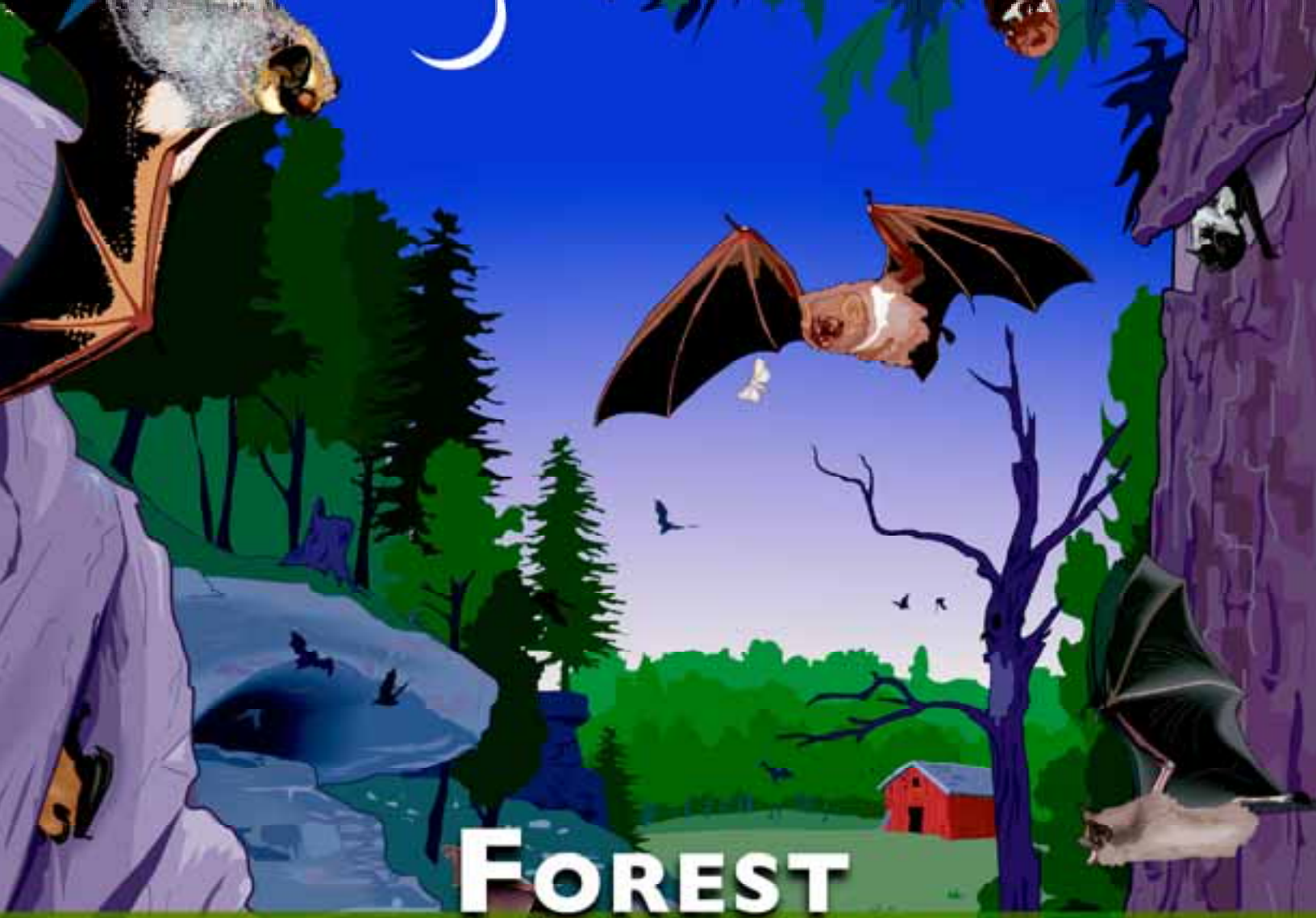

Forest Management & Bats

Daniel A.R. Taylor

Bat Conservation International
www.batcon.org

Bat Basics

More than 1,100 species of bats account for almost a quarter of all mammal species.

Bats are exceptionally vulnerable to extinction, in part because they are the slowest-reproducing mammals on Earth for their size, most producing only one young annually.

Contrary to popular misconceptions, bats are not blind, do not become entangled in human hair and seldom transmit disease to other animals or humans.

Bats are the only mammals capable of true flight. Most bat species use an extremely sophisticated biological sonar called echolocation to navigate and hunt for food. Some bats can detect an object as fine as a human hair in total darkness.

Worldwide, bats are primary predators of night-flying insects. A single little brown myotis, a common resident of North American forests, can consume 1,000 mosquito-sized insects in just one hour.

All but four of the 47 species found in the United States and Canada feed solely on insects, including many destructive agricultural pests. The remaining species feed on nectar, pollen and the fruit of cacti and agaves and play an important role in pollination and seed dispersal in southwestern deserts.

The 20 million Mexican free-tailed bats at Bracken Cave, Texas, eat approximately 200 tons of insects nightly.

A colony of 150 big brown bats, which often roost in tree cavities, can eat enough cucumber beetles each summer to eliminate up to 33 million of their rootworm larvae, a major agricultural pest.

Desert ecosystems rely on nectar-feeding bats as primary pollinators of giant cacti, including the famous organ pipe and saguaro of Arizona.

Bat droppings in caves support whole ecosystems of unique organisms, including bacteria useful in detoxifying wastes, improving detergents and producing gasohol and antibiotics.

More than half of American bat species are in decline or already listed as endangered. Losses are occurring at alarming rates worldwide.

During cold weather, many bats hibernate in caves, mines or other sites that provide stable, cool temperatures. Others migrate to warmer climates, sometimes traveling up to a thousand miles or more.

For their size, bats are among the world's longest-lived mammals. The little brown myotis, a common forest bat, has a documented life span of up to 34 years in the wild.

Forest Management & Bats

Daniel A.R. Taylor

Because more than half of the non-industrial forest lands in the United States are privately owned, forest landowners play a critical role in the stewardship of our wildlife resources. This publication will introduce you to a group of wildlife that is particularly vital to forest ecosystems, but also one of the least-studied and most-misunderstood: bats. It will demonstrate how basic forest-management practices that improve forest health and productivity can also maintain and enhance habitat for these fascinating and beneficial animals.

As primary predators of night-flying insects, bats play an essential role in maintaining forest health. Many bats can eat nearly their own body weight in insects each night. These include moths, beetles and other destructive pests. Although long neglected in forest-management planning, bats are essential to the health of forest ecosystems, fulfilling the same roles by night that birds do by day. Helping bats is a wise investment in America's forests.

Acknowledgements

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National Fish and Wildlife Foundation

Bat Conservation International
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USDA NRCS
Natural Resources Conservation Service

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Habitat Needs of Bats

Habitats required by bats have three basic components: resources for roosting, foraging and drinking. Almost all North American bats rely on forests for survival.

More than half roost in dead and dying trees (snags), especially beneath loose bark, in tree cavities and hollows or in crevices left by lightning strikes. Others roost exclusively in the foliage of living trees. In the western United States, the long-eared myotis (*Myotis evotis*) is known to roost under exfoliating bark on stumps and downed logs. These roosts are required for rearing young (maternity roosts), as migratory stopover sites and occasionally for hibernation. The remaining species use forests as foraging habitat or movement corridors, while roosting in caves, old mines, cliff-face crevices, rock piles and human-made structures such as old buildings, bridges and cisterns, which are often located in forested environments. Bats also use many of these features as night roosts where they can rest and digest their food during nightly foraging bouts.

Snags retained in clear-cut harvest units provide immediate and future roosting habitat for bats.

Bats forage along forest edges, over riparian areas (land adjacent to and influenced by bodies of water), along forest roads and trails and in natural forest gaps or harvest-created openings. Feeding strategies vary greatly among forest-dwelling species. Some forage around ground-level shrubs, while others prefer to forage under the tree canopy, in the canopy or above it.

Bats need clean, pooled, open bodies of fresh water that are large enough to enable drinking on the wing and without obstructions from vegetation, fencing or other objects.

Roosting Requirements

Some forest bats roost exclusively in the foliage of living trees; these are often referred to as "tree bats." Other species roost under loose, peeling bark or crevices of dead trees. Others will also use cavities in healthy trees or in those that are damaged or dying. Some bats, such as the big brown bat (*Eptesicus fuscus*) and silver-haired bat (*Lasionycteris noctivagans*), seem to use cavities in either living or dead trees.

Most forest-bat species move frequently between roost trees. This is especially true of maternity colonies, although bachelor (all-male) colonies also exhibit this behavior. This roost switching may be an effort to avoid predators or parasites or to seek a warmer or cooler roost. For snag-roosting bats, switching could also be tied to the temporary nature of dead and dying trees: If a roost tree becomes unstable or falls, the bats will already know of an alternative roost. It is not uncommon for bats to return to the same roost tree or group of trees in the same patch of forest in successive years.

A diversity of snag-decay classes and sizes should be maintained across the landscape. Retaining snags in clumps increases their use by bats.

Roost trees are often located along the edges of forests or in open forest stands, where they generally receive greater solar heating and have a less-obstructed flight approach. In landscapes with steeper topography and cold-air drainage, some evidence suggests that upland and ridge-top trees may be used as roosts more frequently than those in valleys and canyon bottoms.

Hoary bats prefer tree roosts along the edges of forest stands.

Dead Trees

The structural characteristics of a dead tree – height, diameter, stage of decay ("decay class") – and its position in the stand and on the landscape appear to be the most

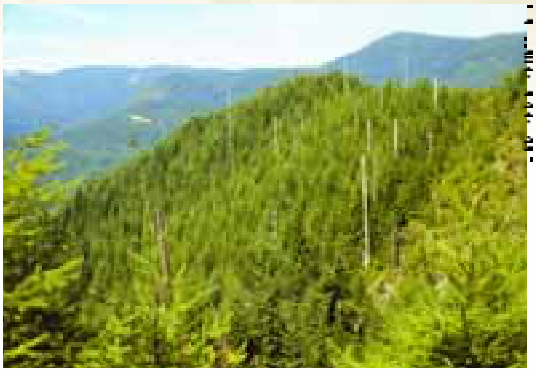
important factors in determining its suitability as a roost site. These factors affect the roost's temperature, an important component in roost selection. The species of the tree is important only as it relates to these structural attributes. Tree species that are more susceptible to fungal infestations attract cavity excavators such as woodpeckers. Also, those that retain bark for longer periods are more likely to provide appropriate roosting spaces.

While the habitat needs of forest bats vary by species, geographic area and climate, bats that roost under the bark or in crevices and cavities of dead trees frequently select the largest available snags, which often extend above the forest canopy. This is especially true for roosts of maternity colonies, since larger snags better retain the sun's warmth, which benefits the pups. Males often roost alone or in bachelor colonies and appear to use a wider range of snag sizes. Maternity colonies of more than 500 bats have been recorded emerging from cavities or under the exfoliating bark of snags in both eastern and western forests, demonstrating just how important a single dead tree can be to maintaining local bat populations. The majority of snag-roosting bats prefer trees in the earlier stages of decay [*Figure 1*], with an ample amount of loose, peeling bark.

A female eastern red bat with two pups. Red bats roost in the foliage of a variety of trees and are known to hibernate in leaf litter on the forest floor.

Living Trees

Some of the forest bats that roost under bark, in cavities or in lightning-strike crevices in dead trees also use these same features in healthy living trees or those that are damaged or dying. For example, the evening bat (*Nycticeius humeralis*) of the southeastern United States is often found roosting in cavities in living fork-topped loblolly pine trees in both managed and unmanaged forest stands. In bottomland hardwood forests of the southeastern U.S., the Rafinesque's big-eared bat (*Corynorhinus rafinesquii*) and southeastern myotis (*Myotis austroriparius*) form maternity colonies in the hollow trunks of large, living gum and beech trees with basal cavities. In parts of their range, these bats have also been found roosting under bridges and in old buildings and cisterns.



Forests can be successfully managed for both wood products and bat habitat, as long as adequate roosts, foraging habitat and water sources are provided across the landscape.

Foliage-roosting (or "tree") bats roost exclusively in the foliage of a wide variety of living trees, both evergreen and deciduous. They often choose dominant or co-dominant, large-crowned trees, roosting in locations that offer suitable temperatures, humidity and protection from bad weather and predators. Tree bats often have two to four pups and roost singly or in small groups. Tree bats from northern regions migrate south, where they often hibernate beneath leaf litter on forest floors in winter. Some tree bats, such as the Seminole bat (*Lasiurus seminolus*) and northern yellow bat (*Lasiurus intermedius*), often roost in clumps of Spanish moss, and northern and southern yellow bats (*Lasiurus ega*) will roost beneath the dead, hanging fronds of fan palms. The eastern red bat (*Lasiurus borealis*) roosts in a variety of tree species and forest habitats.

Forest Management and Bat Habitat

Forest-management practices such as logging or prescribed burning can have positive or negative effects on bats by altering the distribution and abundance of living and dead trees used for roosting or the number of forest openings and edge habitat used for foraging. With proper planning

Figure 1: Classes of snags

and implementation, forest health can be maintained or improved while providing a sustainable supply of fiber for forest products. Non-timber values can be protected, and bat-roosting and -foraging habitat and drinking resources can be enhanced, greatly benefiting bat populations.

Roosting Trees

Roosts are often considered the most important habitat component, and roost switching appears to be essential for most species. The most important action forest landowners can take to maintain bat populations is to provide a continuous supply of potential roost trees. These include snags in various stages of deterioration (especially those in early stages of decay), hollow trees and the green and dying trees that can provide future snags. Dozens of other wildlife species that depend on dead and dying trees for habitat will also benefit.

A typical Class 3 snag retained in a clear-cut harvest unit. Such snags are short-lived and normally offer less habitat value to bats than Class 1 or 2 snags.

In addition to the following recommendations, most state forestry agencies, county extension offices and state or federal wildlife management agencies can provide guidelines and recommend practices for maintaining snags, green trees and other forest structures that are tailored to local conditions. It is important to note that the U.S. Office of Safety and Health Administration (OSHA) has strict guidelines regarding where snags may be retained on intensively managed forests due to the inherent danger of operating machinery around dead trees. These guidelines must be incorporated into any snag maintenance and protection program.

How Many? The exact number of roost trees needed to maintain forest-bat populations is unclear and likely varies by forest type and region. Bats that use live trees can find roosts in most forests, but managers need to ensure that enough dead and dying trees are left for the species that depend on them. Bats need multiple roosts, and because snags are a short-lived resource (especially in the East), the availability of suitable roost trees for snag-roosting bats fluctuates over time. Federally managed forests and many state forestry regulations specify a minimum number of trees to leave for wildlife, but forest owners should, whenever possible, leave as many dead, damaged, dying and cull (defective) live trees as possible and as safety and silvicultural objectives permit.

Older, more mature forest stands produce more snags, so well-distributed, variably sized patches of mature and old-growth forest should be maintained where possible. Also, some stands could be managed through extended harvest rotations. Careful management is required to provide snags of sufficient numbers and size to ensure the long-term welfare of bat populations. Although developed for the Pacific Northwest, the DecAID Decayed Wood Advisor (see *Sources of Assistance*) is one of the most thorough resources available for snag and wildlife leave-tree planning in managed forests and can be adapted to other regions. Because our knowledge of how many roost trees are needed is limited for many species and regions of the country, these recommendations should be taken as suggestions rather than strict guidelines.

Large Class 2 snags located within a gap in the forest provide ideal roost sites for many species of forest-dwelling bats. A maternity colony of long-legged myotis uses this snag.

Which ones? The structure of a snag is more important than its species, although some tree species make better snags than others. Emphasize larger-diameter snags because they generally remain standing and retain bark longer and support a greater variety of bats and other wildlife than smaller snags. In general, retain snags in the early stages of decay (*Figure 1*, Classes 1 and 2) rather than more-decayed ones, tall and large-diameter snags rather than smaller ones, and snags with more bark cover than those with little cover. In conifer-dominated and mixed-conifer stands, leave as many hardwoods as possible that have natural or woodpecker-excavated cavities.

Timber-harvesting machinery, such as this feller-buncher, can be used to create snags by topping live trees.

Where? Snags should be well distributed across the landscape, including along drainage bottoms, upland slopes and ridge tops. Preference should generally be given to maintaining snags along forest-stand edges and other open areas where they receive more sunlight. When practicing even-aged management, such as clearcuts, shelterwoods and seed-tree cuts, and where silvicultural and logging safety objectives are not compromised, consider leaving snags either evenly distributed across harvest units or in patches. Leaving snags in patches interspersed with green trees helps keep them from being blown over by high winds, as will leaving them in locations with protection from prevailing winds. This also makes it easier to conduct management operations. In landscapes that are intensively managed for timber, snags can be maintained primarily in streamside management zones, forested corridors and other less-intensively managed habitats. In coniferous forests, foliage-roosting bats that prefer broadleaf deciduous trees often are concentrated within riparian zones, since they usually contain more broadleaf vegetation.

Green tree retention: Natural fall rates will eventually reduce snag numbers unless new snags develop naturally or are created. Leave as many large green or cull trees as possible as "leave trees" to become future snags. Cull trees include those with broken tops, forked tops, wounded areas or other defects that reduce their commercial value. For example, recent research in Mississippi and Georgia found that evening bats use fork-topped pine trees in thinned-pine plantations.

Snag creation: In stands where snags are limited or absent, one option is to alter or kill living trees to create snags. This allows the number of snags created and their locations to be chosen by the forest manager. Methods for snag creation include girdling, topping with chain saws, injecting with herbicides and the use of mechanical harvesting equipment (fellers). Creating snags can mitigate the loss of natural habitat, but retaining existing structures is the most cost-effective and ecologically sound method.

Foraging Habitat

Bats feed on a variety of night-flying insects, catching them in the air or picking them off vegetation. Most bats prefer to hunt in small to medium forest openings or gaps, like those created by timber harvests, roads and water courses or by lakes and ponds. Bats often forage along the vertical or horizontal edges where these habitats or different-aged forest stands meet and along forest corridors and buffer strips.

Smaller, more maneuverable bats, such as the northern long-eared myotis (*Myotis septentrionalis*) and small-footed myotis (*Myotis leibii*) in the east and the long-eared myotis in the west, can forage in cluttered vegetation in the forest understory and in very small forest gaps. Larger, faster-flying and less maneuverable bats, such as the hoary bat (*Lasiurus cinereus*), often forage

These Class 2 snags positioned on the edge of a gap in the forest provide excellent roosting and foraging habitat for bats. These natural openings can be simulated with group-selection harvest techniques.

Crevices in trees are used as roosts by a number of forest-bat species. An endangered Indiana myotis is using this one.

above the forest canopy, in larger forest openings and along the edges, as well as over clearings, wetlands or rivers.

Bat-foraging activity is often concentrated in riparian zones and in gaps in older, more-diverse forest stands. Riparian habitat is especially important because it provides drinking water and high-quality foraging habitat, as well as high-quality roosting habitat in more level terrain where cold-air drainage is not a factor. Beaver ponds provide high-quality bat habitat that combines drinking, foraging and roosting resources. Bats often follow corridors of forest when traveling from roosts to feeding areas.

Forest-management practices that create small forest openings may foster development of suitable foraging habitat and may even enhance roosts located along forest gaps and edges. Bats often forage along edges between intact forests and cut areas. Smaller harvest areas increase edge habitat per unit area, promoting plant and insect diversity that is beneficial to bats and other wildlife. However, some bat species cannot forage in the middle of large (at least 120 acres [48.5 hectares]) regenerating stands. Roost-tree loss should be minimized when creating openings so that the loss of roosts doesn't offset the benefits of increased foraging habitat. The following table lists some commonly used forest-management practices and their potential benefits to bat habitat.

HARVEST

Management Regime	Treatment	Description
Even-aged management: Begins with the complete, or nearly complete, removal of existing timber to create a new stand with young trees of approximately the same age. Small stands of different age classes can form a diverse assemblage of habitats.	**Clearcuts:** Harvest of essentially all trees in a stand.	Creates edge habitat for foraging. Smaller, irregular-shaped units are better for bats than larger blocks. Flush of herbaceous growth following timber removal can provide rich food sources for insects preyed on by bats. Snags and green or cull reserve trees left standing can add value as potential roosts.
	Shelterwood and **Seedtree cut:** Removal of most trees in a stand, leaving only those needed to produce seed and/or provide shade for regenerating a new stand. Overstory trees are usually removed after regeneration is established. More trees are left with shelterwood harvests than with seedtree cuts.	Like recent clearcuts, these create edge habitat, foraging space and a food source for insects. Trees left on-site provide some mature forest structure until they are harvested. Value to bats and other wildlife can be greatly increased if adequate snags and green trees are left and if overstory trees are retained through the next harvest.
Uneven-aged management: Individual and small groups of mature trees are harvested, leaving a variety of tree sizes and ages. Uneven-aged management creates small canopy gaps similar to those formed by natural forest disturbances.	**Group selection:** Small groups of trees removed for regeneration of new age classes; width of cut rarely exceeds twice the height of the mature trees. Moderately shade-intolerant species can benefit from this harvesting method because larger openings are created.	Promotes diverse forest structure, characterized by mosaic of mature forest-roosting habitat and small to medium gaps for foraging, with substantial increases in herbaceous vegetation favorable to production of bats' insect prey.
	Single-tree selection: Individual trees of all size classes removed more or less uniformly throughout the stand to increase growth of remaining trees and provide space for regeneration.	Maintains diverse forest structure and roost trees, while creating small gaps and enhancing edge habitat for foraging. Promotes diverse vegetation structure and some increases in herbaceous vegetation, favorable to production of bats' insect prey.

SITE PREPARATION

Treatment	Description
Prescribed fire: Prescribed burning for site preparation after harvest is conducted to eliminate undesirable vegetation and increase availability of soil nutrients for tree seedlings.	Increases herbaceous and shrub growth that can increase abundance and diversity of insect prey. Care must be taken to prevent the loss of snags and green-reserve (wildlife) trees left as roosting habitat.
Herbicides: Selective herbicide use may control undesirable vegetation. Plant response varies depending on the herbicide, time of application, rate and forest conditions.	Herbicides can be useful, often when combined with prescribed fire, for restoring early-succession plant communities and controlling undesirable vegetation. In the southeastern U.S., they have been used to promote the development of herbaceous vegetation, which can increase the abundance of insect prey and open up foraging space for bats in stand interiors by controlling woody stems.
Mechanical treatments: Shearing, raking, windrowing and bedding are all mechanical methods used to clear debris and prepare soil seedbeds for tree planting.	Increases herbaceous and shrub growth that can increase the abundance and diversity of insect prey.

TIMBER AND WILDLIFE STAND IMPROVEMENTS

Treatment	Description
Thinning: Thinning removes weak or suppressed trees and opens growing space for remaining healthy trees. Thinning can be used to remove trees from the lower or upper crown level or to increase spacing and growth in forest plantations, and may be conducted at different times and intensities depending on the silvicultural system and objectives.	Thinning benefits bats by increasing flight space in the stand and sunlight to the stand floor, which increases herbaceous growth for bats' insect prey. Heavier thinning (e.g., 150-200 trees/acre [370-500 per hectare] in southern pine) is preferred for habitat improvement.
Prescribed fire: Used to reduce forest fuels to decrease the risk of wildfire and for ecological restoration. Prescribed fire can effect changes in plant community composition, tree densities, stand structure and soil and hydrological conditions. Most prescribed burns are carried out under cool, moist conditions to reduce the chance of wildfire.	Bats may benefit from fire by the creation of new roost trees through direct or indirect fire mortality (via disease, insect or fungal attack). Fire can also decrease forest tree density and increase openings, thereby improving foraging space and travel corridors, allow more light to reach and warm roost trees, and increase insect prey diversity and abundance by increasing herbaceous and shrub growth. Prescribed burning can have short-term detrimental effects on bats by eliminating some snags and stumps used for roosting. Raked firebreaks can be created around snags, or the bases sprayed with retardant, to protect them. Prescribed burns and fires occurring when bats are rearing young (April-July) or in deep hibernation (mid-winter) can have negative impacts on local populations. In the southeastern U.S., red bats and Seminole bats sometimes hibernate among leaf litter and may be unable to escape burns conducted on very cold days. However, these short-term losses must be weighed against the long-term benefits to the ecosystem.
Forest corridors, leave strips, buffer strips: Includes strips of unmanaged forest between managed stands, windbreaks, shelterbelts and other plantings.	In addition to providing edge habitat for foraging, forest corridors and buffer strips can be used as travel corridors and may provide roost trees.
Riparian habitat management: Maintaining the integrity of riparian zones in managed forests is a critical aspect of good forest stewardship. Vegetative communities and landscapes associated with water are the most important habitats for most bat species. Although these features represent a relatively small proportion of the landscape, they often provide more concentrated sources of shelter, food and water than drier, upland forest habitats. In coniferous forests, broadleaf deciduous trees are often concentrated in the riparian zone, providing roosts for the foliage-roosting bats that prefer them.	Riparian areas are one of the highest quality foraging habitats available to bats. If compatible with other riparian-habitat management objectives, selective harvest that minimizes disturbance can enhance riparian bat-foraging habitat. The width of streamside zones affects understory development within these zones. Narrow zones will allow sunlight penetration and subsequent development of a dense midstory layer that may be unfavorable to bats and other wildlife species. All state forestry agencies have Best Management Practices or standards and guidelines that address local riparian buffer area/stream management zone management. However, these guidelines are designed to protect water quality and may recommend narrower streamside zones than would be most beneficial to wildlife.

Water Resources

When active, all but the most desert-adapted bat species must have daily access to clean water for drinking, especially during lactation and periods of increased activity. Several species will also arouse to drink during hibernation. Some bat species usually roost near or forage over water. Gray myotis (*Myotis grisescens*), little brown myotis (*Myotis lucifugus*), Yuma myotis (*Myotis yumanensis*), southeastern myotis and eastern pipistrelles (*Pipistrellus subflavus*) prefer to forage over lakes, rivers and ponds. Eastern red bats, hoary bats, Indiana myotis and big brown bats are known to use waterways for travel and foraging.

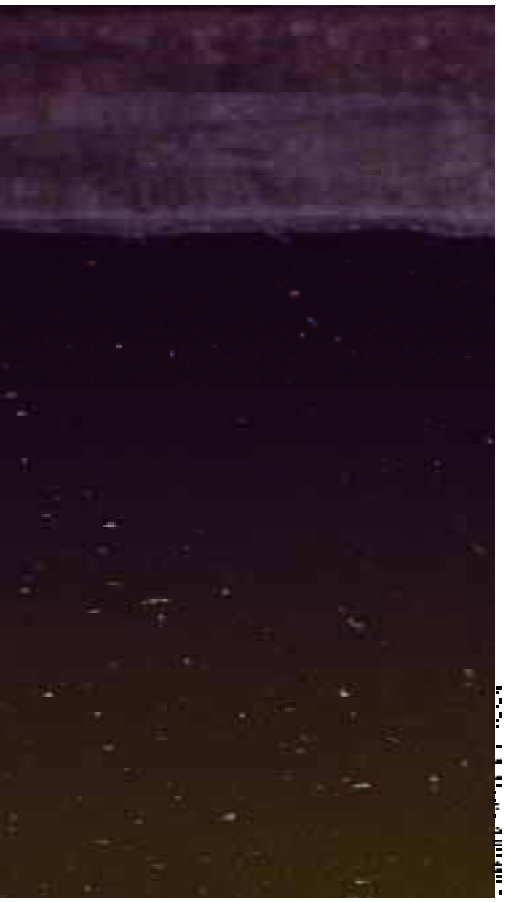
*Bats typically drink on the fly. This western small-footed myotis (*Myotis ciliolabrum*) has just swooped down on a pond to quench its thirst.*

Ponds, seasonal pools and bogs and meadows with pooled, standing water offer important drinking and foraging resources for forest bats. Along with riparian zones, beaver ponds are among the most valuable aquatic resources, as they provide drinking, roosting and foraging habitat in close proximity. In

Large streams provide foraging and drinking habitat for bats. I-beam style concrete bridges and bridges with vertical crevices (expansion joints) can provide ideal roosting sites when they span such streams.

eastern forests, even temporary water-holding features such as road ruts are often used by bats. Troughs, tanks and other livestock-watering facilities are critical watering sites for bats in some western forests and may be an overlooked resource for eastern forest bats.

Fo rest-management practices that eliminate or limit access to water or degrade water quality through siltation can negatively affect bats. Forest buffers and adherence to state forestry Best Management Practices (e.g., c a reful placement of skid roads) are very effective at protecting water quality at forest ponds, seasonal pools, wet meadows and bogs. Note, however, that Best Management Practices are designed for water-quality protection, not for creating wildlife habitat per se, so forest landowners may want wider buffers than recommended if the goal is to provide more wildlife habitat and mimic mature forest conditions. Landowners can get copies of state Best Management Practices through their state forestry offices, county cooperative extension offices and other landowner assistance programs.



Small woodland ponds can often be created using earthen catchments in locations that capture natural surface runoff or by piping water from natural springs. This type of pond can provide high-quality foraging and drinking habitat for bats and many other wildlife species when located in a small, natural or created forest opening. An excellent resource for creating small ponds is listed in the Sources of Assistance section, as is information on obtaining copies of Best Management Practices.

Natural and created ponds provide important drinking sites for bats. Creating and maintaining ponds like this one in Kentucky are important considerations for managing bats and other wildlife across forest landscapes.

Other Resource Needs

Geologic Resources

Several species of bats that roost in trees from spring through autumn spend their winters in caves, mines and other geologic features, such as cliff-face crevices, rock outcrops, rock shelters and boulder fields. Some species also occasionally use geologic resources as day roosts during summer. These geologic features are often found in the forest matrix. Dense aggregations of bats, sometimes numbering in the

Hubbard's Cave in Tennessee is nestled in mixed forest land and is used as a critical hibernation site by half a million endangered gray myotis. An enormous bat-friendly gate now protects the bats from winter disturbance by humans.

hundreds of thousands or even millions, hibernate, rear young or night-roost in the small percentage of caves or abandoned mines that provide suitable temperature characteristics. In eastern North America, few caves, mines and cliff crevices are warm enough or able to trap enough bat body heat to be used as maternity roosts. Those that do can be extremely important. Sites used for hibernation must provide cool, stable temperatures while protecting bats from freezing. Because these sites are uncommon, bats may travel hundreds of miles to reach a suitable hibernation site. Sites that don't meet these criteria may be used by colonies of bachelors and non-reproductive females as breeding sites, night roosts or for stopovers during migration.

Bat roosts in geologic features are easily disturbed or destroyed. The greatest threats are disturbance from human commercial and recreational activities. All bats naturally arouse periodically during hibernation, but forced arousals due to disturbance cause them to use fat reserves that may be required for survival. Disturbance at maternity sites can cause females to abandon their young.

Caves, mines, cliff faces, rock shelters and talus slopes often provide essential roosts that should be identified and protected during land alterations. Habitat surrounding important caves and mines, which may include an entire watershed, should be carefully managed to avoid negative impacts. Timber harvests near caves and mines should be conducted carefully to avoid impacting roost environments by changing airflow patterns, sun exposure, humidity, groundwater flow or by increasing public access.

With properly designed buffers, forest-management activities can be implemented while maintaining integrity of geologic resources. Forest landowners and managers should consult state agencies responsible for managing wildlife and cave resources to determine appropriate mitigation measures. Public education, interpretive signs, closing access roads and trails, fencing and gating can help reduce roost disturbances. Properly constructed, bat-friendly gates placed across important cave and mine entrances can prevent human entry while allowing many bat species to enter and exit. Inappropriate gates, however, may exclude bats, increase predation or negatively affect airflow and temperature. See the Sources of Assistance section for resources that provide direction for planning, building and installing bat gates.

Artificial Roosts & Other Human Structures

Human-made structures, such as buildings, bridges, culverts, dams, abandoned railroad and highway tunnels, abandoned military bunkers and old cisterns, have become essential roost sites for many bat species, especially where natural roosts have been eliminated. Because roost availability is a major factor influencing bat survival and population size, artificial roosts and human structures can be extremely important conservation tools where natural roosts have been lost. Although artificial roosts should not be viewed as a substitute for good habitat management, they can provide crucial alternatives during habitat recovery when natural roosts are scarce.

Concrete bridges with vertical crevices (expansion joints) can provide ideal roosts and sometimes accommodate very large, regionally important bat colonies. Concrete bridges in forested environments are often important sites for social interaction and night roosting and may attract several species of bats. The best roosts are in concrete bridges that are 10 feet (3 meters) or more above ground and heated by the sun. Bridges and culverts can be retrofitted with simple and inexpensive modifications that create excellent roosting habitat for large numbers of bats. These modifications can be incorporated during original construction at little or no additional cost.

Buildings have become primary roosts for many bats, with at least 20 species known to use them. Big brown bats and little brown myotis have adapted exceptionally well and now appear to rely primarily on human-made structures over wide areas. Older and abandoned houses, sheds, barns and other human structures in the forest environment often provide habitat for important bat colonies, including rare and sensitive species. In parts of the southeastern United States and Pacific Northwest, many of the largest known maternity colonies of big-eared bats (*Corynorhinus spp.*) have been found roosting in old buildings in forested environments. Old buildings that harbor bat colonies can be shored up and stabilized, and bats have on several occasions moved into replacement structures built nearby.

At least a dozen bat species have been reported to use bat houses and other artificial roosts. Occupancy rates continue to increase

Endangered gray myotis (Myotis grisescens), like many other bat species, hibernate on the ceilings and walls of appropriate caves during the winter.

as designs are tested and improved. The best-occupied bat houses are multichambered units at least 24 inches (61 centimeters) tall and with crevices ¾ to 1 inch (19 to 25 millimeters) wide with roughened landing and roosting surfaces. They are painted black in the coolest climates and lighter colors in the warmest to facilitate appropriate solar heating. They should be mounted at least 12 feet (3.6 meters) off the ground on the sides of wood or concrete buildings or on poles (not on trees) in small openings or edge habitats near streams, rivers or lakes.

In the southeastern U.S., cinder-block artificial roosts that are 12 feet (3.6 meters) high and 4 feet (1.2 meters) across with openings in the sides and at the base have been built in forested environments to mimic the trunks of the large, hollow gum trees once common in bottomland hardwood forests. These roosts are being colonized by both Rafinesque's big-eared bats and southeastern myotis, two species of concern in southeastern forests.

In Arizona, long-lasting and realistic-looking polyresin "bat bark" has been successfully tested as a substitute for natural, peeling tree bark. Three bat species were reported using more than 80 percent of the artificial bark roosts installed. Detailed information on construction and placement of all of these artificial roosts is available on BCI's website at ***www.batcon.org***.

"Concrete trees" like this one in Texas were designed by Bat Conservation International to simulate the large tree hollows that some forest bats require for roosts. This one was occupied within months by Rafinesque's big-eared bats.

A Sampling of Forest Bats

Big brown bat
Eptesicus fuscus

The big brown bat is North America's largest tree-cavity-roosting bat. It is copper to chocolate-brown colored with a broad, sparsely furred nose. Its forearm length is 1.7 to 2 inches (42 to 52 millimeters) and its wingspan is 13 to 16 inches (330 to 406 millimeters). Found in every U.S. state and most Canadian provinces, it is one of our most commonly encountered bats.

While still found roosting in tree hollows during the summer, many summer roosts are now in attics, barns and other human-made structures, including bat houses. Big brown bats hibernate in caves, mines, deep rock crevices, tree snags and buildings. They can survive subfreezing body temperatures, enabling them to occupy a wide variety of winter roosts.

Big brown bats roost and forage in a variety of habitats, but are most abundant in deciduous forests, often in areas of mixed agriculture. They usually prey on small beetles but also consume stinkbugs, moths, froghoppers, flying ants, caddisflies, crickets and katydids. They are an important consumer of agricultural and forest pests. Individuals have been recorded living up to 20 years.

Little brown myotis
Myotis lucifugus

Little brown myotis vary from pale to chocolate brown and have forearms of 1.3 to 1.6 inches (34 to 41 millimeters). Their wingspans are 8.7 to 10.6 inches (222 to 269 millimeters).

They are often the most abundant species in forested areas, especially near water. Summer colonies form in tree cavities, buildings and bat houses. They hibernate in caves and old mines, sometimes migrating hundreds of miles to reach a suitable site. Hibernating populations of 300,000 to 500,000 individuals have been documented. Some abandoned mines may hold a million or more.

Mothers give birth to one young each summer. Pups are capable of adult-like flight 20 to 27 days after birth. Although most nursery colonies feed over water, non-reproductive little brown myotis hunt in a wide variety of habitats, including stream and forest borders, trails, cliff faces, meadows, farmland and in nearly every kind of forest. Favored prey include many aquatic insects, such as midges, mayflies, mosquitoes and caddisflies. One little brown myotis can capture more than 1,000 mosquito-sized insects in a single hour. Life spans of more then 34 years have been reported in the wild.

Northern myotis
Myotis septentrionalis

About the same size as the little brown myotis, the northern myotis bat can be distinguished by its long, narrow ears, which measure 0.5 to 0.7 inches (14 to 19 millimeters).

In the fall, the northern myotis is commonly found at cave and mine entrances, where some hibernate. However, large numbers have been reported entering caves in March, leading to the suspicion that they hibernate outside, perhaps in cliff-face crevices. In summer, females congregate in groups of 3 to 60 individuals at maternity roosts in snags. Small nursery colonies also have been found in attics, behind wooden window shutters, beneath wooden shingles and in bat houses.

Northern myotis are relatively slow flyers that are adapted to hunting in cluttered environments, where they often pick insects directly off foliage. These bats seem to prefer feeding beneath the canopy level, often 3 to 10 feet (1 to 3 meters) above ground along forested hillsides and ridges. They mostly eat moths, but also beetles, flies, midges, mosquitoes, caddisflies and leafhoppers.

Evening bat
Nycticeius humeralis

Slightly smaller than the little brown myotis, the evening bat is dark brown with black wings and ears. It resembles a smaller version of the big brown bat. Evening bats are found from the East Coast to eastern Nebraska and south through eastern Texas to northern Mexico. Evening bats in the northern part of their range are believed to migrate southward in the fall and apparently hibernate beneath leaf litter on the forest floor.

Females give birth to two or sometimes three pups, which are capable of flight within 20 days of birth. In addition to roosts in tree crevices and behind loose bark, evening bats are known to roost in cavities created where the tops of live pine trees fork, as well as in buildings and bat houses. A maternity colony of over 400 individuals was recorded under the bark of one dead pine tree.

Evening bats prefer to forage along edges of mature forests, in clearings and over waterways. A colony of 300 evening bats consumes an estimated 6.3 million insects per summer, typically feeding heavily on spotted cucumber beetles, a costly crop pest to vine plants and corn crops. The evening bat appears to have a relatively short life span, perhaps only a few years.

Long-legged myotis
Myotis volans

The long-legged myotis, typically dark brown, is identified by its relatively short ears and long, dense fur extending along the underside of the wing membrane from the body to a line joining the elbow and the knees. It is similar in size to the little brown myotis. Its range stretches across western North America from southeastern Alaska, British Columbia and Alberta in Canada to Baja California and central Mexico and eastward through the Great Plains and Texas. It lives primarily in coniferous forests, but also occurs seasonally in riparian and desert habitats.

The long-legged myotis primarily roosts under exfoliating tree bark and in tree hollows but has also been found in abandoned buildings, cracks in the ground and cliff crevices. It will sometimes hibernate in caves and old mines. It is a rapid, direct flyer and often travels considerable distances while foraging. It feeds in and around the forest canopy, primarily on moths and other soft-bodied insects. Life spans of more than 21 years have been reported.

Silver-haired bat
Lasionycteris noctivagans

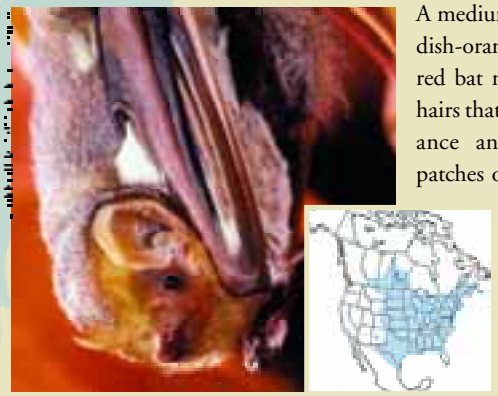
The silver-haired bat has black or dark brown fur with silver tips. Unlike the red or hoary bat, it has no contrasting markings on the wrists and shoulders. Silver-haired bats are among the most abundant bats in forested areas of northern North America.

Most of these bats overwinter in the southern third of the continent and return north in the spring. In areas of relatively mild coastal climate, such as coastal

British Columbia, Alaska and New York, however, they may remain year-round. Hibernation sites include small tree hollows, loose tree bark, woodpiles, cliff-face crevices, cave entrances and, rarely, buildings.

Silver-haired bats are slow, highly maneuverable flyers that typically feed in areas sheltered by vegetation, over streams or ponds, along roadsides and in or near coniferous or mixed coniferous and deciduous forests. They feed on flies, midges, leafhoppers, moths, mosquitoes, beetles, true bugs and flying ants. Silver-haired bats can live to at least 12 years.

Eastern red bat
Lasiurus borealis



A medium-sized bat with a reddish-orange coat, the eastern red bat may have white-tipped hairs that give it a frosty appearance and always has white patches of fur on the shoulders and wrists. It is one of the most abundant bats in many parts of its range, but appears to be in decline.

Red bats roost in the foliage of a variety of deciduous trees and conifers. Hanging by one foot, wrapped in their furred tail membranes, they are well concealed and resemble dead leaves. They roost alone or in family groups consisting of a mother and her young, although they form groups for migrating to milder regions where they hibernate. Males and females are thought to migrate in separate groups and may travel with other bat species.

The average litter size is three pups, but a female may have as many as five offspring. In the southeastern and south-central United States, red bats are known to hibernate in grass clumps and leaf litter on the forest floor. They forage in a variety of habitats, mostly along the edges of pastures, croplands or other openings dotted with large deciduous trees. Red bats eat mostly moths, but also feed on beetles, planthoppers, leafhoppers and spittlebugs.

Hoary bat
Lasiurus cinereus

Hoary bats are larger than big brown bats and have mahogany-colored fur tipped with white, which gives them a hoary (frosted) appearance. They have a distinctive, yellowish-brown collar under the chin and yellowish ears edged in black. They occupy the widest range and variety of habitats of any North American bat, living from Argentina and Chile northward through Canada. Hoary bats roost in foliage in pine-hardwood forests of the eastern United States and in deserts and ponderosa pine forests of the Southwest, but they are most abundant in mixed deciduous forests and croplands of the Plains States and in coniferous forests of the Pacific Northwest.

The hoary bat usually roosts alone or in family groups of a mother and her young, except during migration. These bats are seldom seen. In winter, a few have been found in Spanish moss, squirrel nests, woodpecker holes and on the trunks of trees.

During summer, they prefer tree roosts in edge habitats close to foraging areas. Hoary bats hunt relatively large insects, mostly moths, in open areas in meadows, over streams and rivers or above stands of trees at canopy level. They are highly territorial, returning to feeding sites night after night. From August through October, hundreds of hoary bats may migrate together. In the U.S., most hoary bats apparently overwinter in coastal areas. These bats are believed to live 6 to 7 years.

Rafinesque's big-eared bat
Corynorhinus rafinesquii

Rafinesque's big-eared bats are grayish-brown with very long ears (1 to 1½ inches [25 to 38 millimeters]) and large facial glands on each side of their snout.

They are nonmigratory and traditionally roost in large hollow trees in mature Southeastern lowland pine and hardwood forests, especially in cypress-gum stands near permanent water or in upland oak-hickory forests on the Cumberland Plateau. As this habitat has gradually disappeared, many colonies now roost under concrete bridges or in abandoned buildings that are prone to human disturbance and structural collapse. Artificial roosts may be required to provide alternatives in areas where traditional roosts have been lost.

Maternity colonies include up to 200 females and young, often roosting in dimly lit areas. In northern regions, some may hibernate in caves, abandoned mines, wells and old cisterns, either singly or in clusters. In southern areas, most appear to remain active year-round, except during the coldest and most inclement weather. They are very agile flyers, capable of picking insects off foliage. They often forage within three feet (1 meter) of the ground. Moths are their most common prey, but other insects, including horseflies, are also taken. Big-eared bats may live up to 10 years in the wild.

Sources of Assistance

A variety of federal, state, private and nonprofit organizations can provide landowners with financial and technical assistance to improve fish and wildlife habitats in forests. The following is a partial list of agencies or organizations with programs specifically tailored to forestry and wildlife conservation.

Federal, State and County

Natural Resources Conservation Service: Since 1935, the Natural Resources Conservation Service (originally called the Soil Conservation Service) has provided leadership in a partnership effort to help America's private-land owners and managers conserve their soil, water and other natural resources. NRCS employees provide technical assistance based on sound science and suited to each landowner's specific needs. NRCS provides financial assistance for many conservation activities. Participation is voluntary. ***www.nrcs.usda.gov***

U.S. Department of Agriculture Forest Service: The Forest Service was established in 1905 to sustain the health, diversity and productivity of the nation's forests and grasslands for present and future generations. The mission of the Forest Service is to achieve quality land management under the sustainable, multiple-use management concept to meet the diverse needs of people. This includes providing technical and financial assistance to state and private forest agencies and landowners, encouraging them to practice good stewardship and quality land management in meeting their specific objectives. ***www.fs.fed.us***

Cooperative State Research, Education, and Extension Service (CSREES): An agency within the U.S. Department of Agriculture, CSREES is the federal partner in a network of thousands of scientists, educators and extension staff and volunteers who carry out its programs throughout the United States, its territories and beyond. Most of these partners work at or through land-grant universities, with one or more such institutions in each U.S. state and territory and in the District of Columbia. ***www.csrees.usda.gov/qlinks/partners/state_partners.html***

DecAID: The Decayed Wood Advisor: DecAID is a tool to help you manage snags, down wood and partially dead trees for biodiversity. The online advisor can help you to determine how much and what size of decayed wood to leave, what matches general "unharvested" conditions, and what insects and pathogens create dead wood. It also provides a synthesis of literature and statistics on wildlife use and an inventory of snags and down wood. Information: ***www.treesearch.fs.fed.us/pubs/6233***

A Guide to Creating Vernal Ponds: Biebighauser, Thomas R. 2003. USDA Forest Service, 33 pages. Information for building and maintaining an ephemeral wetland. ***www.ducks.org/CMS/states/Files/Kentucky/vernal.pdf***

Non-Government Organizations

The American Tree Farm System (ATFS): The ATFS certifies owners of tree farms and NIPF lands in the United States that maintain strict sustainable forestry-management practices. Certification requires that landowners pass an inspection every five years. In addition to producing timber, landowners must protect watershed quality, wildlife habitat and soil and provide recreational opportunities. For information, contact the American Forest Foundation's website at www.affoundation.org or call ***1-888-889-4466.***

Longleaf Alliance: Established in 1995 to coordinate a partnership between private-land owners, forest industries, state and federal agencies, conservation groups, researchers and others interested in managing and restoring longleaf pine forests for their ecological and economic benefits. The Alliance provides information on restoring and managing longleaf pine forests for timber and wildlife in the southeastern U.S. ***www.longleafalliance.org***

Sustainable Forestry Initiative® (SFI): A comprehensive system of principles, objectives and performance measures developed by professional foresters, conservationists and scientists that combines perpetual growing and harvesting of trees with the long-term protection of wildlife, plants, soil and water quality. The SFI Program is overseen by the Sustainable Forestry Board (SFB), an independent 501(c)3 organization, which is responsible for maintaining and enhancing the SFI Standard and verification procedures. ***www.aboutsfi.org***

Forest Stewardship Council: The Forest Stewardship Council (FSC) is an international network that promotes responsible management of the world's forests. FSC brings people together to find solutions to problems created by poor forestry practices and to reward good forest management. Landowners and companies that sell timber or forest products seek certification as a way to verify to consumers that they have practiced forestry consistent with FSC standards. Independent certification organizations are accredited by FSC to carry out assessments of forest management to determine if standards have been met. ***www.fsc.org***

For detailed information about bat species, bats' habitat and conservation needs, forest management, upcoming conferences, workshop opportunities, recent research and much more, visit Bat Conservation International online at:

www.batcon.org