Advisory Note

Techniques and approaches contained in this handbook are not all-inclusive, nor universally applicable. Designing stream restorations requires appropriate training and experience, especially to identify conditions where various approaches, tools, and techniques are most applicable, as well as their limitations for design. Note also that product names are included only to show type and availability and do not constitute endorsement for their specific use.
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Technical Supplement 3D

Introduction

In the past, bats (order Chiroptera) have been one of the most feared and misunderstood creatures (fig. TS3D–1). Today, as researchers are beginning to unravel the secrets of the world’s only flying mammals, bats are declining worldwide. Misconceptions and folklore concerning bats have been passed along for generations, and unfortunately, this has led to the senseless killing of colonies of millions of bats, sometimes in a single destructive act. Most bats only produce one pup a year; therefore, recolonizing a decimated population and replenishing a once occupied cave may take decades. With thanks to extensive conservation and education, bats are making a comeback both in the United States and worldwide.

The diversity of bat species, the habitats they occupy, and their behavioral and social features are impressive (Fenton 1997). Occurring worldwide except for the Polar regions and a few isolated islands, there are more than a thousand known bat species, and this number continues to increase (Mickleburgh, Hutson, and Racey 2002; Engstrom and Reid 2003). Some species, such as Mexican free-tailed bats (Tadarida brasiliensis), undertake extensive seasonal migrations. Other species migrate for food, such as the long-nosed bats (Leptonycteris spp.) and the Mexican long-tongued bat (Choeronycteris mexicana), which are thought to travel along nectar corridors. Species such as endangered gray bats (Myotis grisescens) and Indiana bats (M. sodalis) migrate more locally between summer roosts and winter hibernacula. Elevational migration routes may also occur. They are thought to be a strategy of the spotted bat (Euderma maculatum), which lives in southwestern regions.

Bats have an extraordinary dietary diversity. Different species feed specifically on insects, fish, frogs, blood, fruit, or nectar. In the United States, bats are voracious feeders on night-flying insects, and three species of nectar/pollen feeding bats live in the extreme southern regions bordering Mexico. Insectivorous species typically consume more than 50 percent of their body weight in bugs nightly (Harvey, Altenbach, and Best 1999). Consider the 20 million Mexican free-tail bats from Bracken Cave, Texas, the largest concentration of mammals in the world. They devour approximately 200 tons of pests a night. Only 150 big brown bats (Eptesicus fuscus) are required to protect farmers from 33 million corn rootworms (Diabrotica spp.) each summer Bat Conservation International (BCI) 2000. The pollinating species of bats in the Southwest is important for the survival of agaves and columnar cacti. The beneficial and economical role bats play for humans and ecosystems is clear.

Habitat

An increased availability of roost diversity usually corresponds to an increased population and diversity of bat species (Findley 1995). Cave bats or forest-dwelling species are generally colonial species that roost in caves, crevices, hollow trees, or under loose bark. The Indiana bat, for example, uses caves for hibernation during the winter months and tree cavities or beneath exfoliating bark of various trees in the summer (Kurta et al. 1992). Some cavity dwelling species will also use manmade structures such as mines, bridges, culverts, and bat houses (fig. TS3D–2). Several suitable roosts
in an area may provide a colony of bats with the necessary thermal variation required throughout the day and allow escape from parasites or predators (Lewis 1995).

Tree bat species typically roost solitarily or in small groups in foliage or moss at different canopy levels. Young red bats (Lasiusurus borealis), for example, have been observed roosting higher in trees than adults (Constantine 1966). Studies have suggested that female and male bats use different habitats and roosting sites (Brigham 1991; Cryan, Bogan, and Altenbach 2000). Findley (1995) suggests that differences in morphology, flight maneuverability, and echolocation proficiency affect partitioning of foraging and roosting habitat between species. Thus, species, age, sex, reproductive condition, or migratory status may account for differences in roost and habitat selection among bats. Overall, a diverse landscape and forest stratification with a multifaceted arrangement of potential roosting and foraging areas, even in suburban areas, appears to be important for healthy bat populations (Evelyn, Stiles, and Young 2004).

Since fresh water is critical to their survival, bats are closely associated with riparian environments (Martin 2001) (fig. TS3D–3). Riparian areas are of particular importance to bats, possibly due to their high resource of flying insects (Barclay 1991), especially for species in arid regions (Bell 1980).

Riparian areas also offer an abundance of snags, which are important roosting sites for many species of bats. Tuttle (1976) suggests that roost selection may be determined by proximity to required resources such as water, forage areas, and hibernation sites, thus, reducing energy expenditure by reducing travel distance. For example, there is a decreased growth rate and higher mortality rate among juvenile gray bats where greater distance is traveled from roosting sites (caves) to their preferred foraging habitat, which is over water. Research also suggests that riparian zones act as important travel corridors, space for open flight, and forest edges which are frequently used for feeding and migration by some bat species (Wunder and Carey 1994).

**Status and impacts**

Of the 45 species of bats that occur in the continental United States and Hawaii, 6 species are considered to be federally endangered and 20 are species of concern (Harvey, Altenbach, and Best 1999). The International Union for Conservation of Nature and Natural Resources lists 10 bat species on the Red List of Threatened Species (IUCN 2002) (table TS3D–1). Species of concern, former category 2 candidates, are those sensitive species in which data pertaining to biological vulnerability and threat is not yet available to justify a

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**Figure TS3D–2**  
Maternal colony of Rafinesque’s big-eared bats (Corynorhinus rafinesquii) roosting beneath a concrete bridge

**Figure TS3D–3**  
Healthy riparian areas are important to bats for roosting and foraging
threatened or endangered status. Due to their nocturnal behavior, capability of flight, and the frequent remote location of their roosts, bats are one of the most difficult groups to research and to monitor. Although many species of bats in the United States appear to be declining, little is known about the populations and ecology for many species (Arnett 2003; O’Shea, Bogan, and Ellison 2003).

Intentional killing, vandalism, cave exploration and commercialization, and closure of abandoned mine entrances have greatly reduced roosting habitat for many bat species in the United States (Harvey, Altenbach, and Best 1999). Disturbance to hibernating bats can be detrimental due to the potential loss of needed energy reserves, which must last until summer emergence. Endangered gray bats, for example, are especially vulnerable since 95 percent of the population hibernate in only 11 caves in the Southeast (Harvey, Altenbach, and Best 2001). Disturbance to maternal colonies when newborn are present may also be injurious to bats since frightened mothers may drop their young or abandon the roost (Harvey et al. 1999). Natural disasters such as flooding can also effect populations, but human disturbance is the primary cause of their decline.

Loss of healthy riparian systems, especially in the southwest where permanent water sources are in decline, also negatively impact bat populations. Use of pesticides and other toxicants may contaminate water and food sources, and the loss of mature trees and snags may limit roost availability. Other causes of decline may include clearcutting, strip mining, and human encroachment into dwindling habitats (Martin 2000).

Conservation

Fortunately, a greater understanding of these beneficial creatures has led to great strides in their conservation. For example, protection of caves and mines through properly designed gates has shown considerable success for endangered and sensitive species (Tuttle 1977; Tuttle and Taylor 1998) (fig. TS3D–4). Placement of artificial roosts in roost-deficient areas or where colonies have been evicted from homes or buildings has also been valuable to various bat species. Burke (1999), Brittingham and Williams (2000), and Arnett and Hayes (2000) attracted bats to flat-bottomed bridges by installing specially constructed bat boxes. Continued research, innovation, management, and education have been, and will be, critical for the future of this unique group of animals.

Nonprofit organizations such as BCI have been educating people, advancing research efforts, and establishing collaboration efforts around the world for 20 years. The North American Bat Conservation Partnership (NABCP) was established in 1999 to support continentwide conservation efforts. They formed an alliance of working groups, researchers, nongovernmental organizations, and state and Federal agencies from Canada, the United States, and Mexico. This partnership has identified conservation priorities through a strategic plan, which will guide the future direction of research, education, and management (Keeley, Fenton, and Arnett 2003).

Another collaboration, the Program for the Conservation of Migratory Bats between Mexico and the United States (PCMM), was developed in 1995 due to declining bat populations in Mexico. Its objectives are to protect and conserve migratory species and to sustain their ecological roles and evolutionary processes (Medellin 2003). Partnerships and collaboration efforts such as these have demonstrated their important role in curtailing the rapid decline of bats in the United States and worldwide.
### Table TS3D–1: General habitat, distribution, and status of federally protected bat species in the United States

<table>
<thead>
<tr>
<th>Species</th>
<th>Status</th>
<th>U.S. distribution</th>
<th>General habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phyllostomidae</strong></td>
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</tr>
<tr>
<td>California leaf-nosed bat <em>(Macrotus californicus)</em></td>
<td>SOC VU</td>
<td>Southern CA, AZ extending into the southern tip of NV, and the extreme western portion of NM</td>
<td>Lowland desert habitat; abandoned mine tunnels may be used as day roosts and night roosts may include buildings, bridges, porches, or rock shelters</td>
</tr>
<tr>
<td>Mexican long-tongued bat <em>(Choeronycteris mexicana)</em></td>
<td>SOC LR/nt</td>
<td>Southern portion of CA, AZ, and southern tip of NM</td>
<td>Occupies a range of habitats from arid thorn shrub to tropical deciduous forest and mixed oak conifer; inhabits caves, buildings, and abandoned mines</td>
</tr>
<tr>
<td>Lesser long-nosed bat <em>(Leptonycteris curasoae yerbabuenae)</em></td>
<td>FE VU</td>
<td>South central and southeastern part of AZ and the extreme southern region of Mexico</td>
<td>Desert-scrub habitat; occupies abandoned mines and caves in areas consisting of agaves, yuccas, saguaros, and organ pipe cacti</td>
</tr>
<tr>
<td>Greater long-nosed bat <em>(Leptonycteris nivalis)</em></td>
<td>FE EN</td>
<td>Big Bend region of TX</td>
<td>Occupies a range of habitats from sparsely vegetated deserts to pine-oak woodlands; generally inhabits deep caverns, but will use hollow trees, mines, culverts, and buildings</td>
</tr>
<tr>
<td><strong>Vespertilionidae</strong></td>
<td></td>
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<tr>
<td>Spotted bat <em>(Euderma maculatum)</em></td>
<td>SOC</td>
<td>West central U.S.</td>
<td>Mostly occupies rocky arid to semiarid terrain such as desert, scrub areas, or ponderosa pine forest</td>
</tr>
<tr>
<td>Allen’s big-eared bat <em>(Idionycteris phyllotis)</em></td>
<td>SOC</td>
<td>Extreme southern NV, southern third of UT, throughout AZ, and the southwestern quarter of NM</td>
<td>Riparian habitats above 3,000 feet; common in coniferous forests and pine-oak forest canyons; maternity colonies of 30 to 150 individuals have been found in mine shafts, boulder piles, lava beds, and under bark of large ponderosa pine snags</td>
</tr>
<tr>
<td>Hawaiian hoary bat <em>(Lasiurus cinereus semotus)</em></td>
<td>FE</td>
<td>Hawaiian Islands: Kauai, Oahu, Maui, and Hawaii</td>
<td>Coastal and lowland forested areas; on Kauai, occurs primarily in open wet areas near forests; roosts in trees or rock crevices</td>
</tr>
<tr>
<td>Southeastern bat <em>(Myotis austroriparius)</em></td>
<td>SOC</td>
<td>Wide spread distribution in the Southeast</td>
<td>Roosts primarily in caves in the North and in the South will utilize buildings, bridges, hollow trees; maternity colonies have been located mainly in caves and hardwood swamp areas</td>
</tr>
<tr>
<td>Western small-footed bat <em>(Myotis ciliolabrum)</em></td>
<td>SOC</td>
<td>Western U.S.</td>
<td>Arid habitats associated with cliffs, talus fields, prairies; roosts in crevices, clay banks, beneath rocks in the ground, and under bark in barns; hibernates in caves and mines</td>
</tr>
<tr>
<td>Western long-eared bat <em>(Myotis evotis)</em></td>
<td>SOC</td>
<td>Western U.S.</td>
<td>Confierous forests, typically only at higher elevations in southern areas (between 7,000 and 8,500 feet) and semiarid shrublands, sage, chaparral, and agricultural areas; roost in tree cavities, beneath exfoliating bark of both living trees and dead snags, buildings, cliffs, and sink holes; pregnant bats often roost at ground level in rock crevices, fallen logs, and in the crevices of sawed-off stumps</td>
</tr>
<tr>
<td>Species</td>
<td>Status</td>
<td>USFW</td>
<td>IUCN</td>
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<tr>
<td>Gray bat (<em>Myotis grisescens</em>)</td>
<td>FE</td>
<td>EN</td>
<td>Cave regions of AR, MO, KY, TN, and AL</td>
</tr>
<tr>
<td>Eastern small-footed bat (<em>Myotis leibii</em>)</td>
<td>SOC</td>
<td>—</td>
<td>Eastern U.S.</td>
</tr>
<tr>
<td>Arizona bat (<em>Myotis lucifugus occultus</em>)</td>
<td>SOC</td>
<td>—</td>
<td>Southwestern U.S.</td>
</tr>
<tr>
<td>Indiana bat (<em>Myotis sodalis</em>)</td>
<td>FE</td>
<td>EN</td>
<td>Cave regions in the Eastern U.S.</td>
</tr>
<tr>
<td>Fringed bat (<em>Myotis thysanodes</em>)</td>
<td>SOC</td>
<td>—</td>
<td>Western U.S.</td>
</tr>
<tr>
<td>Cave bat (<em>Myotis velifer</em>)</td>
<td>SOC</td>
<td>—</td>
<td>Southern KS, western OK, and the southwestern states</td>
</tr>
<tr>
<td>Long-legged bat (<em>Myotis volans</em>)</td>
<td>SOC</td>
<td>—</td>
<td>Western U.S.</td>
</tr>
<tr>
<td>Yuma bat (<em>Myotis yumanensis</em>)</td>
<td>SOC</td>
<td>—</td>
<td>Western U.S.</td>
</tr>
<tr>
<td>Rafinesque’s big-eared bat (<em>Corynorhinus rafinesquii</em>)</td>
<td>SOC</td>
<td>VU</td>
<td>Southeastern U.S.</td>
</tr>
<tr>
<td>Virginia big-eared bat (<em>Corynorhinus townsendii virginianus</em>)</td>
<td>FE</td>
<td>VU*</td>
<td>KY, NC, VA, WV</td>
</tr>
<tr>
<td>Ozark big-eared bat (<em>Corynorhinus townsendii ingens</em>)</td>
<td>FE</td>
<td>VU*</td>
<td>AR, OK, possibly MO</td>
</tr>
</tbody>
</table>
### Table TS3D-1

General habitat, distribution, and status of federally protected bat species in the United States—Continued

<table>
<thead>
<tr>
<th>Species</th>
<th>Status</th>
<th>U.S. distribution</th>
<th>General habitat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western big-eared bat (Corynorhinus townsendii pallescens)</td>
<td>USFW SOC</td>
<td>VU*</td>
<td>Along the west coast</td>
</tr>
<tr>
<td>Townsend's (Pacific) big-eared bat (Corynorhinus townsendii)</td>
<td>USFW SOC</td>
<td>VU*</td>
<td>Western U.S.</td>
</tr>
</tbody>
</table>

| Molossidae | | |
|------------|--------|-------------------|-----------------|
| Florida mastiff bat (Eumops glaucinus floridanus) | USFW SOC | — | Southern tip of FL | Hardwood hammocks |
| Western mastiff bat (Eumops perotis californicus) | USFW SOC | — | Southwest U.S. | Areas with natural springs; roosts in crevices high in cliffs |
| Underwood's mastiff bat (Eumops underwoodii) | USFW SOC | LRnt | South central AZ | Organ Pipe Cactus National Monument, Baboquivari Mountains; roosts in woodpecker cavities within saguaro cacti |
| Big free-tailed bat (Nyctinomops macrotis) | USFW SOC | — | Southwest U.S. | Rocky habitats; roosts in crevices in cliffs, known to use buildings |
| Mexican free-tailed bat (Tadarida brasiliensis) | USFW — | LR/nt | Southern U.S. (largest populations in the West) | Occupy various habitats ranging from desert to pine-oak forests; utilize limestone caves and abandoned mines in the Southwest, manmade structures such as bridges and buildings in the Southeast, colonies also found in hollow trees |

FE = Federally endangered  
SOC = Species of concern  
EN = Endangered  
VU = Vulnerable  
LR/nt = Lower risk/near threatened  

Notes:  
* Subspecies are not distinguished