit foxes. Escape dens help kit foxes avoid predation by coyotes and may provide secure sites for pup rearing.

- An investigation of strategies to facilitate survival of kit foxes crossing agricultural lands was initiated in 2001. This project is on-going, and represents a new approach to kit fox conservation in that it involves the establishment of a Safe Harbor Agreement with Paramount Farms. The DFG has contributed funding, derived from federal sources, for this effort.

- An investigation was completed in January 2003 on the efficacy of using search dogs and fecal DNA analyses as a non-invasive strategy for collecting demographic and ecological data on San Joaquin kit foxes. A doctoral dissertation and several manuscripts are being prepared that report the results of this effort. The technique proved to be useful where specially trained searchers were employed. Research confirmed Numerous locations throughout the historic range of San Joaquin kit foxes confirmed that
populations still exist in western Kern County and the Carrizo Plain National Monument and along the west side of the San Joaquin Valley north to Santa Nella. Despite the extensive search effort, no kit fox sign was found along the west side from Santa Nella to Contra Costa County, or in Valley floor locations north of Kern County. One kit fox was observed in eastern Merced County.

Various other studies have been conducted with San Joaquin kit foxes to examine social ecology and range-wide genetic exchange, kit fox-red fox interactions, and kit fox use of agricultural lands. Several manuscripts for scientific journal publications and technical reports for these past and ongoing studies have been produced.

Protection for the kit fox is addressed in several conservation plans. Some examples of these plans include the Kern County Valley Floor and Waste Facilities HCPs, Kern Water Bank HCP, Metropolitan Bakersfield HCP, and the PG&E San Joaquin Valley HCP. Despite these efforts, and other conservation efforts, San Joaquin kit foxes continue to decline throughout their range and are close to extinction in the northern most part of the range in Contra Costa and Alameda counties.

The status in 2003 of the San Joaquin kit fox: Declining.
Island fox  
*Urocyon littoralis*

**State**  
Threatened  
1971

**Federal**  
Endangered  
2004

**General Habitat:**
The island fox occurs on the six largest California Channel Islands, as follows: San Miguel, Santa Rosa, Santa Cruz, Santa Catalina, San Nicolas, and San Clemente. The fox appears to use most habitat types found on these islands.

**Description:**
This small fox has pepper-and-salt upper pelage with underfur that is rufous or buffy in color, with a dorsal median black stripe ending in the black tip of the tail. Faces are marked by distinctive black, white, and rufous-colored patterns. At 12 to 13 inches in height and 3 to 4 pounds, the island fox is about the size of a housecat. The island fox feed largely on insects, mice, and wild-growing fruits. They can live as long as 10 years, generally mate for life and give birth to litters of 2-5 pups in mid-April.

**Status:**
The island fox is endemic to the Channel Islands and is distributed as six genetically distinct subspecies, one on each of the six largest Channel Islands: San Miguel, Santa Rosa, Santa Cruz, San Nicolas, Santa Catalina, and San Clemente. On March 5, 2004 the Channel Island Fox of Santa Cruz, Santa Rosa, San Miguel, and Santa Catalina Islands were federally listed as endangered species. Fox populations on at least four of the six islands have experienced recent catastrophic declines - as much as 95% over 1994 population levels. The total island fox population is currently estimated at about 1300 individuals. This precipitous decline resulted in the island fox being listed as critically endangered by the International Union for Conservation of Nature (IUCN). Many experts fear the island fox could become extinct without implementation of recovery activities and intensive management. The NPS released a recovery strategy for foxes on the northern Channel Islands in 2003. The island fox is threatened primarily by golden eagle predation. Loss and degradation of its habitat, a result of overgrazing by non-native animals, disease, and low natural recruitment also threaten this species.

Golden eagle predation is severely impacting the island fox, which has no native predator. Golden eagles first arrived on Santa Cruz Island, and then spread to San Miguel and Santa Rosa Islands, in the 1990s. The first golden eagle nest was observed in 1999. Prior to that time, golden eagles were only occasional visitors to the Channel Islands. Feral pigs, introduced by early settlers on the islands in the 1850s, provide abundant year-round prey for the golden eagles, which now have established resident populations. The eagles also use the island fox as a prey species. The pigs adversely altered the native vegetation on the Channel Islands and restructured the food web. The pigs, and other introduced non-native animals, have fragmented native vegetation and converted stands of coastal sage scrub, chaparral, and oak woodlands to non-native annual grassland. The loss of plant species limits the native plant food sources available to the fox and reduces the numbers and availability of small animal prey species. Loss of vegetation structure has eliminated cover for the island fox, increasing its vulnerability to predation.
Island fox populations have declined dramatically as a result of predation by golden eagle. Research has provided correlation between the establishment of eagles on the islands and the decline of the island fox. On Santa Cruz island, the population of 1500 - 2000 individuals in 1993 dropped to fewer than 100 individuals in the wild by 2003. The cause of death in 21 of 29 foxes was due to golden eagle predation. On San Miguel Island, the first recorded fox mortality attributed to eagle predation was in 1995, the year in which the first golden eagle was sighted on the island. The San Miguel Island fox population showed dramatic decline, similar to that on Santa Cruz Island over the same time period, dropping from about 450 individuals to 39. A radiotelemetry study during 1998-1999 confirmed that golden eagle predation was the major cause of fox mortality on San Miguel Island. All but one of the 39 remaining foxes is now in captivity. Of the ~1700 foxes reported on Santa Rosa Island in 1994, 56 remain. All 56 individuals are in captivity. Similar trends are seen on Santa Catalina Island (~1300 in 1994; 220 in 2003). A monitoring study of the San Nicholas Island population was begun in the summer of 2000. There are an estimated 734 animals in the wild. In an attempt to safeguard remaining foxes and augment natural reproduction, the entire wild populations of San Miguel and Santa Rosa Islands and a portion of the populations of Santa Catalina and Santa Cruz islands were placed into captive breeding programs. Captive-breeding began on San Miguel Island in 1999, on Santa Rosa Island in 2000, and on Santa Cruz Island in 2002.

Possibly related to the influx of golden eagles is the decline and elimination of the bald eagle on the Channel Islands. The bald eagle occurred historically on the islands but disappeared by the 1960s as a result of egg-thinning caused by eating prey contaminated with DDT. Bald eagles nested on the perimeters of the islands near to their marine prey base. The bald eagle is highly territorial, and golden eagles were not resident on the Channel Islands when bald eagles were there in large numbers. Once the bald eagles were eliminated, a niche that could be occupied by another large raptor was available. NPS is reintroducing the bald eagle to the islands in conjunction with capturing the remaining golden eagles on the Channel Islands. The Santa Cruz Predatory Bird Group is working with the USFWS, NPS, and TNC to remove golden eagles from the Santa Cruz, Santa Rosa, and San Miguel Islands. They have removed 32 eagles and relocated them into suitable habitat in northern California. None of these eagles has returned to the Channel Islands according to telemetry data obtained from the released eagles. NPS estimates that six golden eagles, two pair and two lone eagles, remain on Santa Cruz Island. There were active nests on Santa Cruz and Santa Rosa Islands in 2003. Golden eagle predation on the island fox continues on Santa Cruz Island. The most recent eagle predation event occurred in November 2003.

The interactions between the golden eagle, bald eagle, feral pig, and island fox exemplify one of many challenges facing conservation biologists: how to protect a critically endangered species being impacted by another protected species. The proposal to removal golden eagles from the Channel Islands is not without controversy although capturing the remaining eagles is critical to the survival of the island foxes. Removal of feral pigs is part of a conservation plan prepared by NPS for Santa Cruz Island. The plan is based on the eradication of the island pigs with the goal of eliminating the eagles’ prey base. Removal of the eagles must be concurrent with eradication of the feral pigs so that the eagles do not concentrate prey activities on the island fox.

Populations of the fox on the southern three islands have faced other threats. The San Clemente Island population (~1000 animals in 1994; 500-875 in 2003) has been impacted by a history of severe overgrazing, use of the island as a Navy bombing range, a widespread feral cat problem, and predator management activities to protect the island loggerhead shrike, another federally-listed species. In an attempt to offset fox predation of the shrikes, the Navy implemented control activities for non-native predators (black rat and feral cat), as well as for the island fox. The Navy euthanized 13 foxes and shipped 15 foxes off the island to zoos. Euthanasia ceased in 1999. Subsequently, foxes were captured and held in captivity while fledgling shrikes were vulnerable to predation. Vehicle collisions are another source of fox mortality on San Clemente Island. On San Nicolas Island, vehicle collisions are the largest documented mortality source, with an average of 13 fox carcasses attributed to vehicle collisions recovered each year. The population on Santa Catalina Island was decimated by an outbreak of canine distemper in 1999-2000. The disease was likely introduced by an unvaccinated pet dog brought to the island. The Catalina Island Conservancy, with assistance from the Institute for Wildlife Studies, began a field vaccination program for wild foxes and a captive breeding program. The field vaccination program is part of a multifaceted
recovery program initiated in 2000. According to Institute for Wildlife Studies, the wild population of foxes on Santa Catalina Island is estimated at about 220 adults.

Morphological and genetic variation within and among populations of island foxes has been studied by a number of researchers. The levels of variability found support differentiation of the island fox into subspecies. The genetic data shows that inter-island diversity is greater than intra-island diversity. Genetic evidence suggests that the island foxes descended from the gray fox on the California mainland during one colonization event that occurred approximately 10,000-16,000 years before present. The genetic studies have also revealed that the populations on San Miguel and San Nicholas Islands have the lowest genetic variability of the island fox populations. This lack of variability could be attributed either to extensive inbreeding or a genetic bottleneck resulting from low population densities. A genetic bottleneck refers to a reduced pool of genetic material usually due to a catastrophic event that reduces the size of the original population. The foxes on San Nicholas Islands have essentially no variability and their population consists largely of adult animals. Low levels of reproduction observed for the foxes on San Nicholas Island and in captivity may be due to such a bottleneck. Genetically, the foxes on San Miguel are most closely related to foxes on Santa Rosa Island. Populations on these islands also occur at such low population numbers that they are highly vulnerable to random extinction events. NPS has funded genetic studies on all foxes in the captive breeding program. The results are being used to ensure that interbreeding between closely-related animals does not occur and to maximize the limited diversity that does occur. Introduction of foxes to the captive breeding program from another island may be necessary to increase the genetic diversity of the San Nicholas and Santa Rosa Island foxes.

In 2001, DFG received funds to initiate a candidate conservation agreement for island fox on Santa Cruz Island. This effort will include implementation of many of the actions included in the NPS recovery strategy. In 2002, the DFG used federal funds to help eliminate feral pigs from Santa Cruz Island. Six fenced enclosures will be built by TNC. Each enclosure will constitute a discrete management unit of about 12,000 acres. The DFG will manage public hunts within each enclosure to eliminate pigs.

DFG has participated in the Island Fox Conservation Working Group (IFCWG). The IFCWG is a team of experts convened by the NPS in 1999 and 2000 to recommend appropriate recovery actions for the island fox. The group is a loose affiliation of representatives of public agencies, landowners, conservancies, zoological institutions, nonprofits, and academia concerned about conservation efforts for the island fox. Its initial purpose was to evaluate the status of island foxes on park lands and to make findings regarding appropriate recovery actions. Their focus later broadened to include all six subspecies. Individual working groups exchanged information on a variety of topics including captive breeding, veterinary care, and management of wild populations. They contributed to development of a recovery plan for the fox on the three northern islands.

The NPS released the recovery strategy for review in August 2003. Recovery strategy objectives are to remove mortality factors for all populations, augment fox populations through captive breeding, establish monitoring and management programs to protect the fox populations, and implement habitat restoration activities. The overall goal of the recovery strategy is to minimize the threat of extinction for the three subspecies of foxes under NPS jurisdiction. This recovery strategy can also be applied to the other islands. A Channel Island Fox Integrated Recovery Implementation Team was formed in 2004 and is currently working on developing a coordinated recovery implementation strategy. In the absence of active, intensive management based on the best available science, the island fox is in danger of extinction.
**Guadalupe fur seal** *Arctocephalus townsendi*

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**General Habitat:**
The Guadalupe fur seal is a pelagic species most of the year, occurring in Pacific Ocean waters as far south as the Mexico/Guatemala border, and as far north as the Point Reyes National Seashore in California. When ashore, this seal occupies rocky caves and crevices and sandy beaches.

**Description:**
Guadalupe fur seals are medium-sized eared seals (Family Otariidae). They have dense gray-brown underfur covered with course guard hairs that tend to bleach out on the head and shoulders of adult males. Their appearance is very similar to the northern fur seal (*Callorhinus ursinus*) but the Guadalupe fur seal is distinguished by a pointed muzzle. Males reach six feet in length and 350 pounds in weight, while females reach five feet in length and 100 pounds in weight. The maximum life span is estimated to be 17 to 20 years.

**Status:**
Guadalupe fur seals were thought to be extinct in the late 1800’s and early 1900’s but in 1928, two fur seals were sighted at Isle de Guadalupe off the coast of Mexico. The major cause of the Guadalupe fur seal’s decline was commercial hunting in the late 1700’s and early 1800’s. The species was exterminated in southern California waters by 1825. Commercial sealing continued in Mexican waters through 1894. The Guadalupe Fur Seal is included in the *IUCN Red List of Threatened Animals* as Vulnerable. Potential threats to the seal include injury or mortality due to entanglement in gill nets. Although human-caused mortalities to the Guadalupe fur seal have not been reported in California waters since specific records were kept starting in 1983, similar information is not available for Mexican waters. Juvenile female Guadalupe fur seals have been found stranded in central and northern California with net abrasions around the neck, fish hooks and monofilament line, and polyfilament string.

Guadalupe fur seals breed on Isla de Guadalupe and Isla Benito del Este off the coast of Baja California, Mexico. Mating occurs approximately one week after pups are born; females bear a sole pup. In 1997 one Guadalupe fur seal was born on San Miguel Island off the California coast. The population is considered to be a single stock because all are recent descendants from one breeding colony at Isla Guadalupe, Mexico. The species has undergone
an extreme genetic bottleneck; this reduction in genetic diversity may influence further population expansion. Male seals are occasionally observed on rocky beaches of the southern Channel Islands. Little information exists on the diet or foraging behavior of this subspecies. However, it is believed that Guadalupe fur seals feed in deep waters on species of krill, squid, and small, schooling fish.

The most recent population estimate was made in 1993, and the estimate was 7,408 fur seals. Researchers estimate that the population is growing at a rate of approximately 14 percent. Mexican law fully protects the species and Guadalupe Island was declared a pinniped sanctuary by the Mexican government in 1975. The IUCN/SSC Seal Specialist Group recommended research to determine numbers and population limits for the Guadalupe Fur Seal, allowing an assessment of population status and development of conservation measures. No information is available for gillnet fisheries or related mortalities in Mexican waters.

The Status in 1997-1999 of the Guadalupe fur seal: Increasing to Stable
**Wolverine**

*Gulo gulo*

**State:** Threatened 1971

**Fully Protected**

**Federal:** None

**General Habitat:**
The wolverine is reported from a series of habitat types within an elevation range of 1,600 feet to over 14,000 feet. Based on the number of sightings in California, habitat generally consists of open terrain near or above timberline.

**Description:**
The wolverine resembles a small, short-legged bear with a coarse shaggy coat and a bushy tail. The coat is heavy and dark brown with two broad, light-colored bands extending from the shoulder to meet at the base of the tail. Wolverines typically weigh 35 to 60 pounds and measure 35 to 45 inches long, including a six to 10 inch tail. They stand about 14 to 18 inches at the shoulder. Their jaws are very powerful and are adapted to crush and shear frozen meat and bones. Sexes appear similar except that males are 25 to 35 percent larger than females. Wolverines subsist on a variety of foods including small- and medium-sized mammals, birds, insects, berries, and fungi. Carrion, especially in the form of large ungulates, is believed to be an important component of the diet, particularly during winter.

**Status:**
Wolverines are often regarded as animals of high-elevation habitats; however, sightings collected by the DFG over the past several decades indicate that the species inhabits a variety of habitat types within an elevation range between 1,600 feet and 14,200 feet. The mean elevation of over 150 sightings in California is about 8,000 feet. Habitat generally consists of open terrain at or above timberline.

The present and historical ranges of the species are rather similar. The historic range encompassed an area from Mount Shasta in the southern Cascade Range south to Monache Meadows in the Sierra Nevada of Tulare County. Portions of the North Coast Range are also included in the historical range. No population density data are available on the wolverine in the State due to difficulties involved in studying such an elusive and far-ranging species. An estimate of 50 to 100 wolverines was made over 20 years ago based on available habitat and home range information from studies in other parts of North America.

Specific threats to the wolverine are unknown. No management plans for this species have been prepared, partly because of the difficulty in collecting data and limited financial resources. No State or federal land-use planning documents address the habitat needs of wolverines at the present time.
Individual research programs, being carried out primarily by USFS and university biologists, continue to place remote camera stations out each winter in an attempt to photograph wolverines. The technique works well with a variety of species, including wolverines in other states, and has been adapted to a variety of research objectives since the DFG’s initial attempts with wolverines. Although none have been recorded yet, the primary goal of the ongoing study remains to document the occurrence of wolverines in selected habitats within the suspected range by the use of remote sensor cameras associated with a carrion bait station. An ongoing study, begun in 1997 in Lassen Volcanic National Park, to locate and capture Sierra Nevada red foxes for radio telemetry may offer a further opportunity to incidentally photograph wolverines.

The status in 2003 of the wolverine: Unknown.
Sierra Nevada bighorn sheep  
*Ovis canadensis sierrae*  
(*O. canadensis californiana*)

**State** | **Threatened** 1971  
Endangered 1999  
Fully Protected

**Federal** | **Endangered** 2000

**General Habitat:**
The Sierra Nevada bighorn sheep is found on the eastern slopes of Sierra Nevada from alpine habitat down to Great Basin scrub. Sierra Nevada bighorn sheep occur in five distinct geographic areas along the Sierra Nevada that are defined, from north to south, as: Lee Vining Canyon, Mono County (reintroduced); Wheeler Ridge, Inyo County (reintroduced); Mount Baxter, Inyo County (native); Mount Williamson, Inyo County (native); and, Mount Langley, Inyo County (reintroduced). Basic habitat requirements include open, rocky, and precipitous slopes that are important to sheep for detecting and evading predators. These bighorn sheep occur as high as 14,000 feet in the summer and typically descend to lower elevations in the winter, depending on severity of storms.

**Description:**
The Sierra Nevada bighorn sheep is one of two subspecies of mountain sheep found in California, and one of four found in North America. Both males and females have horns. The horns of males are massive and may grow to full curl when viewed from the side, and horns of females are 10 to 12 inches long and rather goat-like in appearance. Adult males may be 40 inches tall at the shoulder and weigh 200 pounds. Females weigh approximately 140 pounds. Formerly called *Ovis canadensis californiana*, the accepted name for the species is now *O. canadensis sierrae*.

**Status:**
Action was taken in 1999 by the California Fish and Game Commission to list Sierra Nevada bighorn sheep (SNBS) as endangered under the State endangered species act. In addition, it was listed as endangered under the Federal endangered species act the same year. Listing under the Federal act became permanent in 2000. Those actions were taken in response to a significant decline in the population, from an estimated 310 individuals in 1985.
to an estimated 100 individuals in 1999. Causes of the decline remain uncertain, but may have included predation, changes in habitat use, severe winters, and accidental deaths.

The Sierra Nevada bighorn sheep is one of the most endangered subspecies of large mammals in North America. Because of this, and concomitant high levels of public concern, the Department of Fish and Game was provided funding through a member's legislative request to implement a recovery program for these sheep. That funding allowed the Department to establish a long-term, comprehensive population recovery program. Elements of the recovery program include intensive population monitoring, reducing mortality, reestablishing additional populations in historical range of the species, and preparing for, and potentially implementing, captive breeding as a means to ensure the availability of translocation stock to increase populations and geographic distribution. Funding for the recovery program has since become part of the Department's budget base. Continued monitoring of all bighorn sheep populations in the Sierra Nevada remains a high priority, and recovery will be dependent upon continued availability of monies for this important conservation effort. Since the recovery effort was initiated, the number of Sierra Nevada bighorn sheep has increased to an estimated 300 individuals.

The status in 2003 of the Sierra Nevada bighorn sheep: Increasing.
**Peninsular bighorn sheep** *Ovis canadensis cremnobates*

**State** Threatened 1971  
**Federal** Endangered 1998

**General Habitat:**
Peninsular bighorn sheep inhabit dry, rocky, low-elevation desert slopes, canyons, and washes from the San Jacinto and Santa Rosa Mountains near Palm Springs, California south into Baja California, Mexico. Mountains in this geographic area collectively are referred to as the Peninsular Ranges. Bighorn sheep in the Peninsular Ranges seldom occur above 4,000 feet. Proximity to sources of standing water such as springs, creeks, and oases are also important elements of their habitat.

**Description:**
Males and females both have horns; those of males are curled but those of females are slightly curved and are goat-like in appearance. Adult males can weigh in excess of 200 pounds, and females weigh approximately 125 pounds.

**Status:**
Bighorn sheep inhabiting the Peninsular Ranges were recognized originally as a distinct subspecies (*Ovis canadensis cremnobates*), but recently have been assigned to *O. c. nelsoni*. State-listed threatened status remains for the bighorn sheep occupying the Peninsular Ranges, and sheep in that area were listed in 1998 as an endangered population segment under the Federal Endangered Species Act. In listing the Peninsular bighorn sheep as endangered, the USFWS determined that the sheep are in danger of extinction throughout a significant portion of their range due to disease, insufficient lamb recruitment, habitat loss, habitat degradation and fragmentation by urban and commercial development, and predation coinciding with low population numbers. The greater bighorn sheep population in the Peninsular Ranges is considered a metapopulation: each ewe group, or subpopulation, is essential for the survival and recovery of the overall population.

Loss of winter forage sites and lambing sites, off-highway vehicle use within the range of the species, impacts to water sources, overgrazing by cattle and domestic sheep, exposure to diseases of domestic livestock, and the spread of rangeland weeds have adversely affected these animals. Habitat fragmentation, often a result of human encroachment into native habitat, restricts the sheep to small or isolated areas, limits movement of the sheep between subpopulations (referred to as ewe groups), and results in genetic isolation. Since 1970, metapopulations of bighorn sheep have experienced additional fragmentation as a result of the expansion of the interstate highway system in southeastern California. Some reestablishment of populations has occurred since then via translocation. In the 1990’s, heavy mountain lion predation in conjunction with lowered lamb recruitment rates suppressed bighorn populations. Although a healthy bighorn population can withstand predation, a population debilitated by low survivorship and disease is often not able to survive additional threats.
The impacts of human encroachment into bighorn sheep habitat have been well documented in the preparation of the Coachella Valley MSHCP. Hiking trails located in bighorn habitat and vehicular use in proximity to the sheep have resulted in sheep avoidance of areas normally used. When golf courses and residential developments have been located within Peninsular bighorn sheep habitat, some ewe groups have become habituated to foraging in urban areas. Foraging around dwellings is especially problematic during the warm season when native food plants dry out and become less palatable. At least five bighorn sheep apparently died after eating toxic ornamental plants in the Coachella Valley (oleander has been implicated), and intestinal nematode parasites have been detected in bighorn sheep that graze regularly on lawns. Bighorn sheep at the urban interface are also threatened by domestic dogs, automobiles, and drowning. For example, a six-year study conducted by the Bighorn Institute, a conservation and research group working with USFWS, BLM, and DFG, showed that urbanization accounted for 34% of the adult bighorn mortalities in the Coachella Valley area. Over a three-month period, law enforcement officers and Bighorn Institute personnel herded groups of bighorn sheep off Highway 111 over 24 times.

The Coachella Valley MSHCP Plan Area supports four of the eight subpopulations, or ewe groups, of the Peninsular bighorn sheep metapopulation. Each ewe group is designated by the name of the area in which they occur: the San Jacinto Mountains group, the northern Santa Rosa Mountains group, the southern Santa Rosa Mountains group, and the Deep Canyon group. These ewe groups form the basis for the four recovery regions in the federal recovery plan. The Plan ensures conservation of habitat and connectivity among the four areas through conservation of 168,350 acres of essential habitat (97%). Three conservation areas will protect essential habitat for the bighorn sheep: Cabezon Conservation Area, Snow Creek/Windy Point Conservation Area, and Santa Rosa and San Jacinto Mountains Conservation Area. Special measures will be implemented in these areas to ensure protection of bighorn during lambing season and to minimize human impacts on bighorn habitat.

In 1997, a working group was formed to collaborate on a federal recovery plan for bighorn sheep in the Peninsular Ranges. The working group included representatives from the DFG, DPR, BLM, USFWS, USFS, University of California, Agua Caliente Band of Cahuilla Indians, Bighorn Institute, and the Zoological Society of San Diego. Following listing of the peninsular bighorn sheep in 1998, the working group was reorganized as a recovery team. In 2000, the Recovery Plan for Bighorn Sheep in the Peninsular Ranges was completed, and currently is being implemented. The primary charge of the recovery team is to advise the USFWS with respect to actions that will conserve and maintain bighorn sheep in viable numbers through the application of scientifically based management decisions.

Critically important to the long term survival of bighorn sheep in the Peninsular Ranges, and in California in general, is the maintenance of “connectivity” between areas occupied by subpopulations, which facilitates emigration and immigration and, thereby, gene flow and opportunities to colonize vacant habitat. In 1994, the number of bighorn sheep in the Peninsular Ranges was estimated at 360 adults, distributed among eight distinct population segments. Subsequent surveys have yielded population estimates that suggest an upward trend in numbers. In 2002, the total number of bighorn sheep occupying the Peninsular Ranges was estimated to be 670. Population assessments from ground monitoring and aerial surveys will continue as part of the recovery effort. Long-term monitoring provides information on the ecology of the sheep and documents habitat use, nutritional levels, disease exposure, nursing rates, survival rates, and causes of death.

In 2001, the Federal Cooperative Endangered Species Conservation Fund was been used to protect one particular ewe group in the Coachella Valley. These grants are authorized by Section 6 of the Endangered Species Act and enable states to work with private landowners, conservation groups, and other agencies to initiate conservation planning efforts and acquire and protect habitat to support the conservation of threatened and endangered species. The Northern Santa Rosa ewe group was most impacted by the urban environment where its home range corresponds to the boundaries of the City of Rancho Mirage. This ewe group declined considerably from its historic levels in the 1970’s. Given high levels of mortality, it was unlikely that the Northern Santa Rosa ewe group would survive without intervention. The City of Rancho Mirage, USFWS, DFG, and the Recovery Team
agreed that a barrier fence along the wildland/urban interface would be the solution to the high mortality rates experienced by the Northern Santa Rosa ewe group. Funding was used to acquire a key parcel, thereby facilitating fence construction. Additional acquisitions under this fund are proposed.

The status in 2003 of bighorn sheep in the Peninsular Ranges is increasing.
Giant kangaroo rat *Dipodomys ingens*

**State:** Endangered 1980  
**Federal:** Endangered 1987

**General Habitat:**
Giant kangaroo rats require annual grassland and shrubland habitats with sparse vegetative cover and soils that are well drained, fine sandy loams with slope generally less than 10 percent. Areas of low annual precipitation and infrequent flooding are preferred by this species for establishment of permanent colonies. The historical range extended from Merced County south to Kern County and west to eastern San Luis Obispo and northern Santa Barbara counties.

**Description:**
Giant kangaroo rats are small mammals with elongated hind limbs for hopping and external cheek pouches for carrying food to their burrows. The giant kangaroo rat is the largest of all kangaroo rats and weighs from 4.6 to 6.4 ounces. The total length is 12 to 13 inches, including a tail that is six to eight inches. Giant kangaroo rats subsist almost entirely on the seeds of annual plants such as brome grasses and filaree. The animals harvest, stack, and dry caches of grasses and forbs near the entrance of their burrows. Giant kangaroo rats inhabit a territory, known as a precinct that averages 20 feet in diameter where a shallow burrow system, about 12 inches deep, is constructed. Each kangaroo rat maintains and defends an individual territory in a colony that may consist of from two to thousands of precincts.

**Status:**
The historical range of the giant kangaroo rat extended from Merced County south to Kern County and west to eastern San Luis Obispo and northern Santa Barbara counties. Populations were most numerous in areas with sparse vegetative cover and low annual precipitation. Today very little undisturbed suitable habitat remains. The loss of original habitat to agricultural conversion may be as much as 98 percent. Five relatively small areas totaling 12-square miles remain that support population densities typical of those existing prior to 1950.

In 1997, several population assessment studies confirmed that the giant kangaroo rat population had dramatically declined along with that of many other kangaroo rats in the southern San Joaquin Valley. At other locales such as the Elkhorn Plain in eastern San Luis Obispo County the declines were not as severe. In 1998 and 1999 giant kangaroo rat numbers began to increase at the Elkhorn Plain study area. Genetics studies, initiated in 1993, continue on this and other kangaroo rat species, and are yielding valuable information that can be applied to
recovery strategies for all endangered kangaroo rats.

In 1997, an additional research effort began at the Lokern Area in western Kern County to further investigate the role of livestock grazing on species and habitats on the floor of the San Joaquin Valley. However, few giant kangaroo rats have been caught on plots in the Lokern Study Area since the beginning of the study. Researchers did, however, capture the most individuals in any year of the study in 2002 when they caught three in each of two treatment plots (out of four). In addition, a colony of about 20 individuals was seen near one of these treatment plots. Although numbers have remained fairly low throughout the study, giant kangaroo rats have only been caught in plots grazed by cattle, never in any of the four ungrazed plots. In a separate study initiated by BLM in 1993 at a location about 3 km north of the Lokern Study Site, researchers have captured giant kangaroo rats twice a year since 1993. Population numbers were as high as 110 individuals caught in a six-night census when the study began, decreased to 0 for both sessions in 1998 (dense grass year), and has steadily increased back up to about 45-70 individuals caught in 2002/2003. Trends in population size seem correlated with the amount of grass cover: the less grass, the greater the number of giant kangaroo rats caught.

The conversion of native habitat to agricultural uses remains the greatest threat to the species. Ongoing studies, initiated in 1987 at the Elkhorn Plain, an area that is now included in the Carrizo Plain National Monument, which was established in 2000, indicate a healthy population that is reproducing well during years with adequate rainfall. Researchers from the Endangered Species Recovery Program conduct giant kangaroo rat population censuses twice a year at the Elkhorn Plain study area.

The recovery options for the giant kangaroo rat are addressed, along with those for 33 other species of plants and animals, in the USFWS 1998 Recovery Plan for Upland Species of the San Joaquin Valley, California. The DFG is involved in several conservation efforts for the giant kangaroo rat. Some of the efforts include the Metropolitan Bakersfield HCP, the California Department of Corrections Electric Fence HCP, the Coles Levee area 2081 Agreement, and the Arco Western Energy HCP. Despite these conservation efforts, habitat loss remains the primary obstacle to recovery with only populations on established preserve lands secure for the foreseeable future.

The status in 2003 of the giant kangaroo rat: *Stable to Declining.*
Natural History and Identification of Bats in Central Coastal California (A-E).

Mark R. Stromberg, Hastings Reservation

The best way to introduce the bats is probably by showing you a picture or two for each and then giving you a bit of information on the natural history of the bats. I will present them in alphabetical order, using their scientific names. The photos are mostly from a great book ("Bats of America" by Roger Barbour and W. H. Davis. 1969 Univ. of Kentucky Press). This book has a good key to the bats of North America. A Key to the California Bats will allow you figure out which bat you have in hand. Photos should not be used elsewhere without permission. Contact Bat Conservation International for photographs of bats. Amy Fesnock of Pinnacles National Monument straddling San Benito and Monterey Counties, made the bat voice recordings. Bat vocalizations are recorded with special microphones that can hear sounds that are 10x higher in frequency than humans can hear. To let us hear the sounds, they were translated by dividing the frequency by 10; thus a 20,000 Hz sound is beyond most of our hearing and is presented here as 2,000 Hz. Jeff Froke, Santa Lucia Preserve, on the southwestern flanks of Carmel Valley provided information on bat distribution there. Other information is derived from the files at Hastings.

Pallid Bat

Antrozous pallidus

Pallid bats have great ears! They can also see pretty well. But, like all bats, they use their voices to make ultrasonic sounds that bounce back to their ears and these reflected sounds let the bats "see" flying insects and the environment they are flying through. Pallid bats occur from British Columbia to west TX and south to Baja and Central Mexico. Pallid bats are generally found in grasslands and desert habitats. Populations can be non-migratory and are known to winter in places from CA to KS. Mating occurs in Oct, and like other bats, sperm and egg don't meet until spring. Gestation takes about 9 weeks, with young born in spring. Colonies or parts of colonies with only females ("maternity roosts") gather in rock crevices and old buildings, starting in Apl. Females often have two young each year and nurse them for 6-8 weeks. Females breed in the summer after they are born. Adults probably hibernate over much of range.

Pallid bats are medium-sized (total body length 92-135 mm) and often feed on the ground early in the night. They can run on folded wings and hind feet; they can hop around to catch insects. They then retire to night roosts where they hang out to digest their catch (Jerusalem crickets, scorpions, grasshoppers, beetles, etc.). They may feed again near dawn. By daylight, they retire to "day roosts" in rock crevices where they hide. Pallid bats are known from Pinnacles, Hastings and Santa Lucia Preserve.
**Big Brown Bat**

*Eptesicus fuscus*

Photos by Roger Barbour (L) and Merlin Tuttle (R)

Probably about the largest bat we have with uniform brown fur (total length 105-118 mm). Brown bats are very common in North America, and occur in most habitats, including old buildings. Often seen flying around city lights, where they feed on flying insects. Breeding occurs in the fall, with maternity colonies forming the following spring. Often, two are born, and each may be as much as 10% of mother's weight at birth! Young can fly at 3-4 weeks. Adults can live up to 18 years. Feeding bats eat up to 3 grams/hour and a typical barn colony of 500 bats can remove hundreds of pounds of insects (mostly beetles) each year. Non-migratory, hibernating in cool, dry caves. Hibernation may use up 1/3 of body weight. Drink by flying over water and scooping sips while airborne. Hawks and Great Honed Owls are known predators. Big brown bats are known from Pinnacles, Hastings and Santa Lucia Preserve.

**Western Mastiff Bat**

*Eumops parotis*

In the United States, this is our largest bat, with long, narrow wings. About half of the tail is free from the membrane between hind legs. Large ears join at the midline in front. Ears nearly cover the eyes and if laid forward, extend beyond the nose. Mastiff bat fur is bicolored- white at the base and gray or brownish gray at tips. Three widely separated populations occur in the world- Argentina to Brazil, Cuba, and southwest U.S. Permanent residents, prefers rugged canyons, cliffs and rock walls of arid habitats. Groups of 2-3 to maybe 100, they retreat into deep, narrow rock crevices. Will roost in buildings. Fly during hot days, and active most nights. Roost require vertical entry (overhangs) and bats need to drop 10-20 feet to launch into flight. Emit high-pitched piercing cry every 2-3 seconds that can be heard by humans for 1,000 feet. Young (usually 1 per female) born in spring. Males and females together year-round. Fly up to several thousand feet in altitude, taking many small insects. Enter daily torpor in Dec Jan and Feb. Active year round, less so in winter. Throat gland secretes overpowering odor in breeding season, stong odor at other times. Only known at Pinnacles National Monument in Monterey County area.
**Pallid bat, *Antrozous pallidus***  
*Elizabeth D. Pierson & William E. Rainey*

**Description:** *Antrozous pallidus* is a large (forearm = 45-60 mm), long-eared vesperilionid bat. It can be readily distinguished from all other California bat species by a combination of large size, large eyes, large ears, light tan coloration, a pig-like snout, and a distinctive skunk-like odor. Although color varies from very light, almost blonde, in desert populations, to tan along the coast and farther north, the overall impression is of a light colored bat. No other species has fur this light. It lacks the nose-leaf found in *Macrotus californicus* and the bilateral nose lumps found in *Corynorhinus townsendii*. *Myotis evotis* is much smaller and has dark, rather than pale colored, ears. *Euderma maculatum*, which also has light ears, can be distinguished by its unique pelage coloration -- black with three large, white dorsal spots.

Pallid bats sometimes leave characteristic sign. Remains of scorpions, Jerusalem crickets, sphinx moth wings, and/or long-horned beetles in association with bat guano, indicate the presence of pallid bats. It is possible, however, to find pallid bat guano deposits that do not have culled insect parts.

**Taxonomic Remarks:** *A. pallidus*, a member of the Family Vespertilionidae, was first described in 1856 from a specimen collected in El Paso, Texas (LeConte 1856). The first record of *A. pallidus* for California was from Old Fort Tejon, Kern County (Merriam 1897). Based on morphometric analyses, there are six currently recognized subspecies of *A. pallidus*, with three (*A. p. pacificus*, *A. p. pallidus*, and *A. p. minor*) occurring in California (Martin and Schmidly 1982). The primary characteristic used to separate subspecies is size. Since genetic analyses have not been conducted on California populations, geographic boundaries between the subspecies have not been clearly delineated, and specimens for most localities have not been examined, we treat all California *Antrozous* as *A. pallidus*. Koopman (1993) recognizes two species of *Antrozous*, *A. pallidus* and *A. dubiaquercus*, whereas others (Engstrom and Wilson 1981, Engstrom et al. 1987) place the latter species in a separate genus, *Bauerus*.

**Distribution:** Pallid bats are known from Cuba, Mexico and Baja California, through the southwestern and western United States, into southern British Columbia. They occur as far east as Kansas, Oklahoma, and Texas, and throughout much of the United States west of the Rocky Mountains (Hall 1981, Martin and Schmidly 1982). In California, the species occurs throughout the state in a variety of habitats including low desert, oak woodland and coastal redwood forests, extending up to 3,000 m elevation in the Sierra Nevada.

According to Martin and Schmidly (1982), *A. p. pacificus*, the largest subspecies, occurs along the coast and in the coast ranges west of the Central Valley. *A. p. minor*, the smallest subspecies, occurs in the Colorado River basin and adjacent mountain ranges. *A. p. pallidus* occurs throughout the rest of the state (including western San Diego County, the Central Valley, all of the Sierra Nevada and areas east of the crest, and, farther north, all areas east of the coast ranges). Martin and Schmidly (1982) describe an area of intergradation in the Klamath Mountains between *A. p. pacificus* and *A. p. pallidus*. According to Hall (1981), *A. p. pallidus* is confined to the area east of the Sierra Nevada crest, south of Lake Tahoe. The subspecific status of *A. pallidus* populations in California warrants further investigation.

**Life History:** Pallid bats are colonial, with a typical colony containing 30-70 animals, although colonies of several hundred have been found. Colonies form in the spring (March-May), and stay together until October (Barbour and Davis 1969). These colonies can be bachelor groups, but usually consist of adult females and their young. Pallid bats mate in the fall or winter, but, as is
typical of northern hemisphere vespertilionids, the females do not actually become pregnant until the spring. They give birth to one or two young in early summer (Orr 1954). Young are born in an altricial state, dependent on their mothers for at least 6 weeks. They are deaf at birth and begin to respond to low frequency vocal communications at about 6 days of age, and have hearing equivalent to that of an adult by 12 days of age (Brown 1976, Brown et al. 1978). The young accompany their mothers when first learning to fly and forage (Brown and Grinnell 1980). Although they are weaned at 6-8 weeks, the young are not self-sufficient until the fall when colonies disperse. Recapture data from the upper Sacramento River drainage suggest that females in that part of California do not reproduce until they are two years old (Rainey and Pierson 1996). Lewis (1993) showed that reproductive success was positively correlated with temperature for a pallid bat population in Oregon. Pallid bats are not known to migrate, and are presumed to spend the winter hibernating close to their summer roosts. No wintering aggregations have been found, although hibernating individuals have been detected close to or in the same structures as the summer roosts (Barbour and Davis 1969, C. Scott pers. comm.).

Pallid bats forage primarily on large (20-70 mm) arthropods, caught on the ground or gleaned off vegetation. Prey items include flightless arthropods, such as scorpions (Vejoridae), ground crickets (Gryllacridae), solpugids (Solpugidae), and darkling ground beetles (Tenebrionidae); largely ground-roving forms, including scarab beetles (Scarabaeidae), predacious ground beetles (Carabidae), carrion beetles (Silphidae), and short-horned grasshoppers (Acrididae); and vegetation-dwelling insects, including cicadas (Cicadidae), katydids (Tettigoniidae), praying mantids (Mantidae), long-horned beetles (Cerambycidae) and sphingid moths (Sphingidae) (Hatt 1923, Borell 1942, Barbour and Davis 1969, Hermanson and O’Shea 1983).

Radiotelemetry (P. Brown pers. comm.) and the known behavior of favored prey items suggest pallid bats fly close to the ground, and land on the ground to capture prey. Light-tagging studies have also documented animals feeding on the wing, 10-20 ft (3-6 m) off the ground (pers. obs.). Discarded large arthropod remains most commonly found in pallid bat roosts in California are Jerusalem crickets, cicadas, long-horned beetles, and scorpions (D. Pierson and W. Rainey pers. obs.). Although pallid bats use echolocation to assess habitat, they apparently locate prey primarily by listening (Bell 1982). Pallid bats have also been reported as visitors to fruits and flowers (Barbour and Davis 1969, Howell 1980). Although they are presumably feeding on insects associated with these plants, they also appear to serve as pollinators of some desert plants (Herrera et al. 1993).

Habitat: Although pallid bats are frequently associated with desert areas and the Sonoran Life Zone (Barbour and Davis 1969, Hermanson and O’Shea 1983), Orr (1954), who studied this species extensively in California, described the species as occurring in a number of habitats, including coniferous forests, nonconiferous woodlands, brushy terrain, rocky canyons, open farm land, and desert. In our observations (D. Pierson and W. Rainey) in northern California, this species is associated with oak habitat, particularly lower elevation oak savannah. It is also found in association with coast redwoods; and mid- to higher elevation coniferous forest (Orr 1954, Rainey et al. 1992). It is, for example, one of the species most frequently observed in Giant Sequoia groves at ca. 2,000 m (Pierson and Heady 1996).

Pallid bats are primarily a crevice roosting species, and select daytime roosting sites where they can retreat from view. Common roost sites are rock crevices, old buildings, bridges, caves, mines, and hollow trees (Barbour and Davis 1969, Hermanson and O’Shea 1983). Recent radiotracking efforts in the west, including California, suggest that pallid bats are far more dependent on tree roosts than was previously realized. They have been located in tree cavities in oak, Ponderosa pine, coast redwood and giant Sequoia (Rainey et al. 1992, Cross and Clayton 1995, Pierson and Heady 1996).
On Santa Cruz Island, however, radio-tagged animals selected rock crevices and buildings, despite abundant oak woodland (Brown et al. 1984). Pallid bats are also one of the species most predictably associated with bridges. They sometimes roost in expansion joints by day, but more commonly are found night roosting, particularly under concrete girder structures (Lewis 1994, Pierson et al. 1996). They are also often associated with buildings, ranging from collapsing barns and historically significant sites (e.g., some of the missions) to some relatively recent structures.

Roost temperature may be a limiting factor in roost selection. Cliff-roosting pallid bats in Arizona selected crevices that remained warm and stable (ca. 30°C) in the summer, and tracked ambient temperature fluctuations in spring and fall (Vaughan and O’Shea 1976). Pallid bats are intolerant of roost temperatures above 40°C (Licht and Leitner 1967), and often occupy roosts that offer a varied temperature regime. In attic settings, the animals emerge from crevices to roost on open rafters when roof temperatures become excessive. Pallid bats are very sensitive to disturbance at the roost. When disturbed, they generally retreat into crevices, and with repeated disturbance, may abandon the roost. Their response time is slow, however, making them vulnerable to shooting and other forms of vandalism, and their loyalty to a chosen roost (particularly buildings, mines, bridges) is generally high.

In central coastal California, pallid bats are most frequently found foraging in open oak woodland, but also feed in forested canyons (E. Pierson and W. Rainey pers. obs.). Radiotracking studies have shown that animals generally feed within 6-8 km of their roost, and have regularly occupied feeding areas (E. Pierson and B. Rainey unpubl. data; P. Brown pers. comm.).

**Status**: Class II. Although the status of *A. pallidus* has not been investigated, bat biologists have noted a definite decline in populations in recent years in California (P. Brown pers. comm.; E. Pierson and W. Rainey pers. obs.). For example, in 1980, four substantial pallid bat roosts were known in Napa County, and two in southern Sonoma County. Only one of these is still occupied, and when last checked, had many fewer animals than in 1980. This decline may be due to the conversion of oak woodlands to vineyards in the Napa Valley. This species, although it will coexist with humans in rural settings, appears to be intolerant of suburban and urban development. In the San Francisco Bay area, there are museum records for pallid bats from the Stanford University campus for 1895-1951, for San Francisco in 1948-1950, and for Berkeley from 1883-1945. Available data suggest this species is extirpated from all these localities. Recent surveys of the Presidio in San Francisco found no pallid bats despite the persistence of small remnant patches of suitable oak habitat (Pierson and Rainey 1995). Although there have been numerous records of bats on the UC Berkeley campus in the past 20 years, none have been pallid bats. The species does persist in the more rural eastern portions of Alameda and Contra Costa counties, and in parts of Marin County, particularly in the vicinity of Point Reyes National Seashore and in proximity to oak woodland.

P. Brown (pers. comm.) has noted precipitous declines in populations in coastal southern California since the 1970s. Yet, at that time, only one of 12 roost sites documented by Krutzsch (1948) in the 1940s was still occupied (P. Brown pers. comm.). Destruction of buildings and urban expansion likely account for observed declines in Los Angeles, Orange, and San Diego counties.

Current timber harvest practices, particularly the selective removal of hardwoods and large Ponderosa pine snags, likely pose a serious threat to pallid bat populations in forested areas. Additionally, at lower elevations, oak habitat is being lost to suburban expansion and agricultural conversion. The rapidly growing human population of the Sierra foothills is a case in point. Because pallid bats frequently roost in buildings, they often are excluded by renovations or by the
desire of property owners to be rid of them. Because their roosting sites are often highly visible (e.g., open rafters) and the animals display considerable roost loyalty, they are often targeted by pest control operators and vandals. This species is often associated with historic buildings in which their presence is typically viewed as a hazard by property managers. Pallid bats colonies could also be impacted by bridge modifications and/or replacements, inappropriate mine/cave closures, and human induced alterations of rock features (e.g., blasting of cliffs for road construction or inundation for water impoundment).

**Management Recommendations:** Status surveys are necessary, particularly in areas where apparent declines have occurred or where habitat conversion is most intense. More information is needed on the habitat requirements of pallid bats, particularly in forested settings. Genetic studies, using non-lethal sampling techniques, should be conducted to resolve subspecies issues.
Red bat, *Lasiurus blossevillii*

*Elizabeth D. Pierson & William E. Rainey*

**Description:** *Lasiurus blossevillii* is a medium sized bat with a short rostrum, short rounded ears, and a heavily furred interfemoral membrane (Barbour and Davis 1969, Shump and Shump 1982). It can generally be distinguished by the brick-red color of its fur. The color, however, can vary from intense red to yellow-brown. It can, nevertheless, be distinguished from the other *Lasiurus* species with which it could be most readily confused based on size. *L. blossevillii* has a forearm of 35-45 mm. *Lasiurus xanthinus*, which generally has more yellow fur, is larger, with a forearm of 45-48 mm. *Lasiurus cinereus* is considerably larger, with a forearm of 46-58 mm. The pelage of *L. cinereus* is generally dark grey, with frosted white tips, a yellow face, and ears rimmed in black. Although *L. blossevillii* can appear somewhat frosted and have a yellowish tinge to its fur, it is never as dark, nor as frosted, as *L. cinereus*.

**Taxonomic Remarks:** The red bat is generally included in the genus *Lasiurus* (Family Vespertilionidae) as *L. borealis* (Koopman 1993). Hall (1981), who reverted to an earlier generic name, *Nycteris*, mapped the distribution of six subspecies, with all California animals referred to *N. borealis teliotis*. Genetic studies (Baker et al. 1988, Morales and Bickham 1995) support the separation of red bats into four separate species, with all animals in the western United States, Mexico, Central America, and South America referable to *L. blossevillii*.

**Distribution:** *L. blossevillii* has a very broad distribution reaching from southern British Columbia, through much of the western United States, through Mexico and Central America, reaching as far south in South America as Argentina and Chile (Hall 1981, Shump and Shump 1982).

In California, the majority of records are from the coastal areas from the San Francisco Bay area south, plus the Central Valley and surrounding foothills, with a limited number of records from southern California, extending as far east as western Riverside and central San Diego counties. Red bats have been captured or seen on three occasions on Santa Cruz Island (P. Brown pers. comm.). There are no records from the lower desert, from higher elevations in any of the mountain ranges, nor from the east side of the Sierra Nevada. Red bats have been captured in Nevada, however, just a mile east of California and the White Mountains (J. Szewczak pers. comm.). Currently, the most northern locality in California is from the upper Sacramento River near Dunsmuir, Siskiyou County (Rainey and Pierson 1996).

There are multiple records for red bats in the San Francisco Bay area in the spring, fall, and winter months, including records from Golden Gate Park in San Francisco (Grinnell 1918, Orr 1950, Constantine 1959). Although reproductive females and young do occur in coastal California in the summer (Constantine 1959, C. Scott and P. Winters pers. comm.), they are more likely to be located inland, particularly in the Central Valley, where they can find the desired summer temperatures of 80-95°F (Constantine 1959). Immature animals from several localities in eastern Contra Costa County have been turned in to rehabilitation facilities during June and July in recent years (C. Scott pers. comm.).

**Life History:** Reproductive patterns in red bats are summarized by Shump and Shump (1982). Whereas most vespertilionid bats have a single young per year, red bats have litters of up to five. No information is available on *L. blossevillii*, but *L. borealis* has a mean litter size of 3.2 young (Shump and Shump 1982). In the midwest, *L. borealis* are born around the middle of June. In California, two young about 2 weeks old were found in Contra Costa County on July 1 (C. Scott pers. comm.). Young are born at about 0.5 g. each, and can fly at 3-6 weeks of age. This species mates in the late
summer or early fall. Females become pregnant in spring and have a pregnancy of 80-90 days.

Red bats forage on a number of insect taxa, flying at both canopy height and low over the ground (Shump and Shump 1982). The limited dietary information has all come from *L. borealis* in the eastern U.S. No information is available on the diet of *L. blossevillii* in California. In a study conducted in Indiana, Whitaker (1972) found that red bats ate 26% moths. Other studies (summarized in Shump and Shump 1982) have also found Homoptera, Coleoptera, Hymenoptera, and Diptera in the diet.

Red bats are migratory, and there are records of them on the east coast being found a considerable distance out to sea (Norton 1921, Carter 1950). The most striking account of migration comes from Mearns (1898), who describes “great flights of them the whole day.”

**Habitat:** *L. blossevillii* roosts in the foliage of trees and shrubs, predominantly in edge habitats adjacent to streams and open fields (Shump and Shump 1982). Constantine (1959) found the species roosting in fruit trees (apricot and orange) in the Central Valley of California. An analysis of these roost sites by Constantine (1959) suggested the bats selected trees that were well-pruned and 4.5-6.0 m in height, with roost sites typically located 2.6 m above the ground. The trees had rigid branches and short stems which resisted the wind, a spreading canopy, and lacked lower limbs that might provide perches for predatory birds. The roosting site was usually dark, well sheltered from above, with open exposure for free flight below. Dalquest (1945) noted daytime roosting sites for *L. blossevillii* in tamarisk windbreaks along irrigation ditches in California’s Central Valley. Although *L. borealis* has been reported roosting in caves in Kentucky and Missouri (Quay and Miller 1955, Myers 1960), this behavior has never been seen in *L. blossevillii*.

Although they have been observed foraging around lights in urban areas (e.g., Shump and Shump 1982), Constantine (1959) found red bats primarily in areas distant from human habitation. In Canada, Furlonger et al. (1987) found they foraged around lights in towns and rural areas, more than in urban areas. The animals studied by Orr (1950) in Golden Gate Park in San Francisco were roosting in *Sparmannia africana*, a large-leafed, exotic, evergreen plant commonly planted in gardens in the Bay area. On Santa Cruz Island, red bats were observed foraging among native oaks and ironwood trees (Brown et al. 1994). Winter behavior of this species is not well understood. Saugey et al. (1994) recently documented, through a radiotracking study in Arkansas, that when temperatures dropped, some individuals moved from trees to hibernate in the leaf litter. Red bats apparently arouse from hibernation on warm days to feed (Shump and Shump 1982), and Orr’s observations suggest that this species forages periodically during the winter in the San Francisco Bay area (Orr 1950).

**Status:** Class II. The status of this species in California is not currently known, although it occurs relatively rarely in net captures, in Department of Health Services records, and at rehabilitation facilities (D. Constantine pers. comm., C. Scott pers. comm., W. Rainey and E. Pierson unpubl. records)

Given what is known of the distribution and habitat needs of this species in California, it is possible to identify a number of threats, and hypothesize population declines and extirpations in certain areas, as follows:

**Predation:** Predation, other than human disturbance, is rarely an issue for bat species which seek cryptic and protected diurnal retreats (e.g., crevices). It can, however, be a factor for the foliage dwelling lasiurines. There are a number of reports in the literature of red bats being attacked and
killed by birds, particularly jays (Allan 1947, Downing and Baldwin 1961, Wilks and Laughlin 1961, Elwell 1962, Hoffmeister and Downes 1964, Horsley 1991). There is also a record of red bats being eaten by an opossum (*Didelphis virginiana*) (Sperry 1933). Since both jays and opossums thrive as commensals with humans, it is likely that predation from these species has increased for red bats. Additionally, a significant proportion of the red bats turned in to rehabilitation facilities has been retrieved from domestic cats.

**Agricultural Conversion of Riparian Zones:** Past records have shown a close association between red bats and riparian corridors. Particularly important are those associated with the major river systems that drain the Sierra Nevada. Agricultural conversion has led to significant loss of riparian corridors in the Central Valley, and thus has reduced both roosting and foraging habitat for *L. blossevillii*.

**Storage Reservoirs:** Storage reservoirs occur on most of the major rivers draining the Sierra Nevada, and are particularly prevalent at lower elevations, at ca. 200-600 m. A significant amount of riparian vegetation has been submerged by these reservoirs. Mist netting surveys in the Los Banos Creek drainage, at the site of a proposed reservoir, documented an association between *L. blossevillii* and the large stand of mature sycamores in that drainage. Additionally, the changes in downstream flooding regimes resulting from dam construction lead to altered riparian vegetation.

**Pesticides:** Constantine (1959) documented that *L. blossevillii* roosts in fruit trees in the Central Valley. Many fruit orchards are subjected to particularly intense pesticide treatments. Although the effects of aerially sprayed organophosphates on *L. blossevillii* have not been specifically examined, documentation of negative impacts on raptors (Wilson et al. 1991) suggests potential problems for bats.

**Fire:** The finding of Saugey et al. (1994) that red bats may move down to the leaf litter when temperatures drop raises questions regarding potential impacts from fire, particularly controlled burns which are conducted in either the spring or fall.

**Management Recommendations:** Given the high association of this species with agricultural and riparian areas, a status review, particularly in the Central Valley and surrounding foothills, is urgently needed. Radiotracking should be conducted to characterize roost sites and foraging habitat. It is likely that the species would benefit from any reduction in pesticide use, and restoration of riparian habitat.
Terrestrial Mammal Species of Special Concern in California, Brylski et al. 1998

RED BAT
_Lasiurus blossevillii_

Locations verified by authors
(captures, observations, museum records)

- Post - 1978
- 1978 and before
- Constantine 1998
- No CNDDB records

1:4,880,000
Wildlife Branch KFian12169
Lepus californicus
Black-tailed Hare

Family: Leporidae (Rabbits and Hares)

Description

The black-tailed jackrabbit is usually gray to light brown in color. It is most active at night when temperatures are low. It controls its body heat by regulating blood flow to its large ears. It is a herbivore whose natural enemies include foxes, coyotes, eagles, bobcats, great horned owls, hawks, and snakes.

Black-tailed jackrabbits range in length from eighteen to twenty-five inches with the female generally larger than the male. They weigh between six and eight pounds. Black-tailed jackrabbits can reach speeds up to thirty-five miles per hour and can leap up to twenty feet.

Range and Habitat

The black-tailed jackrabbit lives in rangelands throughout the central and western United States. It can be found throughout California up to elevation above 12,000 feet in the highest mountains. It is the most common hare in California.

Natural History

The black-tailed hare lives 5-6 years. Its mating season is year-round if the quantity and quality of its food are adequate. The female's gestation period is thirty days; her litter averages between three and four young. She can bear more than one litter per year.

Conservation Status

The local subspecies of the black-tailed jackrabbit is considered a species of special concern by the California Department of Fish and Game.
California Wildlife Habitat Relationships System
California Department of Fish and Game
California Interagency Wildlife Task Group

DESERT WOODRAT
*Neo*om*a lepida*

Family: MURIDAE
Order: RODENTIA
Class: MAMMALIA

Written by: P. Brylski
Reviewed by: H. Shellhammer
Edited by: R. Duke
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DISTRIBUTION, ABUNDANCE, AND SEASONALITY

The desert woodrat occurs in California in 2 disjunct areas. It is found in northeastern California in Great Basin areas of eastern Modoc Co. to southeastern Lassen Co. Inhabits virtually all of southern California, with range extending northward along the coast to Monterey Co., and along the Coast Range to San Francisco Bay. In southeastern California, found from southern Mono Co. south throughout the Mojave Desert and from north-central Tulare Co. south through the Tehachapi and San Bernardino Mts. Common to abundant in Joshua tree, pinyon-juniper, mixed and chamise-redshank chaparral, sagebrush, and most desert habitats. Also found in a variety of other habitats. Most abundant in rocky areas with Joshua trees. Elevational range from sea level to 2600 m (8500 ft). Northern and elevational distribution may be limited by temperature (Lee 1963, MacMillen 1964).

SPECIFIC HABITAT REQUIREMENTS

Feeding: Eats buds, fruits, seeds, bark, leaves, and young shoots of many plant species. In coastal scrub, prefers live oak, chamise, and buckwheat as food plants (Meserve 1974). Creosote, cholla, and prickly-pear are eaten in the Mojave Desert (MacMillen 1964, Cameron and Rainey 1972). In juniper/sagebrush habitats, ate Mormon-tea, rattlesnake weed, mustard, sagebrush, and buckwheat (Stones and Hayward 1968).

Cover: Houses are constructed with twigs, sticks, cactus parts, rocks, depending on availability of building materials. The house usually is built against a rock crevice, at the base of creosote or cactus, or in the lower branches of trees. Rock crevices appear preferred where available, but woodrats generally adapt to virtually any situation. Houses are used for nesting, food caching, and predator escape.

Reproduction: Nests of dried vegetation, usually fibrous grass parts or shredded stems, are located within the stick house. Suitable nesting sites or nesting materials may limit distribution.

Water: Largely dependent upon prickly pear for water balance in desert habitats, although can be sustained on creosote year-round (Lee 1963, MacMillen 1964).

Pattern: Moderate to dense canopies preferred. Desert woodrats are particularly abundant in rock outcrops and rocky cliffs and slopes (Hall 1946, Miller and Stebbins 1964).

SPECIES LIFE HISTORY

Activity Patterns: Active yearlong. Mainly nocturnal, but also crepuscular and occasionally diurnal (Stones and Hayward 1968, Miller and Stebbins 1964).
Seasonal Movements/Migration: None.

Home Range: In coastal sage scrub, home range was about 0.04 to 0.2 ha (0.10 to 0.5 ac) (MacMillen 1964, Bleich and Schwartz 1975). Average linear movements in same habitat were about 14 m (46 ft)/night. In sagebrush-juniper habitat, males moved 80 m (262 ft)/night, and females 45 m (147 ft) (Stones and Hayward 1968). In coastal sage habitat, density averaged 3.5 to 12.3/ha (1.4 to 4.9/ac) in one study (MacMillen 1964) and 30/ha (12/ac) in another (Bleich and Schwartz 1975). In jumping cholla cactus habitat, density averaged 38/ha (15/ac) (Brown et al. 1972). In sagebrush-juniper habitat densities averaged 2.8/ha (1.1/ac) (Stones and Hayward 1968).

Territory: Aggressively solitary. Territory probably equals home range. Woodrats may defend succulent plants (water sources) against other species, and perhaps prevent other species from obtaining water during droughts (MacMillen 1964).


Niche: The desert woodrat is a moderate-sized folivore/granivore. Competitors include cricetid and heteromyid rodents. Woodrat houses provide shelter for a variety of small vertebrates. Predators include snakes, owls, and predatory mammals. This woodrat is commonly parasitized by bot fly larvae.

REFERENCES


San Joaquin kit fox  *Vulpes macrotis mutica*

**State:** Threatened  1971  
**Federal:** Endangered  1967

**General Habitat:**
Kit foxes occur in the remaining native valley and foothill grasslands and chenopod scrub communities of the valley floor and surrounding foothills from southern Kern County north to Los Baños, Merced County. In addition, smaller, less dense populations are thought to exist further north and in the narrow corridor between Interstate 5 and the Interior Coast Range from Los Baños to Alameda and Contra Costa Counties. Portions of Monterey, Santa Clara, San Benito, San Luis Obispo, and Santa Barbara counties are also included in the range of the San Joaquin kit fox.

**Description:**
The kit fox (*Vulpes macrotis*) is the smallest canid species in North America. San Joaquin kit foxes have an average body length of 20 inches, an average tail length of 12 inches and stand about nine to 12 inches at the shoulder. These slender-built mammals are characterized by relatively long legs and large, conspicuous ears. Adult males weigh about five pounds, and adult females weigh about 4.6 pounds.

**Status:**
Currently, kit foxes occur in the remaining native valley and foothill grasslands and chenopod scrub communities of the valley floor and surrounding foothills from southern Kern County north to Los Baños, Merced County. Distribution is spotty within this broad range. In addition, smaller, less dense populations are thought to exist further north and in the narrow corridor between Interstate 5 and the Interior Coast Range from Los Baños to Contra Costa County. Portions of Monterey, Santa Clara, San Benito, San Luis Obispo, and Santa Barbara counties are also included in the range of the San Joaquin kit fox. Studies and information from various sources indicate that a density of one kit fox per square mile in suitable habitat is a reasonable figure to use to estimate
populations based on known acreage of habitat, although densities can range from less than one to over six foxes per square mile.

Loss of native habitat to various kinds of agriculture (e.g., cotton fields and vineyards), and residential and commercial developments remain the principal threats to this species. Several research projects funded by the DFG and studies by cooperators, begun in the mid-1990s and continuing to the present, are yielding more information about the habitat needs and biology of the kit fox. The recovery actions recommended for the kit fox are contained in the USFWS Recovery Plan for Upland Species of the San Joaquin Valley, California, which was completed in 1998. The kit fox is described as a keystone species (i.e., a species essential to the health of the natural community), and efforts to save habitat for this species will result in benefits to other endangered plant and animal populations.

Long-term ecological studies at the Elk Hills Naval Petroleum Reserve in western Kern County terminated several years ago following the sale of the Reserve to private interests in the late 1990's. However, the landmark research that was conducted over a period of more than a decade is currently being published in a number of journal articles and will make valuable contributions to our understanding of the biology, ecology, and management of the species and its recovery. Considerable research activity has been initiated or continued for the kit fox in recent years. One study, started in 1997, examines the special case of the kit fox in the urban environment. Kit foxes have been captured, radio-collared and their movements monitored within the city of Bakersfield, Kern County. This field phases of this investigation of the demography and ecology of San Joaquin kit foxes in urban environments will continue through June 2004, and then data analyses and report and manuscript preparation will be conducted. Preliminary results have indicated that urban kit fox populations exhibit favorable demographic patterns, and that conservation of these populations could contribute to overall recovery efforts. The DFG has contributed funding, derived from federal sources, and support for this project.

Other studies on the San Joaquin kit fox include:

- An investigation of the effects of two-lane highways on San Joaquin kit foxes was initiated in 2001 and data collection will continue through June 2004. Results from this investigation will be used to develop strategies to mitigate road effects on kit foxes. Kit foxes are impacted by highways through direct road killing mortalities as well as indirectly through habitat loss and fragmentation effects.

- A study of the effects of livestock grazing and agricultural burning, as well as other farmland and ranchland activities on competitive interactions between San Joaquin kit foxes and coyotes was initiated in January 2003 and data collection will continue through June 2004. Results from this investigation will assist in developing habitat management strategies that may benefit kit foxes on these private lands.

- Research on the use of artificial den structures by San Joaquin kit foxes was initiated in May 2001 and data collection will continue through June 2004. Results from this investigation will be used to develop strategies to mitigate den loss and also to enhance den availability in areas where natural dens are a limiting factor for kit foxes. Escape dens help kit foxes avoid predation by coyotes and may provide secure sites for pup rearing.

- An investigation of strategies to facilitate survival of kit foxes crossing agricultural lands was initiated in 2001. This project is on-going, and represents a new approach to kit fox conservation in that it involves the establishment of a Safe Harbor Agreement with Paramount Farms. The DFG has contributed funding, derived from federal sources, for this effort.

- An investigation was completed in January 2003 on the efficacy of using search dogs and fecal DNA analyses as a non-invasive strategy for collecting demographic and ecological data on San Joaquin kit foxes. A doctoral dissertation and several manuscripts are being prepared that report the results of this effort. The technique proved to be useful where specially trained searchers were employed. Research confirmed Numerous locations throughout the historic range of San Joaquin kit foxes confirmed that
populations still exist in western Kern County and the Carrizo Plain National Monument and along the west side of the San Joaquin Valley north to Santa Nella. Despite the extensive search effort, no kit fox sign was found along the west side from Santa Nella to Contra Costa County, or in Valley floor locations north of Kern County. One kit fox was observed in eastern Merced County.

Various other studies have been conducted with San Joaquin kit foxes to examine social ecology and range-wide genetic exchange, kit fox-red fox interactions, and kit fox use of agricultural lands. Several manuscripts for scientific journal publications and technical reports for these past and ongoing studies have been produced.

Protection for the kit fox is addressed in several conservation plans. Some examples of these plans include the Kern County Valley Floor and Waste Facilities HCPs, Kern Water Bank HCP, Metropolitan Bakersfield HCP, and the PG&E San Joaquin Valley HCP. Despite these efforts, and other conservation efforts, San Joaquin kit foxes continue to decline throughout their range and are close to extinction in the northern most part of the range in Contra Costa and Alameda counties.

The status in 2003 of the San Joaquin kit fox: Declining.
Big free-tailed bat
*Nyctinomops macrotis*

Identifying Characteristics: *Nyctinomops macrotis* can be distinguished from other molossids (free-tailed bats) based on size. With an adult forearm of 58-64 mm it is larger than *T. brasiliensis* or *N. femorosacca*, and smaller than *Eumops perotis*. Also, it has vertical grooves or wrinkles on the upper lip, which are lacking in *Eumops*.

Current Geographic Range: *N. macrotis* ranges from most of South America northward to include Mexico, Arizona, New Mexico, southern and western Texas, southern California and southeastern Nevada, southern Utah, and north to central Colorado. The species is migratory, and there are some extralimital records from British Columbia, Iowa, Kansas, and South Carolina. The known elevational range is from near sea level to about 8,500 ft. *N. macrotis* appears to be mainly an inhabitant of rugged, rocky habitats in arid landscapes. It has been found in a variety of plant associations, including desert shrub, woodlands, and evergreen forests. It appears to be associated with lowlands, but has been documented up to 8,000 ft.

Life History: This species is a seasonal migrant, and a powerful flyer. The species forms maternity colonies, and females bear one young in late spring or early summer. Lactating females have been taken in July, August and September, and volant juveniles recorded in August. Maternity roosts have been documented in rock crevices, with evidence of long term use. It appears that the return to the roost site by this bat involves ritualized behavior, including a general reconnaissance of the site and several landing trials before entry. Owls are the only documented predators of this species. *N. macrotis* has an audible echolocation call, which is characterized as loud. Little is known about the species population dynamics and ecology.

Big free-tailed bats roost mainly in crevices and rocks in cliff situations, although there is some documentation of roosts in buildings, caves, and tree cavities. *N. macrotis* forages almost entirely on large moths, but some data exist to document occasional foraging on other insects, including grasshoppers, beetles, crickets, leafhoppers and flying ants.

Threats: No known threats to the species have been identified to date. However, some of the general threats to bats could apply, including impacts to foraging areas from grazing, riparian management, the use of pesticides, and in some places disturbance to the roost site (e.g. water impoundments).
Fringed myotis
Myotis thysanodes

Identifying Characteristics: The fringed myotis is distinguished by its relatively long ears and a conspicuous fringe of stiff hairs on the trailing edge of the uropatagium. The pelage varies in color from pale to rich brownish, individual hairs being lead-gray at their bases. Total length of five individuals from northwestern Colorado averaged 86.8 mm; length of forearm averaged 40.1 mm; and weight averaged 7.5 g. The wingspan is 265-300 mm. The ears are 17-20 mm long on the fringed myotis.

General Habitat Characteristics: Typical vegetation of the habitat includes ponderosa pine, pi-on, juniper, greasewood, saltbush and scrub oak. The animals roost in rock crevices, caves, mines, buildings and trees. Where this species has been studied well, migration seems not to be extensive. The fringed myotis feeds on such arthropods as moths, daddy longlegs and beetles. They forage along water, above shrubs and woodlands or low over meadows, emerging to feed about two hours after sunset.

Current Geographic Range: This is a western species, ranging from the Isthmus of Tehuantepec in Mexico north to British Columbia, Montana and Wyoming. The animals apparently occur as scattered populations at moderate elevations on the Western Slope, along the foothills of the Front Range and the mesas of southeastern Colorado. Max. elevation is 7,500 feet.

Life History: Breeding takes place in fall; ovulation, fertilization, implantation and gestation occur in spring. Up to several hundred females congregate in nursery colonies. Males are solitary while the young are reared. In a typical season, all mature females breed. The single young is produced after a gestation of 50 - 60 days. Newborn young are hairless and pinkish, and their eyes are closed. Growth is rapid, however, and they can fly by 20 days old. Maximum known longevity is 11 years, although the average lifespan is much shorter.

Source: Colorado Division of Wildlife
<llink>http://wildlife.state.co.us/WildlifeSpecies/Profiles/Mammals/BatsofColorado/FringedMyotis.htm</llink>
Pallid Bat
Antrozous pallidus

- **Identifying Characteristics:** Pallid bats are medium-sized (total body length 92-135 mm) and often feed on the ground early in the night. They can run on folded wings and hind feet; they can hop around to catch insects. They then retire to night roosts where they hang out to digest their catch (Jerusalem crickets, scorpions, grasshoppers, beetles, etc.). They may feed again near dawn. By daylight, they retire to "day roosts" in rock crevices where they hide.

- **General Habitat Characteristics:** Pallid bats have great ears, and can also see pretty well. Pallid bats are generally found in grasslands and desert habitats. Colonies or parts of colonies with only females ("maternity roosts") gather in rock crevices and old buildings, starting in April.

- Females often have two young each year and nurse them for 6-8 weeks. Females breed in the summer after they are born. Adults probably hibernate over much of range.

- **Current Geographic Range:** Pallid bats occur from British Columbia to west TX and south to Baja and Central Mexico. Pallid bats are known from Pinnacles, Hastings and Santa Lucia Preserve.

- **Life History:** Populations can be non-migratory and are known to winter in places from CA to KS. Mating occurs in Oct, and like other bats, sperm and egg don’t meet until spring. Gestation takes about 9 weeks, with young born in spring.
Western red bat
Lasiurus blossevillii

Identifying Characteristics: Lasiurus blossevillii can be distinguished from all other western bat species except the eastern red bat by its distinctive red coloration, and can be distinguished from L. borealis by its slightly smaller size and lack of frosted appearance.

Life History and General Habitat Characteristics: Western red bats mate in late summer or early fall. Females become pregnant in spring and have a pregnancy of 80-90 days. Females may have litters of up to five pups per year. This species is considered to be highly migratory. Although generally solitary, western red bats appear to migrate in groups and forage in close association with one another in summer. The eastern red bat has been found hibernating in leaf-litter. Predators reported for L. blossevillii include birds (e.g., scrub jays, falcons, accipiters, owls, roadrunners), opossums, and domestic cats.

L. blossevillii is typically solitary, roosting primarily in the foliage of trees or shrubs. Day roosts are commonly in edge habitats adjacent to streams or open fields, in orchards, and sometimes in urban areas. There may be an association with intact riparian habitat (particularly willows, cottonwoods, and sycamores).

Roost sites are generally hidden from view from all directions except below; lack obstruction beneath, allowing the bat to drop downward for flight; have dark ground cover to minimize solar reflection; have nearby vegetation to reduce wind and dust; and are generally located on the south or southwest side of a tree. L. blossevillii may occasionally use caves.

Western red bats generally begin to forage one to two hours after sunset. Most typically have an initial foraging period corresponding to the early period of nocturnal insect activity, and a minor secondary activity period corresponding to insects that become active several hours before sunrise. Reported prey items include homopterans, coleopterans, hymenopterans, dipterans, and lepidopterans.

Current Geographic Range: L. blossevillii has a broad distribution reaching from southern British Columbia in Canada, through much of the western United States, through Mexico and Central America, to Argentina and Chile in South America.

Threats: Loss of riparian zones, primarily due to agricultural conversion and creation of water storage reservoirs has reduced both small red bat roosting and foraging habitat of red bats. The intensive use of pesticides in fruit orchards may constitute a threat to roosting bats and may significantly reduce the amount of insect prey available. Controlled burns may be another significant mortality factor for red bats that roost in leaf litter during cool temperatures.
San Diego Desert Woodrat
Neotoma lepida intermedia

General Habitat Characteristics: Eats buds, fruits, seeds, bark, leaves, and young shoots of many plant species. In coastal scrub, prefers live oak, chamise, and buckwheat as food plants. Creosote, cholla, and prickly-pear are eaten in the Mojave Desert. In juniper/sagebrush habitats, ate Mormon-tea, rattlesnake weed, mustard, sagebrush, and buckwheat.

Houses are constructed with twigs, sticks, cactus parts, rocks, depending on availability of building materials. The house usually is built against a rock crevice, at the base of creosote or cactus, or in the lower branches of trees. Rock crevices appear preferred where available. Houses are used for nesting, food caching, and predator escape. Nests of dried vegetation, usually fibrous grass parts or shredded stems, are located within the stick house. Suitable nesting sites or nesting materials may limit distribution. Moderate to dense canopies preferred. Desert woodrats are particularly abundant in rock outcrops and rocky cliffs and slopes.

Current Geographic Range: In southeastern California, found from southern Mono Co. south throughout the Mojave Desert and from north-central Tulare Co. south through the Tehachapi and San Bernardino Mts. Common to abundant in Joshua tree, pinyon-juniper, mixed and chamise-redshank chaparral, sagebrush, and most desert habitats. Also found in a variety of other habitats. Most abundant in rocky areas with Joshua trees. Elevations range from 0 to 2600 m.

Life History: Active yearlong. Mainly nocturnal, but also crepuscular and occasionally diurnal. No seasonal movements/migration. In coastal sage scrub, home range was about 0.10 to 0.5 ac. In coastal sage habitat, density averaged 1.4 to 4.9/ac in one study and 12/ac in another. Aggressively solitary. Woodrats may defend succulent plants (water sources) against other species.

Breeds from October to May, depending on the habitat. Nesting is solitary. Gestation period is 30-36 days. Litter size 1-5. Predators include snakes, owls, and predatory mammals. This woodrat is commonly parasitized by bot fly larvae.

Photo Credit: L. Indges, California Academy of Science.

Identifying Characteristics:
Desert woodrats are 22-38 cm long with a 9.5-18 cm long tail. They weigh 109-136 g. They have a compact body, lengthy long-haired tail, large ears, and large, slightly bulging, black eyes. Their feet are strongly built for grasping. Desert woodrats are a pale to dark gray washed with yellow above, light undersides, grayish to yellowish below, and gray at the base of the throat region. Hair bases are slate gray. Their tail, over half of the body length, is distinctively bicolored. Their hind feet are white.
Western Mastiff Bat
Eumops parotis

Identifying Characteristics:
Largest bat in the U.S., with long, narrow wings. About half of the tail is free from the membrane between hind legs. Large ears join at the midline in front. Ears nearly cover the eyes and if laid forward, extend beyond the nose. Mastiff bat fur is bicolored - white at the base and gray or brownish gray at tips.

General Habitat Characteristics: Roost require vertical entry (overhangs) and bats need to drop 10-20 feet to launch into flight. Emit highpitched piercing cry every 2-3 seconds that can be heard by humans for 1,000 feet.

Current Geographic Range: Three widely separated populations occur in the world - Argentina to Brazil, Cuba, and southwest U.S. Permanent residents, prefers rugged canyons, cliffs and rock walls of arid habitats.

Life History: Groups of 2-3 to maybe 100, they retreat into deep, narrow rock crevices. Will roost in buildings. Fly during hot days, and active most nights. Young (usually 1 per female) born in spring. Males and females together year-round. Fly up to several thousand feet in altitude, taking many small insects. Enter daily torpor in Dec, Jan, and Feb. Active year round, less so in winter. Throat gland secretes overpowering odor in breeding season, stong odor at other times. Only known at Pinnacles National Monument in Monterey County area.
Townsend’s Big-eared Bat
*(Corynorhinus townsendii)*:
A Technical Conservation Assessment

Prepared for the USDA Forest Service,
Rocky Mountain Region,
Species Conservation Project

October 25, 2006

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COVER ILLUSTRATION CREDIT

Townsend’s big-eared bat (*Corynorhinus townsendii*) in flight (© R. Smith). Original artwork by R. Smith. Used with permission.
SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF TOWNSEND’S BIG-EARED BAT

There is general concurrence among bat biologists that there has been a downward trend in abundance of Townsend’s big-eared bat (Corynorhinus townsendii) in the western portion of its range over the past half-century. Western populations, which are the focus of this assessment, do not enjoy federal legislation protecting either them or their habitat. Various regional, state, and private organizations consider Townsend’s big-eared bat to be vulnerable to extirpation due to: 1) apparent rarity and long-term decline in numbers; 2) narrow roosting requirements; 3) loss, modification, and disturbance of roosting habitat; and 4) general lack of information regarding the species.

The likelihood of long-term persistence of Townsend’s big-eared bat in Region 2 and elsewhere can be enhanced by actions that address the primary threats to the species (listed below). Though we summarize the threats below in order of priority, it should be recognized that the best results will come from concurrently addressing these threats when crafting and implementing management plans.

- **Loss, modification, and disturbance of roosting habitat resulting from:**
  - **Uninformed closure of abandoned mines:** This is probably the most egregious act regularly performed by management agencies with respect to cavernicolous species of bats in general and Townsend’s big-eared bat specifically. At a minimum, closure of historic or abandoned mines eliminates potential roosting habitat for Townsend’s big-eared bat. In the worst case scenario, bats using a mine when it is closed have little chance of escape, resulting in both loss of habitat and direct loss of bats.
  - **Recreation:** Human activity at roosts, particularly recreational exploration of caves and mine interiors, may lead to abandonment of the roost or unnecessary expenditure of crucial energy reserves. Like other bats, Townsend’s big-eared bat is particularly sensitive to variations in survival and reproductive output. Therefore, human activity in and near roosts must be curbed, especially during reproductive and hibernal periods.
  - **Renewed mining at historical sites:** An increase in renewed mining can directly impact Townsend’s big-eared bats using abandoned mines in two ways:
    - by disturbing and displacing bats that may have been using a mine
    - by eliminating potential roosting habitat.
  
  Furthermore, renewed mining can liberate heavy metals and other toxic materials, leading to contaminated water impoundments. In either case, with its close association to abandoned mines and reliance on open water for drinking, Townsend’s big-eared bat may be more susceptible to ingestion of toxins following renewed mining at historical sites.

- **Loss, modification, and disturbance of foraging habitat resulting from:**
  - **Elimination of forest canopy:** Although Townsend’s big-eared bat forages in a variety of habitat types, its flight and echolocation style makes it well suited to forage among the canopies and along the edges of mature forested stands. This species typically does not use large clear-cuts or regenerating stands in early seral stages.
  - **Elimination or alteration of wetland habitat:** Forest wetlands represent abundant sources of insect prey and fresh water for drinking. Activities that reduce the productivity of wetlands likely impact local populations of Townsend’s big-eared bat by reducing the quality of important foraging and drinking sites. Activities that alter the surface and subsurface hydrology of wetlands, including draining, stream diversion, and removal of shrub and overstory vegetation (e.g., through logging or grazing), ultimately reduce the value of wetlands to this species. As well, activities that increase sediment loads into wetlands (e.g., logging, grazing, road construction, mining) likely alter wetland soil and water chemistry and thus have potential to decrease the value of the wetland to Townsend’s big-eared bats.
  - **Conversion of native shrub and grasslands to urban or agricultural uses:** Encroachment of urban development and agriculture into areas of native vegetation likely alters the composition and abundance of insect prey in an area, and may affect the ability of Townsend’s big-eared bat to find adequate prey. Encroachment may also disturb roosts by increasing the rate of human visitation, and increasing predation pressure from cats and other generalist predators associated with human settlement.
Exposure to environmental toxins: Pesticides and heavy metals, if ingested by bats, can cause death or reduce reproductive ability. Pesticide application can indirectly affect bats via reduction of insect prey. Accumulation of pesticides and their residues in fat and brain tissue of bats may represent under-appreciated sources of mortality and loss of reproductive output. In addition, when bats drink from water impoundments produced by industrial or mining activities, they risk ingesting toxins and heavy metals, which may result in mortality of the bats.

To insure the long-term persistence of Townsend’s big-eared bat in Region 2, the following conservation elements should be employed to address the noted threats, as discussed in the body of this assessment:

Institution of long-term education program: As with other species of bats, Townsend’s big-eared bat is often the victim of accidental or deliberate destruction, both to individual colonies and to their habitat. In part, this may result from commonly held misconceptions about bats and the lack of understanding by the public of the benefits that bats provide. Therefore, conveying the positive benefits of bats and dispelling baseless myths about them form the base for a strong management-oriented conservation program for this species.

Protection of known roosting sites: Townsend’s big-eared bats are extremely sensitive to disturbance at roosts sites, particularly during the reproductive season and during hibernation. Disturbances during these times likely contribute to reduced reproductive output. Populations are especially susceptible to variations in survival and reproductive output. Therefore, human activity in and near roosts must be minimized or eliminated, especially during reproductive and hibernal periods.

Assessment of patterns of roost use and movement: Townsend’s big-eared bat is often assumed to exhibit a high degree of roost-site fidelity. Although certain types of colonies may show high fidelity to roosts (e.g., maternity colonies in caves), others may not (e.g., hibernation colonies in mines). A better understanding of patterns of roost use and fidelity is necessary to adequately protect roosting habitat through time and to adequately assess population trends.

Timber harvest regimes, prescribed burns, and other vegetation management actions should strive to maintain a mosaic of mature forest canopy that can be perpetuated through time.

Elimination of exposure to toxins: Chronic exposure to pesticides and mining-related contaminants have probable but hard to quantify effects on Townsend’s big-eared bat and other species of bats. Efforts to remediate indirect sources of exposure to toxins and eliminate direct exposure will benefit this and other species of wildlife.

Monitoring of populations: To effectively assess the population status of and quantify the effectiveness of conservation practices on Townsend’s big-eared bat, systematic monitoring of known colonies must be initiated and conducted at local and regional scales.
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INTRODUCTION

This conservation assessment is one of many being produced for the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). Townsend’s big-eared bat (Corynorhinus townsendii) is the focus of an assessment because it is a sensitive species within Region 2. Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or in habitat capability that would reduce the species’ distribution [FSM 2670.5 (19)]. A sensitive species may require special management, so knowledge of its biology and ecology is crucial. This assessment addresses the biology, conservation status, and management of Townsend’s big-eared bat throughout its range, but with an emphasis on Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal of Assessment

Species conservation assessments produced as part of the Species Conservation Project are designed to provide land managers, biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species, based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to prescribe management. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed elsewhere and examines management that has been implemented.

Scope and Limitations of Assessment

This assessment examines the biology, ecology, conservation status, and management of Townsend’s big-eared bat with specific reference to the geographic and ecological characteristics of USFS Region 2. Although much of the literature on the species synthesized herein may originate from field investigations outside the region, this document places that literature in the ecological and social contexts of the central Rocky Mountains.

Townsend’s big-eared bat comprises five recognized subspecies in the United States. Generally, three of the subspecies (Corynorhinus townsendii australis, C. townsendii pallescens, and C. townsendii townsendii) maintain a western distribution while the other two subspecies (C. townsendii ingens and C. townsendii virginianus) sustain isolated populations in the eastern portion of the continent. The focus of this assessment is on the western group, as neither member of the eastern portion occurs in Region 2. Throughout this document, we may refer to these subspecies groupings as the western group and the eastern group, or generically as Townsend’s big-eared bats. Further, because of taxonomic uncertainty and morphological and ecological similarities within the western group, we refer simply to these bats as C. townsendii.

In producing the assessment, we reviewed refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies. Not all publications on Corynorhinus townsendii are referenced in the assessment, nor were all published materials considered equally reliable. The assessment emphasizes refereed literature because this is the accepted standard in science. Non-refereed publications and reports were incorporated when refereed information was otherwise unavailable. Additionally, assessing the efficacy of current management and conservation strategies for C. townsendii must remain speculative until data are available across broad spatial and temporal scales.

Treatment of Uncertainty

To foster an understanding of the conservation needs for Corynorhinus townsendii, this assessment develops a general depiction of the biology and requirements of the species, the information for which has been gleaned from a number of sources, some more reliable than others. Yet even the most reliable sources – those that withstood the scrutiny of peer evaluation – must not be considered infallible. Science progresses most surely when competing ideas about how the world works are measured against observations within an experimental framework that permits isolation of sources of variation (e.g., Hilborn and Mangel 1997). However, studies conducted on free-ranging animals, particularly those that are cryptic and capable of landscape-scale movements (e.g., bats) often are not tractable within an experimental framework. These types of studies, therefore, often rely on alternative approaches that, while useful, tend to limit the applicability of the results to the specific time and place in which the study occurred.
For species such as *Corynorhinus townsendii* that are generally rare and very patchy in distribution, these difficulties are magnified, and most research on the species has been qualitative and descriptive in nature. In this assessment, the strength of evidence for particular ideas is noted, and when appropriate, alternative explanations are described. While well-executed experiments represent a strong approach to developing knowledge, alternative approaches such as modeling, critical assessment of observations, and inference are accepted as sound approaches to understanding features of biology.

**Publication of Assessment on the World Wide Web**

To facilitate their use, species conservation assessments are being published on the Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, it facilitates revision or updating of the assessments, which will be accomplished based on protocols established by Region 2.

**Peer Review**

In keeping with the standards of scientific publication, assessments developed for the Species Conservation Project have been externally peer reviewed prior to their release on the Web. This assessment was reviewed through a process administered by the Society for Conservation Biology, which chose two recognized experts (on this or related taxa) to provide critical input on the manuscript.

### Table 1. Current federal and state status and Natural Heritage Program rankings of Townsend’s big-eared bat (*Corynorhinus townsendii*) in USDA Forest Service Region 2. See Appendix A for description of Rank codes.

<table>
<thead>
<tr>
<th>Species or Subspecies</th>
<th>Global/National Rank</th>
<th>Colorado</th>
<th>Kansas</th>
<th>Nebraska</th>
<th>South Dakota</th>
<th>Wyoming</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. townsendii</em></td>
<td>G4 / N4, N2N3</td>
<td>S&lt;sup&gt;2&lt;/sup&gt;&lt;sup&gt;b&lt;/sup&gt;</td>
<td>S&lt;sup&gt;2&lt;/sup&gt;&lt;sup&gt;b&lt;/sup&gt;</td>
<td>S&lt;sup&gt;1&lt;/sup&gt;&lt;sup&gt;b&lt;/sup&gt;</td>
<td>S2S3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>S1B&lt;sup&gt;b&lt;/sup&gt;, S2N&lt;sup&gt;b&lt;/sup&gt;, NSS2&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td><em>C. t. ingens</em></td>
<td>Endangered</td>
<td>G4T1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><em>C. t. virginianus</em></td>
<td>Endangered</td>
<td>G4T2</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><em>C. t. pallescens</em></td>
<td>SPOC&lt;sup&gt;a&lt;/sup&gt;</td>
<td>G4T4</td>
<td>S&lt;sup&gt;2&lt;/sup&gt;&lt;sup&gt;c&lt;/sup&gt;, SC&lt;sup&gt;c&lt;/sup&gt;</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><em>C. t. townsendii</em></td>
<td>SPOC&lt;sup&gt;a&lt;/sup&gt;</td>
<td>G4T3T4</td>
<td>—</td>
<td>—</td>
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</table>

<sup>a</sup>SPOC = Species of Concern (former USFWS C2 species)

<sup>b</sup>Indicates Natural Heritage Program Rank

<sup>c</sup>Indicates Fish and Wildlife Program Rank. SC = Species of Concern (non-statutory category); NSS2 = (Native Species Status 2): Species in which: populations are declining, extirpation appears possible; habitat is restricted or vulnerable but no recent or on-going significant loss; species may be sensitive to human disturbance, OR; populations are declining or restricted in numbers and/or distribution, extirpation is not imminent; ongoing significant loss of habitat.” (Wyoming Game and Fish Department 2005).

---

**MANAGEMENT STATUS AND NATURAL HISTORY**

**Management Status**

Western populations of Townsend’s big-eared bat (*Corynorhinus townsendii* pallescens and *C. townsendii townsendii*) are not currently listed under Federal Endangered Species legislation. However, they were formerly Candidate 2 (C2) species under the Endangered Species Act (U.S. Fish and Wildlife Service 1994) and are now considered a Species of Concern (non-statutory ranking) by the U.S. Fish and Wildlife Service (USFWS; Table 1). The USFWS has listed two eastern subspecies (*C. townsendii ingens* and *C. townsendii virginianus*) as endangered since 1979 (U.S. Fish and Wildlife Service 1979).

Bureau of Land Management

The Bureau of Land Management in Colorado and Wyoming consider *Corynorhinus townsendii* a sensitive species, defined as: (1) a species under status review by the USFWS/National Marine and Fisheries Service (NMFS); or (2) a species whose numbers are declining so rapidly that federal listing may become necessary; or (3) a species with typically small or widely dispersed populations; or (4) a species that inhabits ecological refugia or other specialized or unique habitats. (Bureau of Land Management Colorado 2000, Bureau of Land Management Wyoming 2001).

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<sup>1</sup>Refer to Appendix A for detailed descriptions of Management Status Abbreviations used in this section.
USDA Forest Service

Region 2 of the USFS ranks *Corynorhinus townsendii* as a sensitive species. Within the USFS, sensitive species are: “those plant and animal species identified by the Regional Forester for which population viability is a concern as evidenced by: a) significant current or predicated downward trends in population numbers or density, or b) significant current or predicated downward trends in habitat capability that would reduce a species’ existing distribution” (USDA Forest Service 1994).

State Wildlife Agencies

The Wyoming Game and Fish Department manages *Corynorhinus townsendii* Native Species Status 2 (NSS2). This designation is given to species for which either: “populations are declining, extirpation appears possible; habitat is restricted or vulnerable but no recent or on-going significant loss; species may be sensitive to human disturbance, or populations are declining or restricted in numbers and/or distribution, extirpation is not imminent; ongoing significant loss of habitat.” (Wyoming Game and Fish Department 2005). Wyoming also includes Townsend’s big-eared bat as a Species of Greatest Conservation Need in their Comprehensive Wildlife Conservation Strategy (Wyoming Game and Fish Department 2005).

Colorado and South Dakota consider Townsend’s big-eared bat a Species of Concern. Although this designation carries no statutory authority, bats in both states are listed as nongame species and as such are protected from unlawful take or possession (Colorado Revised Statutes §33-2-104; South Dakota Codified Laws §34A-8-6). In addition, Kansas and Nebraska consider *Corynorhinus townsendii* to be a nongame Species in Need of Conservation (Kansas Administrative Regulation §115-15-2; Nebraska Administrative Code §163-4-010). This designation is functionally equivalent to other state’s Species of Concern category. Species in Need of Conservation are not considered threatened or endangered and thus do not receive legal protection. However, they are protected from take or possession without permit (Kansas Administrative Regulation §115-15-2; Nebraska Administrative Code §163-4-010).

Natural Heritage Ranks

NatureServe, the association of Natural Heritage organizations, ranks species’ status across their global (G ranks) and National (N ranks) ranges. The two western subspecies are regarded as G4 taxon, indicating that they are “apparently secure, although the species may be quite rare in parts of its range, especially at the periphery” (Keinath et al. 2003). Nationally, Townsend’s big-eared bat is considered an N4 species in the United States and an N2N3 species in Canada (Figure 1).

In addition to Global and National Ranks, each state or province ranks a species’ status within its own geopolitical boundaries (referred to as S rank). Within USFS Region 2, state heritage ranks for *Corynorhinus townsendii* include S1 (“Critically Imperiled”) in Nebraska and Wyoming, S2 (“Imperiled”) in Colorado and Kansas, and S2S3 (“Imperiled/Vulnerable”) in South Dakota (Table 1; see Table A1c for detailed descriptions of S ranks).

Western Bat Working Group

The Western Bat Working Group (WBWG) considers Townsend’s big-eared bat a High Risk species throughout its range. A High Risk species, according to WBWG, is one that “should be considered the highest priority for funding, planning, and conservation actions” because “based on available information on distribution, status, ecology, and known threats, these species are imperiled or are at high risk of imperilment” (WBWG web page; http://www.wbwg.org/spp_matrix.html).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Regulatory mechanisms

To our knowledge, there are currently no federal or state regulatory mechanisms in place in Region 2 or elsewhere to provide specific statutory protection to the western subspecies of *Corynorhinus townsendii* or its habitat. However, cave and mine roosting habitat may be protected through one of several existing laws or regulations. A particularly useful resource for cave management on federal lands is available from the Umpqua National Forest (2004). This handbook outlines federal laws and USFS regulations pertaining to conservation and management of caves on federal lands. Among the laws and regulations are the Federal Cave Resources Protection Act (FCRPA), the Organic Administration Act, the Antiquities Act of 1906, and the Archeological Resources Protection Act (ARPA).

Seasonal or permanent restrictions issued under Subpart B Orders, which are issued under authority of Section 16 of the United States Code (U.S.C.), may
protect roosting habitat in mines. In addition, the ARPA may be a vehicle for the protection of mines, provided that the mine is at least 100 years old and has some archeological importance. We discuss each act and its potential uses in the Tools and practices section below.

Management plans

There are no specific strategies at the federal level for conservation of Townsend’s big-eared bats in the West. However, because of the similarity in biology and ecology between the eastern and western subspecies, and because the effectiveness of management plans for eastern subspecies may suggest how similar actions would fare in the West, we briefly discuss the objectives set out for recovery of the eastern subspecies, and whether they have been effective.

The USFWS has listed the two eastern subspecies of Corynorhinus townsendii as endangered since 1979 (U.S. Fish and Wildlife Service 1979). The principal tenets of the recovery plan for both the Ozark and Virginia big-eared bats (C. townsendii ingens and C. townsendii virginianus, respectively) are to:

- obtain and/or maintain management authority of caves within the range
census and monitor all known maternity colonies and hibernacula

- identify additional maternity colonies and hibernacula

- protect roosts from disturbance and destruction, and protect essential foraging habitat and movement corridors (U.S. Fish and Wildlife Service 1995).

The second and third goals pertain directly to management and conservation of the species and specify how population trends are to be monitored. The last goal sets out the management actions – protection of vital habitat components – expected to help the populations rebound. By all accounts, protection of these habitat components has been successful in halting or reversing population declines in the two subspecies. In a 2001-2002 report to Congress, USFWS indicated that numbers of Virginia big-eared bats were increasing and that recovery goals were 50 to 75 percent met. The recovery status of Ozark big-eared bats was lower (0 to 25 percent), but populations were listed as stable (U.S. Fish and Wildlife Service 2002). Inasmuch as these management objectives have been successful in mitigating population declines in the East, we suggest that western populations of Townsend’s big-eared bats also stand to benefit from similar protections.

Conservation strategies

Current conservation strategies consist of state-specific plans that address bat conservation for all bats within a state, and one multi-state plan that is specific to Townsend’s big-eared bat. All of these plans are similar in that they outline the natural history of the species included in the plans, identify threats to their persistence, and discuss hurdles to effective conservation of the bats.

**Idaho conservation effort assessment and strategy for Townsend’s big-eared bat**

*The Species Conservation Assessment and Conservation Strategy for the Townsend’s Big-Eared Bat* (Pierson et al. 1999) is a comprehensive summary of the status and conservation needs for Townsend’s big-eared bats in the West. At the broadest level, the goal of the Idaho Conservation Effort (ICE) was to identify “proactive conservation strategies for species at risk of being listed...under the Endangered Species Act” (Pierson et al. 1999). When considering Townsend’s big-eared bat, the ICE recognized that a state-specific conservation effort may be insufficient to address rangewide declines of the species. The ICE, therefore, invited participation from resource managers and researchers from other western states during the development of its conservation strategy for *Corynorhinus townsendii*. Representatives from seven western states and two federal agencies participated, and from this core group the Western Bat Working Group was formed in 1994. The conservation document for Townsend’s big-eared bat that resulted remains an excellent source of information and management strategies for the species, no doubt due in part to the strength of its interagency input and breadth of its geographic coverage. Being a seminal work in this regard and as testimony to its potential, the ICE strategy for Townsend’s big-eared bat was adopted by the Western Association of Fish and Wildlife Agencies (WAFWA). The ICE strategy identified several key conservation elements and provided management guidelines aimed at protecting these elements. Among these guidelines were standards for management of caves and mines (including renewed mining at historical mines), toxic material impoundments associated with mining, pesticide spraying, vegetative conversions, and timber harvest. We will borrow and incorporate many of these guidelines in the Management section below, thus we will not go into further detail here. The reader is directed to the ICE document (Pierson et al. 1999) for more detail, and to the website of the Western Bat Working Group (http://www.wbwg.org/) for updates on the strategy.

**Western states with general bat conservation strategies**

Several western states have begun to address the conservation needs of bats through the development of documents outlining conservation needs and strategies for bats endemic to each particular state. To date, Arizona, Colorado, Nevada, and South Dakota have completed conservation plans for bats. Although the formats of the documents vary somewhat from state to state, each provides an overview of the conservation status of the bats found within the state and identifies important conservation elements (e.g., roosting habitat, foraging habitat). In addition, each was drafted by a group of management and research biologists with

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2States and Provinces represented by WAFWA include Alberta, Arizona, British Columbia, California, Colorado, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming.
interest in or experience with bat management and conservation. Generally, this included members of each state’s Bat Working Group, which are, in turn, part of the Western Bat Working Group.

Consistent among the state plans is the implication of disturbance and destruction of roosts in local and range-wide declines of Townsend's big-eared bat. Consequently, the plans promote, as core conservation elements for *Corynorhinus townsendii*, protection of known roosts and identification and protection of additional roosts. Although these documents are state-specific, the conservation strategies put forth may generally be considered applicable throughout the western range of *C. townsendii*.

**Arizona**: The Arizona Bat Conservation Strategic Plan (Hinman and Snow 2004) is based on the outline provided by the North American Bat Conservation Partnership’s State Planning Guide (Tuttle 2004), and it includes sections on resources important to bats such as roosts, foraging habitat, water, and migration corridors. Within each of these, a list of species that use each type of resource (e.g., cave roosts) and the threats to the resource are delineated.

For *Corynorhinus townsendii*, the Arizona plan identifies several priority actions including:

- understanding movement patterns and roost switching in cave and mine roosts
- identification of roosting and foraging habitat requirements
- evaluation of the effectiveness of bat-friendly cave closures
- evaluation of the effectiveness of such closures in mine reclamation.

In addition, the Arizona plan outlines strategies for long-term monitoring of historic and current known roosts to establish population estimates and trends; monitoring the effects of management actions, human disturbance, and artificial assistance (e.g., man-made watering holes) on bat populations; public outreach and education about the benefits of bats; and better understanding of the effects of urbanization on bat populations.

**Colorado**: The Colorado Bat Conservation Plan (Ellison et al. 2003a) identified *Corynorhinus townsendii* as the species with the highest conservation priority in Colorado based on consideration of five major categories that directly impact bats or their habitat:

- mining
- cave and crevice management practices
- forest management practices
- rangeland management practices
- urban development.

Within each of these categories key issues, goals, objectives, and management and research needs are identified.

The inclusion of urban development as a potential major impact on bats speaks to the thoroughness of this document, and such threats, though sometimes overlooked, should be a consideration in areas where rapid urban development encroaches upon native habitat. The spread of urban development into previously undeveloped areas may not impact roosting habitat directly (i.e., caves and mines are likely to remain intact), but previously isolated roosting habitat may experience greater human visitation if urban development occurs near these structures. As well, conversion of native vegetative communities to neighborhoods and commercial and industrial zones may change diversity and abundance of insect prey and fragment or eliminate foraging/commuting corridors.

**Nevada**: The Nevada Bat Conservation Plan (Altenbach et al. 2002) takes a hierarchical approach, outlining strategies for conservation of specific habitat types (called “Bat Habitat Conservation Guilds”) that are based first on roosting preferences (e.g., tree-dwelling, cave-dwelling, crevice-dwelling) and second on the foraging/watering habitat of the bats comprising them. Within each of the conservation guilds, high priority and secondary priority species and appropriate conservation strategies are listed.

In the Nevada Bat Conservation Plan, *Corynorhinus townsendii* is identified as a high priority species in one roosting guild (Natural Cave, Mine Shaft and Mine Adit Roosting Habitat) and two foraging/watering guilds (Water Source Foraging and Drinking Habitat; Forest Woodland Foraging Habitat). With regard to roosting habitat, the Nevada plan identifies as its major management goal the reversal of population declines seen at caves and mines throughout the state. Explicit strategies that are suggested to meet this goal
include identification and protection of current and historic roosts and minimization of disturbance at and near known roosts.

**South Dakota:** The South Dakota Bat Conservation Plan (South Dakota Bat Working Group 2004) is novel in the emphasis placed on public education and outreach to help minimize threats to bats. Many of the threats are surmised to originate in a general lack of knowledge about bats by the public, and are exacerbated by commonly propagated misinformation about bats. Educating the public about the benefits of healthy bat populations and dispelling commonly held myths about bats can only help managers convince a skeptical public that conserving bats is worthwhile. The South Dakota plan also emphasizes inter-agency cooperation and data sharing within the state to meet research needs and coordinate conservation activities. This level of cooperation is likely to be key for many states faced with tight funding for non-game species of wildlife.

**State Wildlife Grants Program**

In addition to bat-specific conservation strategies, all 50 states are currently completing a Comprehensive Wildlife Conservation Strategy, as required by the Consolidated Appropriations Act of 2005 (Public Law 108-447) for federal funding through the State Wildlife Grants Program. This program is intended to augment the ability of state wildlife management agencies to manage and conserve wildlife, especially non-game species, by providing federal funding for wildlife in need of conservation and their habitat. States are required to compile a list of Species in Greatest Need of Conservation, and the comprehensive strategy must identify the means by which states will monitor and manage these species and their habitat. All five states within USFS Region 2 (i.e., Colorado, Kansas, Nebraska, South Dakota, Wyoming) include Townsend’s big-eared bat on their list of Species in Greatest Need of Conservation.

**Biology and Ecology**

**Description and systematics**

**Morphology**

Townsend’s big-eared bat is a medium-sized bat with overtly large ears and characteristic bilateral horseshoe-shaped lumps on the muzzle (Figure 2). The lumps, actually enlarged pararhinal glands that produce sebaceous secretions, are apparently involved in mating (Pearson et al. 1952, Quay 1970) and give the bat one of its common names, the lump-nosed bat. The dorsal hairs are gray at the base, and the tips vary from pale cinnamon to blackish brown. Ventral hairs are gray at the base and brown or buff at the tips (Kunz and Martin 1982). Length of ear and tragus are 30 to 39 mm (1.2 to 1.5 inches) and 11 to 17 mm (0.4 to 0.7 inches) respectively (Kunz and Martin 1982). The ears are erect and point slightly forward in flight. However, during torpor and hibernation, one or both ears may be coiled tightly along the head (in the shape of a ram’s horn) leaving only the long pointed tragus visibly erect (Barbour and Davis 1969). Length of the forearm ranges from 39 to 48 mm (1.5 to 1.9 inches) (Clark and Stromberg 1987). Overall length is 90 to 112 mm (3.5 to 4.4 inches), and mass of adults ranges from 5 to 13 g (0.17 to 0.46 oz.).

Females tend to be slightly larger than males (Kunz and Martin 1982). However, size is an equivocal and unreliable character, and females may be distinguished from males only upon examination of genitalia or the presence of mammary glands and nipples (Racey 1988). The altricial young are born naked with eyes closed and ears flaccid. In one study, neonates averaged 2.4 g (0.08 oz.) with a forearm of 16.6 mm (0.65 inches) at birth, with no significant difference in morphological characters between males and females (Pearson et al. 1952).

Within Region 2, Townsend’s big-eared bat is unlikely to be confused in hand with other species of bats. However, two species with morphological traits similar to Corynorhinus townsendii occur in Region 2 (Table 2). The spotted bat (Euderma maculatum) occurs in western portions of Colorado and Wyoming and may be associated with caves and mines (Watkins 1977). It lacks pararhinal glands on the muzzle, and it has very large ears. The spotted bat can be distinguished from Townsend’s big-eared bat primarily by its larger, broader, and paler ears and by its distinctive pelage. Spotted bats also have black dorsal fur with contrasting white spots on the shoulders and rump, and white ventral fur.

Another morphologically similar species, the pallid bat (Antrozous pallidus), occurs in western Colorado, south-central Kansas, and the interior of Wyoming outside of the northwestern mountains, northeastern grasslands, and extreme southeastern corner of the state. Pallid bats have pararhinal glands on the muzzle, but they are not as pronounced as those in Townsend’s big-eared bats are. Pallid bats differ in appearance from Townsend’s big-eared bats primarily
Distinguishing features of Townsend’s big-eared bat. The very large ears and fleshy lump on the nose (pararhinal gland) differentiate this species from other North American bats. A) adapted from Menzel et al. 2002. B) by Phil Henry. Used with permission.

Table 2. Morphometrics for Townsend’s big-eared bat and two morphologically similar species in USDA Forest Service Region 2.

<table>
<thead>
<tr>
<th>Species</th>
<th>Ear Length (mm)</th>
<th>Forearm Length (mm)</th>
<th>Total Length (mm)</th>
<th>Mass (g)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Corynorhinus townsendii)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Euderma maculatum)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pallid bat</td>
<td>21-37</td>
<td>45-60</td>
<td>92-135</td>
<td>14-29</td>
<td>Hermanson and O’Shea (1983)</td>
</tr>
<tr>
<td>(Antrozous pallidus)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

by having smaller ears and a larger body. In addition, the dorsal fur of pallid bats is darker at the tips than at the base, whereas Townsend’s big-eared bat has fur with light tips and dark base. Also unlike Townsend’s big-eared bats, pallid bats generally roost in rock crevices. Although pallid bats are known to use caves or mines as day roosts (Hermanson and O’Shea 1983, Ports and Bradley 1996) and hibernacula (Nagorsen and Brigham 1993), they are often found in crevices within the structure, whereas Townsend’s big-eared bats does not use crevices (Barbour and Davis 1969).

Echolocation

The echolocation of Corynorhinus townsendii (Figure 3) is well suited to the bat’s hawking/gleaning mode of foraging flight. Townsend’s big-eared bat uses a broadband, frequency modulated (FM) call that is most effective for short-range target detection amongst background clutter. This type of echolocation would be expected of bats like C. townsendii that are capable of slow, highly maneuverable flight (Norberg and Rayner 1987) and that forage around or directly from vegetation. The calls are characterized by FM pulses that sweep downward from a maximum frequency of about 40 kHz to a minimum frequency of about 30 kHz. Each pulse comprises a fundamental harmonic and one or more secondary harmonics. The duration (and therefore the bandwidth) of the fundamental harmonic of the echolocation pulse is short, relative to other insectivorous bats. However, C. townsendii makes greater use of secondary harmonics, thereby increasing
Figure 5. Sonogram of the echolocation call of Townsend’s big-eared bat recorded by an Anabat® frequency-division detector. The x- and y-axes represent time (ms) and frequency (kHz) respectively. This call is about 150 ms long and the fundamental harmonic sweeps from 40 to 30 kHz. Note that the upper set of pulses represents a secondary harmonic of the call, which has less energy (i.e., is quieter and less readily detected) than the fundamental harmonic. Because Anabat detectors usually record only the fundamental harmonic for most species of bats, the presence of the secondary harmonic can be used to identify Townsend’s big-eared bat. However, caution and experience are necessary to differentiate secondary harmonics from call echoes deflected from flat water or the presence of multiple bat calls, as these phenomena yield call files that look similar. Townsend’s big-eared bat produces relatively low intensity calls (i.e., quieter) compared to some other species of bats, and may be under-represented in acoustic surveys as a result.
the effective bandwidth of the call (Fenton 1982). The echolocation calls of *C. townsendii* are of relatively low intensity (i.e., not very loud), limiting somewhat the effectiveness of using acoustic detectors to confirm their presence.

Although acoustic tools to monitor echolocation calls of foraging bats have gained popularity and enjoy widespread use, specialized skills and knowledge are required to correctly interpret the results from surveys employing these tools. We address this issue in more detail in the Tools and practices section below.

**Systematics**

Townsend’s big-eared bat is in class Mammalia, order Chiroptera, family Vespertilionidae, and tribe Plecotini. In addition to the genus Corynorhinus, Plecotini contains the New World genera Euderma and Idionycteris and the Old World genera Barbastella, Otonycteris, and Plecotus.

Townsend’s big-eared bat has been alternately classified as Plecotus or Corynorhinus. Based on phylogenetic evidence (Frost and Timm 1992, Tumlinson and Douglas 1992) that supports Allen’s (1865) use of Corynorhinus rather than Plecotus (Cooper 1837, Handley 1959), *C. townsendii* is the currently accepted and genetically supported scientific binomial (Bogdanowicz et al. 1998) for Townsend’s big-eared bat. Prior to Handley’s (1959) revision of New World plecotines, *C. townsendii* was sometimes referred to as *C. rafinesquii* (e.g., Dalquest 1947, Pearson et al. 1952).

Five subspecies of *Corynorhinus townsendii* are recognized: *C. townsendii australis*, *C. townsendii pallescens*, and *C. townsendii townsendii* in the western United States and Mexico, and *C. townsendii ingens* and *C. townsendii virginianus* in the Ozark and Appalachian regions, respectively (Kunz and Martin 1982, Piaggio and Perkins 2005). We refer to the latter two subspecies as eastern subspecies throughout this document. The western subspecies may interbreed where they co-occur, but the two eastern populations are geographically isolated and do not interbreed.

Townsend’s big-eared bats in Region 2 are generally considered to be *Corynorhinus townsendii pallescens* (e.g., Pierson et al. 1999). However, recent molecular work suggests that both *C. townsendii pallescens* and *C. townsendii townsendii* occur broadly in Region 2 (Figure 4) and that populations in Kansas are *C. townsendii australis* (Piaggio and Perkins 2005). Until and if such time as subspecies distinctions and associated ranges carry statutory implications, the occurrence of interbreeding (Pierson et al. 1999) and inherent morphological and ecological similarities render distinctions tenuous from a management perspective. Hence, for the purposes of this document, we refer to Townsend’s big-eared bats in Region 2 simply as *C. townsendii*.

**Distribution and abundance**

*Corynorhinus townsendii* is distributed broadly throughout western North America, and it occurs in two disjunct, isolated populations in the central and eastern United States (Figure 4). In the West, this species’ range extends from the Pacific coast north to southern British Columbia, south to central and southern Mexico and the Baja Peninsula. The eastern-most extent of the western range includes the Black Hills of South Dakota and Wyoming, a small region of south-central Kansas, and western portions of Texas and inland eastern Mexico.

In Region 2, the most widespread distributions of *Corynorhinus townsendii* occur in Colorado and Wyoming (Table 3, Figure 5). Distribution of the bat elsewhere in Region 2 is relatively restricted, reflecting the eastern limit of the species’ range. This eastward limitation is likely driven by the same forces that shape the bat’s regional and local distribution. Because of its narrow roosting preferences, local distribution of Townsend’s big-eared bat tends to be restricted by the presence of suitable roosting habitat (i.e., primarily caves and mines, but also lava tubes, abandoned buildings, and large tree hollows) (Kunz and Martin 1982). At the state level, data on known occurrences may be complemented with projections of where *C. townsendii* is likely to occur. To that end, GAP analyses for *C. townsendii* and associated predictive distribution maps are available for Colorado, South Dakota, and Wyoming (Figure 6, Figure 7, Figure 8). The reader should note, however, that although these predictive maps have some value for identifying areas likely to support Townsend’s big-eared bat by highlighting areas with high potential for occurrence, they cover relatively large areas and rely on digital cover data that are coarse in detail. Thus, these maps should be considered a rough, “first guess” of potential distribution at about the time they were created and subject to the constraints of input data. Details about how distributions were predicted can be found in each state’s GAP reports (available through the National Gap Analysis web page: http://www.gap.uidaho.edu/).
Figure 4. Range-wide and USDA Forest Service Region 2 (outlined in bold) distribution of Townsend’s big-eared bat (Corynorhinus townsendii). Inferred distribution of the three western subspecies based on DNA analysis (Piaggio and Perkins 2005). The large westernmost distribution (1) corresponds to C. townsendii townsendii. The central distribution (2) represents C. townsendii pallescens, and the southernmost distribution (3) represents C. townsendii australis. Note that these distributions of subspecies differ from those based on morphological characteristics suggested by Handley (1959), who limited C. townsendii townsendii to the Pacific coast. According to the distribution above, C. townsendii pallescens is more limited in distribution than previously thought, whereas C. townsendii townsendii is more widespread. Also according to this distribution, all 3 western subspecies are predicted to occur in Region 2, with C. townsendii townsendii occurring throughout Wyoming and in South Dakota, C. townsendii pallescens occurring in central and southwestern Colorado, and C. townsendii australis occurring in Kansas. The eastern populations (4 and 5) are C. townsendii ingens and C. townsendii virginianus, respectively. Adapted from Piaggio and Perkins (2005).

Table 3. Distribution by county of Townsend’s big-eared bat in USDA Forest Service Region 2. Data compiled from a variety of sources including state natural heritage databases and state wildlife division publications.

<table>
<thead>
<tr>
<th>State</th>
<th>Counties of Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kansas</td>
<td>Barber, Comanche, Kiowa</td>
</tr>
<tr>
<td>Nebraska</td>
<td>Sheridan†</td>
</tr>
<tr>
<td>South Dakota</td>
<td>Custer, Fall River, Harding, Lawrence, Meade, Pennington</td>
</tr>
<tr>
<td>Wyoming</td>
<td>Albany, Bighorn, Carbon, Converse, Crook, Fremont, Goshen, Hot Springs, Johnson, Laramie, Natrona, Niobrara, Park, Platte, Sheridan, Sweetwater, Washakie</td>
</tr>
</tbody>
</table>

†Known only from a single male specimen found hanging on a screen door in 1972. Unless other confirmed sightings exist, this sighting may be considered anomalous.
Figure 5. Range map (tan polygon) and known occurrences (blue dots) for Townsend’s big-eared bat in Region 2. Green polygons represent national forests and grasslands. Data on occurrences are from the Wyoming Natural Diversity Database (WYNDD Database 2001).

Figure 6. Predicted distribution of Townsend’s big-eared bat in Colorado. Light green and dark green areas indicate areas of known or likely occurrence. Light tan and dark tan areas indicate areas of unlikely or no known occurrence. Image from Colorado Gap Analysis Project (Shrupp et al. 2000).
Figure 7. Known and predicted distribution of Townsend’s big-eared bat in South Dakota. Image from South Dakota Gap Analysis Project (Smith et al. 2002).

Figure 8. Predicted potential distribution of Townsend’s big-eared bat in Wyoming. Blue indicates species expected to be present in primary habitat. Tan indicates species expected to be present in secondary habitat. White indicates species not present. Note that expected distribution is overestimated as modeling was based on vegetative coverages, but important roosting habitat (caves, mines and buildings) are not mapped at this scale. Image from Wyoming Gap Analysis Project (Merrill et al. 1996).
Most authors note that Townsend’s big-eared bat is not very abundant anywhere in its range (Barbour and Davis 1969, Kunz and Martin 1982). This relative rarity is often attributed to patchy distribution and limited availability of suitable roosting habitat, but it may also reflect intrinsic limitations in the species’ life history (Humphrey and Kunz 1976). The generalization of modest abundance appears to hold within Region 2 as well. For instance, recent surveys at abandoned mines and caves in Colorado have revealed 14 maternity roosts, most of which contained fewer than 50 individuals (K. Navo personal communication 2003), and a survey of 99 caves in Colorado found no more than six *Corynorhinus townsendii* individuals in any one cave (Siemers 2002). However, Townsend’s big-eared bat can be locally abundant, as one of the largest colonies of hibernating *C. townsendii* in the western United States (estimated at 800 to 900 individuals) is found in the Black Hills of South Dakota (Choate and Anderson 1997).

No population estimates are available for *Corynorhinus townsendii* in the West, and indeed, reliable estimates of population densities of bats are notoriously difficult to obtain and are often logistically impractical (O’Shea and Bogan 2003; also see our discussion below in Tools and practices section). The availability and quality of roosting and foraging habitat, local environmental conditions, natural population fluctuations, and the interactions of all these factors ultimately influence the number of bats in a given area at a given time.

To our knowledge, the following are the only published estimates of density for *Corynorhinus townsendii* in the West, and although crude, they provide our only insight into local population densities. Humphrey and Kunz (1976) estimated that Townsend’s big-eared bats achieved densities of one bat per 38 ha (94 acres) on a small tract in Kansas and Oklahoma, and Pearson et al. (1952) estimated densities of one per 126 ha (311 acres) and per 170 ha (420 acres) in northern California and on Santa Cruz Island off the coast of California, respectively. However, these estimates must be considered cautiously and should not be extrapolated to other areas. The estimate from northern California is likely not reliable owing to unjustified and untested assumptions. Moreover, each represents a snapshot in time of populations at the three locations, and thus they are best suited as baseline data for those locations.

The eastern subspecies, federally listed as endangered (U.S. Fish and Wildlife Service 1979), have received more rigorous monitoring of populations. As of 2001, numbers of Townsend’s big-eared bats in Oklahoma and Arkansas (*Corynorhinus townsendii ingens*) were estimated at fewer than 1700 individuals (Harvey and Redman 2002). Numbers of Virginia big-eared bats (*C. townsendii virginianus*) as of 2000 were estimated to be 18,442 individuals (Currie 2000).

**Population trend**

A general decline in the numbers of cave-dwelling species of bats in North America was recognized as early as the 1950’s, with reports of declines continuing through the 1960’s and early 1970’s (Mohr 1953, Manville 1962, Booth 1965, Henshaw 1972). Despite this, detailed long-term data on which to base estimates of population trends for many species of bats are generally lacking (Fenton 2003). However, the limited survey data available for *Corynorhinus townsendii* at a few known nursery sites and hibernacula in the West have lead to speculation of a general decline in numbers. For example, surveys for *C. townsendii* at historic roost sites in California from 1987 to 1991 indicated a 52 percent reduction in numbers of maternity colonies and a 55 percent decline in number of animals (Pierson and Rainey 1998). In Oregon, half of the known colonies were believed to have been either extirpated or had experienced substantial decline in numbers (Pierson et al. 1999).

**Activity and movement patterns**

The daily and annual activity patterns of *Corynorhinus townsendii* mirror those of most other north-temperate species of bats and are dictated largely by daily cycles of light and dark and seasonal cycles of warm and cold. Bats of the north temperate regions of the world are active primarily during the summer months when insect prey is available and warm temperatures facilitate cost-efficient thermoregulation. Bats avoid winter food scarcity either by hibernating or by migrating to warmer climes. In areas where winter temperatures predominantly remain below freezing, bats are rarely seen outside the hibernation roost during winter.

During the summer months, bats are most active during the crepuscular periods of the day. During the daylight hours, bats typically remain secluded in the day roost (Barbour and Davis 1969), where they are generally inactive. As twilight approaches and darkness falls, bats emerge from their roosts to forage for insects and drink water. Foraging activity by bats generally peaks 1 to 2 hours after sunset, remains at low levels throughout the night, and often exhibits another smaller
peak just before sunrise. The drop-off in foraging activity after the initial peak is correlated with a decrease in aerial activity by insects. During this period, bats use night roosts to rest and digest food (Perlmeter 1995). Often, a second smaller peak in activity before sunrise is seen, and it may reflect bats commuting to day roosts while opportunistically exploiting aerially-active insects (Hayes 1997). Lactating females typically forage for longer periods, probably to meet increased energetic demands, and early in lactation females return to the roost several times per night to nurse their young (e.g., Clark et al. 1993).

Harsh winter conditions coupled with lack of insect prey mean that bats face increased thermoregulatory costs at a time when the source of energy for thermoregulation is reduced or absent. Many bats solve the problem of overwinter survival through the use of deep physiological torpor known as hibernation during which the animal allows body temperature to fall to within 1 to 2 °C of ambient conditions (Schmidt-Nielsen 1997). Hibernation leads to substantial reductions in energy expenditure, and it allows animals to survive many months without access to food (Humphries et al. 2002).

**Diel cycle**

Townsend’s big-eared bat is reported to be a late-flyer relative to other bats (Kunz and Martin 1982). They may begin flying within the roost up to 30 minutes before sunset (Clark et al. 1993), but typically, they leave the roost from 45 to 60 minutes after sunset (Clark et al. 1993, Dobkin et al. 1995, Fellers and Pierson 2002). Townsend’s big-eared bats may fly directly to foraging sites after emergence without foraging en route (Adam et al. 1994), or they may forage immediately upon emergence near the roost for a few hours before moving to foraging sites farther from the roost (Dobkin et al. 1995). Lactating females appear to forage all night although they return to the day roost to nurse the young several times. Males and non-lactating females tend to show a bimodal pattern of foraging activity, with the largest peak occurring during the first 1 to 2 hours following sunset and another smaller peak just prior to sunrise (Pierson et al. 1999). After the initial feeding period, *Corynorhinus townsendii* selects a night roost, often in a warm cave or cave analog, to rest and digest food. Night roosts tend to be in different structures than day roosts (Pierson et al. 1999). In general, lactating female bats appear to make less use of night roosts than other bats (Barclay 1982) because they must return to the day roost during the night to nurse their young (Kunz 1974, Barclay 1982, Racey and Swift 1985, Waldien and Hayes 2001). Townsend’s big-eared bats appear to follow this pattern as well (Cockrum and Cross 1964, Clark et al. 1993, Adam et al. 1994).

Moon phase is thought to affect foraging activity patterns in bats, with bats hypothesized to be less active on bright, moonlit nights (e.g., Morrison 1978, Usman et al. 1980). However, moon brightness did not affect flight activity in *Corynorhinus townsendii ingens* in Oklahoma (Clark 1991), and recent evidence suggests that activity levels for bats are not correlated with lunar phase or ambient light levels (Hecker and Brigham 1999, Karlsson et al. 2002). Although definitive effects of moonlight on foraging behavior in bats remain to be shown, it is highly unlikely that Townsend’s big-eared bat chooses to forgo or reduce foraging during the period of each month when the moon is large. If moon phase affects the foraging behavior of Townsend’s big-eared bat at all, a likely scenario is that the bat spends more time near and within vegetation, perhaps as a predator avoidance strategy (e.g., Reith 1982), but more likely as it follows shifting distributions of insects. For instance, Hecker and Brigham (1999) showed that foraging activity of insectivorous bats was greater within and above forest canopy on moonlit nights, a result that is non-congruent with predator avoidance behavior, but that is likely a response to shifts in insect (particularly lepidopteran) activity (Hecker and Brigham 1999 and references therein). Since it is probable that such shifts in foraging patterns reduce the success rate of captures at ground-based mist-nets (the most typical deployment of mist-nets), the impression of lower levels of activity on moonlit nights is probably misleading and underscores one of several inherent difficulties in accurately assessing movement patterns by insectivorous bats (see also our discussion below in Tools and methods section).

**Annual cycle**

Like most temperate-zone bats, *Corynorhinus townsendii* escapes the harsh conditions and lack of prey during winter by hibernating. Hibernation occurs from early fall through early spring. Movements toward hibernacula begin in late summer (Pearson et al. 1952) after dissolution of maternity colonies, and Townsend’s big-eared bats typically begin to arrive at hibernacula in October. Males often arrive before females (Pearson et al. 1952). In California, Kansas, and Oklahoma, maximum numbers were present in January (Pearson et al. 1952, Humphrey and Kunz 1976). Movement to hibernacula may require northward or elevational migration to find roosts with suitable temperatures for hibernation (Pierson et al. 1999).
Available evidence suggests that *Corynorhinus townsendii* use interim roosts (to which they show little fidelity) while moving between summer and winter grounds (Pearson et al. 1952, Dobkin et al. 1995). Interim roosts appear to serve as “staging grounds” and may foster commingling of the sexes for breeding, serve to apprise juveniles of the location of hibernacula, or promote synchronous arrival of pregnant females at maternity roosts.

**Habitat**

**General requirements**

Townsend’s big-eared bat is unequivocally associated with areas containing caves and cave-analogs for roosting habitat. Beyond the constraint for cavernous roosts, habitat associations become less well defined. Generally, Townsend’s big-eared bats are found in the dry uplands throughout the West, but they also occur in mesic coniferous and deciduous forest habitats along the Pacific coast (Kunz and Martin 1982).

Townsend’s big-eared bat requires spacious cavern-like structures for roosting (Pierson et al. 1999) during all stages of its life cycle. Typically, they use caves and mines, but *Corynorhinus townsendii* have been noted roosting in large hollows of redwood trees (Fellers and Pierson 2002), in attics and abandoned buildings (Dalquest 1947, Fellers and Pierson 2002), in lava tubes (Handley 1959, Hinman and Snow 2004), and under bridges (Keeley 1998, Adam and Hayes 2000, Fellers and Pierson 2002). In Utah, 85 percent of surveyed caves and 21 percent of surveyed mines were used as day roosts in summer (Sherwin et al. 2000a), and 27 percent of all structures surveyed showed signs of occupancy (**Table 4**). In coastal California, five of six known maternity colonies were in old buildings; the sixth was in a cave-like feature of a bridge (Fellers and Pierson 2002).

A combination of internal complexity and dimensions, and size of the openings appear to drive Townsend’s big-eared bat use of particular caves and mines as roost structures. These parameters likely reflect the diversity of internal roosting conditions that a structure is likely to offer bats. For instance, a structure with greater internal complexity and dimensions (e.g., natural cave) likely affords a greater variety of temperature and humidity regimes, and hence more roosting opportunities for bats as roosting requirements change (e.g., early pregnancy versus lactation). Size of opening may influence the accessibility of predators to roosts. Perhaps more importantly, though, the size of openings tends to regulate and maintain temperature and humidity profiles within roosts via air exchange.

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**Table 4.** Occupied roosts by elevation zones and habitat types for Townsend’s big-eared bat in Utah. Adapted from Sherwin et al. (2000a).

<table>
<thead>
<tr>
<th>Elevation</th>
<th>Number of Roosts Surveyed (% of Total Surveyed)</th>
<th>Number of Roosts Occupied (% of Total Occupied)</th>
<th>Percentage of Total Roosts Surveyed That Were Occupied</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1700 m</td>
<td>75 (10.5)</td>
<td>53 (70.6)</td>
<td>7.4</td>
</tr>
<tr>
<td>1701-2000 m</td>
<td>139 (19.4)</td>
<td>79 (56.8)</td>
<td>11.0</td>
</tr>
<tr>
<td>2001-2300 m</td>
<td>115 (16.1)</td>
<td>36 (31.3)</td>
<td>5.0</td>
</tr>
<tr>
<td>2301-2600 m</td>
<td>123 (17.2)</td>
<td>27 (21.9)</td>
<td>3.8</td>
</tr>
<tr>
<td>2601-2900 m</td>
<td>142 (19.9)</td>
<td>0 (0.0)</td>
<td>0.0</td>
</tr>
<tr>
<td>2901-3200 m</td>
<td>92 (12.9)</td>
<td>1 (1.1)</td>
<td>0.1</td>
</tr>
<tr>
<td>3201-3500 m</td>
<td>29 (4.0)</td>
<td>0 (0.0)</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>615</td>
<td></td>
<td>27.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Number of Roosts Surveyed (% of Total Surveyed)</th>
<th>Number of Roosts Occupied (% of Total Occupied)</th>
<th>Percentage of Total Roosts Surveyed That Were Occupied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riparian</td>
<td>18 (2.5)</td>
<td>2 (0.11)</td>
<td>0.3</td>
</tr>
<tr>
<td>Sagebrush-grass steppe</td>
<td>156 (21.8)</td>
<td>69 (44.2)</td>
<td>9.6</td>
</tr>
<tr>
<td>Juniper woodland</td>
<td>118 (16.5)</td>
<td>76 (64.4)</td>
<td>10.6</td>
</tr>
<tr>
<td>Mountain brush</td>
<td>100 (14.0)</td>
<td>41 (41.0)</td>
<td>5.7</td>
</tr>
<tr>
<td>Aspen</td>
<td>170 (23.8)</td>
<td>5 (0.03)</td>
<td>0.7</td>
</tr>
<tr>
<td>Mixed conifer</td>
<td>153 (21.4)</td>
<td>3 (0.02)</td>
<td>0.4</td>
</tr>
<tr>
<td>Total</td>
<td>1230</td>
<td>60.54</td>
<td>27.4</td>
</tr>
</tbody>
</table>
between surface and subterranean habitats (Richter et al. 1993, Roebuck et al. 1999).

Most maternal roosts in California had entrances that were at least 15 cm (6 inches) high and 31 cm (12 inches) wide, and heights of roosts ranged from 2.4 to 4.9 m (8 to 16 ft.), with an area large enough to permit flight (Pierson and Rainey 1998). In Utah, bats were more likely to occupy caves and mines with single, low entrances that did not exceed 1.5 m (5 ft.) in height, and maternal colonies tended to be located in larger, more complex sites that had multiple openings and were generally subject to minimal human disturbance (Sherwin et al. 2000b). Other external and internal characteristics (e.g., aspect and width of opening, tunnel length, and amount of internal airflow) were not associated with probability of use in summer (Sherwin et al. 2000b). Similar results were reported for roosts in Nevada and Utah (Sherwin et al. 2003) and the Black Hills of South Dakota (Tigner and Dowd Stukel 2003).

Throughout its western range, *Corynorhinus townsendii* roosts in a variety of vegetative communities, and at a range of elevations (Table 5), and there appears to be little or no association between local surface vegetative characteristics and selection of particular subsurface roosts in either eastern or western populations (Wethington et al. 1997, Sherwin et al. 2000b, 2003). This suggests that the bats select roosts based on internal characteristics of the structure rather than the surrounding vegetative community. In Colorado, Townsend’s big-eared bat is reported to occur across all four of Colorado’s ecoregions (i.e., Wyoming Basin, Colorado Plateau, Southern Rocky Mountains, Central Shortgrass Prairie) (Ellison et al. 2003a) and in at least five community types (i.e., Saxicoline brush, sagebrush, semidesert scrub, pinyon-juniper woodland, ponderosa pine woodland) (Ellison et al. 2003a). Because Townsend’s big-eared bat has also been reported to roost at elevations approaching 3048 m (10,000 feet) in Colorado (Siemers 2002), we surmise that this bat also uses roosts in lodgepole pine and subalpine spruce-fir communities, at least in the southern Rockies. Association with vegetative communities in Colorado reflects the distribution of roosting habitat in these communities and does not

<table>
<thead>
<tr>
<th>Location</th>
<th>Vegetative Community</th>
<th>Roost Structures</th>
<th>Elevation Range</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado</td>
<td>Saxicoline brush, sagebrush, semidesert scrub, pinyon-juniper woodland, ponderosa pine woodland, montane forest and subalpine forest</td>
<td>Caves and mines</td>
<td>1866-3014 m</td>
<td>Ellison et al. (2003a), Siemers (2002)</td>
</tr>
<tr>
<td>California and Nevada</td>
<td>Mojave and Great Basin desert scrub, pinyon-juniper woodland, bristlecone-limber pine forest</td>
<td>Caves and mines</td>
<td>1372-3188 m</td>
<td>Szcewczak et al. (1998)</td>
</tr>
<tr>
<td>(White and Inyo Mountains)</td>
<td></td>
<td></td>
<td>(4500-10,460 ft.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(550 - 7520 ft.)</td>
<td></td>
</tr>
<tr>
<td>Utah</td>
<td>Sagebrush-grass steppe, juniper woodlands, mountain brush</td>
<td>Caves and mines</td>
<td>1350- &gt;2600 m</td>
<td>Sherwin et al. 2000b</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(4430- &gt;8500 ft.)</td>
<td></td>
</tr>
<tr>
<td>Central California and Washington</td>
<td>Coastal lowlands, cultivated valleys, hills with mixed vegetation</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Handley (1959)</td>
</tr>
</tbody>
</table>
preclude the presence of the species in other vegetative community types provided suitable roosting habitat is available. In central California and Washington, Townsend’s big-eared bats are associated with coastal lowlands, cultivated valleys, and nearby hills covered with mixed vegetation (Handley 1959). In montane areas of California and Nevada, Townsend’s big-eared bats are found in Mojave and Great Basin desert scrub and pinyon-juniper woodland habitats (Szewczak et al. 1998). Summer roosts in Arizona are found in desert scrub, oak woodlands, oak-pine forests, pinyon-juniper forests, and coniferous forest habitats. Hibernacula in Arizona are primarily in uplands and mountains in cold caves, lava tubes, and mines (Hinman and Snow 2004).

### Roosting habitat

Townsend’s big-eared bats in Colorado have been found roosting during the summer in caves that range in elevation from 1866 to 3014 m (6122 to 9890 ft.) (Siemers 2002). In northern Utah, bats roosted at elevations ranging from 1350 to 2440 m (4430 to 8000 ft.), with only one of 263 caves and mines located above 2600 m (8500 ft.) found to be occupied (Sherwin et al. 2000b). In Arizona, Townsend’s big-eared bat is most common at elevations above 915 m (3000 ft.), but hibernacula range from 168 to 2294 m (550 to 7520 ft.) (Hinman and Snow 2004). In the White and Inyo Mountains of California and Nevada, two maternity colonies were found at approximately 1710 m (6000 ft.) in Great Basin desert scrub habitat, and hibernacula ranged from approximately 1372 to 3188 m (4500 to 10,460 ft.) within Great Basin desert scrub, pinyon-juniper, and bristlecone-limber pine forest habitats (Szewczak et al. 1998) (Table 5).

Internal conditions appear to drive roost selection more than surface conditions do (Sherwin et al. 2000b). Temperature and humidity are thought to play important roles, and these variables depend on the depth and complexity of the structure and airflow. Bats appear to prefer roosts with low to moderate levels of airflow, likely because airflow helps to keep roosts from getting too warm or too cold.

### Hibernacula: Caves and mine tunnels with stable, cold temperatures that remain above freezing and that have moderate airflow appear to characterize hibernation roosts used by Townsend’s big-eared bats (Genter 1986, Pearson et al. 1952). Hibernating individuals are often found far enough into caves or mines to be near the zone of total darkness (Schmidly 1991), but close enough to the entrance to be in relatively cold, well-ventilated areas. Temperatures inside hibernacula are reported to range from −1.9 to >10 °C (28.5 to 50 °F) (Peason et al. 1952, Pierson et al. 1999).

Hibernacula are generally viewed as housing large aggregations of bats that can number into the 10’s or 100’s of thousands (Barbour and Davis 1969), but abundance of hibernating *Corynorhinus townsendii* appears to be much lower (Table 6). Physical and abiotic requirements for hibernacula are restrictive, and this may lead to relatively few suitable hibernation sites. For instance, in some parts of the range, caves used for summer roosts are too warm for successful hibernation (Graham 1966), and bats likely migrate in latitude or elevation to suitable sites that are probably shared with groups from other areas. Thus, suitable hibernacula may harbor denser aggregations of bats than summer roosts (Table 6). Because mating occurs at hibernacula both before and after the onset of hibernation, and because these roosts likely house bats from a wide geographic area, hibernacula may play an important role in maintaining genetic diversity among western populations of Townsend’s big-eared bats, as is the case for other species of bats (Burland et al. 2001).

Because hibernating bats are physically inert due to their highly reduced metabolic rate, they are incapable of escaping direct disturbance or outright aggression in any temporally meaningful way. Disturbance may lead to unnecessary arousal from hibernation and concomitant expenditure of crucial energy reserves (Thomas 1995). If disturbance leads to abandonment, then the expense of flight and of locating alternate suitable hibernacula markedly increases the risks to which the bats are subjected.

### Maternity roosts: Maternity roosts comprise reproductive females and their young of the year. Adults males are occasionally found in maternity roosts, often early in the season, but they appear not to be part of the social unit as they may be found roosting apart from the group. Mating can be ruled out as a reason for the presence of males since copulation cannot commence until late summer. Considering the high degree of inter- and intra-season fidelity exhibited by maternity colonies to particular roosts, and the relatively low annual reproductive rate of *Corynorhinus townsendii*, maternity roosts are also considered to have high conservation value.

Internal temperature, which dictates energy expenditure by bats, appears to drive the selection of maternity roosts. For example, maternity roosts of *Corynorhinus townsendii* in California ranged between 18 and 30 °C (64 and 86 °F) and were significantly
Table 6. Summary of abundance of Townsend’s big-eared bat in the western United States based on capture records and survey observations.

<table>
<thead>
<tr>
<th>Method of Capture or Observation</th>
<th>Number Captured or Observed</th>
<th>Roost Type or Season Observed</th>
<th>Location</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal survey</td>
<td>~100 + approx. same number of juveniles</td>
<td>Not applicable</td>
<td>Senator Mine, California</td>
<td>Howell (1920)</td>
</tr>
<tr>
<td>Mist-netting over water, Cave survey</td>
<td>43 (3rd most abundant)</td>
<td>Summer</td>
<td>Badlands National Park, South Dakota</td>
<td>Bogan et al. (1996)</td>
</tr>
<tr>
<td>Internal survey</td>
<td>33 (3rd most abundant)</td>
<td>Early &amp; late summer</td>
<td>Colorado (Karst regions)</td>
<td>Siemers (2002)</td>
</tr>
<tr>
<td>Internal survey</td>
<td>85 adult females (avg)</td>
<td>Maternity</td>
<td>Marin Co., California</td>
<td>Pearson et al. (1952)</td>
</tr>
<tr>
<td>Internal survey</td>
<td>60 adult females (avg)</td>
<td>Maternity</td>
<td>Napa Co., California</td>
<td>Pearson et al. (1952)</td>
</tr>
<tr>
<td>Internal survey</td>
<td>111-201 (avg = 144)</td>
<td>Hibernaculum</td>
<td>Shasta Co., California</td>
<td>Pearson et al. (1952)</td>
</tr>
<tr>
<td>Internal survey</td>
<td>22-93 (avg = 51)</td>
<td>Hibernaculum</td>
<td>Shasta Co., California</td>
<td>Pearson et al. (1952)</td>
</tr>
<tr>
<td>Internal survey</td>
<td>30</td>
<td>Hibernaculum</td>
<td>Siskiyou Co., California</td>
<td>Pearson et al. (1952)</td>
</tr>
<tr>
<td>Internal survey</td>
<td>23-183 (avg = 103)</td>
<td>Hibernaculum</td>
<td>Napa Co., California</td>
<td>Pearson et al. (1952)</td>
</tr>
<tr>
<td>Internal survey</td>
<td>~90</td>
<td>Not applicable</td>
<td>Spring Cave, Colorado</td>
<td>Finley et al. (1983)</td>
</tr>
<tr>
<td>Internal survey</td>
<td>46-148</td>
<td>Hibernaculum</td>
<td>Torgac Cave, New Mexico</td>
<td>Jagnow (1988)</td>
</tr>
<tr>
<td>Internal survey</td>
<td>110 (including juveniles)</td>
<td>Maternity</td>
<td>Northern Black Hills, South Dakota</td>
<td>Tigner and Dowd Stukel (2003)</td>
</tr>
<tr>
<td>Internal survey</td>
<td>7-37 (avg = 26; n = 3)</td>
<td>Hibernaculum</td>
<td>Northern Black Hills</td>
<td>Tigner and Dowd Stukel (2003)</td>
</tr>
<tr>
<td>Internal survey</td>
<td>~300</td>
<td>Hibernaculum</td>
<td>Jewel Cave National Monument, South Dakota</td>
<td>Tigner and Dowd Stukel (2003)</td>
</tr>
</tbody>
</table>

\(^a\)Includes males and females. Males were always more numerous. Surveys occurred over 3 winters.

\(^b\)Includes males and females. Females were always more numerous. Surveys occurred over 2 winters.

warmer than random structures (Pierson and Rainey 1998). However, during early pregnancy, maternity colonies appeared to choose cooler sites (either in the same roosts or in different roosts) than during late pregnancy and lactation (Pierson and Rainey 1998) when female’s energetic demands are greatest (Kurta et al. 1989). By choosing cooler sites during early pregnancy, when energetic costs are lower, females can save energy by using torpor.

Bachelor roosts: As the name suggests, these roosts generally house groups of adult males during the non-mating season. Bachelor roosts likely have less constrained thermal requirements than maternity roosts and hibernacula owing to the generally accepted flexibility of males to utilize more frequent and deeper bouts of torpor as a means of energy savings. However, while conferring energetic savings, torpor also exerts some potential costs such as decreased predator avoidance. Thus, adult males may select bachelor roosts based on disturbance levels rather than specific thermal requirements. If so, then bachelor colonies may roost in dangerous (to humans) and generally inaccessible caves or mines that likely receive little disturbance. As with other roost types, efforts to protect these structures from disturbance and destruction will benefit Townsend’s big-eared bats.

Foraging habitat

Townsend’s big-eared bat has been noted foraging in a wide variety of habitats (Pierson et al. 1999) throughout its western range, and this may reflect the need to roost where structures are available as opposed to within a particular vegetative zone. Given its wing morphology, which permits slow maneuverable flight and the ability to hover and glean insects from vegetation (Norberg and Rayner 1987), *Corynorhinus townsendii* is expected to forage primarily in and near vegetation, and to engage in little if any of the open-air hawking that is characteristic of swift-flying species such as hoary bats (*Lasiurus cinereus*). Thus, suitable foraging
habitat for *C. townsendii* will likely be a heterogeneous mosaic of forested and edge habitats, including riparian zones, which are also used for commuting and drinking (e.g., Fellers and Pierson 2002). Areas with substantial beaver activity enhance the quality of foraging habitat by increasing ecosystem productivity (Naiman et al. 1986), providing gaps in the forest canopy, providing small, quiet ponds for drinking, and causing an increase in insect activity.

Individuals or colonies appear to favor specific foraging locations to which they show a high degree of fidelity and where they forage extensively, usually amongst foliage of trees and shrubs and along forest edges (Clark et al. 1993, Adam et al. 1994, Ports and Bradley 1996, Fellers and Pierson 2002). Female *Corynorhinus townsendii* in Nevada tended to forage in forested areas, including pinyon-juniper, mountain mahogany, mixed-fir, and riparian deciduous habitats, but they appeared to avoid foraging in open sagebrush/grassland steppe (Bradley 1996). In California, both males and females foraged along the edges of riparian vegetation dominated by Douglas-fir, California bay, and willow species, but they also avoided open grasslands both when traveling and foraging (Fellers and Pierson 2002). In Oregon, bats foraged in sagebrush shrubsteppe and in open ponderosa pine woodlands, with little foraging activity in more densely forested areas (Dobkin et al. 1995).

Characteristics of foraging habitat for the eastern subspecies appear to be similar to those observed in the West, with the exception that in some cases, bats in the East appeared to forage more in open areas. Townsend’s big-eared bats in West Virginia foraged over hayfields early in the evening but moved to forest habitat later in the night (Pierson et al. 1999). In Kentucky, Townsend’s big-eared bats foraged along cliffs and within forested habitats, but they avoided open areas while traveling and foraging (Adam et al. 1994). In Oklahoma, *Corynorhinus townsendii* foraged over pastures, crops, and native grasslands, as well as along intermittent streams, but in all cases, they foraged near wooded edges (Clark et al. 1993). Proximity to vegetation in general, and especially while foraging in more open areas, appears to be a consistent pattern; *C. townsendii* in California showed close association with scattered trees and shrubs while foraging in more open areas (Fellers and Pierson 2002).

*Seasonal and life history shifts*

Townsend’s big-eared bat uses caves and cave-like structures during all parts of its life cycle. Individuals may move within and among roosts during summer and winter (Genter 1986, Sherwin et al. 2003). During hibernation, these bats commonly change position within a hibernaculum or move to a nearby roost, presumably to find temperatures that are more suitable. Roost movement in the summer likely occurs for the same reason.

Townsend’s big-eared bat is a relatively sedentary species and appears not to engage in long distance migrations. Reported movement between summer roosts and hibernacula ranges from 3.1 to 64 km (2 to 40 miles) (Kunz and Martin 1982). Maximum-recorded distances moved vary by geographic location. In California, maximum known distance traveled to hibernaculum is 32 km (20 miles) (Pearson et al. 1952), and in Kansas, movements of 40 km (25 miles) are known (Humphrey and Kunz 1976). Big-eared bats in West Virginia and Kentucky are known to have moved 64 km (40 miles) to hibernacula (Barbour and Davis 1969). The greater distances observed in the eastern subspecies may reflect the relatively limited number of hibernation roosts in the East (Pierson et al. 1999). As with other species of bats, *Corynorhinus townsendii* appears to engage in elevational migrations between seasons, probably to find roosts with conditions necessary for various life stages. In the Black Hills, *C. townsendii* hibernates at an elevation of approximately 1600 m (5250 ft.), but captures of females during summer are known from elevations below 1300 m (4265 ft.) (Cryan et al. 2000). Similarly, maternity colonies in the Black Hills are known from elevations below 1300 m (4265 ft.) (Cryan et al. 2000).

Based on re-sighting of banded Townsend’s big-eared bats in the Black Hills and in the Great Plains, most bats are re-sighted in the cave in which they were originally banded (Tigner and Dowd Stukel 2003) and/or in nearby caves (Humphrey and Kunz 1976). The two largest hibernating populations known from the Black Hills (i.e., Jewell Cave and a natural cave approximately 9 miles to the north) showed no evidence of common roosting (Tigner and Dowd Stukel 2003). However, because some individuals were unbanded and some of those that were banded may have been missed during surveys, mixing between the roosts cannot be ruled out. Re-sightings of banded bats in the Black Hills at sites other than where the bats were banded demonstrate that movement between roosts occurs, but movement distance is generally low. Of the five re-sightings in different locations, the farthest was 18 km (11 miles) from its original site, and the others were within 4 km (2.5 miles) (Tigner and Dowd Stukel 2003).
Area requirements

Although some general patterns of the size of areas used by Townsend’s big-eared bats can be drawn from knowledge of the area over which some bats have traveled while carrying radio-transmitters, little is understood about the minimum area necessary to support a group of bats. In all likelihood, the minimum required area will vary spatially and temporally, depending on the myriad factors that influence energy costs for bats. Availability of food and water, temperature, precipitation, density of intra- and interspecific competitors, as well as the complex interactions of these factors are all likely to alter area requirements by influencing energy costs for bats.

In general, females appear to increase the distance traveled to foraging sites as the reproductive cycle progresses (Table 7), and females appear to travel farther than males. During the latter stages of reproduction (i.e., lactation and post-lactation), females of the two eastern subspecies appear to increase their foraging areas. In Kentucky, female Corynorhinus townsendii virginianus increased their foraging areas from 60 to 263 ha (148 to 650 acres) between pregnancy and post-lactation; males decreased their foraging areas during the same period (Adam et al. 1994). Males traveled a maximum of 8.4 km (5.2 miles) to foraging areas in Kentucky, whereas females were never found more than 3.65 km (2.25 miles) from roosts (Adam et al. 1994). Clark et al. (1993) observed a four-fold increase (1 to 4.2 km) in median distance traveled to foraging sites by C. townsendii ingens between early lactation and late lactation in Oklahoma, and one female traveled more than 7 km (4 miles) to foraging sites during late lactation. In Nevada, females traveled from 0.8 to 6.4 km (0.5 to 4 miles) from roosts to foraging areas in mid-August, a period that would coincide with late lactation (Bradley 1996). Similar results were reported for C. townsendii during the post-lactation period in coastal central California (mid-September). Foraging areas for females were centered 3.2 ± 0.5 km (2 ± 0.3 miles) from

Table 7. Spatial patterns of foraging by female Townsend’s big-eared bat (Corynorhinus townsendii) in different reproductive stages.

<table>
<thead>
<tr>
<th>Subspecies and Reproductive Period</th>
<th>Location and Timing of Study</th>
<th>Duration of Study</th>
<th>Distance Traveled to Foraging Areas or Size of Foraging Area&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. townsendii&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early pregnancy</td>
<td>Central Oregon</td>
<td>9 weeks</td>
<td>Range: 5-24 km</td>
<td>Dobkin et al. (1993)</td>
</tr>
<tr>
<td>C. t. pallescens</td>
<td>East-central Nevada</td>
<td>2 weeks</td>
<td>Range: 0.8-6.4 km</td>
<td>Bradley (1996)</td>
</tr>
<tr>
<td>Post-lactation&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Mid-August</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. t. townsendii</td>
<td>Coastal central California</td>
<td>10 days</td>
<td>3.2 ± 0.5 km to center of activity areas</td>
<td>Fellers and Pierson (2002)</td>
</tr>
<tr>
<td>Post-lactation&lt;sup&gt;4&lt;/sup&gt;</td>
<td>Mid-September</td>
<td></td>
<td>(EL): 1.0 (range: 0.5-2.0) km; Foraging area – 89.9 ha</td>
<td>Clark et al. (1993)</td>
</tr>
<tr>
<td>C. t. ingens</td>
<td>East-central Oklahoma</td>
<td>7 weeks</td>
<td>km; Foraging area – 156.9 ha</td>
<td></td>
</tr>
<tr>
<td>Early lactation – late lactation</td>
<td>8-17 June (early lactation)</td>
<td></td>
<td>(LL): 4.2 (range: 1.1-7.7) km; Foraging area – 65.5 ha</td>
<td></td>
</tr>
<tr>
<td></td>
<td>28 June-7 July (mid-lactation)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>17-26 July (late lactation)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. t. virginianus</td>
<td>Eastern Kentucky</td>
<td>14 weeks</td>
<td>(PR): Foraging area – 60.5 ha</td>
<td>Adam et al. (1994)</td>
</tr>
<tr>
<td>Pregnancy – post-lactation</td>
<td>10-15 May (pregnancy)</td>
<td></td>
<td>(L): Foraging area – 98.8 ha</td>
<td></td>
</tr>
<tr>
<td></td>
<td>17-22 June (lactation)</td>
<td></td>
<td>(PL): 0.74 ± 0.42 km; maximum distance = 3.65 km;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6-11 August (post-lactation)</td>
<td></td>
<td>Foraging Area – 262.8 ha</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup>Distance traveled was not reported in some cases. In these cases, we present the size of foraging areas.

<sup>2</sup>Subspecies undifferentiated. Study area was within the zone of intergradation of C. t. pallescens and C. t. townsendii.

<sup>3</sup>Reproductive stage not identified. Based on the timing of reproductive stages in other areas, mention of maternity colonies and timing of returns to roosts (between 0300 and 0500 hrs), we make the assumption that the bats were post-lactating.

<sup>4</sup>Sample included one nulliparous female.
various habitat components to address the importance of spatial arrangement of area efficiently. Although no studies have specifically water influences an animal’s ability to use a particular arrangement and juxtaposition of shelter, food, and the energetic costs for the animal. Thus, the spatial the size of the animal’s home range, and the greater must travel to connect these elements, the greater will be their home range (Bradley 1996). The farther an animal 

While it is unclear why females travel longer distances to foraging sites as lactation progresses, we may speculate that it is to meet the increased energetic demands of lactation, to allow newly volant young to exploit nearby foraging areas, or because young are able to go longer without nursing, mothers may be less constrained to remain near roosts. Whatever the reason, Townsend’s big-eared bats do not appear to range very far from the roost, even when considering the increased distances traveled by reproductive females. However, there is no good way to determine how far is too far for Corynorhinus townsendii to travel, and it will likely vary from place to place and from season to season. All else being equal, the greater the distance that bats must travel to foraging or drinking sites, the greater will be their energy expenditure.

**Landscape context**

Of primary importance to animals is the ability to find shelter, food, and water. Most animals have a home range in which these elements are available and familiar to the animal. For example, although female Corynorhinus townsendii in Nevada showed high fidelity to their maternity roost, they displayed familiarity with and casual use of other roosts within their home range (Bradley 1996). The farther an animal must travel to connect these elements, the greater the size of the animal’s home range, and the greater the energetic costs for the animal. Thus, the spatial arrangement and juxtaposition of shelter, food, and water influences an animal’s ability to use a particular area efficiently. Although no studies have specifically addressed the importance of spatial arrangement of various habitat components to C. townsendii, our understanding of what constitutes suitable foraging habitat, combined with knowledge of travel distances and patterns, suggests that foraging and drinking habitat located near roosts and/or connected by vegetated patches or corridors may be necessary to support colonies of C. townsendii.

Townsend’s big-eared bats appear not to travel very far from roost sites to forage or drink. Published estimates of distances traveled from roost to foraging areas report a maximum distance of 10.5 km (6.5 miles), but the distance traveled is usually substantially less. For instance, during the study that recorded the distance of 10.5 km, females traveled on average 3.2 km (2 miles) to foraging sites, and males ventured a mean distance of 1.3 km (0.8 miles) from roosts (Fellers and Pierson 2002). Compared to some species of bats that routinely travel distances several-fold farther (e.g., hoary bats), use of such small areas by Corynorhinus townsendii suggests that landscape context could be a limiting factor. This might be explained by their low wing-loading and their rounded wings, which allow very agile flight, but which also result in relatively inefficient forward flight compared to bats with higher wing-loading and more pointed wing tips (Norberg and Rayner 1987). Given that other similar-sized species with similar wing morphology (e.g., western long-eared bat [Myotis evotis]) also maintain small foraging areas (Waldien and Hayes 2001), energetic costs associated with commuting may constrain C. townsendii and other species of bats that share similar wing morphology to forage near roosts. Whatever the reason, maintaining foraging and drinking habitat within close proximity to roosts may be necessary to allow C. townsendii to meet energetic needs efficiently. If so, an important corollary is that removal or alteration of habitat that reduces the productivity of foraging or drinking areas (e.g., clear-cutting, water diversion, draining wetlands) near roosts may result in extirpation of colonies, whereas activities that increase the value of a site (e.g., selective thinning, water impoundment) will likely benefit bats roosting nearby and may increase the likelihood of long-term persistence of colonies using these sites.

Several authors (e.g., Limpens and Kapteyn 1991, Verboom and Huitema 1997) have noted a propensity for bats in general to use forest-edge habitat, and even to avoid open areas while commuting and foraging, and this appears to be true for Corynorhinus townsendii as well. In Kentucky, male C. townsendii virginianus consistently used an abandoned logging road in forested habitat to commute to foraging areas, and females tended to fly along the edges of cliffs while traveling to foraging areas (Adam et al. 1994). Townsend’s big-eared bats in Nevada and California also used forest edges and other linear landscape elements while commuting (Ports and Bradley 1996, Fellers and Pierson 2002). Use of such linear landscape elements may provide orientation cues, profitable foraging habitat, and, perhaps, shelter from predators of the bats. In addition, movements within vegetated stream corridors or near forest edges may reduce flight costs by buffering bats from windy conditions. Indeed, it is partly because of lower winds that insects tend to collect in such places (Lewis 1970). This may also help to explain why C. townsendii observed crossing open grassland dropped down sharply and flew at a height of about 1 m (3 ft.), whereas they otherwise flew from
10 to 30 m (33 to 100 ft.) above the ground (Fellers and Pierson 2002). In the Rocky Mountains, where natural disturbances maintain patterns of patchy forest habitats (Howe and Baker 2003), *C. townsendii* likely relies on edges and linear landscape elements for foraging and commuting, as they do in other parts of their range. Although gaps in forest canopies and the creation of edge habitat may benefit the bats, too much open space is likely to have negative consequences. Several reports indicate that Townsend’s big-eared bats tend to avoid large openings such as grazed pastureland (reviewed in Pierson et al. 1999).

The connectivity of habitat features can influence how an animal utilizes habitat in their home range. For species that tend to avoid open areas, accessibility to foraging sites may require linear or closely situated habitat patches that they can use while commuting. Consequently, for *Corynorhinus townsendii*, connectivity may be especially important as commuting distance from roosts to foraging or drinking habitat increases. Given that females appear to increase the size of foraging areas and distances commuted as the reproductive season progresses (Clark et al. 1993, Adam et al. 1994), foraging sites that are more distant from roosts will be more accessible if connected by vegetated linear elements (e.g., ravines and stream corridors).

**Food habits**

Reports indicate that *Corynorhinus townsendii* is a moth specialist (e.g., Whitaker et al. 1977, Dalton et al. 1986, Clark 1991, Burford and Lacki 1998), with more than 90 percent of the diet consisting of lepidopterans (reviewed in Pierson et al. 1999). Preferred prey items include small (6 to 12 mm) moths from the families Noctuidae, Geometridae, Notodontidae, and Sphingidae. However, *C. townsendii* appears to forage opportunistically on other prey items (e.g., beetles and flies) as well (Pierson et al. 1999).

In the West, *Corynorhinus townsendii* forage in woodlands, canopy gaps, vegetated stream corridors, and other linear landscape elements but avoid foraging and traveling in open areas and grazed lands (Pierson et al. 1999). Owing to their wing and echolocation morphology, *C. townsendii* are capable of efficient foraging among foliage and of gleaning insects directly from substrates (Norberg and Rayner 1987), and they are predicted to forage primarily in close proximity to foliage and amongst forest canopy. Where foraging patterns by *C. townsendii* have been documented, this association appears to hold (e.g., Bradley 1996, Fellers and Pierson 2002). Individuals or colonies may show high fidelity to particular foraging sites (Bradley 1996, Fellers and Pierson 2002), as well as to routes of travel between roost and foraging grounds (Fellers and Pierson 2002). While commuting, *C. townsendii* tends to follow the same linear features (e.g., stream corridors, forest edges) around which it forages (Fellers and Pierson 2002), and as noted above, connectivity of habitat patches may greatly influence the accessibility of foraging sites to *C. townsendii*.

**Breeding biology**

Pearson et al. (1952) conducted the most thorough analysis of breeding biology and behavior of *Corynorhinus townsendii* to date. Except where otherwise noted, the information on breeding that follows is summarized from their work.

**Breeding phenology**

Initiation of sperm production in adult males begins in the spring and continues slowly until late summer when there is a rapid increase in the size and volume of the accessory glands. Juvenile males produce sperm, albeit in small numbers, which apparently do not migrate into the epididymides. Thus, males are effectively sterile until their second year. Once the hibernation period ends and the bats disperse, males are completely dissociated from the reproductive process. Males play no role in rearing young and are rarely present in the roosts of pregnant and lactating females (Kunz and Martin 1982). Thus, care and nurturing of the young falls solely to the female.

Townsend’s big-eared bat is seasonally monoestrous (Figure 9), and females enter estrous in late summer or early autumn. Mating is most vigorous during this period. Copulation may also take place sporadically through the winter during periodic arousals from torpor. Although coitus primarily occurs in the hibernacula, some females arriving at the hibernacula in late October were already inseminated, suggesting onset of copulation before arrival at hibernation roosts (see discussion below in Breeding behavior). Females store sperm during the hibernation period and do not ovulate until arousing from hibernation in spring. Due to the physiological constraints imposed by hibernation, females suspend normal progression of the reproductive cycle following estrous and mating. Delayed fertilization is one of several reproductive delay strategies employed by bats and other mammals. It is the most commonly described strategy among species of bats that hibernate (Oxberry 1979), and in all likelihood, it is the strategy employed by Townsend’s
big-eared bat. As with other reproductive delays, it is hypothesized to synchronize parturition to periods of optimal food resources and developmental conditions for the young (Racey 1979). Delayed fertilization entails the prolonged storage of sperm in the female reproductive tract following copulation and during the hibernation period. Upon emergence in the spring, ovulation occurs and fertilization, implantation, and gestation then progress normally (Neuweiler 2001). The gestation period varies from 40 to 60 days, and the duration apparently depends on ambient temperature (Kunz and Martin 1982) and levels of precipitation (Grindal et al. 1992). Parturition occurs mid-summer, coinciding with periods of high prey availability. In general, timing of parturition appears to be unrelated to latitude. Parturition began in late May in California, mid-July in Washington state, and June in Texas (Kunz and Martin 1982). Juveniles are volant by 3 weeks of age, but they continue to receive milk for up to 6 weeks following birth.

The most important factors influencing the duration of gestation and the timing of parturition in insectivorous bats relate to the ability of females to allocate energy to the developing fetus or offspring. Females in poor body condition and yearling females generally give birth later than adult females with greater energy reserves. When spring and summer temperatures are low and precipitation is high, bats face higher thermoregulatory costs and lower prey availability, resulting in increased use of torpor and concomitant delays in fetal development and offspring growth and development (Racey 1969). Under these conditions, females of other species of bats may forego reproduction and abort or resorb the embryo (Grindal et al. 1992, Lewis 1993); this likely also occurs with Townsend’s big-eared bats. During an unusually cool wet year in the Black Hills, no juvenile Corynorhinus townsendii were captured, and surveys at two maternity colonies indicated either very late parturition (probably early August) or no births during that summer. In contrast, parturition occurred in mid-May the previous year (Tigner and Dowd Stukel 2003).

Breeding behavior

For bats that hibernate, mating generally occurs at hibernacula but may also occur at “swarming sites” or interim roosts after dissolution of maternity colonies but before the onset of hibernation (e.g., Thomas et al. 1979). Swarming sites may be used as hibernacula by some or all of the individuals that aggregate there (Thomas et al. 1979). In general, males mate with multiple females, and multiple males inseminate a female. It is possible, but not known, that select male Corynorhinus townsendii may sire a disproportionate share of offspring, as is the case for other mammals (including bats) with this type of mating system. For example, Watt and Fenton (1995) found evidence of skewed paternity among maternal colonies of the little brown bat (Myotis lucifugus). Although the situation with respect to Townsend’s big-eared bat is unresolved (and, to our knowledge, has not been studied), work on a similar species, the brown long-eared bat (Plecotus auritus), in Europe provided evidence that while males from different colonies typically sired offspring, there was no indication of skewed paternity among offspring (Burland et al. 2001). Because brown long-eared bats are similar to Townsend’s big-eared bats in having limited dispersal and high natal philopatry (Burland et al. 2001), sires from colonies outside the areas in which maternity colonies occur likely serve to minimize inbreeding and to increase genetic diversity (Veith et al. 2004).
Males appear to be largely responsible for initiation of breeding, while females appear to be passive participants in the copulatory process. Pearson et al. (1952) noted pre-copulatory behavior by observing four males and one unmated female in the laboratory. Males approached the pendant female from the front while vocalizing (“making twittering sounds”) and embraced her. For a period of some minutes during the embrace, the male “vigorously rubbed his snout over the face, neck, forearms and ventral surface of the female.” This behavior was thought to involve the enlarged nose glands (Figure 2) and was interpreted to be an attempt to encourage capitulation of the female. The female apparently was unyielding, however, and no description of copulatory behavior was recorded. Pearson et al. (1952) observed one instance of copulation in a cave, and they noted that the pair was oriented “in the usual manner of copulating mammals.”

**Fecundity and survivorship**

Because of their unique life histories, bats produce relatively few offspring during each reproductive cycle compared to other small mammals. Like many other insectivorous bats, Townsend’s big-eared bat produces a maximum of one young per year. Additionally, females are apt to forego reproduction in some years due to poor body condition, low prey availability, or cool temperatures (Grindal et al. 1992, Lewis 1993, Racey and Entwhistle 2000, Barclay et al. 2004). Because initiating pregnancy upon spring arousal from hibernation requires some minimum level of energy reserves (Kunz et al. 1998), females that emerge from hibernation with very low energy stores may not be capable of the additional energetic requirements of pregnancy and lactation. In addition, females that initiate pregnancy may abort if subsequently faced with cool, wet weather and concomitant reduction in prey availability and increased thermoregulatory costs. For example, Lewis (1993) found a negative correlation with spring temperatures and proportion of non-breeding females in pallid bat colonies, and Grindal et al. (1992) concluded that high levels of precipitation during spring and summer resulted in increased incidence of non-reproductive females in little brown bats and Yuma myotis (*Myotis yumanensis*). Therefore, the maximum annual reproductive output of one offspring per female for Townsend’s big-eared bat is likely not realized for all females every year. Because conditions in the hibernacula (e.g., temperature, frequency of arousal) influence, in part, body condition in the spring, increased levels of disturbance during the winter may also affect reproductive output.

Bats in general have remarkably long life spans for their size. Paradiso and Greenhall (1967) recorded an age of 16 years 5 months for an individual *Corynorhinus townsendii* in California, and more recently a new longevity record of greater than 21 years was established (Perkins 1994). Although these data cannot be considered to represent average values for *C. townsendii*, they do demonstrate the remarkable potential for longevity that appears to be characteristic of bats. Such life spans reflect high survivorship in adults. However, juvenile survivorship appears to be much lower in *C. townsendii* and other species of bats. The mortality rate of juvenile *C. townsendii* was estimated to be 38 to 54 percent (Pearson et al. 1952). Survival in subsequent years, however, jumps markedly to about 80 percent (Pearson et al. 1952). Loss of some bats between birth and their first full summer must surely be attributable to a lack of sufficient fat reserves to survive hibernation. However, Pearson et al. (1952) noted relatively few young bats present in hibernacula, which led them to speculate that most juvenile mortality occurred prior to the bats entering hibernation. Whatever the mechanism, the fact remains that juvenile bats experience relatively high rates of mortality while adults appear to have high probability of surviving.

The lack of more recent studies on survivorship in *Corynorhinus townsendii* and other species of bats may be surprising. However, it is important to recognize that such studies rely primarily on resighting or recapture of banded individuals, the latter of which is often done in hibernacula or maternity roosts and requires handling of substantial numbers of bats (e.g., Mohr 1952, Hitchcock 1965). These activities, common in the mid-1900’s, were largely discontinued by the 1970’s. Concern that the activities of researchers were, in concert with other extrinsic factors, effecting a decline in numbers of cave-dwelling species of bats (Mohr 1952), resolutions were adopted in the early 1970’s that limited the tolerance of such research (Henshaw 1972). In particular, the widespread practice of bat banding was deemed a potential source of added mortality because of the possibility of injuries from bands (e.g., Humphrey and Kunz 1976, Pierson and Fellers 1993) and because banding often occurred at hibernacula. Thus, the practice of bat banding fell out of favor and remains so today (e.g., Baker et al. 2001).

**Population demography**

**Life history parameters**

As a group, bats live longer and have lower reproductive output than would be predicted for
mammals of their size (Barclay and Harder 2003). Bats may live several decades, and most give birth only once per year to one or two pups, a life history that contrasts markedly from small terrestrial mammals. Nocturnality and flight are characteristic traits of bats, and these have played important roles in the evolution of life histories of bats (Barclay and Harder 2003), primarily by reducing predation pressure (Speakman 1995).

An important consequence of their low reproductive rate is that bat populations that experience rapid declines may be unable to replenish their numbers in the absence of immigration. This is a particular concern for species such as Corynorhinus townsendii that are relatively sedentary and exhibit a high degree of site fidelity (Kunz and Martin 1982).

Spatial characteristics and genetic concerns

Currently, no studies are available that address the level of genetic diversity within populations of Corynorhinus townsendii. The distribution of C. townsendii tends to be restricted by the presence of caves and mines that are not distributed uniformly across the landscape, and may be separated by patches of unsuitable habitat. Therefore, local populations may exist in relative isolation, and opportunity for immigration into unoccupied habitat may be limited. Consequently, gene flow between populations may be also limited. As shown with other species, it is possible that genetic diversity may be maintained by mixing of individuals from different parts of their range when they aggregate at hibernacula or interim roosts where mating occurs (e.g., Burland et al. 2001). However, C. townsendii appears to be a relatively sedentary species that is not known to engage in long-distance migration to hibernation sites (Kunz and Martin 1982), so it is unclear how extensive such mixing might be for this species. Further research is necessary before conclusions on the degree of genetic isolation among populations of C. townsendii can be drawn.

Life history model

The information presented here detailing the influence of life history parameters on population levels is summarized from matrix models created by Dave McDonald and Takeshi Ise for this conservation assessment. Because of the highly technical nature of the methods, we have summarized the most important results and findings from the models, and we refer the reader to Appendix B for a more technical discussion of the model results. Specifically, we discuss how birth rate, survival rate, and probability of reproduction at various age classes affect population structure. Additionally, we interpret the results of the model in the context of current theories regarding chiropteran life history, which suggest that factors identified by the model as being most influential to population dynamics of Corynorhinus townsendii result in part from their evolutionary history.

Model description

Terms in the model: Three inputs are used to model population dynamics: \( P_i \) describes the probability of survival from one age class to the next (i.e., a survival rate); \( B_i \) describes the probability that a female will reproduce in the \( i^{th} \) age class; \( m_i \) describes the number of female offspring produced by the \( i^{th} \) female and captures the concept of fertility or fecundity (Table 8). Collectively, these three inputs are termed the vital rates of the model. In addition, because both \( P_i \) and \( B_i \) effect changes in the number of individuals in younger or older age classes, they are referred to as transitions. The relationship between these terms and the number of individuals in each age class is expressed graphically in the life cycle diagram (Figure 10) and in matrix form (Table 9).

Features and assumptions of the model: The life history model is an age-structured population model, based on Leslie matrices, that examines how various life history attributes combine to influence population dynamics in a closed population, with specific reference to females. That is, the model focuses on the distribution of females among various age classes and how class-specific vital rates drive population dynamics through time. These models are widely applicable to many biological systems and taxa, which has led to their frequent use in conservation biology (Mills et al. 1999).

The model comprises a series of discrete bins (age classes or stages) wherein individuals advance from one age class to the next, and where the probability of advancing (i.e., the probability of surviving from age \( i \) to age \( i+1 \)) depends on and varies by class. Similarly, the probability that a female will reproduce, and the number of female offspring she bears will vary among age classes. Thus, the model may be viewed as a system in which individuals flow from birth (youngest age class) to death while producing some number of offspring along the way, and the reproductive output of all age classes replenishes the pool of individuals in the youngest age class. The model is iterated across
**Table 8.** Parameter values for the component terms \((P_i, m_i, and B_i)\) that make up the vital rates in the projection matrix for Townsend’s big-eared bat.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Numeric value</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(m)</td>
<td>0.5</td>
<td>Number of female offspring produced by a female</td>
</tr>
<tr>
<td>(B_1)</td>
<td>0.9</td>
<td>Probability of reproduction of Age Class 1</td>
</tr>
<tr>
<td>(B_a)</td>
<td>0.95</td>
<td>Probability of reproduction of Age Class 2 to 5 (adult females)</td>
</tr>
<tr>
<td>(P_{21})</td>
<td>0.576</td>
<td>First-year survival rate</td>
</tr>
<tr>
<td>(P_a)</td>
<td>0.85</td>
<td>Annual survival rate of adults</td>
</tr>
</tbody>
</table>

**Figure 10.** Age-classified life cycle graph for Townsend’s big-eared bat. The numbered circles (nodes) represent the six age classes. The arrows (arcs) connecting the nodes represent the vital rates — transitions between age classes such as survival \((P_{ji})\) or fertility (the arcs pointing back toward the first node from Nodes 1 through 5). Note that reproduction begins at the end of the first year, and that the reproductive arcs include terms for survival of female parent \((P_i)\) as well as number of female offspring per female \((m_i)\).

**Table 9A. Symbolic values.**

<table>
<thead>
<tr>
<th>Stage</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(P_{21}mB)</td>
<td>(P_{32}mB)</td>
<td>(P_{43}mB)</td>
<td>(P_{54}mB)</td>
<td>(P_{65}mB)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>(P_{21})</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>(P_{a})</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>(P_{a})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>(P_{a})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(P_{a})</td>
<td></td>
</tr>
</tbody>
</table>

**Table 9B. Numeric values.**

<table>
<thead>
<tr>
<th>Stage</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.259</td>
<td>0.4038</td>
<td>0.4038</td>
<td>0.4038</td>
<td>0.4038</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.576</td>
<td>0.85</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>0.85</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>0.85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>0.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.85</td>
<td></td>
</tr>
</tbody>
</table>
a number of generations, and the outcome of these iterations is a discrete estimate of population growth ($\lambda$) through time.

It is important to note that these models are designed to assess the effects of changes to intrinsic, rather than extrinsic, factors. For instance, the contribution of a particular age class to increases in population size (i.e., births) will depend both on the probability of surviving to that class and the probability of reproducing in that age class (Figure 10), but not on specific perturbations affecting habitat availability or quality. Nonetheless, if a perturbation (extrinsic factor) is known to affect an intrinsic factor in a specific manner, say, by reducing fertility or survivability of a particular age class, then revised estimates of those intrinsic factors can be incorporated into a revised model. Knowing the relative importance of age-specific life history variables in terms of population dynamics, therefore, permits analysis of which terms are most important for population dynamics.

Model results and discussion: The major results from the life history model are that both survival and fertility are key factors to population viability of Corynorhinus townsendii, but survival appears to be more important to overall population dynamics. In particular, females in the second age class are expected to be key components of populations of C. townsendii. These females, having successfully transitioned to Age Class 2 (i.e., survived their first winter), are not only substantially more likely to survive future winters (85 percent versus 58 percent for Age Class 1 individuals), but they also have the greatest reproductive value (Table 10). Therefore, extrinsic factors that lower or restrict recruitment of females into Age Class 2 will have disproportionate effects on population dynamics. Moreover, in the absence of density-dependent survival or reproduction, a decline in first-year survival (i.e., lower recruitment of second-year females) is likely to generate a cascading effect that may have serious consequences for long-term population stability. That is, reduced recruitment of Age Class 2 females may lead to a slight reduction in the number of juveniles, which in turn could lower the pool of individuals that may be recruited into the second age class.

Results of the model presented thus far are derived from a deterministic model, in which life history parameters were not permitted to vary. This restriction was necessary to tease apart important transitions, and it highlighted the importance of survival of Age Class 2 females relative to other age classes. An alternative use of the model is to gauge the effects of stochastic variation in these values by allowing life history variables to fluctuate.

Based on outcomes from the stochastic model (Table 11), three important results are discernable: 1) variation in survival rates had a somewhat greater effect on $\lambda$ than did variation in fertilities; 2) negative population effects were exacerbated by slight fluctuations in the magnitude of the variation, and; 3) population dynamics were negatively affected as variation in values for life history variables increased, even though average vital rates remained the same as under the deterministic model. Cumulatively, these results suggest that Corynorhinus townsendii are vulnerable both to stochastic fluctuations in reproduction rate and to variations in survival.

The matrix model points to adult survival as the primary source of stability in populations of Townsend’s big-eared bat, but it tells us little about why this should be the case. To understand the reasons why, and to evaluate whether the results of this model are consistent with life history theory in general, we now review some current theory regarding the evolution of bat life histories.

Table 10. Reproductive values for female Townsend’s big-eared bats. Reproductive values can be thought of as describing the “value” of an age class as a seed for population growth relative to that of the first (newborn or, in this case, egg) age class. The reproductive value of the first age class is always 1.0. The relatively low peak reproductive value is highlighted.

<table>
<thead>
<tr>
<th>Age Class</th>
<th>Description</th>
<th>Reproductive values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Female newborns ($F_i = 0.2592$)</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>Adult females ($F_i = 0.40375$)</td>
<td><strong>1.29</strong></td>
</tr>
<tr>
<td>3</td>
<td>&quot; &quot;</td>
<td>1.04</td>
</tr>
<tr>
<td>4</td>
<td>&quot; &quot;</td>
<td>0.75</td>
</tr>
<tr>
<td>5</td>
<td>&quot; &quot;</td>
<td>0.40</td>
</tr>
<tr>
<td>6</td>
<td>Maximum Age Class</td>
<td>0.00</td>
</tr>
</tbody>
</table>
From a life-history standpoint, temperate-zone insectivorous bats are characterized by a combination of relatively long life span and low annual reproductive output. This condition departs radically from the life histories of other small mammals, which generally reproduce quickly and die young (Findley 1993). A recent analysis of the life history of bats identified reduction in extrinsic mortality (spurred by the development of flight) as a key factor in the evolution of longevity in bats, and proposed that increased longevity in turn allowed low annual reproductive output (Barclay and Harder 2003). Thus, low extrinsic mortality and low fecundity have become tightly coupled during the evolution of bats. This coupling underscores the importance of survival relative to fertility and is consonant with the results of the matrix model. This further highlights the need to minimize or eliminate extrinsic sources of mortality to conserve populations of *Corynorhinus townsendii* from peril.

Another consequence of the unique life histories of bats, and one that follows from the link between longevity and low reproductive output, is that females may increase their fitness by foregoing reproduction during “bad” years. Because *Corynorhinus townsendii* cannot produce more than one offspring per year per female, the ability to offset lost reproductive output from “bad” years with more than one offspring per female during “good” years does not exist. Hence, when levels of extrinsic mortality exceed those under which the life histories of bats evolved, population declines are almost certainly the inevitable outcome.

| Table 11. Summary of three variants of a stochastic projection for Townsend’s big-eared bats. |
|----------------------------------------------------------|-----------------|-----------------|-----------------|
| **Input factors:**                                       | Variant 1       | Variant 2       | Variant 3       |
| Affected cells                                           | $P_i$           | $P_i$           | $P_i$           |
| S.D. of random normal distribution                      | 1/4             | 1/4             | 1/3.5           |

| **Output values:**                                       |                  |                  |                  |
| Deterministic $\lambda$                                 | 1.00010          | 1.00010          | 1.00010          |
| # Extinctions / 100 trials                               | 20               | 66               | 82               |
| Mean extinction time                                     | 1,657.4          | 1,344.2          | 1,135.3          |
| # Declines / # survived pop                             | 73/80            | 31/34            | 18/18            |
| Mean ending population size                              | 8,254.5          | 2,166.2          | 365.0            |
| Standard deviation                                       | 41,190.3         | 5,895.7          | 865.2            |
| Median ending population size                            | 299.16           | 134.11           | 49.93            |
| Log $\lambda$                                           | -0.00269         | -0.00548         | -0.00766         |
| $\lambda_s$                                             | 0.9973           | 0.9945           | 0.9924           |
| % reduction in $\lambda$                                | 0.279            | 0.557            | 0.773            |

From a life-history standpoint, temperate-zone insectivorous bats are characterized by a combination of relatively long life span and low annual reproductive output. This condition departs radically from the life histories of other small mammals, which generally reproduce quickly and die young (Findley 1993). A recent analysis of the life history of bats identified reduction in extrinsic mortality (spurred by the development of flight) as a key factor in the evolution of longevity in bats, and proposed that increased longevity in turn allowed low annual reproductive output (Barclay and Harder 2003). Thus, low extrinsic mortality and low fecundity have become tightly coupled during the evolution of bats. This coupling underscores the importance of survival relative to fertility and is consonant with the results of the matrix model. This further highlights the need to minimize or eliminate extrinsic sources of mortality to conserve populations of *Corynorhinus townsendii* from peril.

Another consequence of the unique life histories of bats, and one that follows from the link between longevity and low reproductive output, is that females may increase their fitness by foregoing reproduction during “bad” years. Because *Corynorhinus townsendii* cannot produce more than one offspring per year per female, the ability to offset lost reproductive output from “bad” years with more than one offspring per female during “good” years does not exist. Hence, when levels of extrinsic mortality exceed those under which the life histories of bats evolved, population declines are almost certainly the inevitable outcome.

Community ecology

**Figure 11** presents an envirogram for Townsend’s big-eared bat. An envirogram provides a graphical representation of the web of factors that influence the ability of a species to survive and reproduce, but it does not represent the relative strength or importance of the factors. Much of the community ecology of *Corynorhinus townsendii* discussed in the following sections is captured graphically in this envirogram, which is divided into three basic types of elements influencing bat ecology: resources, malentities, and predators (Andrewartha and Birch 1984).

Townsend’s big-eared bat (as well as other species of bats) fills important ecological roles by providing unique and important ecosystem services (Ducummon 2000, Agosta 2002). Insectivorous bats, such as *Corynorhinus townsendii*, are the only night-time consumers of flying insects. Because many species of insect pests are nocturnally active (Wilson 2004), they are available to bats as prey. Bats may therefore represent effective and essentially free sources of biological control, particularly when pest populations peak. During outbreaks, bats may shift diet to the relatively more abundant pest species (Wilson 2004). Therefore, they may mitigate pest-related damage and loss, and provide concomitant economic benefits. Colonies of Mexican free-tailed bats (*Tadarida brasiliensis*) and big brown bats (*Eptesicus fuscus*) regularly consume vast quantities of insects, many of which are responsible for substantial economic damage to agricultural crops.
Figure 11. Envirogram for Townsend’s big-eared bat (after Andrewartha and Birch 1984).
Predators and competitors

Community ecology of bats is greatly influenced by their life histories, which are typically characteristic of K-selected species: low reproductive rates, long life span, and low extrinsic mortality (Findley 1993). Bats' nocturnal activity, aerial foraging, and secretive roosting habits have all served to reduce predation pressure, but they do not completely escape predation. Townsend's big-eared bat may be more susceptible to predation than some other species of bats owing to its colonial and visible roosting habits. Predators such as snakes, raptors, and small mammalian carnivores take bats opportunistically (Barbour and Davis 1969, Fenton et al. 1994) although specific reports of predation are few. Thus, the ecosystem and community ecology roles played by bats likely provide benefits that exceed any of the negatives usually attributed to bats. Effectively conveying this message to the public, which often holds a generally negative perception of bats, is likely to pay benefits in the form of increased support for conservation efforts. See our discussion below under Tools and practices for a more detailed discussion of education goals and strategies.

Insectivorous bats also are influential in transferring soil nutrients, notably nitrogen, from foraging areas to roosting areas, via their feces (Pierson 1998). Thus, the ecosystem and community ecology of K-selected species: low reproductive rates, long life span, and low extrinsic mortality (Findley 1993). Bats' nocturnal activity, aerial foraging, and secretive roosting habits have all served to reduce predation pressure, but they do not completely escape predation. Townsend's big-eared bat may be more susceptible to predation than some other species of bats owing to its colonial and visible roosting habits. Predators such as snakes, raptors, and small mammalian carnivores take bats opportunistically (Barbour and Davis 1969, Fenton et al. 1994) although specific reports of predation are few. Thus, the ecosystem and community ecology roles played by bats likely provide benefits that exceed any of the negatives usually attributed to bats. Effectively conveying this message to the public, which often holds a generally negative perception of bats, is likely to pay benefits in the form of increased support for conservation efforts. See our discussion below under Tools and practices for a more detailed discussion of education goals and strategies.

North-temperate bat communities appear to be saturated (Findley 1993), suggesting that competition may be an important factor in structuring bat communities. However, the extent to which competition drives the structure of these assemblages remains equivocal (Findley 1993, Kingston et al. 2000). Although patterns in the structure of local bat assemblages often are suggestive of resource partitioning (e.g., Aldridge and Rautenbach 1987, Crome and Richards 1988), there is as yet little direct evidence of competition between species.

Although Townsend's big-eared bat is known to share roost sites with other species (see below) and visit the same watering holes that are used by other species of bats (e.g., Adams et al. 2003), no studies have attempted to directly assess competitive interactions between Townsend's big-eared bat and other species of bats. However, several attempts to demonstrate competition between morphologically similar species of insectivorous bats have been made by focusing on the degree of niche overlap between similar sympatric species. For example, morphologically similar species of *Myotis* showed greater dietary overlap in allopatry than in sympatry (Husar 1976), and morphologically similar sympatric species of *Myotis* segregated foraging space and prey items (Arlettaz 1999, Siemers and Swift 2006). These lines of evidence, while not conclusively demonstrating competition, nonetheless illustrate that for bats exploiting essentially the same prey resource in similar ways, the means to avoid direct competition exist (Siemers and Swift 2006). In addition, different species of bats often emerge to forage at different and often predictable times (Jones 1965, Barbour and Davis 1969, Fenton et al. 1980), a behavior that may represent temporal partitioning of resources. For example, the silver-haired bat (*Lasionycteris noctivagans*) alters its activity period when sympatric with ecologically similar species such as Eastern red bat (*Lasiurus borealis*), the hoary bat, and the big brown bat (reviewed in Kunz 1982). However, because competition is difficult to demonstrate, even between closely related sympatric species (Arlettaz 1999), questions regarding the extent to which competition shapes the ecology of Townsend's big-eared bat remain open.
Parasites and disease

In general, a number of external parasites complete all or part of their life cycles on bats, and two species of fleas (Nycteridopsylla vancouverensis and Myodopsylla palposa) have been identified from Townsend’s big-eared bats (Haas et al. 1983). Although the effects of parasites on bats are generally unknown, Lewis (1995) hypothesized that reduction of parasite loads should increase fitness and may partially explain roost-switching behavior.

As with other mammals, Corynorhinus townsendii can be a vector for the rabies virus, but no estimates of the prevalence of rabies in Townsend’s big-eared bat exist. In general, the incidence of rabies in wild populations of bats appears to be exceedingly low (see below), and it poses minimal threat to humans (Constantine 1979, Constantine et al. 1979) and no threat to the persistence of the species. Despite the facts of the situation, the perception of bats as deadly vectors of rabies has greatly harmed their image and resulted in public desire to exterminate bats. Bat Conservation International (BCI), provides a concise account of the bat-rabies connection on its website (http://www.batcon.org/), from which some of the following information was derived.

Historically, most rabies transmission to humans occurred in domestic animals (e.g., cats and dogs), but following widespread pet vaccination programs, wild animals now represent the bulk of animal rabies cases. Wild animals accounted for about 93 percent of animal rabies cases reported to the Centers for Disease Control in 2001, of which 37.2 percent were raccoons, 30.7 percent skunks, 17.2 percent bats, 5.9 percent foxes, and 0.7 percent other wild animals (Krebs et al 2001), but neither the total number and type of animals turned in nor the methods for their collection were reported. The apparently large proportion of bats in this list may be partially due to a recent increase in the prevalence of bats being turned in to disease professionals (Wadsworth Center 2000). Some state-level reports suggest that bats turned into health departments have a lower incidence of rabies infection (often less than 10 percent of cases), suggesting that the prevalence among the entire wild population is smaller still, perhaps on order of 0.5 to 1.0 percent (e.g., Caire 1998, Wadsworth Center 2000, Wilkerson 2001, South Dakota Bat Working Group 2004) or lower (Constantine 1979).

Further, bats rarely transmit fatal rabies infections to humans, as evidenced by the fact that rabies viruses attributed to bats that commonly live in buildings have only been associated with eight human fatalities in all of U.S. history, and the most common bat in Region 2, the little brown bat, has never been documented transferring rabies to humans. Only a bite from an infected bat that breaks the skin can transmit the rabies virus; the virus has not been isolated from bat blood, urine, or feces, and there is no evidence of air-borne transmission in buildings. Thus, the most likely way for someone to get rabies from a bat is to disturb an evidently sick bat to the point that it inflicts a severe bite, and even then, only a small portion of noticeably sick bats actually have rabies. Since normal, healthy bats will usually not allow themselves to be contacted by humans (unless they are in a state of torpor during roosting), virtually all risk of exposure can be eliminated by not handling live bats that allow such contact. If frequent interaction with live bats is a regular occurrence, a highly effective and painless vaccine is available that further reduces risk of transmission. Primary care doctors or public health officials can usually order and administer this vaccine.

More recently, West Nile virus has been confirmed in bats from a small number of cases in the United States (Gould and Fikrig 2004). However, the degree to which bats are exposed to this virus and the potential for population-level effects are currently unknown. Moreover, bats are likely beneficial in controlling West Nile virus through the consumption of mosquitoes, which are the primary vectors for the disease.

Symbiotic and mutualistic interactions

No symbiotic or mutualistic relationships are known between Corynorhinus townsendii and other species of plant or animal. Although C. townsendii is known to share roosts with other species of bats, no hypotheses regarding mutual benefits have been proposed. When other species are found roosting in the same cave or mine as C. townsendii, they are not intermixed, but instead occupy discrete places within the roost.

Species of bats known to occupy roosts with Townsend’s big-eared bats include (in no particular order): pallid bat, Rafinesque’s big-eared bat (Corynorhinus rafinesquii), Mexican big-eared bat (C. mexicanus), California leaf-nosed bat (Macrotus californicus), southwestern myotis (Myotis auricus), California myotis (M. californicus), western small-footed myotis (M. ciliolabrum), western long-eared myotis, little brown bat (M. lucifugus) Indiana bat (M. sodalis), fringe myotis (M. thysanodes), cave myotis (M. velifer), long-legged myotis (M. volans), Yuma myotis, western pipistrelle (Pipistrellus...
hesperus), eastern pipistrelle (P. subflavus), and Mexican free-tailed bat (Jagnow 1988, Pierson et al. 1999 and references therein, López-González and Torres-Morales 2004).

**CONSERVATION AND MANAGEMENT OF TOWNSEND'S BIG-EARED BAT IN REGION 2**

We have divided this chapter into sections on biological conservation status, comprised of extrinsic threats and intrinsic vulnerability, and management. Biological status synthesizes the key parameters noted earlier in this document that define the conservation status of Townsend’s big-eared bat – specifically, abundance and distribution. Following this, sections on intrinsic factors and extrinsic threats highlight elements that affect biological parameters and thus influence the biological status of the species. Intrinsic factors include those things driven primarily by the biology of the species, such as lifespan and reproductive rate, while extrinsic factors are those driven by external forces, such as predation, habitat loss, habitat disturbance, and reduction of prey base. The chapter concludes with a discussion of specific management objectives and the tools and practices that might be used to facilitate the conservation of Townsend’s big-eared bat.

**Biological Conservation Status**

**Abundance and abundance trends**

Although Corynorhinus townsendii is geographically widespread, it exists in relatively low density throughout its range (Barbour and Davis 1969, Kunz and Martin 1982), likely because of the relative paucity of suitable roosting habitat and the resulting patchy distribution this creates. Townsend’s big-eared bat is a colonial species and forms aggregations ranging from one to several hundred individuals (Table 6). The size of any particular colony apparently depends on the type of colony and the time of year. Hibernation colonies may range from a few dozen individuals to over 1000 bats (Ellison et al. 2003b). Maternity colonies are generally smaller, usually consisting of a few dozen individuals, but sometimes reaching a few hundred. Bachelor colonies are much smaller, typically consisting of only a few individuals. Relative to maternity or bachelor colonies, hibernation colonies appear to exhibit considerable temporal variation in size during the cold season, ranging from a few individuals to many hundreds at the same site. Variation in size of hibernating colonies may reflect movement of individuals among several hibernation roosts, with individuals arriving at and departing from roosts throughout the cold season. Hibernation colonies appear to remain most stable during the coldest months.

Pierson et al. (1999) reviewed the status of Corynorhinus townsendii throughout its western range, and compiled information on population numbers and trends for individual states. Below we summarize this information for the states within Region 2, and augment the information with more recent data where appropriate.

**Colorado:** Most of the information for Colorado comes from work conducted after 1990. Siemers (2002) conducted a survey that documented 11 maternity roosts in the state, six in caves and five in mines. The largest of these colonies, about 150 bats, was located in a mine. Each of the other sites held small numbers (1 to 8) of bats. Of the 30 hibernacula known from Colorado, only four were known before 1990. Most contained only a few bats, but one roost held over 200 bats. Recent surveys resulted in documented use of 12 caves (eight of which were previously unknown as roosts) by 33 Townsend’s big-eared bats.

**Kansas:** Information on population status of Corynorhinus townsendii in Kansas was unavailable.

**Nebraska:** Corynorhinus townsendii may not be a resident species in Nebraska, as the only record of occurrence is a single male found roosting on a screen door in 1972.

**South Dakota:** Most work in South Dakota has focused on the Black Hills where three maternity colonies (two with 50 individuals, one with 35 individuals) are known. More recently, Tigner and Dowd Stukel (2003) reported two hibernation colonies in Jewel Cave National Monument that collectively contained approximately 1200 Corynorhinus townsendii. There appears to be a general decrease in C. townsendii roosting in Jewel Cave since the mid 1900’s, with the greatest abundance reported as 3,750 in 1959 and a population low of 593 in 1997, which has increased to between 800 and 1200 in recent years (Ellison et al. 2003b).

**Wyoming:** There is little information available on colony size or status prior to 1994. At least three maternity colonies have been identified: one in an abandoned mine and two in caves, harboring 46, 50+, and 200+ individuals respectively, with an additional cave colony reported by Keinath (2005). Surveys at 59 caves and 17 mines conducted in 1994...
resulted in the identification of 12 occupied sites, most containing one to three bats. At this time, only two hibernacula have been found, each containing fewer than four individuals.

Since the early 1970's, bat researchers have expressed concern about apparent declines in numbers of cave-dwelling species of bats (Henshaw 1972), and Corynorhinus townsendii appears not to have been immune to the forces driving these declines. Some reports indicate that western populations of C. townsendii have declined markedly since the middle of the 20th century (Perkins and Levesque 1987, Pierson and Rainey 1998, Pierson et al. 1999). However, trends in abundance are difficult to assess in the absence of data on abundance through time, and it is important here to note that long-term monitoring data for Townsend’s big-eared bats (and for most other species of bats) are generally lacking and patchy at best. For example, Ellison et al. (2003b) compiled observations on C. townsendii at summer and winter roosts from a wide variety of sources (e.g., federal, state and local reports, Natural Heritage Programs, theses and dissertations, and published articles). Of the counts of C. townsendii at 615 colonies that they compiled, only 21 had time series that allowed analysis of trends (n ≥ 4 distinct years). Of these 21, no trend was detected at 17 colonies. Two hibernacula (including Jewel Cave, SD) and one summer colony had statistically significant declines, while one hibernaculum (Middle Butte Cave, ID) showed a significant increase.

Another difficulty in assessing trends comes from variability in data sets. For example, even for the small proportion of colonies available for analysis by Ellison et al. (2003b), variability of numbers recorded across years at some sites varied greatly (see Appendix 6 in Ellison et al. 2003b), leading to reduced statistical power to detect trends. A cursory look at the data from Ellison et al. (2003b) suggests that significant downward trends might have been detected at three additional colonies if data from a single season’s survey were removed from the data set. This variability in numbers may be attributable to methodological differences among studies and/or years, differences in survey timing, or differences in year-to-year productivity and survival. Alternatively, differences may result in part from roost-switching behavior by Townsend’s big-eared bats that may have coincided with survey events, leading to the appearance of low abundance in certain years. We take up this matter in greater detail below.

For Townsend’s big-eared bat, the primary cause for declines has generally been attributed to disturbance by humans at roost sites and uninformed closure of abandoned mines (Barbour and Davis 1969, Pierson et al. 1999, Lacki 2000). Although many species of bats that roost in caves also roost in other structures in various parts of their range, Townsend’s big-eared bat relies on caves and cave analogs for shelter. Thus, the loss of cavernicolous roosting habitat through disturbance and destruction has likely impacted Corynorhinus townsendii to a greater degree than species with more flexible roosting habits.

As noted above, the best available evidence suggests long-term declines in numbers of Corynorhinus townsendii at historic sites, with blame often assigned to a reduction of suitable roosting habitat through disturbance and destruction. Undoubtedly, increased levels of human intrusion have affected traditional roosting sites in many areas. These actions are well known to lead to roost abandonment by Townsend’s big-eared bat, and abandonment may lead to reductions in numbers if it results in lowered reproductive success and/or reduced overwinter survival (e.g., Humphrey and Kunz 1976). Thus, even without considering direct mortality of bats because of intrusion, there is a plausible nexus between roost disturbance and reduced numbers of bats.

The nexus between roost disturbance and reduced populations relies in part on the assumption that roosts are a limiting factor for Townsend’s big-eared bat. That is, bats that have been disturbed and abandon roosts may have few alternative sites to which they can go, and these alternative sites may not meet the needs of the bats during a particular life stage. However, the assumption that roosts are limited belies the fact there has been an increase in available roosts relative to pre-settlement times throughout the West. The abandonment of subterranean hard-rock mines over the past century has provided ample additional roosting opportunities, and it is clear that Townsend’s big-eared bats readily use these structures. Although recent mine closures throughout the West have removed some of these roosting opportunities (and in some cases entombed bats within), there remain many thousands of abandoned mines that did not exist a century ago. Thus, that the abundance of this species appears to have declined even while roosting opportunities have increased presents a paradox for which there are not yet satisfactory answers. Any number of possible
explanations, ranging from the simple to the complex, might explain the paradox. Here, we focus on the two principle components of the paradox: that abundance of *Corynorhinus townsendii* has decreased, and that roosting opportunities for Townsend’s big-eared bat have increased.

The assumption that the abundance of Townsend’s big-eared bat has declined throughout much of its western range – one that, given its prominence in the published literature, we have cited throughout this document – is generally based on comparisons of results of recent surveys conducted at historical sites with those of historical surveys. These studies often report reduced numbers, and sometimes a reduction in historical habitat (see Pierson et al. 1999 for overview). However, given that Townsend’s big-eared bat appears to switch roosts more often than previously assumed (Sherwin et al. 2003), we can not dismiss the possibility that recent surveys have unintentionally missed some bats that possibly were in alternate (but perhaps unknown) roosts. Whether this has happened and whether, if it has, it can account for the reductions in numbers reported are questions for which we have no definitive answers. Still, these data represent the best estimates currently available. We therefore must assume that they reflect recent trends in abundance, and conclude that declines in *Corynorhinus townsendii* less than or equal to those reported in the literature likely reflect reality.

What, then, are we to make of the fact that roosting habitat has increased during the same period that population declines are reported to have occurred? An increase in roosting habitat should, according to ecological theory, lead to an increase in numbers of those animals that rely on the habitat. Yet, our best evidence indicates that the opposite has occurred. One possible explanation is that although use of abandoned mines by *Corynorhinus townsendii* is common, these roosts may provide poor roosting conditions. For instance, mines used by a local population may be only marginally suitable for rearing offspring or for hibernation, with the result being a long-term decline in population numbers. As well, if bats using mines are exposed to sub-lethal concentrations of environmental toxins that compromise reproductive ability of adults and/or survival of young (reviewed below under Pesticides and Environmental Toxins), then the bats may experience slow or negative long-term population growth. In either case, immigration from other areas could help to bolster populations, but because of its sedentary nature, *C. townsendii* may not readily immigrate into new locales. Moreover, if slow or negative population growth is characteristic of local populations within a region, then an excess of individuals that could drive immigration is not likely to exist. Here, then, is a possible (albeit speculative and untested) scenario by which an increase in roosting habitat has not led to increased numbers of Townsend’s big-eared bats.

An alternative (and equally speculative) explanation for the paradox rests on the idea that abundance of this species is now roughly the same as it has always been, but that the bats are now more dispersed on the landscape leading to a lower overall density of bats. Altenbach and Sherwin (2002) speculated that an increase in the quantity of roosts (i.e., abandoned mines) may have served to distribute bats more evenly in space, but it might not necessarily have resulted in increased numbers of bats. This may seem an unlikely scenario, yet there is no denying that abandoned mines have increased the number of roosting opportunities (relative to pre-European settlement) for Townsend’s big-eared bat, even while populations appear to be on the decline. Altenbach and Sherwin (2002) proposed limitations in availability of energy as a possible mechanism by which this scenario might be realized, but other mechanisms are also possible (e.g., see our discussion above). Moreover, the idea that *Corynorhinus townsendii* might disperse into new habitat and yet not, realize increased numbers was hypothesized earlier. Humphrey and Kunz (1976) previously suggested that *C. townsendii* is a “capable colonizer,” but because of inherent life-history limitations (i.e., below average natality and above average pre-weaning mortality relative to other species of colonial bats in their study area), they may be unable to realize the large populations seen in other species of colonial bats. Thus, although we can be relatively certain that *C. townsendii* are now more dispersed than before hard-rock mining began in the West, they may indeed exist at lower densities than they did previously. If so, survey results that suggest reduced numbers of bats may reflect real reductions at a particular site or sites, but they may not necessarily reflect actual population declines at broader geographic scales.

We must stress that the preceding discussion is highly speculative. Although Townsend’s big-eared bat is almost certainly more dispersed now than it was historically (e.g., Sherwin et al. 2000a), it remains unclear whether such a re-distribution of the population has had negative, neutral, or positive consequences for populations at various geographic scales. If greater numbers of Townsend’s big-eared bat now exist in more locations, it is likely that surveys would have reflected an increase. Thus, we conclude that numbers of *Corynorhinus townsendii* have, for currently unknown reasons, experienced declines throughout the West. Any
actions, therefore, that safeguard known roosts, maintain and enhance roosting opportunities at suspected roosts (e.g., through pre-closure screening and gating of mines), and bolster the quality and quantity of other habitat components (e.g., foraging and drinking areas) are likely to reap conservation benefits.

Distribution trends

Spatial distribution

Townsend’s big-eared bat is distributed widely across western North America. However, local distribution is bounded by the presence of caves and similar structures, most of which are the result of specific geological conditions and processes, and which are not distributed evenly across the landscape. As the distribution of these structures on the landscape is patchy, so too is the distribution of Corynorhinus townsendii. Relatively recent anthropogenic activities have created new roosting opportunities, but most of these new roosts apparently were created within the existing range of C. townsendii (Altenbach and Sherwin 2002).

Within areas containing roosting habitat, there is evidence of sexual segregation by Corynorhinus townsendii during the warm season. In the Black Hills, reproductive females were more abundant at lower elevations than at higher ones. This may reflect the more restrictive thermoregulatory needs of females (Cryan et al. 2000), and it may reflect the distribution of roosts with suitable (i.e., warmer) microclimates for reproductive females. In northwestern Wyoming, males were found roosting singly in less consistently warm environments than the maternity colonies of females (Keinath 2005). In contrast to maternity colonies, hibernacula (usually caves) host both sexes and can be located at higher elevations or in areas that get cold in the winter, presumably to exploit the consistently cool temperatures found in those features. As with summer distributions, the winter distribution of C. townsendii will be determined not only by the location of roosts, but also by the subset of those roosts that have suitable environmental conditions, in this case generally humid areas with temperatures that are consistently just above freezing throughout the hibernation period.

Given the general lack of data on the historic distribution of Corynorhinus townsendii, current distribution trends are difficult to assess. At the broadest scale, there is no evidence of significant range expansion or contraction for C. townsendii. Documented changes in local populations have been quite variable (Altenbach and Sherwin 2002) and do not appear to suggest a consistent range-wide trend. It is possible that local or regional distributions of C. townsendii have become more evenly spread across the landscape over the past decade (Altenbach and Sherwin 2002), but it is difficult to construct a clear or consistent picture of such distribution trends. For instance, the absence of C. townsendii from some previously occupied sites (Perkins and Levesque 1987, Pierson and Rainey 1998, Pierson et al. 1999) might suggest a local decrease in distribution (and is often interpreted as a concomitant decrease in numbers of bats), but the species also appears to be present at some formerly unoccupied sites (O’Shea and Vaughan 1999).

Such conflicting evidence raises more questions than it answers. How have changes in distribution affected population stability and viability at local and regional scales? How are managers and biologists to interpret changes in local or regional distributions? What is the appropriate scale at which to assess these changes, and what are the management implications of distributional changes? These questions are of critical importance to management of Townsend’s big-eared bats and the resources on which they depend. Therefore, the remainder of this section draws on themes developed in the previous sections in an attempt to address these questions and to provide a framework within which to base management and conservation decisions. We begin with a discussion of how distributional changes may influence populations of Corynorhinus townsendii.

As discussed above, additional roosting opportunities for this species have been created for more than a century through the opening and subsequent abandonment of underground mines. Because Corynorhinus townsendii readily use abandoned mines as roosting habitat, the increase in the number of abandoned underground mines may have led to a concomitant expansion in the local or regional distribution of the species. The implications of such changes on populations depend on the extent to which populations are limited by roosting opportunities. Altenbach and Sherwin (2002) proposed three related, but not mutually exclusive, hypotheses to explain how populations may have responded to increased roosting opportunities:

1. The Displacement (Refugia) Hypothesis. It is clear that human disturbance can cause bats, and Corynorhinus townsendii in particular, to abandon caves (see Threats section) although there are a few examples where moderate disturbance has not led to
abandonment (e.g., Sherwin et al. 2000a). Because *C. townsendii* historically roosted in caves, but now regularly roosts in mines as well, it is commonly assumed that mines represent places of asylum into which *C. townsendii* and other cave-dwelling species have been forced by human disturbance at caves. Anecdotal support for this hypothesis comes from cases such as the decline of a cave-based maternity colony of fringed myotis from over 500 females in 1990 to none in 2001, and the coincident increase in the use of a nearby abandoned mine by the colony. Human visitation at the cave during this period increased noticeably and may have been a causative factor. Even given such local shifts, it is not clear that this fully explains patterns of distribution or roost selection at larger scales. It is difficult to extrapolate across scales because such disturbance is not equally expressed throughout the range (e.g., accessibility to caves varies) and availability of caves (particularly those suitable for roosts) varies substantially from location to location.

2. **The Roost-Limited (Range Expansion) Hypothesis.** This hypothesis rests on the assumption that the number of roosts limits distribution and abundance of cave-dwelling species. Since *Corynorhinus townsendii* do not occur where suitable cavernicolous roosting habitat is unavailable, it seems clear that roost availability limits distribution, but the correlation with abundance is more tenuous. If the assumption is valid, then the addition of roosting opportunities in abandoned mines should result in increased population size. However, although a more even distribution of *C. townsendii* and other species has likely resulted from the creation of mines, no discernable trend toward increased abundance at any spatial scale has been documented. As well, roost size and colony size do not appear to be correlated. Assuming that larger roosts provide a greater number of roosting opportunities, this lack of correlation suggests that, in addition to roost limitations, other factors may constrain population size in *C. townsendii*.

3. **The Spilled Milk Hypothesis.** Although the previous two hypotheses have been previously proposed in one form or another, this hypothesis is novel and attempts to disentangle the relationship between distribution patterns and population size. It assumes that the presence of roosts regulates distribution patterns, but that some other (non-density dependent) intrinsic factor constrains population growth (e.g., availability of energy). The analogy is drawn between the volume of milk that exists within a cup and after it is spilled from the cup, where the cup represents roosts, and the milk represents colonies of bats. The volume of milk is constrained by the capacity of the cup. Once spilled, the milk will be more dispersed but the volume does not change. Hence, the addition of roosts on the landscape may serve to more evenly distribute bats (i.e., to “spill” bats across the landscape), but if constraints on population growth other than availability of roosts (e.g., availability of energy) exist, then populations would not necessarily increase in size.

This last hypothesis appears to best explain the observed patterns of distribution and abundance of *Corynorhinus townsendii* in the West. For instance, colonies in mines tend to be smaller and more evenly distributed than those in caves, and size of colonies in mines tends to decrease as distance from portions of range with caves increases (Sherwin et al. 2000a). Thus, although the geographic range of *C. townsendii* has remained relatively static, its local distribution has responded to changing local conditions by becoming more dispersed, without necessarily resulting in increased abundance.

Although hypotheses such as these tend to focus on the theoretical underpinnings of biogeography, there are important management implications associated with each. Effective management of *Corynorhinus townsendii* in Region 2 depends on the scale at which decisions regarding protection of the species and its habitat are made, and those decisions are likely to be site and time specific. For example, in the case of fringed myotis cited above, one might ask whether disturbance leading to displacement had a negative, positive, or neutral effect on the colony. If the disturbance led to a decline in abundance, then the species will have been negatively impacted irrespective of the scale considered. However, if we assume (or know) that numbers remained about the same, the answer will depend on scale. At the regional level, the fact that the same number of bats persists post-disturbance in the same area may lead us to answer that the disturbance was neutral. Locally, however, re-location may involve changes in surface
ownership, management units, or other matters of practical concern, all of which are likely to influence management direction. Even if a displaced colony does not jump geopolitical boundaries, management of a colony in a cave entails different actions and considerations than management of the same colony in a mine (reviewed below), and these things in turn may depend on the scale at which management decisions are made. There are no easy answers, and management approaches must effectively address the issues at the several spatial scales at which bats must be considered. Managers and biologists must determine what events constitute negative impacts and how to maximize long-term stability of populations at multiple scales.

As a final point, the above hypotheses are germane because they lead to fundamentally different conclusions about how changes in distribution affect populations of Corynorhinus townsendii. For example, one important implication of the Spilled Milk Hypothesis is that the recent increase in rates of mine closure may profoundly affect population size at multiple spatial scales because, given that the milk is now spilled onto the table, “if the milk is then wiped away, the total volume of milk [is] reduced” (Altenbach and Sherwin 2002). That is, if populations are now spread thinner, then closure or destruction of roosts used locally by smaller, more dispersed colonies may lead to an overall reduction in abundance at the regional level.

Temporal distribution

Roosts: Given a roost known to hold Corynorhinus townsendii, how likely is it that the bats will be present when the roost is surveyed? Given an unknown (i.e., potential) roost, how many surveys will be required to be confident that no bats use it? These are important questions for management and conservation of Townsend’s big-eared bat because management of roosting habitat depends on knowledge about patterns of roost use, and because much of our information about population size and abundance of C. townsendii is derived from surveys conducted at roosts. Therefore, we discuss in this section what is known about how Townsend’s big-eared bats distribute themselves among roosts between seasons, and the degree to which they move among roosts within a season.

The most conspicuous temporal change in distribution of bats occurs during the transitions between warm and cold seasons. As summer wanes, bats begin movements toward wintering grounds. Because Corynorhinus townsendii roosts in caves or mines year-round, this seasonal event may or may not entail movement from summering to wintering grounds. That is, roosts used during the summer months are sometimes suitable as hibernacula during the winter. For example, at least one cave in Region 2 is used both as a nursery roost during summer and as a hibernaculum during winter (Tigner and Dowd Stukel 2003). However, roosts used by C. townsendii in summer often remain too warm (e.g., because of low elevation) or get too cold (e.g., because of the dimensions of the structure) in winter to be used as hibernacula. Where this occurs, bats move toward more suitable locations for the winter.

Movement to hibernacula begins in late summer or early autumn. Although numbers of bats in a given hibernaculum may be highly variable through autumn, maximum numbers of bats are realized by mid-winter and remain relatively stable through the coldest winter months. As spring approaches, bats begin to arouse more frequently and to move toward summering grounds. In central Oregon, female Corynorhinus townsendii leave hibernacula in April but do not move directly to maternity roosts (Dobkin et al. 1995). During this period of up to 2 months, the bats used interim roosts to which they showed little fidelity (Dobkin et al. 1995). Although the precise timing of these events is likely to vary by location, elevation, climate, etc., it is worth noting because it has generally been assumed that C. townsendii show high fidelity to particular roosts (Kunz and Martin 1982), and the study from Oregon demonstrates that this assumption may not always hold. This in turn has consequences for survey and management of the species. Until very recently, the degree of roost switching that occurs normally has not been extensively studied.

In one of the most comprehensive studies of inter-and intra-season roosting patterns by Corynorhinus townsendii to date, Sherwin et al. (2003) showed that use of caves and mines by Townsend’s big-eared bats appears to be more variable than previously appreciated (see also Sherwin et al. 2000a). Based on repeated surveys at 1392 caves and mines in Nevada and Utah between 1994 and 2001, Sherwin et al. documented a high degree of variability in roost use both within and between seasons, with bats often moving to new roosts several times within a season. In general, bats using mines switched roosts more frequently than those using caves, with hibernacula and bachelor colonies switching roosts more often than maternity colonies. Maternity colonies in mines switched roosts between one and six times (x = 3) during the maternal season, whereas maternity colonies in caves normally used a single cave during the season and across years (Table 12).
Besides human disturbance at roost sites, there are at least two potential explanations for this degree of temporal variability in roost use. The first invokes the empirical relationship between roost fidelity and roost permanence and abundance (Lewis 1995), wherein there appears to be a positive correlation between roost fidelity and highly permanent roosts that occur in low abundance (e.g., caves) and a negative correlation between fidelity and roosts that are more abundant and have low temporal permanence (e.g., mines) (Lewis 1995). A second potential explanation is that roost site conditions may not meet physiological constraints throughout the season. Conditions in the roost can have profound effects on the fitness of bats (e.g., Ransome and McOwat 1994, Thomas 1995). If *Corynorhinus townsendii* are unable to find a single roost that provides the array of conditions necessary to meet physiological needs during various life stages, then they may be forced to seek different roosts during different life stages. If, for example, mines provide a more limited range of environmental conditions (because, for instance, they are shallower, have different airflow regimes, or lack the structural complexity of caves), then this may lead Townsend’s big-eared bats roosting in mines to switch roosts to find more optimal conditions. The same argument could be applied to cave roosts; however, at least within the region studied by Sherwin et al. (2003), colonies displayed greater inter- and intra-seasonal fidelity to caves than mines, suggesting an inherent proclivity by Townsend’s big-eared bat for cave roosts, or a greater diversity of roosting conditions within the structural complexity of caves within and between seasons, or both.

Regardless of the reason, it appears that *Corynorhinus townsendii* exhibits greater temporal roost movement than was previously appreciated. If this observation holds for other portions of the bat’s range, it means that one or two visits to a mine prior to closure may not suffice to establish that Townsend’s big-eared bats do not use the mine. It also means that a single survey conducted at a site once per year to estimate population trends may yield erroneous evidence. We take up this matter in greater detail below in the Tools and practices section.

### Table 12. Patterns of temporal roost use and site fidelity exhibited by Townsend’s big-eared bats in the Great Basin as reflected in effort necessary to eliminate a roost with 90 percent probability. Greater effort was required for groups that switched frequently during a particular season. Use of caves was generally less variable than use of mines. For mines, summer bachelor colonies and small hibernation colonies showed greatest variability in site fidelity and thus required more effort. Large colonies in mines and colonies in caves showed similar patterns of fidelity to particular roosts. Data adapted from Sherwin et al. (2003).

<table>
<thead>
<tr>
<th>Roost Type</th>
<th>Colony Type</th>
<th>Colony Size</th>
<th>Probability (%) of correctly classifying a site as unused during a season with one visit to the site during the season</th>
<th>Minimum number of surveys needed to identify non-roosts with 90% probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mine</td>
<td>Summer</td>
<td>~0</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bachelor</td>
<td>32</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Summer</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maternity</td>
<td>66</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Winter</td>
<td>~0</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Cave</td>
<td>Summer</td>
<td>85</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bachelor</td>
<td>70</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Summer</td>
<td>32</td>
<td>4</td>
<td></td>
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<tr>
<td></td>
<td>Maternity</td>
<td>70</td>
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<td></td>
<td>Winter</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hibernacula</td>
<td>66</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Small colonies were defined as those with 5 or fewer individuals. Large colonies comprised >5 individuals. Use of caves by hibernating colonies was not sensitive to colony size. Greater than 95% of hibernating colonies in caves used a single cave continuously through the cold season. These caves were also used as hibernacula during all years of the study.

Foraging: Most foraging activity by temperate, insectivorous bats occurs soon after sunset, when flying insects are numerous and bats are in need of their first meal since the previous night’s foraging. Townsend’s big-eared bat emerges from its roost and begins foraging later than many other species of bats (Kunz and Martin 1982). Most reports indicate that *Corynorhinus townsendii* begins its nightly foraging about 60 minutes after sunset (Clark et al. 1993, Dobkin et al. 1995). The length of foraging bouts varies, but
initial foraging may last up to 2 hours, followed by a period of rest and digestion at a night roost. Rather than use night roosts, females in the early stages of lactation appear to alternate foraging bouts with return trips to the day roost several times per night to nurse young (e.g., Clark et al. 1993). During late-lactation, females may forage continuously all night long (e.g., Bradley 1996).

As with temporal patterns of roost use, use of foraging areas by Corynorhinus townsendii may also be more variable than has been assumed. Although foraging activity by bats in general at any particular place is likely to fluctuate through time (Hayes 1997), studies of foraging patterns by Townsend’s big-eared bats in Oregon (Dobkin et al. 1995), Nevada (Bradley 1996), and California (Fellers and Pierson 2002) indicate that the bats show high fidelity to particular foraging areas. Although these studies provide important insight into foraging patterns during particular stages of the reproductive cycle, inference to broader temporal patterns is not possible. When a broader period is considered (e.g., over the entire reproductive season), however, patterns emerge that differ from those presumed by fidelity to one or a few foraging sites. For instance, in Kentucky and Oklahoma, reproductive females showed fidelity to particular foraging sites during certain reproductive stages, but they switched locations as the season progressed, with females generally traveling farther to foraging sites and/or increasing the size of foraging areas later in the season (Clark et al. 1993, Adam et al. 1994).

The reason (or reasons) for this shift is poorly understood. One proposed explanation holds that females forage further from roosts to leave nearby foraging sites to newly volant young (e.g., Fellers and Pierson 2002). This is an attractive hypothesis and suggests adaptive behavior that may increase the odds of offspring survival, but the data are insufficient to assess its merits adequately. Another possibility is that during the most energetically demanding stages of reproduction, females cannot afford the energy or the time to fly long distances, and this constraint is reflected in a reduction in distance traveled or size of foraging area. During pregnancy, for instance, females carry the additional weight of the fetus (up to 25 percent of the mother’s mass near term), resulting in increased flight costs and perhaps a tendency to minimize commutes. As well, during the first few weeks of lactation, mothers must return to the roost several times each night to nurse non-volant young (e.g., Clark et al. 1993). Lactating females may therefore forage nearby to minimize energetically expensive flight and time spent commuting that could otherwise be spent nursing or foraging. If so, and all else being equal, females would be expected to be able to increase foraging distance or foraging area during less energetically demanding stages of reproduction (i.e., early pregnancy and late- or post-lactation).

During early pregnancy and late- or post-lactation, females do appear to travel greater distances to foraging sites and/or to increase the size of their foraging areas relative to pregnant and lactating females (Table 7), suggesting that energetic constraints of mothers may be important factors influencing use of particular foraging sites. Although increased travel to foraging sites for late- or post-lactating females may also reflect females bestowing nearby sites to newly volant young, it is difficult to attribute longer commutes during early pregnancy to such behavior. In any case, management efforts to maintain and protect multiple foraging areas in close proximity (e.g., <5 km) to known or probable roosts, as well as foraging sites at distances of up to 10 km (6 miles) from roosts will in all likelihood benefit bats. Such arrangement of foraging habitat would allow reproductive females the flexibility to forage as demands warrant, and allow volant juveniles to exploit nearby foraging sites.

Habitat trends

Roosting habitat

The clearest trends that can be identified in roosting habitat for Corynorhinus townsendii are that mines are being closed at an accelerating rate, often without pre-closure surveys (Altenbach 1998), and that disturbance at caves and abandoned mines over the past 30 years appears to be on the rise (Meier and Garcia 2000). Given the ubiquitous nature of these pressures, and lacking information about trends in cavernicolous roosting habitat for Region 2, it is prudent to assume that trends observed range-wide apply within the Region as well. Mining activity at formerly abandoned sites that have since become used by bats can have effects beyond simple displacement (O’Shea et al. 2000). For example, bats may be exposed to toxic pollutants created by mining operations by drinking from contaminated waters emanating from mines, waste piles, or processing operations; toxins may bioaccumulate in bats that consume prey carrying elevated loads of toxic constituents from mining effluent in their tissues; and indirect effects can occur if mining effluent reduces abundance of insect prey dependent on receiving waters. As stressed in other sections, C. townsendii is extremely vulnerable to degradation of habitat due to its high site fidelity and narrow roosting...
requirements. Thus, if uninformed mine closure, renewed mining at historic sites, and disturbance at cave roosts continue, the downward trend in Townsend’s big-eared bat abundance is likely to continue in Region 2 and elsewhere.

Fortunately, recognition that abandoned mines are valuable to Corynorhinus townsendii and other species of bats, spurred by concerns over declines of cave-dwelling bats (e.g., Henshaw 1972), has gradually prompted efforts to identify and protect such structures (e.g., Bat Conservation International’s North American Bats and Mines Project). A particularly good example of such a program at the state level is the Colorado Bats/Inactive Mines Project. Currently in its 16th year, the project, with the help of volunteers, has screened not less than 3470 mines, resulting in the installation or planned installation of gates at 535 mines (Navo et al. 2002).

Townsend’s big-eared bats showed higher fidelity to cave roosts than to mine roosts in the Great Basin (Sherwin et al. 2003), but cave roosts also showed little sign of human visitation. Elsewhere, caves with a high degree of accessibility to the public or those that are popular with cave explorers are likely to receive persistent levels of visitation within and between years. Even if the disturbance caused by visitations is minimal (which may well not be the case), Townsend’s big-eared bats may not use these caves because of frequent presence of humans, resulting in reduction of available habitat for Corynorhinus townsendii. For example, following several visits by recreationalists during the summer months, a maternity colony abandoned a site in the northern Black Hills that served as both maternity roost and hibernacula. The site’s hibernating population also showed declines, suggesting either additional visitations during winter (Tigner and Dowd Stukel 2003) or unwillingness of bats to return to a site that had experienced disturbance. It is also possible that abandonment of the site resulted in increased levels of mortality of adult or juvenile bats, which were in turn reflected by lower numbers of hibernating individuals.

Foraging habitat

Trends in foraging habitat are difficult to identify, in part because Townsend’s big-eared bat has been shown to forage in a wide variety of habitats. Conversion of native shrub and grasslands for urban development or for agriculture use probably alters the composition and abundance of the insect community, and it may lower the quality of foraging habitat if this shift reduces the prevalence of prey preferred by Corynorhinus townsendii. Draining or altering wetlands and loss of vegetation along riparian corridors may also reduce the quality of foraging sites.

Throughout its range, Corynorhinus townsendii forages heavily among the forest canopy and along forest edges. Thus, harvesting and burning of woodlands in close proximity to roosting colonies may reduce both the quantity and quality of foraging habitat. Pesticide spraying in these areas can also reduce prey availability and contribute to a build-up of toxins in bats if the pesticides bio-accumulate (O’Shea and Clark 2002).

Extrinsic threats

Disturbance and destruction of roosts

Townsend’s big-eared bats are notoriously sensitive to disturbance at roost sites (Kunz and Martin 1982). Many view disturbance at roost sites and elimination of roosting habitat through closure of abandoned mines to be the most serious threats to Corynorhinus townsendii in the West (e.g., Pierson et al. 1999, Hutson et al. 2001, Ellison et al. 2003a). Although few would argue what “closure of abandoned mines” means, disturbance is a general term that can encompass a wide range of activities. These activities may or may not be intended to destroy, harm, or displace bats or their roosting habitat. For the purposes of this document, we define disturbance as any human activity or action that is likely to disrupt the normal pattern of activity for C. townsendii such that chances of survival or reproduction are reduced. This definition has the advantage of being independent of intent or method, and it compels us to consider likely outcomes of a particular action, rather than to rely on knowledge that a particular action is or is not defined as a “disturbance.” Some actions are so blatant that they clearly constitute disturbance. Others, however, are more subtle and require consideration of context. Note also that although natural events such as fires, floods, mudslides, earthquakes, and ice ages all would (and should) constitute disturbance, we will focus on anthropogenic disturbance because, unlike “natural disturbances,” those that result from human activities are often systematic and chronic. Also unlike “natural disturbances,” human actions, particularly management activities, are generally within our control and fall within the purview of this document.

One common source of disturbance involves physical entry into a cave or mine that harbors bats. Although members of organized caving groups (e.g., National Speleological Society) are generally cognizant of the unique and fragile biota in caves and
promote responsible caving practices and protection of cave resources, so-called “amateur recreationalists” decrease the utility of roosting habitat through increased disturbance or arrant destruction (Barbour and Davis 1969). Uninformed explorers, or the simply curious, may not even be aware of the presence of bats inside, but the bats are certainly aware of them. Increased noise levels and the use of bright lights, if prolonged and severe enough, are likely to arouse resting bats to the point that they begin to fly inside the roost. If bats are discovered inside a roost, which is not unlikely given that Corynorhinus townsendii roosts exposed and often low on roost walls, attempts to touch or dislodge roosting bats will almost certainly initiate flight. In either case, for the curious who may have been unaware of the presence of bats, and for whom bats represent scary, evil creatures intent on getting tangled in hair, the sudden presence of flying bats in a confined, darkened space may illicit an aggressive response in “self-protection.” Clearly, such a scenario would be hazardous for bats and humans, particularly those unaccustomed to or unprepared for subterranean exploration.

Even when visitors do not venture far into the roost, the mere presence of humans in or near the mouth of roosts may be enough to disturb the bats roosting within (e.g., Graham 1966, Lacki 2000, Tigner and Dowd Stukel 2003). Increased noise levels, smoke and heat from campfires, and detonation of fireworks and firearms near or into the roost entry all clearly have the potential to disturb roosting bats. If groups are congregated near the roost entry at or close to emergence, bats may be hesitant to exit. For animals with high energetic demands that will not have had food or water for some 14 to 16 hours, delayed emergence, and therefore delayed access to food and water, takes on added significance.

Disturbance of roosting bats is cause for concern at any time, but disturbance at certain times and of certain types of colonies can be especially detrimental to the fitness of the bats. Disturbance of maternity colonies may result in roost abandonment by Corynorhinus townsendii (e.g., Lacki 2000, Tigner and Dowd Stukel 2003), and mothers that abandon roosts may leave non-volant young behind (Altenbach 1998). Unless the young are fully weaned and volant, their chances of survival are low. Disturbance at hibernacula can lead to unnecessary expenditure of vital energy reserves (Thomas 1995), and given the acute vulnerability of hibernating bats and the degree to which their tight energy budgets are already being taxed, disturbance at hibernacula may decrease chances of overwinter survival.

Vandalism at caves or mines, though perhaps less common than other forms of disturbance, may result in outright destruction of roosting bats. In one oft-related case, the largest known wintering western population of Corynorhinus townsendii was lost after arsonists set fire to support timbers in an abandoned mine (Tuttle and Taylor 1998).

Activities that occur outside the roost but that result in changes inside the roost also constitute disturbance. For instance, removal of vegetation near roost entrances can alter airflow and temperature regimes inside the roost. Given that Corynorhinus townsendii appears to select roosts based, in part at least, on these conditions (reviewed in Habitat requirements section), roosts may be rendered unsuitable following timber harvest, brush removal, prescribed burning, road construction, or other surface altering activities near roosts. In addition, actions that alter the flow of surface water can affect bats by flooding roosts or altering internal humidity levels (e.g., by creating or eliminating pools of water inside roosts). Moreover, any of these activities are also likely to change the quantity and quality of foraging or drinking habitat for the bats, which may exacerbate the effects of roost disturbance.

The ongoing reduction in roosting habitat facilitated by wholesale closure of mines throughout the West has likely magnified the negative effects of disturbance on bats in caves and mines (Altenbach 1998). Closure of mines, often done in the interest of public safety or for liability reasons, typically consists of blasting or backfilling openings (Altenbach 1998). Precise estimates of the number of abandoned mines in the West (or in Region 2) are difficult to come by, in part because definitions of what constitutes a mine vary from state to state and across federal land management agencies. According to a report sponsored by the Western Governor’s Association (Anonymous 1998): “Some consider multiple shafts and openings in one location as one mine, others consider each opening, shaft or disturbance a separate abandoned ‘mine’. As such, data…are not comparable among states and cannot be added together to create a westwide picture.” For the same reasons, estimating the number of these mines that have been closed is difficult, but it is probably safe to assume that the number is substantial. For instance, prior to recognition of the potential value of abandoned mines to bats, some 3,000 mines in Nevada were
closed without any type of wildlife surveys (Altenbach 1998). This practice has probably destroyed numerous hibernacula and/or maternity roosts (Altenbach and Sherwin 2002) and has undoubtedly destroyed roosts that Corynorhinus townsendii and other species of bats use intermittently.

Pesticides and environmental toxins

Pesticides may affect bats in two main ways: through bioaccumulation and through reduction in prey abundance. Several aspects of the life history of bats conspire to increase their vulnerability to exposure of pesticide residues even at low levels. Given that most North American bats are insectivores, application of pesticides over large areas of forest and agricultural lands likely decreases the abundance of insect prey. To the extent that application is concentrated in particular areas, local populations of bats that use these areas may be faced with increased foraging costs and commute times, or they may be at risk from direct exposure to the chemicals.

In western forests, efforts to control populations of pest species, some of which are lepidopterans (e.g., spruce budworm, gypsy moth), often include aerial application of pesticides. The pesticides tend not to be species-specific, and numbers of non-target species may be reduced substantially following application (Miller 1992). Because a significant proportion of the diet of Corynorhinus townsendii comprises lepidopterans (Whitaker et al. 1977, Burford and Lacki 1998), actions that reduce the local abundance of moths have the potential to affect local populations of C. townsendii negatively by reducing the prey base. This may lead to a shift in foraging areas as bats search for prey, and most likely will be associated with increased foraging costs. Generally, pesticides do not achieve 100 percent control; some targets survive, and after time populations of insects rebound. Unfortunately, some pesticides produce more enduring legacies.

Organochlorine pesticides (OCPs) and their residues probably have contributed to local or regional declines of bat populations (Clark 1988, 2001). Accumulation of OCPs, even at sublethal levels, poses risks to bats because they elevate metabolic rates in vertebrates. For bats, which have limited fat reserves, increased metabolism could be detrimental (Swanepoel et al. 1999), especially to mothers, young, and hibernating individuals facing intrinsic energy limitations. Although many of the OCPs that proved most harmful to bats (e.g., DDT, DDE, aldrin, dieldrin) have been banned or restricted in the United States since the 1970’s or early 1980’s, they continue to persist in the environment and may still be found in tissue samples from bats (e.g., O’Shea et al. 2001). Particularly grievous characteristics of once-common OCPs and their metabolites include their long residence time in the environment and their tendency to bioaccumulate in the food chain. Bats are especially susceptible to bioaccumulation because they are long-lived and forage at upper trophic levels. Moreover, the lipophilic nature of these contaminants results in their concentration in fat tissue. Hibernating bats rely on fat stores and thus risk mobilizing accumulated residues, and this is particularly so for lean versus fat individuals (Swanepoel et al. 1999). Hence, accumulation of OCPs may disproportionately affect young of the year because they generally enter hibernation with lower fat reserves than adults (Pearson et al. 1952).

It may seem counterintuitive to suggest that juveniles entering hibernation may have accumulated enough pesticide residue in the few months during which they forage on their own to put them at risk. Yet juvenile bats appear to be most susceptible. One explanation for this is that OCPs and their residues concentrate in milk, and young may therefore ingest high doses while nursing (Clark 1988). In one study, concentrations of DDE (the primary metabolite of DDT) in juvenile gray bats (Myotis grisescens) were two orders of magnitude greater (0.28 mg per kg compared to 34 mg per kg) than in juvenile birds from the same area (Clark et al. 1988). These juvenile bats also contained residue of DDD and DDT not found in the birds. In addition, it appears that transfer can begin before birth. Newborns with detectable levels of DDE and DDT demonstrate that these pesticides crossed the placenta in Mexican free-tailed bats (Reidinger 1972, Clark et al. 1975, Theis and McBe 1994), big brown bats (Clark and Lamont 1976), and little brown bats (Clark and Krynis 1978). What has been more difficult to establish is the extent to which such exposure compromises fetal development or offspring survival and growth. It would be valuable to understand if rates of reproductive failure vary with exposure level, or if there are threshold levels below which reproduction and development remain unaffected.

For males, at least, it appears that reproductive failure may in fact be one outcome of exposure to OCPs given that the androgen blocking effects of DDE can lead to interference with sexual development and fertility in males (Clark 1988). This may be cause for concern because, lacking the ability to export much of their residue load to juveniles as females do, concentrations of OCPs tend to be higher in adult
males than in adult females (Clark 1988). If the ability of males to sire offspring is compromised, and/or if juvenile males regularly experience interference with sexual development as a result of transfer of pesticide loads from mothers, then deleterious effects at the population level will likely result. Moreover, because mating occurs at hibernacula and therefore presumably involves bats from relatively disparate areas, lower reproductive output of females in areas without pesticide loads may be attributable to matings with reproductively compromised males. Yet, because of the temporal and spatial separation of the two events, it may be very difficult to attribute low reproductive success to such causes with any certainty.

In addition to pesticides, accumulation of various mining-related toxins (mostly heavy metals) in bats is highly probable in contaminated areas (O’Shea et al. 2000). Bats accumulate heavy metals in various tissues, and many are lethal in small quantities (O’Shea et al. 2000). Metals found in mine waste include cadmium and selenium, both of which bioaccumulate through the food chain and are teratogenic (O’Shea et al. 2000). In addition, other metals (e.g., aluminum, arsenic, cadmium, chromium, copper, lead, mercury, silver, zinc) found in mine waste are toxic to aquatic life and may thus result in reduction in prey availability (O’Shea et al. 2000).

Accumulation of heavy metals may occur through direct exposure and through consumption of contaminated insects or water. For example, where open-pit cyanide-extraction gold mining is common, bats are the most commonly recovered group of mammals found dead near the mining operations, probably from drinking from the surface of leach ponds containing cyanide-laced water (Clark and Holthem 1991). Not only do Townsend’s big-eared bats commonly roost in abandoned mines where they may be exposed to contamination, but renewed mining at historical sites is likely to liberate additional contaminants that would then be available for bio-uptake (O’Shea et al. 2000). Where renewed mining occurs in close proximity to old mines used by Corynorhinus townsendii and other species, there is high potential for increased levels of exposure or contamination through bioaccumulation. In such cases, mine operators should be required to make the ponds inaccessible (e.g., with protective netting) to bats and other species of wildlife.

Targeted areas in Region 2

As outlined above, extrinsic threats to Corynorhinus townsendii in Region 2 relate to roost disturbance and destruction, exposure to pesticides and mining related contaminants, and changes in landscape structure that alter energy budgets. Given that very few areas in Region 2 are immune to any of these threats, biologists and managers should strive to identify specific areas within their jurisdictions that are especially prone to such events, paying particular attention to areas that contain known or suspected occurrences of C. townsendii.

At the regional level, the Black Hills of South Dakota and Wyoming should be considered a high priority, given relatively intense resource extraction and recreational use, and the relative isolation of populations of Corynorhinus townsendii that occur there. Approximately 100 caves occur in or near the Black Hills where limestone outcrops appear at the surface. Two of these caves harbor thousands of Townsend’s big-eared bats during parts of the year (Tigner and Dowd Stukel 2003). In addition, approximately 900 abandoned mines exist in a four-county area around the Black Hills, 360 of which occur on USFS land (Anonymous 1998). Some or all of these mines may house C. townsendii or other species of bats at various times of the year.

Intrinsic vulnerability

As a group, bats are vulnerable to extirpation or extinction because of their unique life histories, notably their low annual fecundity. Townsend’s big-eared bat may be even more susceptible because of its wing morphology, restrictive roosting requirements, sensitivity to disturbance at roost sites, and the ongoing elimination of roosting habitat.

Like most insectivorous bats, Corynorhinus townsendii has low annual fecundity, producing at most one pup per female per year. However, females may forgo reproduction during poor years, and as a result, population growth rates may be even slower than projected. Given these constraints on reproductive output, it is very unlikely that populations can recover quickly from declines.

Because of its wing morphology, Corynorhinus townsendii is highly dependent on local habitat features (i.e., caves/mines, foraging areas, water holes, etc.), which makes them vulnerable to alteration and removal of these features. Indeed, aspect ratio, a component of wing design, is a significant predictor of extinction risk in bats (Jones et al. 2003, Safi and Kerth 2004). Low aspect ratio wing design increases extinction risk, most likely through its correlation with biological
factors that are the focus of extinction processes such as small home range, small colony size, limited dispersal capabilities, and low exchange of individuals among colonies (Jones et al. 2003). Wing design, then, provides a surrogate measure of extinction risk by linking morphology to biological processes that directly influence extinction risks.

The restrictive roosting requirements of *Corynorhinus townsendii* also contributes to their intrinsic vulnerability. The distribution of suitable roosts on the landscape is patchy, and *C. townsendii* tends to show high fidelity to particular sites. Hence, *C. townsendii* is especially susceptible to habitat alteration and natural events that alter the ability of those areas to support colonies. It may also be difficult for *C. townsendii* to re-colonize patches of suitable habitat given their poor dispersal and migratory capabilities.

The now-common use of abandoned mines by Townsend’s big-eared bats may also contribute to their vulnerability. The movement of *Corynorhinus townsendii* into abandoned mines over the past 100 years or so may have led to an increase in the local or regional distribution of the species, but it apparently has not led to greater numbers of bats. Although it is not clear why the addition of roosting sites has not equated with increases in abundance (Altenbach and Sherwin 2002; reviewed above), the more dispersed nature of current distributions may increase extinction risks at the local level, particularly given ongoing removal of roosting habitat (e.g., through mine closure). As an analogy, consider a person hopping across a wide creek on emergent stones. Once across, if natural or other processes remove the stones, then the person is effectively cut-off from returning. If local distributions of *C. townsendii* became more spread out by “hopping” across the landscape “on” abandoned mines, as current patterns of distribution suggest (Sherwin et al. 2003), subsequent destruction of mines may effectively cut-off dispersal and migration between colonies. Such fragmentation may render local colonies more susceptible to extinction through stochastic variation in population cycles, variation and shifts in climate, and other processes that effect population dynamics.

Exacerbating vulnerability due to narrow roosting requirements, *Corynorhinus townsendii* is intolerant to roost disturbance and extremely susceptible to vandalism and destruction during hibernation. Disturbance at roosts may increase energetic costs and disrupt social structure if bats abandon roosts in search of other more secluded roosts. Sites to which *C. townsendii* have historically been faithful are likely separated by patches of unsuitable habitat. Therefore, the bats may be unaware of, or unable to reach, other suitable areas.

Vulnerability to disturbance is most pronounced for hibernation and maternity colonies, in part because of their reliance on torpor as a means of balancing energy budgets. Townsend’s big-eared bat uses shallow torpor outside of the hibernal period and deep torpor (i.e., hibernation) during the winter. The fact that temperate-zone bats in general, and *Corynorhinus townsendii* specifically, must rely on torpor reflects the tight energy balance under which they live. Disturbance during the maternal period may result in unnecessary energy expenditure, and disturbed maternity colonies may abandon the roost (e.g., Humphrey and Kunz 1976, Lacki 2000). If this occurs before pups are volant, then mothers may simply abandon their pups (Altenbach 1998). Hibernating individuals are especially vulnerable because disturbance during hibernation can cost bats up to 68 days worth of crucial fat reserves during arousal (Thomas 1995) and because they are essentially helpless until they can raise body temperature enough to attempt flight or escape, which may take up to an hour (Thomas 1995). As one account relates:

> “At Carter Caves State Park, Kentucky, in the winter of 1957, hundreds of bats were killed by being stoned from the low ceiling. In December of 1958, vandals discharged fire crackers and homemade bombs in the midst of the clusters. On December 26, 1960, three boys, moments before our arrival, tore great masses of bats from the ceiling and trampled and stoned the helpless animals. Thousands fell into the stream which flows through the cavern and were drowned before they could rouse from their torpid state. An estimated 10,000 bats were killed.”
> (Mohr 1972).

Fortunately, reports such as this one are rare. However, they are not so rare as to dismiss this one as the isolated actions of a few miscreants. Other similar reports exist (though this one is particularly disturbing for the wanton nature of the actions and magnitude of mortality), and many others are probably not witnessed or documented at all. Even when events are documented, they might not be reported widely. For instance, an account on the website of the California Department of Fish and Game (http://www.dfg.ca.gov/watchable/bats2.html) chronicles:

> “caves and mines [used for ‘parties’] frequently strewn with beer cans, shotgun shell casings, fireworks, or other litter. [and] evidence of
cruel vandalism in the form of hair spray cans, matches, and incinerated bats [being] not uncommon in easily accessible caves and mines."

Another case that, to our knowledge, has never been "officially" published involved the destruction and loss of the West’s largest known wintering population of Corynorhinus townsendii after arsonists entered a mine where the bats were hibernating and set fire to the support timbers (cited in, among others, Tuttle and Taylor 1998). These events, and others like them, illustrate starkly the extreme vulnerability of hibernating bats.

Management Implications and Potential Conservation Elements

Because adult survival appears to be key to maintaining viable populations of Corynorhinus townsendii (see Life history model), conservation efforts focused on protecting bats from extrinsic harm (e.g., disturbance or destruction at roosts) appear likely to yield the greatest benefits to this species. Given the acute vulnerability of hibernating bats to disturbance, protection of hibernacula should be of prime importance. Although fertility was not identified as being the most sensitive life history variable affecting population dynamics, reproduction rates clearly will affect population dynamics. Thus, adequate protection of maternity roosts will serve the dual function of minimizing human-caused mortality and, all else being equal, of maximizing reproductive success.

Protection of roosting sites, however, without regard to other landscape elements that are important to Corynorhinus townsendii may result in less than optimal results. Therefore, protection of foraging and drinking sites must also be considered as these elements contribute to energy and water balance in bats. Finally, other extrinsic threats (e.g., exposure to environmental toxins) likely threaten the long-term persistence of C. townsendii and other species of bats, and the greater the degree to which the negative effects of such threats can be mediated the greater the likelihood that viable populations can be maintained.

Roosting sites

Roost destruction and disturbance represent the most persistent and serious threats to Corynorhinus townsendii. Authors treating the conservation status of C. townsendii and other cave-dwelling species invariably implicate degradation of roosting habitat through disturbance and elimination of roosting habitat through mine closures in observed population declines (e.g., Tuttle 1979, Pierson et al. 1999). Uninformed closure of abandoned mines eliminates current or potential roosts, further fragments the landscape with respect to roosting habitat, and potentially increases the degree of isolation that colonies experience. This situation is exacerbated when increased disturbance at roosts compels bats to abandon sites. Thus, roosting sites are arguably the most important conservation element for C. townsendii in Region 2 and elsewhere.

Based on the relative value of particular types of roosts to various life stages of Corynorhinus townsendii and on the relative value of those life stages to overall population viability, we consider hibernation roosts to be of highest conservation priority, followed by maternity roosts and bachelor roosts. Hibernacula represent vital refugia from periods of severely reduced food supplies and below-freezing temperatures, and they are critical to the year-to-year survival of bats using them. Moreover, they are presumed to be relatively rare on the landscape. Maternity roosts are crucial components contributing to reproductive success, and therefore they clearly factor into local population stability and viability.

The value of abandoned mines to the populations of Townsend’s big-eared bat that use them is also considered high, particularly if traditional roosting habitat in caves has been compromised. Colonies that may formerly have roosted in caves may now be dispersed among abandoned mines, and rates of mine closure have been increasing (Meier and Garcia 2000). Therefore, efforts to identify and protect mines used by Townsend’s big-eared bat and other species of bats should be considered important components of a conservation strategy.

Foraging sites

Foraging habitat for Townsend’s big-eared bat typically consists of shrub and woodland habitat that harbor high abundances of moths and other insects. Foraging often occurs along the interface of two or more habitats. Although Corynorhinus townsendii appear to avoid large, open areas and areas of dense, regenerating forests, estimates of canopy coverage necessary to create suitable foraging conditions are unknown. It is likely that a mosaic of habitat conditions (e.g., mid- to late seral forest stands, riparian-shrub and grassland-shrub habitats) in close proximity to roosts will provide the necessary suite of conditions to allow C. townsendii to efficiently meet energetic demands (e.g., Wunder and Carey 1996).
Based on wing and echolocation morphology, *Corynorhinus townsendii* is expected to forage in more cluttered habitats and to avoid foraging in open areas (e.g., Aldridge and Rautenbach 1987). Like other species of bats, *C. townsendii* probably forages opportunistically by exploiting concentrations of insects, and it likely forages heavily in riparian areas (Fellers and Pierson 2002), around wetlands, and in the lee of forest edges or ridges where insects concentrate (Lewis 1970). Foraging sites that have dense and structurally diverse vegetation may support greater abundances of insect prey and provide escape from potential avian predators. Foraging sites that offer these characteristics are likely to be preferred to those that do not.

Very few studies have fully elucidated ecological responses of bats to changes in quantity or quality of foraging sites, and none has focused on *Corynorhinus townsendii*. This is not surprising given the large number of potential factors (and their interactions) that likely influence the attractiveness of foraging sites for *C. townsendii* and other species of bats, and given the limitations inherent in observational studies. Although we can be fairly certain that some actions will decrease the utility of foraging areas for *C. townsendii*, the relative contribution of any of them, or the combined effects of more than one, are difficult to predict a priori. In part, this is because any single action that alters foraging habitat is likely to do so in multiple ways, resulting in confounding effects. For example, removal of vegetation at foraging sites may:

- reduce overall prey abundance
- shift availability of particular prey species
- alter how efficiently *C. townsendii* is able to forage at the site
- alter the number of species competing for insects at the site.

In addition, “removal of vegetation” can occur at varying degrees (e.g., overstory versus understory removal, selective harvest, clear-cut harvest), each of which is likely to affect overall quality of foraging habitat differently.

**Drinking sites**

Like most animals, bats must drink water to maintain water balance. Bats drink by skimming the surface of calm water bodies, and they appear to avoid open water with too much clutter (i.e., vegetation). Local or physiological conditions may increase the reliance of bats on sources of open water. For example, bats that live in arid environments (e.g., much of the western United States) and lactating females are likely to depend even more on water sources than other bats. Therefore, maintenance of wetland and riparian habitats and other sources of open fresh water (e.g., water impoundments) at local scales should be considered an important conservation element. Drinking sites located near either roosting or foraging sites should be maintained, but drinking sites that are contaminated with heavy metals or other pollutants pose a serious danger to bats and other species of wildlife that drink from them, and bats should be excluded from using these sites until remediation can occur.

**Landscape context**

Roost, foraging and drinking sites each constitute only one piece of the puzzle necessary for conserving *Corynorhinus townsendii*. All three of these are required in a suitable spatial arrangement, so increasing the probability of long-term persistence of *C. townsendii* in Region 2 will require managing for all of these habitat components in concert.

Because *Corynorhinus townsendii* does not travel very far from roost sites to forage or drink, maintenance of foraging and drinking habitat within close proximity to roosts may be necessary to support colonies using those roosts. Accessibility to foraging and drinking sites can be enhanced if patches of suitable habitat connect those components and roosts. That is, habitat features that function to decrease flight costs (e.g., wind), to decrease risk of predation, and provide foraging opportunities are likely to benefit local populations.

The size of an area necessary to sustain colonies is difficult to predict, and ultimately it will depend on several site-specific factors, including availability of water, abundance of insect prey, time of year, reproductive status of the bats, and size of colony. Nonetheless, actions that tend to increase the fragmentation of a particular landscape are likely to affect bats by increasing energy expenditure and decreasing availability of prey, and such actions are likely to reduce the carrying capacity of an area. Removal of streamside vegetation through logging or grazing practices, removal of mid- to late-successional vegetation through logging or burning, and conversion of native shrub and grassland habitat through urbanization or other land-use practices are likely to increase fragmentation and negatively impact populations of *Corynorhinus townsendii* and other species of bats.
in Region 2. Actions that lead to fragmentation at the scale at which *C. townsendii* uses the landscape must therefore be avoided or minimized. Based on published estimates of the size of foraging areas used by *C. townsendii*, a maternity colony may require up to 260 ha (650 acres); however, this number is for eastern populations, and area requirements may be lower in the West due to the generally smaller size of colonies. Conversely, water may be more limiting for western populations than those in the East. Availability of fresh drinking water is necessary for bats, particularly lactating females because they export water in the form of milk. Thus, areas may need to be larger if bats must travel substantial distances to find water.

### Exposure to toxins

Bats’ long life spans, combined with the long residence time of pesticides in the environment and bioaccumulation in the food chain, suggest that chronic long-term exposure and accumulation are likely to occur. High levels of organochlorine pesticides and residues in fat and brain tissue have been linked to precipitous declines of some cave-roosting species of bats (Clark 2001), and there is no reason to suspect that *Corynorhinus townsendii* is less susceptible to the effects of pesticide exposure than other species of bats. In addition, the propensity of *C. townsendii* to roost in abandoned mines means that they may more readily come into contact with mining associated toxins, particularly heavy metals. The accumulation of such toxins in the food chain and consumption of toxin-laced water pose considerable dangers (O'Shea et al. 2000). Given the acute and chronic levels of poisoning, and the teratogenic and mutagenic consequences of exposure to many mining-related contaminants (O'Shea et al. 2000), it is important that exposure to these toxins is minimized. This may require remediation, and because of the large number of abandoned mines on the landscape, it will likely take considerable time. Permitting of new mines, or for renewed mining at historic sites, should include provisions to ensure that operators do not leave behind toxic waste.

### Tools and practices

In this section, we discuss available tools and practices that may be employed to foster conservation on *Corynorhinus townsendii* in Region 2. We first discuss the value of education in the conservation of Townsend’s big-eared bat, and follow with a section to familiarize the reader with basic methodology and timing of Inventory and monitoring efforts. The knowledge from such surveys is critical to effectively implementing conservation measures outlined in the subsequent section on Population and habitat management.

#### Education

Few groups of vertebrates are so widely misunderstood and reviled as bats. Despite valuable ecosystem services provided by bats (see discussion in Symbiotic and mutualistic interactions section), many people are unaware of the value of robust populations of bats. Worse, age-old myths that portray bats as rabid, blood-sucking animals intent on getting tangled in the hair are slow to fade. Bats are often assumed dangerous vectors of several diseases (see discussion in Parasites and disease section), a misconception that, despite evidence to the contrary, is all too often parroted by the media and public health officials (Olnhusen and Gannon 2004). These and other misconceptions hamper effective conservation (Fenton 2003) and may result in hostility toward bats (see discussion in Intrinsic vulnerability section). Therefore, education should be a fundamental component of a conservation strategy for Townsend’s big-eared bat.

It is beyond the scope of this document to outline an education program for bats. However, we provide suggestions regarding what such a program should include and list some avenues of educational information and pre-existing educational programs that could be mustered.

A strong educational program would include components that:

- describe the beneficial role and ecosystem services that bats provide
- debunk baseless myths (especially regarding disease) that lead to vilification of bats
- explain the slow reproductive rate and fragile nature of bat populations and their habitat
- describe the diversity of bat species and their unique biology and morphology.

The forms in which these components may be conveyed to the public are varied. Interpretive trail signs may be used where caves or mines receive heavy and persistent public visitation. Signs could outline the reasons for treading lightly in caves and the penalties for vandalism. Trail signs are not recommended for caves or mines that are relatively secluded and receive little visitation.
Posters, brochures, and other printed materials can be distributed to interested members of the public at local events, from local USFS offices, or in conjunction with other education- or conservation-related presentations to the public; a wealth of such materials is available from Bat Conservation International (www.batcon.org). Informational talks can be very effective and offer the opportunity for interaction with the audience. For example, one of us (JG) regularly gives talks to groups of school-aged children, and regularly discusses bats with the general public. In most cases, questions arise revolving around the myths mentioned above and can be discussed and dispelled immediately.

Those developing an education program will benefit from investigating existing education programs such as the USFS Conservation Education Program (http://www.na.fs.fed.us/spfo/ce/) or similar programs in other agencies and organizations. Additionally, conservation education partnerships with other agencies and organizations can provide a greater resource base, increase access to the public, and may carry greater weight than conservation messages endorsed by a single agency. Those integrating bats into pre-existing education programs will benefit from information and materials available from Bat Conservation International and from soliciting input from local experts (e.g., members of state chapters of the Western Bat Working Group).

Inventory and monitoring

Our goal in this section is to familiarize the reader with basic methodology and timing of various types of surveys for bats, along with the information that may or may not be gleaned from such surveys. It is not our intent, nor is it within the purview of this document, to expound in detail all of the considerations and caveats regarding particular survey methods. Suffice to say, unbiased sampling methods for bats are particularly difficult because of their unique biology (O’Shea and Bogan 2003), and this may affect results and the interpretation of survey efforts. For example, although all sampling methods have biases, those associated with acoustic and capture surveys of bats are such that estimating them is often impossible. We can be fairly certain that both capture and acoustic surveys do not sample all groups of bats consistently, but we are unable to quantify the degree to which this occurs (O’Shea and Bogan 2003). Several aspects of the biology of Corynorhinus townsendii make it a particularly difficult species to survey with these methods. First, because it is a slow flying, highly maneuverable bat, C. townsendii is adept at avoiding mist-nets. Second, the echolocation call of C. townsendii is relatively quiet, which means that acoustic surveys may fail to detect the bat when it is present.

It is also not our intent in this section to provide specific instruction on surveying for bats. Effective sampling often requires specialized skills, experience, and equipment that may not be readily available. Moreover, many biologists will simply not have the time or the mandate to engage in these activities. Those interested in a more thorough discussion of these topics are encouraged to consult any of the excellent references listed below by topic, especially Kunz and Kurta (1988) and O’Shea and Bogan (2003). In addition, state chapters of the Western Bat Working Group will be able to provide specific guidance on the details of planning inventory and monitoring programs in specific areas.

General methods

Three main methods are recommended to survey for bats: capture surveys, acoustic surveys, and visual surveys (Kunz and Kurta 1988). Capture surveys necessarily include disturbance and handling of bats. Acoustic surveys passively record the presence of bats as they echolocate in flight. Human observers can perform visual surveys with or without the aid of optical equipment and electronic devices. Each method has advantages and limitations, and each may be used in conjunction with others. The exact method or combination of methods used will depend on the question or questions of interest. However, surveys should follow existing standard protocols (e.g., Navo 1994, Altenbach et al. 1999, Tuttle 2003) and be designed to occur within roughly the same period during each occurrence to minimize differences attributable to intra-season variability in numbers. Because Townsend’s big-eared bat may switch among several different roosts within a season (Sherwin et al. 2003), surveys should attempt to identify and include nearby alternative roosts. If successful, results from such efforts will be important for understanding movement patterns and may provide predictive and conservation value if movements can be correlated with biotic and/or abiotic conditions.

Capture surveys are most often conducted with mist-nets or harp traps (Tuttle 1974). Because capture surveys necessarily involve handling of bats, information on species, age (Anthony 1988), and sex of captured bats can be collected, as well as data on morphological characteristics (e.g., size and weight) and reproductive status (Racey 1988). However, because Corynorhinus townsendii can easily avoid mist-nets erected at foraging and drinking sites, they may not be
captured during such surveys even if they are present. Therefore, a combination of capture and acoustic surveys may be employed to maximize the probability of detecting *C. townsendii*. Another consideration is that because of the level of disturbance associated with capture surveys, bats captured in mist-nets or harp traps may subsequently avoid these areas. Therefore, capture surveys may be used to establish baseline estimates on species composition and demographic profiles of the species, but repeated capture surveys at roosts or foraging/drinking sites should be avoided.

Acoustic surveys typically employ some type of ultrasonic detector, and are appropriate for detection of the presence of bats, but may not be appropriate for species discrimination (e.g., see Barclay 1999, O’Farrell and Gannon 1999, O’Farrell et al. 1999, and Fenton et al. 2001). Acoustic surveys are not appropriate to estimate size of colonies because the number of bat calls recorded is not a reliable indicator of number of bats. That is, one cannot be sure whether 10 bat calls represents 10 bats or 1 bat flying by the detector 10 times.

Visual surveys are generally effective only at known or suspected roosts, and may be used to estimate colony size provided that only one species of bat is using the roost. Experienced workers may be able to roughly differentiate species by size or flight characteristics, but if species composition is unknown, or when large numbers of bats exit, this method is highly prone to error in species identification and/or individual counts. Visual counts may be conducted internally or externally. Internal counts require entry into a cave or mine, and therefore are generally limited to situations where the safety of surveyors is not compromised by structural inadequacies. Where safe entry and exploration of a cave or mine is questionable, external surveys may be conducted in lieu of internal surveys.

The accuracy of counts using human observers will vary with observer experience, number of bats present, and amount of vegetative clutter surrounding the exit, all of which are likely to influence the number of bats seen and recorded. The effectiveness of human observers may be increased with the use of specialized optics (e.g., night-vision scopes and infrared cameras). Variance in results associated with using human observers may be estimated by using multiple observers at the same exit, or by using a combination of observers and electronic devices (e.g., beam-splitter count devices, video recorders, and photographic equipment).

**Location**

For cavernicolous species of bats, surveys may be conducted either at known or suspected roosts, or at foraging or drinking sites. Because bats roosting in caves or mines are more spatially aggregated within the roost and as they exit the roost than they are during foraging bouts, internal and/or external surveys at roosts are generally necessary to determine colony size and type. Capture and acoustic surveys are often conducted at suspected drinking and foraging sites, and they are generally appropriate to determine which species are present in an area or to determine use of foraging areas. Note, however, that use of acoustic surveys for identification beyond the generic level requires specialized skills and experience, and this type of survey is generally more appropriate for comparing levels of activity among sites.

If capture surveys are deemed to be warranted at roost sites (e.g., at the mouth of a cave or mine), then mist-nets should be avoided, especially if the roost harbors large numbers of bats (ASM 1998). Mist-nets require constant vigilance. Bats captured in nets struggle to free themselves, and safe removal of the bats, even by experienced workers, may take several minutes. During this time, many more bats are likely to become entangled, especially if the net or nets completely cover the roost opening. In such cases, harp traps are the recommended alternative (ASM 1998). Although harp traps must be monitored, they do not require constant attention, and because bats are funneled into a collection bag, they are less prone to injury or predation than those ensnared in mist-nets.

Regular surveys at hibernacula may provide reliable information on long-term population trends because hibernacula tend to be relatively permanent and to accommodate sizeable numbers of bats (Thomas and LaVal 1988). However, due to the sensitivity of hibernating bats to human intrusion (Thomas 1995, Speakman et al. 1991), surveys should be conducted bi-annually. Navo (1994, 1995) and Altenbach and Milford (1995) describe methods and timing for surveys for bats at mines.

Bats emerging from maternity or bachelor roosts may be surveyed non-intrusively by stationing observers at roost exits to count numbers of individuals or by placing electronic counting devices near roost exits (Bagley and Jacobs 1985). Ultrasonic detectors may be used to identify bat presence at a roost, but they
are least preferable for exit-counts because detectors are unable to distinguish multiple detections of an individual from single detections of many individuals. The accuracy of counts using human observers will vary with observer experience, number of bats present, and amount of vegetative clutter surrounding the exit. The use of night-vision equipment may increase the effectiveness of human observers. Variance in results associated with using human observers may be estimated by using multiple observers at the same exit, or by using a combination of observers and electronic devices (e.g., beam-splitter count devices, video recorders, and photographic equipment). Digital infrared video recorders alone or coupled with ultrasonic detection devices can allow exit counts at roosts with minimal observer bias because recorded emergence activity can be replayed at reduced speed to facilitate accurate counts of exiting bats, and it does not involve capture or handling of bats. In addition to improving the accuracy of counts, electronic devices may be used at inaccessible roosts and may be easily deployed at multiple sites. However, electronic devices may not be feasible in areas of frequent human activity, and they require reliable power sources, which may limit their utility.

**Timing**

Capture and acoustic surveys must occur during periods of bat activity and therefore are conducted at night. Capture surveys begin near sunset and may or may not run all night. Bat activity is usually highest in the hours following sunset, so surveys designed to run for a set period (e.g., 4 hours) may yield the largest return per unit effort. External capture and visual surveys at roosts also occur during the evening, but once bats have left the roost to forage, surveys may be considered complete if the goal of the survey is to estimate colony size.

Internal surveys at warm season roosts to determine colony size should occur just prior to and following parturition, when numbers of bats are likely to be most stable. Internal surveys will require specialized training, skills, and equipment. Internal surveys in mines require even greater precaution and experience because abandoned mines are often structurally unstable, may contain poison air and toxic waste, and may have unmarked shafts that drop precipitously. Only qualified personnel should conduct internal surveys of abandoned mines. Once a roost site has been identified, abundance estimates of bats using the site may be obtained by internal visual counts, visual counts of exiting bats, or by deploying passive infrared or night-vision optics near the entrance to record exiting bats. External surveys are preferred in order to minimize disturbance at maternity roosts (ASM 1998).

Because *Corynorhinus townsendii* are generally inactive during the winter, internal surveys will likely be required. These surveys are subject to the safety considerations mentioned above. Surveys to establish use of a cave or mine may be conducted after bats have begun to disperse to hibernation site (generally from mid-September). Surveys to estimate colony size should occur during the coldest months, when numbers within the roost are likely to be most stable.

Results from the Great Basin (Sherwin et al. 2000a, 2003) indicate that colonies of *Corynorhinus townsendii* that use caves exhibit higher sight fidelity, across both time and space, than colonies that use abandoned mines, suggesting that more than one visit will probably be required to establish non-use of a mine by bats (Table 12). Sherwin et al. (2003) modeled lability in roost occupancy by big-eared bats using data collected through internal surveys, exit surveys with low-light binoculars and infrared video cameras, and mist-nets set at the cave or mine entrance. They determined that, on average, four surveys were required to eliminate a mine as a maternity roost with 90 percent probability whereas maternity colonies typically used a single cave for the duration of the maternity season and among years. A minimum of nine surveys was required to eliminate a mine as a bachelor roost whereas only three surveys, on average, were needed to eliminate a cave as a bachelor roost with 90 percent probability. Potential hibernacula required at least eight surveys to be 90 percent sure that they were not used, but large colonies (≥ 5 individuals) show greater fidelity than small colonies (<5 individuals), with large colonies requiring a minimum of two surveys, and small colonies requiring at least 10 surveys.

**Population and habitat management**

The life histories of bats suggest an evolutionary history of stable populations near or at the limit of the environment’s carrying capacity (Findley 1993). If so, ecological theory would predict that an increase in population numbers might be realized from an increase in suitable habitat (Gotelli 2001). Indeed, current management plans and conservation strategies for *Corynorhinus townsendii* focus on increasing habitat (particularly roosting habitat) as a means of increasing numbers of bats (e.g., U.S. Fish and Wildlife Service 1979, Pierson et al. 1999, Altenbach et al. 2002). Since adding new, high-quality roosting
habitat for Townsend’s big-eared bat is likely not a feasible management tool, particularly at large scales, management efforts should focus instead on improving roosting conditions at existing roost sites, stemming the loss of current roosting habitat, and insuring that future potential habitat (e.g., mines slated for closure) are available to bats.

Compared to the steady recruitment of snags used by many forest-dwelling species of bats, cavernicolous structures (particularly caves) are not rapidly being created on the landscape. Although ongoing mining activities may continue to create subterranean habitat, it is unclear whether the rate at which new mines are opened is equal to closure rates. Also unknown is how long new mines will sustain active mining. Because Townsend’s big-eared bats are not likely to use active mines, they remain unavailable as roosts until they are abandoned. In addition, renewed mining at historic sites is likely to displace any bats that may have been using the mine while it was abandoned. Thus, the primary focus of maintaining suitable roosting habitat for Townsend’s big-eared bats is currently through protection of underground roosts that are available at this time.

There are two primary means by which cavernicolous roosting opportunities are decreased, mine closure and ongoing disturbance at caves and mines by human activity. Managers must first identify caves and mines that bats currently use. This is important because mine closures are steadily increasing and often occur in the absence of bat surveys (Altenbach 1998, Meier and Garcia 2000) and without consideration of their current or potential value for bats. Mines slated for closure should first be evaluated for the presence of bats and for their potential as suitable roosting habitat. Suitable mines should then be closed in a way that allows for bat use and should be safeguarded against human disturbance. Where concerns for public safety surround used or potential mine roosts, gating or other methods of excluding the public from the site (e.g., closure of roads or trails leading to the roost) may provide viable alternatives. Eliminating disturbance at cave and mine roosts through seasonal restrictions or gating will also protect roosting habitat. Townsend’s big-eared bat is highly intolerant to human disturbance at roosts (e.g., Pearson et al. 1952, Graham 1966, Humphrey and Kunz 1976, Pierson and Rainey 1998). Thus, seasonal or permanent restrictions may be required for caves or mines that are deemed important as hibernacula or maternity roosts. Closures may be “hard” (e.g., cave or mine gating or road closure) or “soft” (e.g., voluntary compliance with closures that are clearly indicated with signs at trailheads). As mentioned below in Protection and conservation of roosting sites section, the Federal Cave Resources Act and Subpart B Orders provide tools with which land managers can protect important caves and mines.

While the previous paragraphs in this section have emphasized identification and protection of all roosts (i.e., maternity, hibernation and bachelor roosts), we must stress the importance of hibernation roosts in the population management of Townsend’s big-eared bats. Hibernacula play a central role in the year-to-year viability of the populations of bats using them because the ability to use energy stores as efficiently as possible is absolutely crucial to the survival of overwintering bats.

During hibernation, Corynorhinus townsendii is most vulnerable to disturbance and to fluctuations in ambient conditions. Caves or mines with shafts that are deep enough to buffer bats from fluctuations in temperature and that maintain high levels of humidity and moderate airflow are necessary for efficient hibernation and overwinter survival. Roosts that provide this suite of conditions are likely to be relatively rare and highly valuable to the bats that use them. For these reasons, identification and protection of hibernacula should be considered a prime objective in any conservation strategy for C. townsendii.

Finally, although it is important to maintain and protect as many suitable roosts as possible across the landscape, baseline data on abundance and population densities are required to evaluate population trends adequately and to determine the effects of various management decisions on bats. Given the lack of baseline data on historical population sizes, it is imperative to initiate systematic surveys to establish these data for current populations.

Because effective management of Corynorhinus townsendii depends on an understanding of its abundance and distribution, and because land management agencies must spread limited conservation dollars among many competing programs, agencies may benefit from involving the public to the extent practicable. Local caving groups represent a potentially under-appreciated source of information about the presence of bats in caves and mines. These groups often maintain information about the location, condition, and complexity of caves; the extent of human visitation at caves; and how conditions in the cave have changed through time (Altenbach and Sherwin 2002). Considering the number of potential roosts that might
yearly be visited by cavers and the general willingness of such groups to protect both caves and their biota, involvement of these organizations has the potential to greatly increase our understanding of the distribution of *C. townsendii* and the size of local populations (see Table 13 for a list of these groups in Region 2 and contact information).

**Protection and conservation of roosting sites**

Safeguarding roosting habitat is the first step to take toward maintaining viable populations of *Corynorhinus townsendii* in Region 2. Protection of known roosts, particularly those with significant roosting colonies, will most effectively help to achieve this goal. Within Region 2, *C. townsendii* relies primarily on caves and abandoned mines for roosting habitat, and therefore, we focus our attention on the means by which caves and mines may be protected.

The most imminent threat associated with mines and bats is closure of mines in the interest of public safety. Typically, mines are closed by blasting and backfilling, and often with no pre-closure survey to assess mine use by bats (Altenbach 1998). Mine protection begins with pre-closure surveys intended to identify use by bats and, if warranted, construction of bat-friendly gates on mines that are important to bats, but that are deemed threats to public safety. Although caves may not present the same level of public safety concerns as mines, they often receive high levels of recreational use. Caves that harbor colonies of bats and that receive high levels of human visitation must be protected to ensure long-term use by bats.

**Identification of sites:** The first step in protecting important roosting sites is to learn where they are. While some hibernation and maternity roosts are known from Region 2, it is likely that others remain undiscovered by management agencies. Therefore, regular systematic surveys should be initiated to identify important roosting sites. Making such surveys efficient is a potentially difficult task requiring advanced planning. At a large scale, our current understanding of *Corynorhinus townsendii* distribution is depicted in Figure 4 and Figure 5. Further, Colorado, South Dakota, and Wyoming have produced state-wide predictive distribution maps (Figure 6, Figure 7, Figure 8), but these maps likely over-predict distribution and have limited utility at local scales. Managers and biologists can obtain more detailed information by contacting local Natural Heritage Programs and/or Bat Working Groups for occurrence and distribution information in their area. Within areas that *C. townsendii* could inhabit, survey focus should be given to locations with known karst geology (i.e., those likely to contain concentrations of caves) and to areas with abandoned mines. Consultation with federal or state representatives of abandoned mine land reclamation programs may be necessary to identify mine locations, and such interagency cooperation can also help to prioritize surveys of mines slated for closure.

Once important roosts are identified, protection of roosting habitat requires minimizing or eliminating human disturbance at roosts, preventing closure of abandoned mines that are important to bats, and ensuring that surface disturbing activities are done at appropriate times and at appropriate distances from roosts. Several pieces of legislation are available for protection of caves and mines. In some cases, it may be enough to protect important roosts through these or other pieces of legislation. In others, legislation may serve as a precursor to physical measures to restrict entry or access to important sites.

**Legal protection of roosting sites:** The legislative acts highlighted below may be viewed as those most likely to be useful for the protection of caves and mines on federal lands. However, the list may not include all pertinent federal, state, or local legislation, and we encourage managers and biologists to familiarize themselves with relevant laws and regulations in their own jurisdictions.


> “A ‘significant’ cave is defined as a cave located on Federally administered lands that has been evaluated and shown to possess features, characteristics, values, or opportunities in one or more of the following

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3 A useful resource for cave management on USFS lands is published by Umpqua National Forest (UNF 2004), from which much of this information on legislation is derived

4 Also known as the Cave and Karst Resource Protection Act of 1988.
<table>
<thead>
<tr>
<th>Grottos in Colorado</th>
<th>Grottos in or near Wyoming</th>
<th>Grottos in or near Kansas</th>
<th>Grottos in South Dakota</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado Grotto</td>
<td>Armpit Grotto</td>
<td>Kansas Speleological Society</td>
<td>Paha Sapa Grotto</td>
</tr>
<tr>
<td>c/o Gerry Forney</td>
<td>c/o Carol Uhl</td>
<td>c/o Wayne White</td>
<td>c/o Rene Ohms</td>
</tr>
<tr>
<td>680 Emerson St</td>
<td>P.O. Box 244</td>
<td>419 S. Maple</td>
<td>1212 Sherman St</td>
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<tr>
<td>Denver, CO 80218-3216</td>
<td>Laramie, WY 82070-0244</td>
<td>Newkirk, OK 74647</td>
<td>Custer, SD 57730</td>
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<td>Hole-in-the-Wall Grotto</td>
<td>Boston Mountain Grotto</td>
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<tr>
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<td>c/o Robert Montgomery</td>
<td>c/o Uncle Sam’s S. Outfitters</td>
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<tr>
<td>2510 Taft St No. 210</td>
<td>P.O. Box 2102</td>
<td>1494 N. College</td>
<td></td>
</tr>
<tr>
<td>Boulder, CO 80302</td>
<td>Casper, WY 82602</td>
<td>Fayetteville, AR 72703</td>
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</tr>
<tr>
<td>Northern Colorado Grotto</td>
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<td>Kansas City Area Grotto</td>
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<tr>
<td>c/o Frank Leskinen</td>
<td>c/o Thomas Haskett</td>
<td>P.O. Box 16942</td>
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<td>4628 West CO Rd 56</td>
<td>5481 Shenandoah</td>
<td>Kansas City, MO 64133</td>
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<td>Chubbuck, ID 83202</td>
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</tr>
<tr>
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</tbody>
</table>
six resource areas: biota, geologic-mineralogic-paleontologic, cultural, hydrologic, recreational, or educational-scientific.”

This act can affect protection of caves and cave resources in three main ways:

- by limiting public availability of information about locations of caves on federal lands
- by prohibiting any act that interferes with free movement of animals within a cave
- by prohibiting what could broadly be termed “vandalism” of the physical structure at a significant cave.

The FCPRA is probably the strongest legislation available to management agencies for the protection of caves that do not harbor endangered species (which organisms would qualify for legal protection under other legislation). In addition to this legislation, the Forest Service Manual (FSM 2004, as amended), Title 2300, Chapter 2350, Section 2356 concerns Cave Management and provides legislation under the authority of Title 16 of the United States Code (U.S.C.). Legislative measures provided in the Forest Service Manual include:

The Organic Administration Act of June 4, 1897 (16 U.S.C. 551) – Authorizes protection of cave resources from theft and destruction (36 CFR 261.9a, 9b, 9g, and 9h), classification for special interest areas that are managed for recreation use substantially in their natural condition (under 36 CFR 294.1), and special closures under 36 CFR 261.53 to protect threatened cave resources.

Antiquities Act of 1906 (34 Stat. 225; 16 U.S.C. 431 et seq.) – Authorizes criminal sanctions for destruction or appropriation of antiquities. Scientific investigations of antiquities on Federal lands are permissible subject to permit and regulations. Uniform rules and regulations pursuant to this Act are in Forest Service Manual 1530.12.

Archaeological Resources Protection Act (ARPA) October 31, 1979 (16 U.S.C. 470aa) - Clarifies and defines “archaeological resources,” which may include caves and potentially mines. The Act authorizes confidentiality of site location information and permit procedures to enable study and investigation of archeological resources on public lands by qualified individuals. This act may be appropriate to afford some protection to mine sites if various pieces of equipment used in mining or the presence of historic structures either in or near the mine can be demonstrated to have importance to the nation’s development (Olson 2002).

All of these acts may be effective tools for the protection of caves and cave resources, but their suitability for protecting mine roosting habitat appears to be quite limited. Clearly, the protection of caves is an important aspect of a conservation strategy for Townsend’s big-eared bat. However, mines are frequently used by and important to Corynorhinus townsendii, and protection of mines currently or potentially used as roosting habitat should receive appropriate consideration.

If necessary, protection of mines on USFS lands may be provided under so-called Subpart B Orders. Issued under authority of Section 36 of Code of Federal Regulations, these orders are legally enforceable, can be issued quickly, and allow the flexibility to effect seasonal or permanent closure as needed (Nieland and Meier 2002). Specifically, Title 36 (C.F.R.), Subpart B, Sec. 261.53 specifies that:

“When provided in an order, it is prohibited to go into or be upon any area which is closed for the protection of:
(a) Threatened, endangered, rare, unique, or vanishing species of plants, animals, birds or fish.
(b) Special biological communities.
(c) Objects or areas of historical, archeological, geological, or paleontological interest.
(d) Scientific experiments or investigations.
(e) Public health or safety.
(f) Property.”

It is further specified in Sec. 261.51 that closures, restrictions, and other prohibitions issued by such orders be posted in form and location to “reasonably bring the prohibition to the attention of the public.”

Hibernacula should be closed to human visitation and entry during the hibernation period (approximately November 1-April 1). Visitation can be discouraged by posting signs near trailheads or other access points indicating that the cave or mine is closed for the protection of hibernating bats. If necessary, closure can be enforced with the construction of bat-friendly gates at or near the roost entrance (e.g., Ellison et al. 2003a). Seasonal restrictions (April 1-September 1) of known maternity roosts are recommended. Restrictions may be effected in the same manner as above.
If, after such protections have been enacted, visitation, vandalism, or other disturbance continues, then physical means of denying access may be warranted. Where safety or health hazards or liability issues press for complete closure of mines used as roosts, then physically denying access may also be warranted, but likely will not benefit the bats using the mine. A compromise might consist of closing the entrance with a bat-friendly gating.

Gating to protect roosts: Gating serves two general purposes: it protects internal resources from disturbance, destruction, or removal and it protects the public from dangers inherent in subterranean exploration. The latter purpose is especially relevant at abandoned mine sites, which, because they are more susceptible to subsidence and collapse than naturally occurring formations, represent liabilities to the landowner(s).

The popularity of gating as a means of closing mines has increased as the needs and plight of bats have become more topical, and there are many gating success stories (Kennedy 1999, Navo and Krabacher 2005). While the conservation benefits to bats of gating rather than backfilling are obvious, managers must be aware of the costs as well. In short, gates may be a more costly closure method than simply blasting or backfilling an entrance (although this is not always true; Tuttle and Taylor 1998). Gates require long-term monitoring and maintenance, and a poorly designed or constructed gate may alter internal conditions (e.g., airflow and temperature) and may thus result in harm to the colony it was meant to protect (Richter et al. 1993). There may be regulatory issues to consider as well since projects on federal land must comply with National Environmental Policy Act (NEPA) regulations and perhaps other state or local laws (Nieland and Meier 2002).

Design considerations: Gate designs and construction materials vary considerably. It is beyond the scope of this document to discuss details of all designs, or to describe how to build a gate. Readers interested in specific information on this topic are directed to several excellent resources (listed below), and they are encouraged to consult local or national experts and others with experience in cave and mine gating. However, a few general considerations are worth including here.

Pre-construction considerations: Gating requires planning and may be costly and time consuming. Various federal, state, and local agency regulations may need to be considered prior to project implementation. Not all caves or mines will warrant installation of gates, and availability of resources will likely limit the number of gating projects that can be completed. Therefore, it is important to prioritize sites during the planning process. When assigning priorities for gating projects, the following questions (adapted from Brown and Berry 2002) should be considered:

- **Does the roost harbor Threatened or Endangered species, or a species of management concern?** Such roosts should receive high conservation priority.
- **Is the roost a "significant" cave (FRCPA 1988)?** Federal law requires protection of such caves. In some (but not all) cases, protection may require gating.
- **Does the roost contain a maternity or hibernation colony of any bat species?** Such colonies are prone to disturbance-related abandonment and associated mortality and may benefit from the installation of a gate.
- **Does the roost shelter a large number of bats at any season?** Structures with large numbers of bats (e.g., more than 100) should be considered significant roosts and given high priority for gating or other protections. Determination of the size of colony that may be considered “large” will be case-specific. In general, colonies are smaller in the West than in the East.
- **Is the site internally complex with potential for different temperature regimes that may be necessary for bats at different seasons (especially if only a single survey was conducted)?** This is especially important if surveys at a site were limited. That is, a single visit during a single season may not yield bats, but if a site offers a particularly good microclimate for a particular life-stage, then it may receive use at other times of the year.
- **Is there potential for long-term stability of this site?**
- **Are other roosts available in the immediate vicinity for this species?** If alternate sites harbor bats but are subject to disturbance, then gating may provide valuable refuge for the bats.
Other considerations during pre-construction might include whether gating will attract the attention of passers-by. In some cases, roost entries are well hidden by vegetation, topography, or other obstructions, and they may receive little human disturbance as a result (Olson 2002). If gating is likely to increase the occurrence of humans at the entrance (and possibly result in vandalism), then gating may not be the best option. In such cases, re-routing of trails or roads (if they pass near the roost) may be a more effective means of diverting people away from the roost.

**Airflow:** Airflow into and out of caves and mines occurs as a result of various geophysical processes and the particular arrangement of shafts and adits in a mine (Tuttle and Taylor 1998) or of passages in a cave (Roebuck et al. 1999). Airflow effectively regulates temperature inside a cave or mine through surface and subsurface exchange of warm or cold air. Hence, gates must be designed and installed to minimize any restriction of airflow into or out of a structure. Roebuck et al. (1999) provide some general considerations with regard to gates and airflow:

- every cave or mine gate will experience different airflows
- the best location of a cave or mine gate is where the airflow is very slow
- solidity ratio of gates (the proportion of the cross-sectional area available for airflow comprised of the gate) must be kept to a minimum to reduce loss of airflow
- there is less than 1 percent pressure loss for low velocity airflow for typical gate materials at solidity ratios of 60 percent or less.

Where gate design or placement alters airflow, temperature regimes may be affected such that internal conditions are no longer favorable to roosting bats. Appropriate gate designs and placement should be determined by consultation of appropriate references or with persons experienced in these matters.

**Timing:** To avoid disturbance, construction of gates should be scheduled to occur at times when bats are not using the structure. For maternity roosts, construction should not between April and October. At hibernacula, gate construction should not occur between November and April. However, the exact range of dates during which bats are using a particular roost will vary with location, elevation, and local conditions, and will need to be determined on a case by case basis.

**Post-construction considerations:** Land management agencies are responsible for the protection of caves and mines and their resources. Failure to do so may be viewed as negligent and may lead to injury or death. Gates are intended to protect humans from potentially dangerous caves and mines while also protecting sensitive, internal (e.g., biological) resources. However, gates do not last forever. Attachment anchors loosen, and natural processes may degrade or compromise the integrity of the gate. Thus, gates must be monitored on a regular basis and repaired or replaced as necessary.

As with other structures on public land, gates may invite vandalism. Vandals may damage or dig under gates in attempts to gain entry. Regular long-term monitoring of gates should be used to identify and document acts of vandalism. Vandalism may be deterred through a combination of public education, improved gate design, and successful prosecution of vandals. Public education may involve, minimally, informational brochures and/or signs at trailheads or cave entrances explaining the reasons for the closure or restricted access and the penalties for unauthorized entry. Some agencies take education a step further and solicit involvement of recreational users (i.e., local caving groups) or public comment on the proposed gating project before construction begins. Vandalism may be prosecuted under any of several existing laws used for the protection of subterranean resources (reviewed above), and prosecution can be an effective deterrent to further acts of vandalism (Nieland and Meier 2002).

It is also important to conduct post-construction surveys to ensure that bats have continued to use the roosts. If bats are confirmed to have abandoned a roost, it may be a result of changes in internal conditions brought about by gating. In such cases, the gate may need to be modified or replaced.

**Management activities around roosts:** Management activities such as burning, timber harvest, road construction, vegetation alteration, and pesticide application in the vicinity of maternity or hibernation roosts should be conducted to minimize the level of disturbance and risk of direct impact to the colony. In general, if these activities must occur, they should be scheduled during times when bats are not present in the roost. Suggested buffer sizes for various management activities near roosts range from 150 to 500 feet for timber harvest, 250 feet for clear-cutting, and 2 miles
for pesticide spraying (Pierson et al. 1999, Ellison et al. 2003a). Burning of vegetation near roosts has the potential to disrupt roosting bats if smoke is drawn into roosts. In addition, burning may alter the utility of foraging sites.

**Foraging habitat:** Adequate foraging sites should be maintained in close proximity (<5 miles) to roosting sites to minimize commuting costs. Ideally, foraging sites should contain a mosaic of vegetation types and seral stages to enhance the abundance of insect prey. *Corynorhinus townsendii* may use edge habitat and linear landscape elements (e.g., riparian zones) heavily, and alteration of these components should be avoided. Pierson et al. (1999) recommend that not more than half of the forested habitat within 0.5 miles of roosts be subjected to controlled burns per decade, and that no prescribed burning or vegetation alteration of shrub-steppe or pinyon-juniper habitat occur within 1.5 miles of roosts, and then only when bats are not present in the roost.

**Captive propagation and reintroduction**

To our knowledge, no propagation programs exist or are planned for this species. Given the current population status of *Corynorhinus townsendii*, existing conservation funds would be best spent on identification and protection of suitable habitat, particularly that habitat associated with maternity colonies and hibernacula. If population declines become so pronounced that captive propagation and reintroduction become necessary, then the success of these efforts would be questionable without substantial further research. Although many species of bats have been kept in captivity for the purpose of research (Wilson 1988), *C. townsendii* does not appear to do well in captivity (Pearson et al. 1952). Moreover, it is unclear if bats raised in a laboratory would be able to fend for themselves once released.

**Information Needs**

It is clear that we have learned much about the distribution and habits of bats over the past few decades. No doubt, this has resulted in part because of advancements in technology (e.g., bat-detectors and micro-radiotransmitters) that have allowed workers to address questions in new ways. It should be equally clear that we are still in the process of collecting even the most basic information on many species. For instance, *Corynorhinus townsendii* has only recently been confirmed at several locales in Nevada (Ports and Bradley 1996). As another example, a recent survey for bats in caves in Colorado (Siemers 2002) showed that 75 percent of the caves (8/12) that held Townsend’s big-eared bat were not previously known to be used by the bat.

Given the general lack of knowledge about roost sites for *Corynorhinus townsendii* in Region 2 and elsewhere, the information generated by the research presented above is exceptionally valuable for conservation of the species. Further, these examples illustrate an important message, namely that given our current state of understanding with regard to the local distribution of Townsend’s big-eared bats, substantial gains may be realized from modest effort.

We have only just begun to understand, in many places, where bats occur and how many there are, and we have only a notion about the complex ways in which many species of bats interact with the physical environment and how they are likely to respond when humans alter that environment. This is particularly so for cryptic species such as *Corynorhinus townsendii*. Thus, efforts to survey known and suspected habitat regularly for the presence of *C. townsendii* may be nearly as important as protecting known roosts. Although protection of known roosts should be considered a higher priority given the status of *C. townsendii*, the two efforts build upon and complement one another.

Given limitations in our knowledge of population size, patterns of movement, foraging ecology, and extrinsic factors affecting demographics, Pierson et al. (1999) identified four research goals to fill gaps in our understanding and to inform management decisions regarding *Corynorhinus townsendii*:

- assess the degree of variability in roosts throughout the species’ range
- evaluate roost microclimate and structural parameters for predictive screening and site evaluation
- develop a better understanding of foraging ecology, including habitat preferences, responses to land management activities, and baseline data on temporal distribution and abundance of insect prey in occupied areas
- examine the direct and indirect impacts of environmental toxicants, particularly pesticides, on populations.
We would add to this list:

- develop baseline estimates of abundance and population
- develop a better estimate of current population trends
- identify key roosting habitat, particularly hibernacula and maternity colonies
- gain a more thorough understanding of metapopulation dynamics.

It is only through evaluation of population trends, which necessitates reliable baseline population estimates for comparison, that we will know if management efforts are having desired effects. Population trends, in turn, rely on basic knowledge of abundance and density from season to season. Although the logistical hurdles to such an endeavor are not trivial, advancements in technology combined with dedicated management direction and updated evaluation approaches should make this goal more tenable.

The authors find the last item on the above list particularly interesting. *Corynorhinus townsendii* likely faces significant hurdles to recolonization of unoccupied habitat (e.g., low dispersal, specific habitat requirements, and high habitat fragmentation), but no studies have investigated whether colonies are truly isolated or exist in a metapopulation structure. The presence and extent of *C. townsendii* metapopulation(s) could have important implications for conservation of the species, because without such inter-population dynamics, it could be difficult (if not impossible) for areas that have lost populations through extinction to be naturally recolonized.
REFERENCES


Clark, B.S. 1991. Activity patterns, habitat use, and prey selection by the Ozark big-eared bat (Plecotus townsendii ingens). PhD Dissertation, Oklahoma State University, Stillwater, OK.


Clark, D.R., Jr. 2001. DDT and the decline of free-tailed bats (Tadarida brasiliensis) at Carlsbad Cavern, New Mexico. Archives of Environmental Contamination and Toxicology 40:537-543.


Schmidly, D.J. 1991. The bats of Texas. Texas A & M University Press, College Station, TX.


USDA Forest Service. 1994. FSM 5670 R2 Supplement No. 2600-94-2; Region 2 Sensitive Species List. USDA Forest Service, Rocky Mountain Region, Denver, CO.


SELECT REFERENCES FOR SPECIFIC TOPICS

Townsend’s Big-Eared Bat Conservation Plans/Assessments

Western Populations


Eastern Populations


Western Bat Conservation Plans by State

Arizona


Colorado


Nevada


South Dakota


General Methods/Considerations for Surveying and Monitoring Bats


**Survey, Management and Protection of Bats in Caves and Mines**


**General References to Caves in USDA Forest Service Region 2**


**General References About Bats in USDA Forest Service Region 2**


Jones, J.K., Jr. 1964. Distribution and taxonomy of mammals of Nebraska. University of Kansas Press, Lawrence, KS.


Ulrich, T. 1986. Mammals of the Northern Rockies. Mountain Press, Missoula, MT.

**General Bat Biology, Ecology, and Distribution**


APPENDIX A

Explanation of Ranking Codes and Management Status Abbreviations

Table A1a. Wyoming Game and Fish Department status rankings. The Wyoming Game and Fish Department has developed a matrix of habitat and population variables to determine the conservation priority of all native, breeding bird and mammal species in the state. Seven classes of Native Status Species (NSS) are recognized, of which classes 1, 2, 3 and 4 are considered to be high priorities for conservation attention (Wyoming Game and Fish Department 2005).

<table>
<thead>
<tr>
<th>Rank</th>
<th>Definition</th>
</tr>
</thead>
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<tr>
<td>NSS1</td>
<td>Includes species with populations that are greatly restricted or declining (extirpation appears possible) and with ongoing significant loss of habitat.</td>
</tr>
<tr>
<td>NSS2</td>
<td>Species in which: (1) habitat is restricted or vulnerable (but no recent or significant loss has occurred) and populations are greatly restricted or declining (extirpation appears possible); or (2) species with ongoing significant loss of habitat and populations that are declining or restricted in numbers and distribution (extirpation is possible but not imminent).</td>
</tr>
<tr>
<td>NSS3</td>
<td>Species in which: (1) habitat is vulnerable to loss, but not restricted; populations are greatly restricted or declining (extirpation appears possible); species is not sensitive to human disturbance; or (2) habitat is restricted or vulnerable (but no recent or significant loss has occurred) and populations are declining or restricted in numbers or distribution (but extirpation is not imminent); or (3) significant habitat loss is ongoing but the species is widely distributed and population trends are thought to be stable.</td>
</tr>
</tbody>
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NSS = Native Species Status


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<th>Rank</th>
<th>Definition</th>
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<td>GX</td>
<td>Presumed Extinct (species) – Believed to be extinct throughout its range. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.</td>
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<tr>
<td></td>
<td>Eliminated (ecological communities) – Eliminated throughout its range, with no restoration potential due to extinction of dominant or characteristic species.</td>
</tr>
<tr>
<td>GH</td>
<td>Possibly Extinct (species) – Known from only historical occurrences, but may nevertheless still be extant; further searching needed.</td>
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<tr>
<td></td>
<td>Presumed Eliminated (Historic, ecological communities) – Presumed eliminated throughout its range, with no or virtually no likelihood that it will be rediscovered, but with the potential for restoration, for example, American Chestnut (Forest).</td>
</tr>
<tr>
<td>G1</td>
<td>Critically Imperilled – Critically imperilled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 5 or fewer occurrences or very few remaining individuals (&lt;1,000) or acres (&lt;2,000) or linear miles (&lt;10).</td>
</tr>
<tr>
<td>G2</td>
<td>Imperilled – Imperilled globally because of rarity or because of some factor(s) making it very vulnerable to extinction or elimination. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000) or acres (2,000 to 10,000) or linear miles (10 to 50).</td>
</tr>
<tr>
<td>G3</td>
<td>Vulnerable – Globally either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction or elimination. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.</td>
</tr>
<tr>
<td>G4</td>
<td>Apparently Secure – Uncommon but not rare (although it may be rare in parts of its range, particularly on the periphery), and usually widespread. Apparently not vulnerable in most of its range, but possibly cause for long-term concern. Typically more than 100 occurrences and more than 10,000 individuals.</td>
</tr>
<tr>
<td>G5</td>
<td>Secure – Common, widespread, and abundant (although it may be rare in parts of its range, particularly on the periphery). Not vulnerable in most of its range. Typically with considerably more than 100 occurrences and more than 10,000 individuals.</td>
</tr>
</tbody>
</table>

Variant Global Ranks

| G#G# | Range Rank – A numeric range rank (e.g., G2G3) is used to indicate uncertainty about the exact status of a taxon. Ranges cannot skip more than one rank (e.g., GU should be used rather than G1G4). |
| GU   | Unrankable – Currently unrankable due to lack of information or due to substantially conflicting information about status or trends. NOTE: Whenever possible, the most likely rank is assigned and the question mark qualifier is added (e.g., G2?) to express uncertainty, or a range rank (e.g., G2G3) is used to delineate the limits (range) of uncertainty. |
| G?   | Unranked – Global rank not yet assessed. |
| HYB  | Hybrid – (species elements only) Element not ranked because it represents an interspecific hybrid and not a species. (Note, however, that hybrid-derived species are ranked as species, not as hybrids.) |
**Rank Qualifiers**

- **? Inexact Numeric Rank** – Denotes inexact numeric rank
- **Q** Questionable taxonomy that may reduce conservation priority – Distinctiveness of this entity as a taxon at the current level is questionable; resolution of this uncertainty may result in change from a species to a subspecies or hybrid, or inclusion of this taxon in another taxon, with the resulting taxon having a lower-priority (numerically higher) conservation status rank.
- **C** Captive or Cultivated Only – Taxon at present is extant only in captivity or cultivation, or as a reintroduced population not yet established.

**Infraspecific Taxon Ranks**

- **T# Infraspecific Taxon (trinomial)** – The status of infraspecific taxa (subspecies or varieties) are indicated by a “T-rank” following the species’ global rank. Rules for assigning T-ranks follow the same principles outlined above. For example, the global rank of a critically imperilled subspecies of an otherwise widespread and common species would be G5T1. A vertebrate animal population (e.g., listed under the U.S. Endangered Species Act or assigned candidate status) may be tracked as an infraspecific taxon and given a T rank; in such cases a Q is used after the T-rank to denote the taxon’s informal taxonomic status.

**Table A1b (concluded).**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>NX</td>
<td>Presumed Extirpated – Element is believed to be extirpated from the nation or subnation. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.</td>
</tr>
<tr>
<td>SX</td>
<td>Possibly Extirpated (Historical) – Element occurred historically in the nation or subnation, and there is some expectation that it may be rediscovered. Its presence may not have been verified in the past 20 years.</td>
</tr>
<tr>
<td>NH</td>
<td>Critically Imperiled – Critically imperiled in the nation or subnation because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the subnation. Typically 5 or fewer occurrences or very few remaining individuals (&lt;1,000).</td>
</tr>
<tr>
<td>SH</td>
<td>Imperiled – Imperiled in the nation or subnation because of rarity or because of some factor(s) making it very vulnerable to extirpation from the nation or subnation. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000).</td>
</tr>
<tr>
<td>N1</td>
<td>Vulnerable – Vulnerable in the nation or subnation* either because rare and uncommon, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.</td>
</tr>
<tr>
<td>N2</td>
<td>Apparently Secure – Uncommon but not rare, and usually widespread in the nation or subnation*. Possible cause of long-term concern. Usually more than 100 occurrences and more than 10,000 individuals.</td>
</tr>
<tr>
<td>N3</td>
<td>Secure – Common, widespread, and abundant in the nation or subnation*. Essentially ineradicable under present conditions. Typically with considerably more than 100 occurrences and more than 10,000 individuals.</td>
</tr>
<tr>
<td>N?</td>
<td>Unranked – Nation or subnation* rank not yet assessed.</td>
</tr>
<tr>
<td>S?</td>
<td>Unrankable – Currently unrankable due to lack of information or due to substantially conflicting information about status or trends.</td>
</tr>
<tr>
<td>NU</td>
<td>Range Rank – A numeric range rank (e.g., S2S3) is used to indicate the range of uncertainty about the exact status of the element. Ranges cannot skip more than one rank (e.g., SU is used rather than S1S4).</td>
</tr>
<tr>
<td>HYB</td>
<td>Hybrid – Element not ranked because it represents an interspecific hybrid, not a species.</td>
</tr>
<tr>
<td>NE</td>
<td>Exotic – An exotic established in the nation or subnation*; may be native in nearby regions (e.g., house finch or catalpa in eastern U.S.).</td>
</tr>
<tr>
<td>SE</td>
<td>Exotic Numeric – An exotic established in the nation or subnation* that has been assigned a numeric rank to indicate its status, as defined for N1 or S1 through N5 or S5.</td>
</tr>
<tr>
<td>NA</td>
<td>Accidental – Accidental or casual in the nation or subnation,* in other words, infrequent and outside usual range. Includes species (usually birds or butterflies) recorded once or only a few times at a location. A few of these species may have bred on the one or two occasions they were recorded. Examples include European strays or western birds on the East Coast and vice-versa.</td>
</tr>
<tr>
<td>NZ</td>
<td>Zero Occurrences – Present but lacking practical conservation concern in the nation or subnation* because there are no definable occurrences, although the taxon is native and appears regularly in the nation or subnation*. An NZ or SZ rank will generally be used for long distance migrants whose occurrences during their migrations have little or no conservation value for the migrant, as they are typically too irregular (in terms of repeated visitation to the same locations), transitory, and dispersed to be reliably identified, mapped, and protected.</td>
</tr>
<tr>
<td>NP</td>
<td>Potential – Potential that element occurs in the nation or subnation* but no extant or historic occurrences are accepted.</td>
</tr>
</tbody>
</table>
Table A1c (concluded).

<table>
<thead>
<tr>
<th>Rank</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR</td>
<td>Reported – Element reported in the nation or subnation* but without a basis for either accepting or rejecting the report, or the report not yet reviewed locally. Some of these are very recent discoveries for which the program hasn’t yet received first-hand information; others are old, obscure reports.</td>
</tr>
<tr>
<td>SR</td>
<td>Synonym – Element reported as occurring in the nation or subnation*, but the national or state data center does not recognize the taxon; therefore the element is not assigned a national or subnational rank.</td>
</tr>
<tr>
<td>NSYN</td>
<td>N or S rank has been assigned and is under review. Contact the individual subnational* Natural Heritage program for assigned rank.</td>
</tr>
<tr>
<td>SSYN</td>
<td>Not provided Species is known to occur in this nation or subnation.* Contact the individual subnational* Natural Heritage program for assigned rank.</td>
</tr>
</tbody>
</table>

**Breeding Status Qualifiers**

| B   | Breeding – Basic rank refers to the breeding population of the element in the nation or subnation.* |
| N   | Nonbreeding – Basic rank refers to the non-breeding population of the element in the nation or subnation.* |

**Other Qualifiers**

| ?   | Inexact or Uncertain – Denotes inexact or uncertain numeric rank. For SE denotes uncertainty of exotic status. (The ? qualifies the character immediately preceding it in the SRANK.) |
| C   | Captive or Cultivated – Native element presently extant in the nation or subnation* only in captivity or cultivation, or as a reintroduced population not yet established. |

*Subnational indicates jurisdictions at the state or provincial level (e.g. California, Ontario).
APPENDIX B

Detailed Discussion of Life History Model

A life history model was developed for this Species Assessment by D. McDonald and T. Ise. We summarized the main points of their discussion in the body of the assessment. Here we provide the full discussion for readers interested in the complexities of the analysis.

Life cycle graph and model development

The life history described by Knox (1983) provided the basis for a life cycle graph (Figure B1) and a matrix population analysis with a post-breeding census (Cochran and Ellner 1992, McDonald and Caswell 1993, Caswell 2000) for Townsend’s big-eared bat. The model has three kinds of input terms: \( P_i \) describing survival rates, \( m_i \) describing fertilities, and \( B_i \) describing probability of reproduction (Table B1). Table B2a shows the symbolic terms in the projection matrix corresponding to the life cycle graph. Table B2b gives the corresponding numeric values. The model assumes female demographic dominance so that, for example, fertilities are given as female offspring per female. The population growth rate (\( \lambda \)) is 1.000 based on the estimated vital rates used for the matrix. Although this suggests a stationary population, the value is subject to the many assumptions used to derive the transitions and should not be interpreted as an indication of the general well-being and stability of the population. Other parts of the analysis provide a better guide for assessment.

Sensitivity analysis

A useful indication of the state of the population comes from the sensitivity and elasticity analyses. Sensitivity is the effect on \( \lambda \) of an absolute change in the vital rates (\( a_{ij} \), the arcs in the life cycle graph (Figure B1) and the cells in the matrix, \( A \) [Table B2]). Sensitivity analysis provides several kinds of useful information (see Caswell 1989, p.118-119). First, sensitivities show “how important” a given vital rate is to \( \lambda \) or fitness. For example, one can use sensitivities to assess the relative importance of survival (\( P \)) and reproductive (\( F \)) transitions. Second, sensitivities can be used to evaluate the effects of inaccurate estimation of vital rates from field studies. Inaccuracy will usually be due to paucity of data, but it could also result from use of inappropriate estimation techniques or other errors of analysis. In order to improve the accuracy of the models, researchers should concentrate additional effort on transitions with large sensitivities. Third, sensitivities can quantify the effects of environmental perturbations, wherever those can be linked to effects on stage-specific survival or fertility rates. Fourth, managers can concentrate on the most important transitions. For example, they can assess which stages or vital rates are most critical to increasing \( \lambda \) of endangered species or the “weak links” in the life cycle of a pest. Table B3 shows the “possible sensitivities only” matrix for this analysis (one can calculate sensitivities for non-existent transitions, but these are usually either meaningless or biologically impossible – for example, the sensitivity of \( \lambda \) to moving from Age Class 3 to Age Class 2).

Figure B1. Age-classified life cycle graph for Townsend’s big-eared bat. The numbered circles (nodes) represent the six age classes. The arrows (arcs) connecting the nodes represent the vital rates – transitions between age classes such as survival (\( P_i \)) or fertility (the arcs pointing back toward the first node from Nodes 1 through 5). Note that reproduction begins at the end of the first year, and that the reproductive arcs include terms for survival of female parent (\( P_i \)) as well as number of female offspring per female (\( m_i \)).
In general, changes that affect one type of age class or stage will also affect all similar age-classes or stages. For example, any factor that changes the annual survival rate of Age Class 2 females is very likely to cause similar changes in the survival rates of other “adult” reproductive females (those in Age Classes 3 through 5). Therefore, it is usually appropriate to assess the summed sensitivities for similar sets of transitions (vital rates). For this model, the result is that the summed sensitivity of λ to changes in the fertilities

Table B1. Parameter values for the component terms (\( P_i, m_i, \) and \( B_i \)) that make up the vital rates in the projection matrix for Townsend’s big-eared bats.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Numeric value</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>( m )</td>
<td>0.5</td>
<td>Number of female offspring produced by a female</td>
</tr>
<tr>
<td>( B_1 )</td>
<td>0.9</td>
<td>Probability of reproduction of Age Class 1</td>
</tr>
<tr>
<td>( B_a )</td>
<td>0.95</td>
<td>Probability of reproduction of Age Class 2 to 5 (adult females)</td>
</tr>
<tr>
<td>( P_{21} )</td>
<td>0.576</td>
<td>First-year survival rate</td>
</tr>
<tr>
<td>( P_a )</td>
<td>0.85</td>
<td>Annual survival rate of adults</td>
</tr>
</tbody>
</table>

Table B2a. Symbolic values.

<table>
<thead>
<tr>
<th>Stage</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>( P_{21} ) ( mB_1 ) ( P_a ) ( mB_a ) ( P_a ) ( mB_a ) ( P_a ) ( mB_a )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>( P_{21} )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>( P_a )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>( P_a )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>( P_a )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>( P_a )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table B2b. Numeric values.

<table>
<thead>
<tr>
<th>Stage</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.259</td>
<td>0.4038</td>
<td>0.4038</td>
<td>0.4038</td>
<td>0.4038</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.576</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.85</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.85</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.85</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0.85</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table B2. The input matrix of vital rates, \( A \) (with cells \( a_{ij} \)) corresponding to the Townsend’s big-eared bat life cycle graph (Figure B1). The first row of the matrix contains values associated with reproductive output for a given stage class. Values in the other rows represent the probabilities of an individual moving from one stage to the next.

Table B3. Possible sensitivities only matrix, \( S_p \) (blank cells correspond to zeros in the original matrix, \( A \)). The three transitions to which the λ of Townsend’s big-eared bats is most sensitive are highlighted: first-year survival (cell \( s_{21} = 0.476 \)), first-year reproduction (\( s_{11} = 0.370 \)), and survival of Age Class 2 (\( s_{32} = 0.221 \)).

<table>
<thead>
<tr>
<th>Stage</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.370</td>
<td>0.213</td>
<td>0.181</td>
<td>0.154</td>
<td>0.131</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.476</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>( 0.221 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.135</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.062</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In general, changes that affect one type of age class or stage will also affect all similar age-classes or stages. For example, any factor that changes the annual survival rate of Age Class 2 females is very likely to cause similar changes in the survival rates of other “adult” reproductive females (those in Age Classes 3 through 5). Therefore, it is usually appropriate to assess the summed sensitivities for similar sets of transitions (vital rates). For this model, the result is that the summed sensitivity of λ to changes in the fertilities
is important. Townsend’s big-eared bat shows large sensitivity (1.049; 54 percent of total) to changes in fertility (the first row of the matrix in Table B3). First-year survival is 0.476 (24 percent of total), and the summed “reproductive” survival sensitivity is 0.418 (22 percent of total). The major conclusion from the sensitivity analysis is that both survival and fertility are important to population viability.

Elasticity analysis

Elasticities have the useful property of summing to 1.0 and are useful in resolving a problem of scale that can affect conclusions drawn from the sensitivities. Interpreting sensitivities can be somewhat misleading because survival rates and reproductive rates are measured on different scales. For instance, a change of 0.5 in survival may be a big alteration (e.g., a change from a survival rate of 90 to 40 percent). On the other hand, a change of 0.5 in fertility may be a very small proportional alteration (e.g., a change from a clutch of 3,000 eggs to 2,999.5 eggs). Therefore, because elasticities are the sensitivities of $λ$ to proportional changes in the vital rates ($a_{ij}$), the problem of differences in units of measurement is largely avoided. The difference between conclusions based on analyses of sensitivity versus elasticity results from the weighting of the elasticities by the value of the original arc coefficients (the $a_{ij}$ cells of the projection matrix). Management conclusions will depend on whether changes in vital rates are likely to be absolute (guided by sensitivities) or proportional (guided by elasticities). By using elasticities, one can further assess key life history transitions and stages as well as the relative importance of reproduction ($F_i$) and survival ($P_i$) for a given species.

Elasticities for Townsend’s big-eared bats are shown in Table B4. The $λ$ of Townsend’s big-eared bats is most elastic to changes in first-year survival (Age Class 1), followed by the survival of females at Age Class 2 and the survival of females at Age Class 3. The sensitivities and elasticities for Townsend’s big-eared bats do not correspond in rank magnitude of important transitions. The three most important transitions in elasticity are all survival terms, whereas those in sensitivity include reproduction by first-year individuals. First-year reproduction and survival and to a lesser extent survival in subsequent years are the data elements that warrant careful monitoring in order to refine the matrix demographic analysis. Because of the invariant litter size, it might be worth assessing the possibility that probability of reproducing varies with age or with environmental conditions. Any such variation might have non-negligible effects on population dynamics.

Partial sensitivity and elasticity analysis

Partial sensitivity and elasticity analysis assesses the impact on $λ$ of changes in “lower-level terms” (Caswell 2000, pp. 218 and 232). Some transitions (e.g., the $F_i$) include lower-level component terms ($P_i$, $m_i$, and $B_i$) related to the different kinds of transitions in the life cycle (e.g., survival, fertility, and breeding probability terms). Partial sensitivity results indicate that changes in fertility ($m_i$) will have the greatest impact on $λ$ (57.4 percent of the total partial sensitivity), although the size of the litter is nearly invariant (females almost always reproduce exact 1 offspring a year). Changes in the $P_i$ (survival rates) will have the next greatest impact on $λ$ (33.1 percent of the total partial sensitivity). Changes in probability of reproduction ($B_i$) will have less impact on $λ$ (9.5 percent of the total partial sensitivity). Similarly, $P_i$ terms account for 38.9 percent of the total partial elasticity, with 46.6 percent accounted for by $m_i$ terms and 14.4 percent accounted for by $B_i$ terms. Again, every aspect of the analysis suggests that Townsend’s big-

<table>
<thead>
<tr>
<th>Stage</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.096</td>
<td>0.086</td>
<td>0.073</td>
<td>0.062</td>
<td>0.053</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>0.274</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>0.188</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>0.115</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.053</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table B4. Elasticity matrix, $E$ (remainder of matrix consists of zeros). The $λ$ of Townsend’s big-eared bats is most elastic to changes in first-year survival ($e_{21} = 0.274$), followed by survival of Age Class 2 ($e_{32} = 0.188$) and survival of Age Class 3 ($e_{43} = 0.115$). Note the considerably lower relative importance of fertility transitions in the elasticity analysis relative to the sensitivity analysis.
eared bats are most susceptible to habitat degradation that affects reproduction.

Other demographic parameters

The stable (st)age distribution (SAD; Table B5) describes the proportion of each Stage (or age class) in a population at demographic equilibrium. Under a deterministic model, any unchanging matrix will converge on a population structure that follows the stable age distribution, regardless of whether the population is declining, stationary or increasing. Under most conditions, populations not at equilibrium will converge to the SAD within 20 to 100 census intervals. For Townsend’s big-eared bat at the time of the post-breeding annual census (just after the end of the breeding season), newborns represent 32 percent of the population, and the remaining 68 percent consists of adult stages. Reproductive values (Table B6) can be thought of as describing the “value” of a stage as a seed for population growth relative to that of the first (newborn or, in this case, egg) stage. The reproductive value of the first stage is always 1.0. A female individual in Age Class 2 is “worth” 1.3 female newborns, and so on (Caswell 2001). The reproductive value is calculated as a weighted sum of the present and future reproductive output of a stage discounted by the probability of surviving (Williams 1966). The peak reproductive value (1.3) occurs at the second age class, and these females are the most important stage in the life cycle. The relatively small difference between newborn and peak reproductive value (1.3; cf. peak of 2,470 in plains leopard frog) reflects both a fairly even distribution of sensitivity and elasticity values across the life cycle and the high survival rate of first-year individuals relative to adults (an increase of only 48 percent vs. an increase of 1,056 percent in the plains leopard frog). The cohort generation time for the bat is 2.7 years (SD = 1.4 years).

Stochastic model

We conducted a stochastic matrix analysis for Townsend’s big-eared bats. We incorporated stochasticity in several ways, by varying different combinations of vital rates or by varying the amount of stochastic fluctuation (Table B7). Under Variant 1 we subjected first-year survival ($P^{21}$) to stochastic fluctuations. Under Variant 2 we varied the survival of all age classes, $P_i$. Because of the small, invariant litter size, we did not model stochastic variation in the fertilities. Each run consisted of 2,000 census intervals (years) beginning with a population size of 10,000 distributed according to the Stable Age Distribution (SAD) under the

Table B5. Stable age distribution (right eigenvector) for female Townsend’s big-eared bats. At the census, 32 percent of the individuals in the population should be newborns. The remaining 68 percent of individuals will be reproductive adults.

<table>
<thead>
<tr>
<th>Age Class</th>
<th>Description</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Female newborns ($F_i = 0.2592$)</td>
<td>0.319</td>
</tr>
<tr>
<td>2</td>
<td>Adult females ($F_i = 0.40375$)</td>
<td>0.184</td>
</tr>
<tr>
<td>3</td>
<td>“           “</td>
<td>0.156</td>
</tr>
<tr>
<td>4</td>
<td>“           “</td>
<td>0.133</td>
</tr>
<tr>
<td>5</td>
<td>“           “</td>
<td>0.113</td>
</tr>
<tr>
<td>6</td>
<td>Maximum Age Class</td>
<td>0.096</td>
</tr>
</tbody>
</table>

Table B6. Reproductive values for female Townsend’s big-eared bats. Reproductive values can be thought of as describing the “value” of an age class as a seed for population growth relative to that of the first (newborn or, in this case, egg) age class. The reproductive value of the first age class is always 1.0. The relatively low peak reproductive value is highlighted.

<table>
<thead>
<tr>
<th>Age Class</th>
<th>Description</th>
<th>Reproductive values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Female newborns ($F_i = 0.2592$)</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>Adult females ($F_i = 0.40375$)</td>
<td>1.29</td>
</tr>
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<td>3</td>
<td>“           “</td>
<td>1.04</td>
</tr>
<tr>
<td>4</td>
<td>“           “</td>
<td>0.75</td>
</tr>
<tr>
<td>5</td>
<td>“           “</td>
<td>0.40</td>
</tr>
<tr>
<td>6</td>
<td>Maximum Age Class</td>
<td>0.00</td>
</tr>
</tbody>
</table>
deterministic model. Beginning at the SAD helps avoid the effects of transient, non-equilibrium dynamics. The overall simulation consisted of 100 runs (each with 2,000 cycles). We varied the amount of fluctuation by changing the standard deviation of the random normal distribution from which the stochastic vital rates were selected. The default value was a standard deviation of one quarter of the "mean" (with this "mean" set at the value of the original matrix entry \(a_{ij}\) under the deterministic analysis). Variant 3 affected the same transition as Variant 2 \(P_i\) but was subjected to slightly larger variation (SD was \(1/3.5\) [= 0.286 compared to 0.25] of the mean). We calculated the stochastic growth rate, \(\log \lambda_s\), according to Equation 14.61 of Caswell (2000), after discarding the first 1,000 cycles in order to further avoid transient dynamics.

The stochastic model (Table B7) produced two major results. First, altering the survival rates had a somewhat greater effect on \(\lambda\) than did altering all the fertilities. For example, the median ending size under the varying survival of newborns under Variant 1 was 299.2 from the starting size of 10,000. In contrast, varying the survival rates of all age classes under Variant 2 resulted in a further decline of median size to 134.1. This difference in the effects of stochastic variation is predictable largely from the elasticities. \(\lambda\) was more elastic to changes in survival, \(P_i\) than it was to changes in the fertilities. Second, large-effect stochasticity has a negative effect on population dynamics. This negative effect occurs despite the fact that the average vital rates remain the same as under the deterministic model – the random selections are from a symmetrical distribution. This apparent paradox is due to the lognormal distribution of stochastic ending population sizes (Caswell 2000). The lognormal distribution has the property that the mean exceeds the median, which exceeds the mode. Any particular realization will therefore be most likely to end at a population size considerably lower than the initial population size. For Townsend’s big-eared bats under the survival Variant 2, 66 out of 100 trials of stochastic projection went to extinction vs. 20 under the fertilities Variant 1. Variant 3 shows that the magnitude of fluctuation has a potentially large impact on the detrimental effects of stochasticity. Increasing the magnitude of fluctuation also increased the severity of the negative impacts – the number of extinctions went from 66 in Variant 2 to 82 in Variant 3 when the magnitude of fluctuation was slightly amplified. These results suggest that populations of Townsend’s big-eared bats are vulnerable both to stochastic fluctuations in production of newborns (due, for example, to annual climatic change or to human disturbance) and to variations in survival. In contrast to some other life cycles, the relative impacts of stochasticity in fertility and survival are fairly evenly balanced (cf. Blanding’s turtle assessment, where survival effects are dramatically more important than are fertility effects). Pfister (1998) showed that for a wide range of empirical life histories, high sensitivity or elasticity was negatively correlated with high rates of temporal variation. That is, most species appear to have responded to strong selection by having low variability for sensitive transitions in their life cycles. A possible concern is that anthropogenic impacts may induce variation in previously invariant vital rates (such as annual adult survival), with consequent detrimental effects on population dynamics. For the bats, with

<table>
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<tr>
<th>Input factors:</th>
<th>Variant 1</th>
<th>Variant 2</th>
<th>Variant 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affected cells</td>
<td>(P_i)</td>
<td>(P_i)</td>
<td>(P_i)</td>
</tr>
<tr>
<td>S.D. of random normal distribution</td>
<td>1/4</td>
<td>1/4</td>
<td>1/3.5</td>
</tr>
<tr>
<td>Output values:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deterministic (\lambda)</td>
<td>1.00010</td>
<td>1.00010</td>
<td>1.00010</td>
</tr>
<tr>
<td># Extinctions / 100 trials</td>
<td>20</td>
<td>66</td>
<td>82</td>
</tr>
<tr>
<td>Mean extinction time</td>
<td>1,657.4</td>
<td>1,344.2</td>
<td>1,135.3</td>
</tr>
<tr>
<td># Declines / # survived pop</td>
<td>73/80</td>
<td>31/34</td>
<td>18/18</td>
</tr>
<tr>
<td>Mean ending population size</td>
<td>8,254.5</td>
<td>2,166.2</td>
<td>365.0</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>41,190.3</td>
<td>5,895.7</td>
<td>865.2</td>
</tr>
<tr>
<td>Median ending population size</td>
<td>299.16</td>
<td>134.11</td>
<td>49.93</td>
</tr>
<tr>
<td>Log (\lambda_s)</td>
<td>-0.00269</td>
<td>-0.00548</td>
<td>-0.00766</td>
</tr>
<tr>
<td>(\lambda_s)</td>
<td>0.9973</td>
<td>0.9945</td>
<td>0.9924</td>
</tr>
<tr>
<td>% reduction in (\lambda)</td>
<td>0.279</td>
<td>0.557</td>
<td>0.773</td>
</tr>
</tbody>
</table>

---

Table B7. Summary of three variants of a stochastic projection for Townsend’s big-eared bats.
a relatively even balance between the impacts due to fertility and survival changes, and with the small invariant litter size, the life history may not allow the kind of adjustment of risk load that may be possible in other species.

Potential refinements of the models

Clearly, the better the data on survival rates, the more accurate the resulting analysis. Data from natural populations on the range of variability in the vital rates would allow more realistic functions to model stochastic fluctuations. For example, time series based on actual temporal or spatial variability, would allow construction of a series of “stochastic” matrices that mirrored actual variation. One advantage of such a series would be the incorporation of observed correlations between variation in vital rates. Where we varied $F_i$ and $P_i$ values simultaneously, we assumed that the variation was uncorrelated, based on the assumption that factors affecting reproduction and, for example, overwinter survival would occur at different seasons or be due to different and likely uncorrelated factors (e.g., predation load vs. climatic severity or water levels). Using observed correlations would improve on this assumption by incorporating forces that we did not consider. Those forces may drive greater positive or negative correlation among life history traits. Other potential refinements include incorporating density-dependent effects. At present, the data appear insufficient to assess reasonable functions governing density dependence.
References


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Townsend's big-eared bat,
*Corynorhinus townsendii pallescens* and *C. t. townsendii*
Elizabeth D. Pierson & William E. Rainey

**Description:** *Corynorhinus townsendii* is a medium sized (10-12 g) vespertilionid, with an adult forearm of 39-48 mm and ears of 30-39 mm. It shows some geographical variation in color, but generally has buffy brown dorsal fur with somewhat paler underparts (Barbour and Davis 1969, Kunz and Martin 1982). *C. townsendii* can be distinguished from all other western bat species by the combination of a two-pronged, horseshoe-shaped lump on the rostrum, and large, rabbit-like ears. Although other California species have long ears (e.g., the pallid bat, *Antrozous pallidus*, the spotted bat, *Euderma maculatum*, the California leaf-nosed bat, *Macrotus californicus*, and the long-eared myotis, *Myotis evotis*), none of these have the two-pronged nose lump, and most can be distinguished by other features (Pierson et al. 1991).

Although the ears on *C. townsendii* are obvious (erect and facing forward) when animals are alert, they can be difficult to see (curled tightly against the top of the head in the shape of a ram’s horn) when animals are in torpor or hibernation. At such times, the tragus (a narrow prominence on the frontal, external opening to the ear, which is enlarged in many microchiropteran species), remains erect, and can be mistaken for short, sharply pointed ears, leading to misidentification of the species.

**Taxonomic Remarks:** *C. townsendii* is in the Family Vespertilionidae. There are five currently recognized subspecies of *C. townsendii* in the United States (Handley 1959); two (*C. t. townsendii* and *C. t. pallescens*) in the western U.S., two (*C. t. ingens* and *C. t. virginianus*) in the eastern part of the country, and one (*C. t. australis*) with a primarily Mexican distribution, which overlaps with *C. t. pallescens* in western Texas. Only the two western subspecies are found in California.

For most of its taxonomic history, the recognized generic name for this North American species was *Corynorhinus*. Beginning, however, with a taxonomic revision by Handley (Handley 1959) it became known as *Plecotus*. Two recent phylogenetic studies have reviewed relationships among plecotine genera (Frost and Timm 1992, Tumlison and Douglas 1992), and have recommended resurrecting the generic name of *Corynorhinus* to distinguish the North American from the Palearctic forms. Because of publication timing, these conclusions are not addressed in the most recent compilation of mammalian species (Wilson and Reeder 1993), but K. Koopman, who prepared the bat section of this volume, indicates that the name for the genus should revert to *Corynorhinus* (K. Koopman in litt.).

**Distribution:** *C. t. townsendii* occurs in California, Oregon, Washington, Nevada, Idaho, and possibly southwestern Montana and northwestern Utah. *C. t. pallescens* occurs in all the same states as *C. t. townsendii*, plus Arizona, Colorado, New Mexico, Texas, and Wyoming (Handley 1959). Throughout much of their range in California, Idaho, Nevada, Oregon and Washington there are extensive zones of intergradation for the two subspecies. Throughout the zone of intergradation it is frequently impossible to assign individuals to one subspecies or the other. Handley distinguishes the two subspecies based on size and color characteristics, but he also notes that the full spectrum of characteristics for both subspecies can be found within a single population. The results of preliminary mitochondrial DNA studies, using PCR techniques, failed to distinguish between these two subspecies, but this may reflect the relatively conservative region sequenced (cytochrome b) (W. Rainey). For the purposes of this document, we make no distinction between these subspecies.

In California, *C. townsendii* is found throughout most of the state, with populations concentrated in areas offering caves (commonly limestone or basaltic lava) or mines as roosting habitat. The species
is found from sea level along the coast to 1,820 m in the Sierra Nevada (Dalquest 1947, Pearson et al. 1952, Pierson and Rainey 1996a). Outside California it has been found to 2,400 m (Jones 1965, Jones and Suttkus 1972) and 2,900 m (Findley and Negus 1953).

**Life History:** *C. townsendii* is a colonial species, with maternity colonies in California varying in size from a dozen to several hundred animals. Maternity colonies are seasonal, and form in the spring, although the timing varies with latitude. For example, colonies begin to form in March in the desert and central coastal California, and not until June in interior northern California (G. Fellers pers. comm., E. Pierson unpubl. data). A single young is born sometime between May and July (Easterla 1973, Pearson et al. 1952, Twente 1955). *C. townsendii* pups average 2.4 g at birth, nearly 25% of the mother's postpartum mass (Kunz and Martin 1982). Young bats are capable of flight at 2.5 to 3 weeks of age and are fully weaned at 6 weeks (Pearson et al. 1952). Nursery colonies start to disperse in August about the time the young are weaned, and break up altogether in September and October (Pearson et al. 1952, Tipton 1983).

Following the typical pattern for temperate zone vespertilionids, mating generally takes place in the hibernaculum between October and February, with the females storing sperm in the uterine lining until spring, when ovulation and fertilization occur. Females are generally reproductive in their first year, whereas males do not reach sexual maturity until their second year. Gestation length varies with climatic conditions, but generally lasts from 56 to 100 days (Pearson et al. 1952).

Pearson et al. (1952) estimated annual survivorship at about 50% for young, and about 80% for adults. Band recoveries have yielded longevity records of 16 years, 5 months (Paradiso and Greenhall 1967) and 21 years, 2 months (Perkins 1995).

*C. townsendii* is a relatively sedentary species, for which no long-distance migrations have been reported (Barbour and Davis 1969, Humphrey and Kunz 1976, Pearson et al. 1952). The longest movement known for this species in California is 32.2 km (Pearson et al. 1952).

Although diet has not been examined in detail for any California populations, it is likely that *C. townsendii* here, as elsewhere, is a lepidopteran specialist, feeding primarily (>90% of the diet) on medium sized (6–12 mm) moths (Dalton et al. 1986, Ross 1967, Sample and Whitmore 1993, Whitaker et al. 1977, 1981). Shoemaker and Lacki (1993) determined that *P. t. virginianus* differentially selected noctuid moths, with geometrids, notodontids and sphingids also making up a significant portion of the diet. Representatives of the family Arctiidae constituted 37.5% of the available moth prey items, but were not consumed. Sample and Whitmore (1993) identified moth species from wing fragments collected at maternity caves. Of the 28 moth taxa identified, 15 were noctuids. Twenty-one species were forest dwelling, and six were associated with open, field habitats.

In addition to lepidopterans, small quantities of other insects have been detected in the diet of *C. townsendii*, particularly Coleoptera and Diptera (Dalton et al. 1986, Ross 1967, Sample and Whitmore 1993). Hemiptera, Hymenoptera, Homoptera, Neuroptera, Trichoptera, and Plecoptera have also been found sporadically (Dalton et al. 1986, Whitaker et al. 1977).

**Habitat:** *C. townsendii* occurs primarily in rural settings from the inland deserts to the cool, moist coastal redwood forests, in oak woodlands of the inner coast ranges and Sierra Nevada foothills, and lower to mid-elevation mixed coniferous-deciduous forests. Its distribution, however, tends to be geomorphically determined, and is strongly correlated with the availability of caves or cave-like roosting habitat. Population concentrations occur in areas with substantial surface exposures of
cavity-forming rock (e.g., limestone, sandstone, gypsum or volcanic), and in old mining districts (Genter 1986, Graham 1966, Humphrey and Kunz 1976, Kunz and Martin 1982, Perkins et al. 1994, Pierson and Rainey 1996a).

*C. townsendii* is primarily a cave-dwelling species, but also roosts in cave analogues, especially old mine workings (Barbour and Davis 1969, Graham 1966, Humphrey and Kunz 1976). In some areas, particularly along the Pacific coast, it has been found in old, mostly abandoned, buildings with darkened, enclosed cave-like attics and in other anthropogenic structures (e.g., water diversion tunnels and bridges)(Barbour and Davis 1969, Dalquest 1947, Howell 1920b, Kunz and Martin 1982, Pearson et al. 1952, Perkins and Levesque 1987, Brown et al. 1994, Pierson and Rainey 1996a).

This species appears to have fairly restrictive roost requirements (Humphrey and Kunz 1976, Perkins et al. 1994, Pierson et al. 1991). Roost temperature appears to be critical (Lacki et al. 1994, Pearson et al. 1952, Pierson and Rainey 1996a), and varies in maternity roosts throughout California from 19°C in the cooler regions to 30°C in the warmer southern regions (Pierson et al. 1991). Some colonies are known to change roosts during the maternity season, using cooler roosts earlier in the year (Pierson et al. 1991, P. Brown pers. comm., V. Dalton pers. comm.). Roost dimensions are also important. The majority of the roosts examined in California are fairly spacious, at least 30 m in length, with the roosting area located at least 2 m above the ground, and a roost opening at least 15 cm by 62 cm (Pierson et al. 1991). Maternity clusters are always situated on open surfaces, often in roof pockets or along the walls just inside the roost entrance, within the twilight zone.

Hibernation sites are generally caves or mines (Pearson et al. 1952, Barbour and Davis 1969), although animals are occasionally found in buildings (Dalquest 1947, E. Pierson pers. obs.). Deep mine shafts, known to provide significant hibernating sites in New Mexico (Altenbach and Milford 1991), may also be important in California (P. Brown pers. comm.). Winter roosting behavior varies with latitude. In areas with prolonged periods of non-freezing temperatures, *C. townsendii* tends to form relatively small hibernating aggregations of single to several dozen individuals (Barbour and Davis 1969, Pierson et al. 1991, Pierson and Rainey 1996a). Larger aggregations (75-460) are confined to areas which experience prolonged periods of freezing temperatures (Pierson and Rainey 1996a).

Studies in the western U.S. have shown that *C. townsendii* selects winter roosts with stable, cold temperatures, and moderate air flow (Humphrey and Kunz 1976, Kunz and Martin 1982). Individuals roost on walls or ceilings, often near entrances (Humphrey and Kunz 1976, Twente 1955). If undisturbed, individuals will frequently roost < 3 m off the ground (Perkins et al. 1994), and have been found in air pockets under boulders on cave floors (E. Pierson pers. obs.). Temperature appears to be a limiting factor in roost selection. Recorded temperatures in *C. townsendii* hibernacula range from -2.0°C to 13.0°C (Humphrey and Kunz 1976, Genter 1986, Pearson et al. 1952, Pierson et al. 1991, Twente 1955), with temperatures below 10°C being preferred (Perkins et al. 1994, Pierson and Rainey 1996a).

Recent radiotracking and light-tagging studies have found *C. townsendii* foraging in a variety of habitats. Brown et al. (1994) showed that *C. townsendii* on Santa Cruz Island in California avoided the lush introduced vegetation near their day roost, and traveled up to 5 km to feed in native oak and ironwood forest. P. Brown (pers. comm.) also documented *Corynorhinus* foraging in desert canyons with water on the west slopes of the Panamint Mountains in Inyo County. Radiotracking and light-tagging studies in northern California have found *C. townsendii* foraging within forested habitat (Rainey and Pierson 1996), within the canopy of oaks (E. Pierson and W. Rainey unpubl. data), and
along heavily vegetated stream corridors, avoiding open, grazed pasture land (G. Fellers pers. comm.). In Oklahoma, *C. t. ingens* preferred edge habitats (along intermittent streams) and open areas (pastures, crops, native grass) over wooded habitat (Clark et al. 1993). Light-tagging studies in West Virginia (V. Dalton pers. comm.) showed a bimodal foraging pattern for *C. t. virginianus*, with animals foraging over hayfields during the first part of the night, and within the forest later in the night, traveling up to 13 km from the day roost.

**Status**: Class I. Recent surveys conducted by Pierson and Rainey (1996a) for the Department show marked population declines for both subspecies in California, and suggest this species should be recommended for Threatened status in the state. Over the past 40 years, there has been a 52% loss in the number of maternity colonies, a 45% decline in the number of available roosts, a 54% decline in the total number of animals, and a 33% decrease in the average size of remaining colonies for the species as a whole statewide. The status of particular populations is correlated with amount of disturbance to or loss of suitable roosting sites. The populations that have shown the most marked declines are along the coast, in the Mother Lode country of the western Sierra Nevada foothills, and along the Colorado River.

A comparison of former and current population estimates for 18 historically known maternity colonies shows that six colonies (33%) appear to be extirpated; six others (33%) have decreased in size; one (6%) has remained stable; and five (28%) (four of which are protected within national parks) have increased.

A comparison of colony size for historically and currently known colonies, indicates that mean colony size has decreased from 165 (n = 18) to 111 (n = 34). The median colony size has decreased from 100 to 75. There are currently 38 known maternity colonies, occupying 55 known roost sites, with an estimated total population of about 4,300 individuals. Only three of these colonies have adequately protected roost sites.

Hibernating *C. townsendii* have been found historically or during a recent survey (Pierson and Rainey 1996a) at 44 sites (24 in mines, 19 in caves, one in a building). Most of these sites contain fewer than 20 individuals. Only three hibernating colonies number more than 100. The most significant aggregations (all those with >100) occur in the most northern part of the state, particularly Siskiyou County. In other areas, particularly the desert, smaller aggregations (5-20) are more typical, although mine shafts, found by Altenbach and Milford (1991) to house the largest aggregations, remain essentially unexplored in California. Four additional hibernating sites, not visited by Pierson and Rainey (1994) were located in 1979 (Marcot 1984), one of which contained 40-50 individuals.

Threats to *C. townsendii* include the following:

The species is roost limited. The combination of restrictive roost requirements and sedentary behavior would suggest that *C. townsendii* is roost limited, and that roost loss, through disturbance or destruction, has been primarily responsible for population declines in most areas. Although fire, winter storms, or general deterioration are sometimes responsible, in all but two of 38 documented cases, roost loss in California can be directly linked to human activity (e.g., demolition, renewed mining, entrance closure, human induced fire, renovation, or roost disturbance). Population declines are most highly correlated with roost destruction in the San Francisco Bay area, along the northern coast, and in San Diego County, and with roost disturbance in the Mother Lode country and along the Colorado River. Population declines along the Colorado River are also attributable to foraging habitat loss due to agricultural expansion.
Human Activity at Roosts. The intense recreational use of caves and mines in California provides the most likely explanation for why most otherwise suitable, historically significant roosts are currently unoccupied. It is well documented that *C. townsendii* is so sensitive to human disturbance that simple entry into a maternity roost can cause a colony to abandon or move to an alternate roost (Pearson et al. 1952; Graham 1966; Stebbings 1966; Mohr 1972; Humphrey & Kunz 1976; Stehler and Hall 1993; P. Brown pers. comm.). Inappropriate behavior on the part of well-intentioned researchers and others (i.e., entry into maternity roosts, capture of animals in roosts) could also contribute to population declines. Mark recapture studies are not without risk, since at least one wing band design causes serious injuries to *C. townsendii* (Pierson and Fellers 1994). Scientific collecting likely resulted in the extirpation of a population at Prisoner’s Harbor on Santa Cruz Island (Brown et al. 1994).

Closure of Old Mines. Old mines are significant roosting habitat for a number of bat species, particularly *C. townsendii* (Altenbach and Pierson 1995, Pierson and Rainey 1991, P. Brown pers. comm.). Liability and safety concerns have led to extensive mine closure programs in western states, particularly on public lands, often without consideration for the biological values of old mines. If closures are done at the wrong time of year, or without prior biological survey (Altenbach 1995, Navo 1995, Rainey 1995), they can result in the entrapment, and thus elimination of entire bat colonies.

Renewed Mining in Historic Mining Districts. The resurgence of gold mining in the West potentially threatens cave dwelling bat species (Brown and Berry 1991, Brown et al. 1993, Brown 1995). Since open pits, created by current mining practices, are often located in historic mining districts, old mine workings are frequently demolished as part of the ore extraction process. While effective mitigation is possible (Pierson 1989, Pierson et al. 1991), there is currently no legal mandate requiring that existing populations be protected. Renewed mining is known to account for the loss of one substantial colony in the California desert (P. Brown pers. comm.).

Additionally, process water containing cyanide has caused substantial wildlife mortality at a number of mine sites in the West. Although one study found that bats constitute 33.7% of documented wildlife fatalities (Clark and Hothem 1991), they frequently are not considered in assessment of cyanide risks (Nevada Mining Assoc. et al. 1990). A *Corynorhinus* maternity colony in a mine on the west slope of the Inyo Mountains disappeared after an open cyanide pond was constructed within 2 km of the roost (P. Brown pers. comm.). Similarly, process residues in open oil sumps are another significant source of wildlife mortality (Flickinger and Bunck 1987, Esmoil and Anderson 1995).

Loss of Foraging Habitat. It is also possible that destruction or damage of foraging habitat is contributing to the declines in *C. townsendii* populations in some areas, e.g., in urbanized regions, and along the Colorado River, where the native floodplain community has been subjected to extensive agricultural conversion. Also, forest management activities, particularly timber harvest and spraying that kills non-target lepidopteran species may alter the prey base for *C. townsendii*. Perkins and Schommer (1991) suggest that *Bacillus thuringiensis* sprays may suppress Tussock moth and spruce budworm reproduction enough to suppress reproduction in resident *C. townsendii*. Although the effects of grazing have not been specifically addressed for this species, a radiotracking study at Point Reyes National Seashore indicated that telemetered bats avoided grazed pastureland (E. Pierson pers. obs.). Roosting areas adjacent to water sources may be essential for desert populations of *C. townsendii* (P. Brown pers. comm.).

Inadequate Management Policies on Public Lands. Of the 20 largest currently known colonies in California, 13 are on public lands. While the National Park Service and California Department of
Parks and Recreation have made substantial commitments to protecting known roosts, other agencies have been less willing to recognize the biological significance of cave and mine roosts, often against the advice of their own biologists.

**Behavioral Ecology/ Population Biology.** The tendency for *C. townsendii* to roost in highly visible clusters on open surfaces, near roost entrances, makes them highly vulnerable to disturbance. Additionally, low reproductive potential and high roost fidelity increase the risks for the species.

**Management Recommendations:** Given the documented population declines, the precarious status of most known roosts, the pressures on populations from mining, logging, recreational caving, and development, Threatened status under CESA may be warranted.

Steps should be taken to protect key maternity sites, particularly on public lands. In many cases adequate protection could be accomplished by excluding people from the roost site. For caves and mines this generally means gating the roost entrance, using a gate design that excludes people and allows the bats to pass through (Dalton and Dalton 1995, Pierson et al. 1991, Pierson and Brown 1992).

Key populations (based on both size and geographic distribution) should be monitored on an annual or bi-annual basis to document current population trends. Counts should be conducted early in the maternity season (before young are volant) by counting animals upon emergence from the roost, using night vision equipment.

Regulatory agencies need to be informed of the importance of both caves and anthropogenic structures, such as mines, as roosting habitat for *C. townsendii* and other bat species. Too often the biological significance of these habitat features is overlooked in environmental assessment processes.

An appropriate survey protocol needs to be established for *C. townsendii*. Since this species is rarely caught in nets or identified with an acoustic detector, it often escapes detection using standard bat survey techniques. Because roost surveys offer the only viable survey method, and roost disturbance is such a critical issue, guidelines need to be established for survey methods which do not require roost entry (e.g., electronic monitoring devices and night vision equipment) (e.g., Navo 1995, Rainey 1995), or which set standards for roost entry in those cases where access to the roost is necessary.

In light of the findings of Altenbach and Milford (1991) in New Mexico, a policy to regulate destruction of potential hibernating sites should be instituted. For example, no mines or other structures, or caves should be closed or destroyed in the winter months without prior surveys for hibernating bats. Since there appears to be some movement in and out of hibernating sites throughout the winter in most parts of California, monitoring inaccessible portions of potential hibernating sites without entry is possible. At present, however, the only accurate and cost effective way to evaluate large numbers of sites is entry (Altenbach 1995, Navo 1995).

Additional surveys are needed to explore the limits of distribution for *C. townsendii* in California. Although the surveys conducted in 1992-1994 (Pierson and Rainey 1996a) focused on areas of known historical importance, some likely important areas (e.g., some old mining districts) were not investigated at all, and other areas, like the north coast and inner coast ranges, warrant further investigation.

Studies are needed to evaluate the specific effects of roost disturbance, most importantly the impacts on colony composition and reproductive success. This is particularly critical in the Mother Lode
Terrestrial Mammal Species of Special Concern in California, Brylski et al. 1998

TOWNSEND'S BIG-EARED BAT
Corynorhinus townsendii

Locations verified by authors
(captures, observations, museum records)

- Post - 1978
- 1978 and before
- CNDDB 1979 - 1998
- CNDDB 1978 and before

1:4,880,000
Wildlife Branch/KFin12109
Townsend’s Western Big-Eared Bat (Corynorhinus townsendii townsendii)

Status

State: Species of Concern
Federal: None
Other: Western Bat Working Group
High Priority Species

Population Trend

Global: Declining (Pierson et al. 1999)
State: Declining (Pierson 1988, Pierson and Rainey 1996)
Within Inventory Area: Unknown

Data Characterization

The location database for the Townsend’s western big-eared bat (Corynorhinus townsendii townsendii) within its known range in California includes 20 data records dated from 1987 to 2000. Of these records, 6 were documented within the past 10 years; of these, 1 was of high precision and can be accurately located within its survey area. None of these records are located within the inventory area.

A moderate amount of literature is available for the Townsend’s western big-eared bat because of its rare and declining status. Most of the information available is on the natural history, distribution, population status, and threats to this species. A conservation assessment and conservation strategy has been published.

Range

Townsend’s big-eared bats occur throughout most of western North America from British Columbia to central Mexico, east to the Black Hills of South Dakota, and across Texas to the Edwards Plateau (Hall 1981, Kunz and Martin 1982). Isolated, relictual populations of this species are found in the southern Great Plains and the Ozark and Appalacian Mountains (Hall 1981, Kunz and Martin 1982). The subspecies pallescens occurs in Washington, Oregon, California, Nevada, Idaho, Arizona, Colorado, New Mexico, Texas, and Wyoming. The subspecies townsendii occurs in Washington, Oregon, California, Nevada, Idaho, and possibly southwestern Montana and northwestern Utah (Hadley 1959, Hall 1981). In California, the boundary between pallescens and townsendii runs north-south approximately through the center of the Central Valley, with C. t. townsendii on the west side (Hall 1981). This species occurs from near sea level to well above 3,160 meters above sea level (Pearson et al. 1952, Nagorsen and Brigham 1993).
Townsend’s Western Big-Eared Bat (*Corynorhinus townsendii townsendii*)

**Occurrences within the ECCC HCP/NCCP Inventory Area**

Townsend’s big-eared bat is found throughout California, but specific details on its distribution within the central Coast Ranges are not well known. Records of this species include sites in the coastal lowlands and agricultural areas of Marin, Napa, Alameda, and San Mateo Counties and nearby hills (Pierson 1988). However, there are no published records of Townsend’s big-eared bat within Contra Costa County. Because of the scarcity of suitable habitat including mines and caves, it is unlikely that significant maternity roosts of this species occur in the county. However, future research may show that small numbers of individual bats roost in buildings, bridges, or other structures within the inventory area.

**Biology**

**Habitat**

Townsend’s big-eared bats occur in a variety of habitats throughout California, but they are most commonly associated with desert scrub, mixed conifer forest, and pinon-juniper or pine forest habitat. Within these communities, they are specifically associated with limestone caves, mines, lava tubes, and buildings (Dalquest, 1947, 1948; Graham 1966; Pearson et al. 1952; Kunz and Martin 1982; Pierson et al. 1991; Dobkin et al. 1995).

During hibernation, Townsend’s big-eared bats typically prefer habitats with relatively cold (but above freezing) temperatures in quiet, undisturbed places. These areas are often in the more interior, thermally stable portions of caves and mines (Barbour and Davis 1969, Dalquest 1947, Humphrey and Kunz 1976, Pearson et al. 1952, Zeiner et al. 1990). Hibernating bats are often found in ceiling pockets (Pierson et al. 1991). In central California, solitary males and small clusters of females are also known to hibernate in buildings (Pearson et al. 1952, Kunz and Martin 1982). Females may roost in colder places than males during these periods (Pearson et al. 1952).

During spring and summer, females establish maternity colonies in the warm parts of caves, mines, and buildings (Dalquest 1948, Pearson et al. 1952, Twente 1955, Pierson et al. 1991). In California, some maternity roost may reach 30ºC (86ºF) (Pierson et al. 1991). Favoured roost locations for females and young are often in a ceiling pocket or along the walls just inside the roost entrance (Pierson et al. 1991). Night roosts may include buildings or other structures, such as bridges (Pierson et al. 1996, Rainy and Pierson unpublished manuscript).

**Foraging**

Townsend’s big-eared bats feed primarily on small moths, but also take other insects, including flies, lacewings, dung beetles, and sawflies (Whitaker et al. 1977; Kunz and Martin 1982). Radio-tracking studies in northern California
have found Townsend’s big-eared bats foraging within forested habitats and along heavily vegetated stream corridors, avoiding open, grazed pasture land (Pierson and Fellers 1998, Pierson et al. 1999). Individuals may travel up to 13 kilometers from their day roost (Pierson et al. 1999).

Reproduction

Female Townsend’s big-eared bats arrive at maternity roost sites in early spring and give birth to a single offspring in late spring or early summer after an approximately 3-month gestation period (Pearson et al. 1952). In California, young are born over a 3- to 5-week period beginning in late May. Maternity colonies disperse in fall, and mating occurs in fall and winter. The peak of copulations occurs from November through February, although some females apparently mate before arriving at hibernacula (Kunz and Martin 1982). Females are sexually mature and mate in their first autumn. However, as in most bats, females store sperm, and ovulation does not occur until early spring (Pearson et al. 1952). Ovulation may occur either before or after females leave hibernation. Townsend’s big-eared bats are large at birth, weighing approximately 25% of the mother’s postpartum mass (Kunz and Martin 1982). Young grow rapidly, reaching adult size in approximately 1 month, and capable of flight in 2.5 to 3 weeks. They are fully weaned by 6 weeks (Pearson et al. 1952).

Demography

Band recoveries show longevity records of up to 16 years, 5 months (Paradiso and Greenhall 1967) and 21 years, 2 months (Perkins 1994). Pearson et al. (1952) estimated the annual survivorship for Townsend’s big-eared bats was about 50% for young and 80% for adults.

Behavior

Townsend’s big-eared bat is a relatively sedentary species for which no long-distance migrations have been documented (Pearson et al. 1952, Barbour and Davis 1969, Humphrey and Kunz 1976). The longest seasonal movements recorded for this species are 32.2 kilometers in California (Pearson et al. 1952) and 39.7 kilometers in Kansas (Humphrey and Kunz 1976).

Townsend’s big-eared bats hibernate in mixed-sex aggregations of 100 to 500 individuals. They periodically arouse during winter and move to alternate roosts. Individuals actively forage and drink throughout winter (Brown et al. 1994). Hibernation is prolonged in colder areas and intermittent where climate is predominately not freezing (Kunz and Martin 1982).
Ecological Relationships

Townsend’s big-eared bat is a lepidopteran specialist, with a diet consisting of more than 90% moths (Pierson et al. 1999). Night roosts of this species often include other bat species, including pallid bat (*Antrozous pallidus*), big brown bat (*Eptesicus fuscus*), California myotis (*Myotis californicus*), small-footed myotis (*M. ciliolabrum*), long-eared myotis (*M. evotis*), little brown bat (*M. lucifugus*), fringed bat (*M. thysanodes*), long-legged bat (*M. volans*), and Yuma myotis (*M. yumanensis*).

Threats

Townsend’s big-eared bats are highly sensitive to roost disturbance. Activities that can result in significant disturbance or loss of habitat include mine reclamation, renewed mining, water impoundments, recreational caving, loss of building roosts, and bridge replacement (Kunz and Martin 1982, Pierson et al. 1999). Pesticide contamination may also threaten this species in agricultural areas (Geluso et al. 1976).

Conservation and Management

Townsend’s big-eared bat has been classified as a High Priority species by the Western Bat Working Group for all populations throughout its range. This classification indicates that this species is imperiled or is at high risk of imperilment. In 1994, a Townsend’s big-eared bat conservation strategy was initiated as part of the Idaho Conservation Effort. This strategy was prepared by a team of experts from 8 participating states and resulted in the publication of the Species Conservation Assessment and Conservation Strategy for the Townsend’s big-eared bat (Pierson et al. 1999). The species conservation assessment summarizes the life history and habitat requirements, historical and current distribution and abundance of this species throughout its range, its current status, and threats to the species in each state. The conservation strategy is a plan that, if successful, will remove or minimize identified threats and promote restoration or recovery of the species.

Species Distribution Model

A species distribution model was not developed for Townsend’s big-eared bat because the specific habitat features for this species could not be mapped on a regional scale.
**Mammals**

Townsend’s Western Big-Eared Bat (*Corynorhinus townsendii townsendii*)

**Literature Cited**


Mammals

Townsend’s Western Big-Eared Bat (*Corynorhinus townsendii townsendii*)


Western mastiff bat, *Eumops perotis*
Elizabeth D. Pierson & William E. Rainey

**Description:** *Eumops perotis* is one of four molossids which occurs in California. The molossids are distinguished from all other bat species by the presence of a “free-tail,” which extends visibly beyond the edge of the interfemoral (=tail) membrane. *E. perotis* is distinguished from the other molossids on the basis of size. It is by far the largest bat species found in California. It has a wingspan of 53 to 56 cm, a forearm of 75-83 mm, and an adult weight of 60-72 g. The species with which it could most readily be confused is *Nyctinomops macrotis*, another molossid, with a forearm of 58-64 mm. Both have large bonnet-like ears, which extend forward over the eyes and are connected at the midline.

**Taxonomic Remarks:** *E. perotis* is in the family Molossidae. The California form of *E. perotis* was first described by Merriam (1890), and has been recognized as the subspecies *E. p. californicus* since 1932 (Sanborn 1932). The type locality is Alhambra, Los Angeles County. There are nine species currently recognized in the genus *Eumops* (*auripendulus*, *bonariensis*, *dabbenei*, *glaucinus*, *hansae*, *maurus*, *perotis*, *trumbulli*, and *underwoodi*), and two subspecies of *E. perotis* (*californicus* and *perotis*) (Eger 1977). Most species have their centers of distribution in Mexico, Central and/or South America; three (*glaucinus*, *underwoodi*, and *perotis*) occur in the southern United States; only *E. perotis californicus* occurs in California, with the other subspecies, *E. p. perotis*, being confined to South America.

**Distribution:** *E. p. californicus* ranges from central Mexico across the southwestern United States (parts of California, southern Nevada, southwestern Arizona, southern New Mexico and western Texas) (Bradley and O'Farrell 1967, Eger 1977, Hall 1981). Recent distributional information for California is summarized below (from Pierson and Rainey 1996b, c).

Historically, *E. perotis* was known to be broadly distributed in southern California, from the Colorado River to the coast, with records concentrated in the Los Angeles basin and San Diego County (Cockrum 1960, Eger 1977). The most northern records for which specimens were available was a single animal from the San Francisco Bay area (Hayward, Alameda County) (Sanborn 1932) and several records from Yosemite Valley in Yosemite National Park (Natural History Museum, Yosemite National Park). There were also observations of several *E. perotis* at Hetch Hetchy Reservoir in Yosemite National Park (Vaughan 1959), and of a single animal (specimen not available), presumed to be a vagrant, found in 1973 in Butte County, near Oroville (A. Beck pers. comm., Eger 1977).

Although *E. perotis* is a colonial species, it is striking how few of the available records represent colony sites. Most colony records are from southern California. Early in this century, Howell (1920a, 1920b) located several in buildings in the Los Angeles basin (e.g., in Azusa, Colton, and Covina). In the 1940s, Krutzsch (1943, 1945, 1948, 1955) identified two colonies in San Diego County. Additional significant locality records were contributed by Vaughan (1959) who monitored 22 sites, including eight colonies, located primarily in southern California. Leitner (1966) also focused his research on a colony located in a building at Citrus Junior college in Azusa in the Los Angeles basin. D. Constantine (pers. comm.) knew of a colony in a church in Highland in the 1960s. K. Stager (pers. comm.) reported a very large colony eliminated by an exterminator from a house in downtown Los Angeles in the early 1950s. Historically there were only three records of colonial roost sites north of the Los Angeles basin, all located in the 1940s and 1950s by researchers associated with the Museum of Vertebrate Zoology at the University of California, Berkeley -- a colony on the west side of the Central Valley in San Benito County (Dalquest 1946), one in Kern
County near McKittrick (Krutzhc 1955), and one in the Kern River drainage east of Bakersfield (Koford 1948, Krutzsch 1955).

Recent surveys (Pierson and Rainey 1996b, c) have changed the distributional picture for *E. perotis*. It is now apparent that the species is more widely distributed than was previously realized, and significant populations occur in areas for which only single or scattered records were previously available. This species is now known to have a range that extends almost to the Oregon border, with a number of new localities in the western Sierra Nevada foothills and eastern Trinity Alps. Although there were very few records for the Coast Range prior to the 1990s, multiple animals, suggesting resident populations, have now been detected at several localities in the Coast Range south of San Francisco. Historically the only indication that *E. perotis* occurred in the Sierra Nevada was several lower elevation records (Koford 1948, Vaughan 1959). It is now known that significant populations of *E. perotis* occur in many of the Sierra Nevada river drainages, particularly in the central and southern Sierra, i.e., the Stanislaus, Tuolumne, Merced (North and South Forks), San Joaquin, Kaweah, Tule, and Kern rivers. Substantial populations and roost sites have been located in basaltic table formations in the western Sierra foothills, particularly on the lower San Joaquin and Stanislaus Rivers (W. Philpott, T. Rickman, D. York pers. Comm.). Although the largest populations appear to occur at lower elevations, animals have been detected in the warm season as high as 2,600 m elevation in Yosemite National Park (Pierson and Rainey 1996c), and at 2,000 m in Giant Forest (Pierson and Heady 1996). There are no historic records east of the Sierra Nevada crest, but recent (albeit infrequent) acoustic detections at several localities suggest that this species occurs in some of the Mojave Desert mountain ranges (e.g., Coso, Granite and Panamint Mountains) (P. Brown pers. comm.). Also, the species was heard once in Bishop, during the summer of 1996 (P. Brown pers. comm.).

Unlike some molossid species (e.g., *Tadarida brasiliensis*) which undergo long distance seasonal migrations, *E. perotis* appears to move relatively short distances seasonally. Like other molossids, it does not undergo prolonged hibernation, and appears to be periodically active all winter. Although in southern California local populations may change roost sites, they likely remain in an area year-round (Howell 1920a, Krutzsch 1948 and 1955, Leitner 1966, Barbour and Davis 1969). On the western side of the Sierra Nevada, the species likely moves down the river drainages as the weather cools, concentrating during the winter in areas which experience prolonged periods of above freezing temperatures (below 300 m). For example, winter surveys on the Kern River revealed that animals were not occupying a summer roost site at 580 m, but were concentrated near the mouth of the canyon at ca. 245 m (Pierson and Rainey 1996b). Reliable observers have documented that populations are present throughout the winter at three basaltic table mountain formations (near Oroville, Jamestown and Fresno) (B. McMurtry, W. Philpott, T. Rickman, D. York pers. comm.).

**Life History:** Unlike vespertilionids which mate in the fall, North American molossids, including *E. perotis*, appear to mate in the spring and give birth to a single young in early- to mid-summer. Available data suggest, however, that although most *E. perotis* young are born by early July (Krutzhc 1955), parturition dates vary extensively (Barbour and Davis 1969), and births are not synchronous, even within colonies (Cockrum 1960). Juveniles with open epiphyses were captured in mid-August in Yosemite National Park, and in the Coast Range in mid-September (Pierson and Rainey 1996b). An individual, still identifiable as a juvenile, was also captured in the Coast Range in late November (L. Thompson pers. comm.). A lactating female was caught in Anza Borrego Desert State Park in early July, and a series of lactating females in Yosemite Valley in early September (Pierson and Rainey 1996b, c). In a different year, a post-lactating female was caught in Wawona, Yosemite National Park in mid-August (Pierson and Rainey 1995). A series of animals killed by the San Bernardino County Health Department on August 20, 1992, included five
post-lactating females, and three juveniles with open epiphyses (P. Brown pers. comm.).

_E. perotis_ is colonial, but colony size is generally small (fewer than 100 animals) (Barbour and Davis 1969). Howell (1920a) considered even 20 to be a large roost. Although maternity roosts for most bat species contain only adult females and their young, _E. perotis_ colonies contain adult males and females at all times of year (Krutzsch 1955).

_E. perotis_ emerges after dark, and its audible call can be heard flying every hour of the night. The animals are strong, fast fliers, with a likely extensive foraging range. The species has been heard in open desert, at least 15 mi (24 km) from the nearest possible roosting site (Vaughan 1959). Given the frequency with which multiple animals are detected together or in rapid succession, it is possible this species sometimes travels or forages in groups. Generally they move through an area fairly rapidly. An interval of intense acoustic activity will frequently be followed by silence, and foraging will not predictably reoccur at the same site on sequential nights.

The diet appears to be primarily moths (Lepidoptera). Ross (1967) reports that a sample of eight _E. perotis_ from Arizona had eaten only large Lepidoptera (up to 60 mm) and a few Homoptera. Easterla and Whitaker (1972) found that in 18 specimens, almost 80% of the diet was Lepidoptera, and the rest predominantly Gryllidae and Tettigoniidae. At one locality in Arizona, 58% of the diet consisted of small (about 8 mm) hymenopterous insects (Ross 1961). In California, it appears that _E. perotis_ feeds predominantly on moths (Lepidoptera), but also includes beetles (Coleoptera) and crickets (Gryllidae) in its diet (Whitaker et al. in prep.)

**Habitat:** The distribution of _E. perotis_ is likely geomorphically determined, with the species being present only where there are significant rock features offering suitable roosting habitat. It is found in a variety of habitats, from desert scrub to chaparral to oak woodland and into the ponderosa pine belt.

_E. perotis_ is primarily a crevice dwelling species. Natural roosts are often found under large exfoliating slabs of granite, sandstone slabs or in columnar basalt, on cliff faces or in large boulders (Dalquest 1946, Krutzsch 1955, Vaughan 1959). A number of roosts have also been located in appropriately proportioned cracks in buildings (Howell 1920a, Barbour and Davis 1969). Roosts are generally high above the ground, usually allowing a clear vertical drop of at least 10 ft (3 m) below the entrance for flight (Vaughan 1959, Barbour and Davis 1969). Roosts recently located in California were in exfoliating granite, sandstone, or columnar basalt (Pierson and Rainey 1996b). In all cases the bats are in a crevice at least 3.5 m above the ground.

Due to its audible echolocation call, _E. perotis_ can be readily detected in foraging areas. In California, it is most frequently encountered in broad open areas. Its foraging habitat includes dry desert washes, flood plains, chaparral, coastal sage scrub, oak woodland, open ponderosa pine forest, grassland, and agricultural areas.

**Status:** Class II. Recent surveys have shown that _E. perotis_ is more widely distributed, particularly in the Sierra Nevada foothills, than was previously realized (Pierson and Rainey 1996b). The discovery of a number of new localities was likely due to improved detection techniques (i.e., monitoring distinctive audible echolocation), rather than an expanding geographic range. Although researchers had made reference to the audible calls of _E. perotis_ (e.g., Vaughan 1959), this characteristic had not been previously used as a survey tool.

Assessing the status of _E. perotis_ populations presents certain challenges. Unlike many species
which exhibit great roost fidelity, and whose status can be tracked by monitoring colony size at roost sites (e.g., *Corynorhinus townsendii* and several *Myotis* species [Stihler and Hall 1993, Pierson and Rainey 1996a]). *E. perotis* may occupy roost sites in an unpredictable fashion. Krutzsch (1948) followed the Barrett Junction roost over a period of 11 years, and the population varied from 10 to 60 at comparable times of year. Certain roost sites, or series of roost sites, may be critical to particular populations, but not enough is known about the roosting ecology of this species to determine roosting patterns.

An absence of historical records makes it impossible to assess current trends for this species in most areas. In the recent surveys, a paucity of detection events along the north rim of the Los Angeles basin, in an area relatively rich in historic records, does suggest population declines. Although there was a very large colony (200-300 animals) in Azusa in the 1960s, there was no evidence acoustically that the species still occurs in Azusa, nor in the adjacent drainage leading into the San Bernardino Mountains. Likewise, no bats were detected in repeated acoustic surveys in Altadena and Pasadena. A roost in Highland, which had 40-50 adults in 1969 (D. Constantine pers. comm.), had only three bats in September 1992. With the exception of the north rim of the Los Angeles basin, *E. perotis* was detected in most sampled areas for which there were historic records.

There are a number of potential threats to the roosting and foraging habitat of *E. perotis*, which are discussed in detail in Pierson and Rainey (1996b). The following is a summary:

**Urban/suburban Expansion.** The loss of foraging habitat in the Los Angeles basin is likely primarily responsible for what appears to be a decline in *E. perotis* populations in this area. The numerous creek drainages flowing into the Los Angeles basin from the San Bernardino and San Gabriel mountains provided the kind of floodplain, desert wash vegetation, which appears in other settings to be ideal foraging habitat for this species. Most of that habitat has now been lost to urban/suburban development and associated watercourse channelization.

In San Diego County, for example, where houses are situated among boulder jumbles, people can be brought into close contact with these bats, which due to their size and loud vocalizations, are evident when present. Thus colonies in close proximity to human dwellings become vulnerable to disturbance and vandalism of their roosts.

**Pest Control Operations.** Extermination of colonies by pest control operators and public health departments has also been responsible for the elimination of many *E. perotis* in the Los Angeles basin. In this area, where building roosts are relatively more common, these large and noisy bats are very vulnerable to the hysteria which often surrounds bat colonies. K. Stager (pers. comm.) described a situation in a building near the Los Angeles County Museum in which “3 wash tubs full” of *E. perotis* were killed by exterminators in the 1950s. The only two recent colonies known for the Los Angeles basin (a school in Rancho Cucamonga and the Norco City Hall) came to our attention because both colonies were eliminated by public health officials.

**Water Storage and Development.** The same canyons which offer suitable cliff habitat for *E. perotis* also provide basins for storage reservoirs and other water projects. Almost every river which drains the west side of the Sierra Nevada has one or more such reservoirs. It is almost certain that roosting and foraging habitat has been lost at many of these sites (e.g., Hetch Hetchy Reservoir), and is threatened at others (e.g., Los Banos Creek). *E. perotis* has also frequently been detected foraging in the vicinity of reservoirs (e.g., Tulloch Lake, Lake Kaweah, Lake Success), so it is also possible that reservoirs create foraging habitat. The situation needs further evaluation.
Highway Projects. For obvious reasons, substantial cliffs generally occur where they have been carved by river systems. River drainages, because they frequently offer the easiest routes through mountain ranges, are also favored corridors for highway construction. Such construction commonly entails blasting of cliff faces, either for initial highway construction or later improvements (i.e., widening and straightening). Since bats are frequently overlooked in the environmental assessment process, cliff roosting species, such as *E. perotis*, are at risk of both direct impacts from blasting, and long-term loss of roosting habitat from cliff modifications.

Recreational Climbing. There has been an exponential increase in recreational rock climbing in the west in recent years. A recent informal survey by personnel at Yosemite National Park has documented 3,000 new climbing routes within the park, where the unsanctioned use of various technical aids has made previously unclimbable areas accessible (Dept. of Resource Management, Yosemite National Park, pers. comm.). The popular sites, such as El Capitan in Yosemite Valley, literally experience climbing traffic jams, with 20-30 climbers on the face at once. Similarly, columnar basalt cliffs, which occur along the western base of the Sierra Nevada, until recently considered too hot and unpleasant for climbing, have experienced increasingly heavy use since about 1990. Although no information is available regarding what proportion of the crevices used by climbers offer suitable roosting sites for *E. perotis*, it is reasonable to presume that hands or temporary climbing aids inserted into a roost crevice would be cause for disturbance and possible abandonment of a site. If climbers camp overnight on ledges beneath roosts, noise and light could potentially disturb nursery sites. Also, climbers may alter cliff habitat, dislodging unstable rock and clearing ledges.

Mining and Quarry Operations. Mining and quarry operations which impact cliff habitat could potentially remove roosting habitat for *E. perotis*. Additionally, the noise generated by active mining and quarry operations could disturb roosting bats. Quarries may create cliffs, however. One of the colony sites monitored by Vaughan (1959) was in a quarry west of Riverside.

Grazing/Meadow Management. Whereas a number of bat species appear to forage predominantly over water, or along vegetation edges (e.g., riparian zones, forest edges), *E. perotis* frequently forages in open areas, including meadows. To the extent that excessive grazing and trampling of meadows by livestock alters the insect productivity (particularly for lepidopterans), it may impact the foraging habitat of *E. perotis*, and could adversely affect local populations.

Pesticide Spraying and Environmental Contaminants. Pesticides have been shown to have detrimental effects on bat populations (Clark 1981, Clark et al. 1978, 1983). Persistent chlorinated hydrocarbons are now banned. While the shorter half-life organophosphates, now in wide use, are known to have negative impacts on raptors (Wilson et al. 1991), their effect on bats has not been investigated. Short-term neurotoxic insecticides could be lethal or impair maneuverability, leading to reduced foraging efficiency and increased vulnerability to predators. Lepidopteran-specific agents like *Bacillus thuringiensis* result in significant, if short-term, reduction in the prey base for species like *E. perotis* that rely heavily on moths (Sample et al. 1993).

Sensitivity to Human Disturbance. No data are available on the sensitivity of *E. perotis* to human disturbance. Most bat species, however, are sensitive to human intrusion into roost sites, particularly during the maternity season.

Management Recommendations: Recent surveys expanded the known range of *E. perotis*, and suggest that additional surveys should be conducted, particularly in the Coast Range, at higher altitudes in the Sierra Nevada, and on the east side of the Sierra Nevada.
More information is needed on the spatial and temporal distribution of populations. It is not known how loyal colonies are to particular roost sites, and thus whether single roost sites, or roosting areas need to be monitored and protected. Studies need to be conducted to assess the impact of certain human activities, particularly recreational climbing, in the vicinity of roost sites.

Recent surveys identified a number of significant populations. Methods need to be developed for assessment and ongoing monitoring of population size.
Western Mastiff Bat
*Eumops perotis*

Locations verified by authors
(captures, observations, museum records)
- Post - 1978
- 1978 and before

- CNDD 1979 -1998
- CNDD 1978 and before
**Western Red Bat (Lasiurus blossevillii)**

**PROTECTION STATUS NOTES**

Nothing is known about the status of this bat, since like other foliage-roosting bats, it does not form colonies and is difficult to find. However, it is considered a Species of Special Concern in California, Arizona, and Utah, but not in Texas.

**DESCRIPTION**

*Lasiurus blossevillii* can be distinguished from all other western bat species except *Lasiurus borealis* (the eastern red bat) by its distinctive red coloration, and can be distinguished from *L. borealis* by its slightly smaller size and lack of frosted appearance. The only area where these two species are known to overlap is western Texas.

**LIFE HISTORY**

Western red bats mate in late summer or early fall. Females become pregnant in spring and have a pregnancy of 80–90 days. Females may have litters of up to five pups per year. This species is considered to be highly migratory. Although generally solitary, western red bats appear to migrate in groups and forage in close association with one another in summer. The timing of migration and the summer ranges of males and females seem to be different. Winter behavior of species is poorly understood. The eastern red bat has been found hibernating in leaf-litter. Arousal from hibernation on warm days to feed has been reported, as has periodic foraging during the winter in the San Francisco Bay area. Predators reported for *L. blossevillii* include birds (e.g. scrub jays, falcons, accipiters, owls, roadrunners), opossums, and domestic cats.

*L. blossevillii* is typically solitary, roosting primarily in the foliage of trees or shrubs. Day roosts are commonly in edge habitats adjacent to streams or open fields, in orchards, and sometimes in urban areas. There may be an association with intact riparian habitat (particularly willows, cottonwoods, and sycamores). Roost sites are generally hidden from view from all directions except below; lack obstruction beneath, allowing the bat to drop downward for flight; lack lower perches that would allow visibility by predators; have dark ground cover to minimize solar reflection; have nearby vegetation to reduce wind and dust; and are generally located on the south or southwest side of a tree. *L. blossevillii* may also occasionally use caves, as both dead and live western red bats, including a pregnant female, have been collected from Carlsbad Caverns in New Mexico.

Western red bats generally begin to forage one to two hours offer sunset. Although some may forage all night, most typically have an initial foraging period corresponding to the early period of nocturnal insect activity, and a minor secondary activity period corresponding to insects that become active several hours before sunrise. Western red bats have been observed feeding around street lights and flood lights. Reported prey items include homopterans, coleopterans, hymenopterans, dipterans, and lepidopterans.

**DISTRIBUTION**

*L. blossevillii* has a broad distribution reaching from southern British Columbia in Canada, through much of the western United States, through Mexico and Central America, to Argentina and Chile in South America.
In Texas it is known only from the western tip of the Trans Pecos.

**THREATS AND REASONS FOR DECLINE**

Loss of riparian zones, primarily due to agricultural conversion and creation of water storage reservoirs has reduced both small red bat roosting and foraging habitat of red bats. The intensive use of pesticides in fruit orchards may constitute a threat to roosting bats and may significant reduce the amount of insect prey available. Controlled burns may be another significant mortality factor for red bats that roost in leaf litter during cool temperatures.

**ONGOING RECOVERY**

Since the western red bat feeds heavily on moths and often lives in orchards, it is presumed to be highly beneficial to orchardists. Because riparian habitat along streams is one of the most rapidly disappearing in the West, it is possible that this bat has undergone substantial decline due to habitat loss.

**OTHER**

The following areas need more investigation to accurately determine the status of and conserve the red bat in the western U.S.: habitat requirements (especially roost sites and foraging habitat), altitudinal distribution, migration patterns, effects of controlled burns, and effects of pesticide use in orchards.

**For more information**

Additional details can be found in the online version of *The Mammals of Texas* for the Western Red Bat.
Several in the genus Lasiurus are commonly referred to as "tree bats" because they roost only in tree foliage. The desert red bat is a typical tree bat, which is closely associated with cottonwoods in riparian areas at elevations below 6,500 feet. Especially favored roosts are found where leaves form a dense canopy above and branches do not obstruct the bats' flyway below. Desert red bats are also known to roost in orchards, especially in the Sacramento Valley of California. Despite their bright amber color, these bats are actually rather cryptic, resembling dead leaves when they curl up in their furry tail membranes to sleep.

Like all tree bats, this species is solitary, coming together only to mate and to migrate. Tree bats often give birth to twins, and desert red bats can have litters of up to four pups, though three is the average. These bats typically feed along forest edges, in small clearings, or around street-lights where they prefer moths. It is not known exactly where desert red bats hibernate, though they may burrow into leaf litter or dense grass like their eastern counterparts, and they do move to milder coastal areas in the Pacific Northwest. Although largely undocumented, desert red bats appear to have declined markedly in the West due to the loss of lowland riparian forests.

Approximate North American Range:
Yuma Myotis

Distribution, Abundance, and Seasonality

The Yuma myotis is common and widespread in California. It is uncommon in the Mojave and Colorado Desert regions, except for the mountain ranges bordering the Colorado River Valley. Found in a wide variety of habitats ranging from sea level to 3300 m (11,000 ft), but it is uncommon to rare above 2560 m (8000 ft). Optimal habitats are open forests and woodlands with sources of water over which to feed.
Specific Habitat Requirements

**Feeding:** Feeds on a wide variety of small flying insects found by echolocation. This species usually feeds over water sources such as ponds, streams, and stock tanks. Prey includes moths, midges, flies, termites, ants, homopterans, and caddisflies (Easterla and Whitaker 1972, Black 1974, Whitaker et al. 1977, 1981). The Yuma myotis is an efficient forager, sometimes returning to the roost with a full stomach 15 min after dusk (Barbour and Davis 1969). These bats respond to temporary patches of prey, such as ant swarms (Vaughan 1980), although many authors report that regular foraging routes are followed.

**Cover:** Maternity colonies of several thousand females and young may be found in buildings, caves, mines, and under bridges. Warm, dark sites are preferred. Individuals are clustered tightly in the warmest sites when temperatures are low. If temperatures exceed 40Â°C, bats seek cooler locations, and individuals roost farther apart.

**Reproduction:** The Yuma myotis has a relatively poor urine concentrating ability, and frequently is observed drinking.

**Water:** Distribution is closely tied to bodies of water, which it uses as foraging sites and sources of drinking water. Open forests and woodlands are optimal habitat.

**Pattern:** Nocturnal. Hibernates. This species emerges soon after sunset in many areas (Barbour and Davis 1969), but Jones (1965) reported that peak activity was 1-2.5 hr after sunset. Warm temperatures are preferred, and activity may be extended on warm nights. Winter habits are poorly known, but this species apparently hibernates.

**Species Life History**

**Activity Patterns:** Probably makes local or short migrations to suitable hibernacula. Individuals that spend the summer at high elevations probably move downslope.

**Seasonal Movements / Migration:** No data found.

**Home Range:** Territoriality has not been reported. Probably not territorial at feeding or roosting sites; roosts in large groups.
**Territory:** The Yuma myotis, like other California bats, mates in the fall. Dalquest (1947) reported that the season of births lasted from late May to mid-June with a peak in early June. It is likely that some young are born in July in some areas. A single litter of 1 young is produced yearly. The species may live up to 8.8 years (Cockrum 1973).

**Reproduction:** The Yuma myotis may be found feeding and roosting with other bat species, such as *Tadarida brasiliensis* and *Antrozous pallidus*.

**Niche:** This species is difficult to distinguish from *M. lucifugus*, with which it may occasionally hybridize (Harris 1974, Parkinson 1979).

**Comments:** This species is difficult to distinguish from *M. lucifugus*, with which it may occasionally hybridize (Harris 1974, Parkinson 1979).

**Sources & References**

California Department of Fish and Game, 1999.
California's Wildlife, Sacramento, CA.
Written by: J. Harris, reviewed by: P. Brown, edited by: S. Granhom, R. Duke


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**California Animal Facts** | **California's Wildlife**
Western Bat Working Group  
http://www.wbwg.org

Species Accounts
Developed For the 1998 Reno Biennial Meeting
Updated at the 2005 Portland Biennial Meeting

Myotis yumanensis
YUMA MYOTIS

Prepared by: M. A. Bogan, E. W. Valdez, and K.W. Navo

I. DISTRIBUTION: Myotis yumanensis, a member of the Family Vespertilionidae, ranges across the western third of North America from British Columbia, Canada, to Baja California and southern Mexico. In the United States, it occurs in all the Pacific coastal states, as far east as western Montana in the north, and as far east as western Oklahoma in the south.

II. STATUS: Global Rank - G5. State Ranks: AZ - S3S4; CA - S5; CO - S3; ID - S3; MT - S3; NM - S5; NV - S7; OR - S3; TX - S4; UT - S3; WA - S2; WY - S2; BC - S4S5. Former category 2 candidate species. Take regulated by permit in some states.

III. IDENTIFYING CHARACTERISTICS AND LIFE HISTORY: Myotis yumanensis is a small bat that is usually gray or brown to pale tan dorsally with a paler venter of tan or gray; ears and membranes are frequently pale brown to gray. In some areas M. yumanensis is difficult to distinguish from M. lucifugus and caution is required. Both species are usually associated with permanent sources of water, typically rivers and streams, but Yuma myotis also use tinajas in the arid West. It occurs in a variety of habitats including riparian, arid scrublands and deserts, and forests. The species roosts in bridges, buildings, cliff crevices, caves, mines, and trees. Individuals become active and forage just after sunset, feeding primarily on aquatic emergent insects. Their diet is known to include caddis flies, flies, midges, small moths and small beetles. After feeding, they periodically rest at night roosts where the food is digested. Mating is typically in the fall and females give birth to one young from mid-spring to mid-summer in maternity colonies that may range in size up to several thousand; males tend to roost singly in the summer.

IV. THREATS: May be affected by closure of abandoned mines without adequate surveys, some forest management practices, and disturbance of maternity roosts in caves and buildings. Since this species frequently occurs in anthropogenic structures, it is vulnerable to destructive pest control activities. Some riparian-management practices may be detrimental.

V. GAPS IN KNOWLEDGE: No information known on use and acceptance of bat gates, impacts of grazing and riparian habitat management, winter range, and winter roost requirements. Information is needed on geographic variation in roosting and foraging requirements.

VI. RELEVANT LITERATURE:


More bat species accounts available at: [http://www.wbwg.org/species_accounts](http://www.wbwg.org/species_accounts)