IV. FOREST AND WOODLAND MANAGEMENT PRACTICES

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Approximately 34 percent of the land in Colorado is dominated by trees (Schrupp et al. 2000). Depending on elevation, topography, water availability, and disturbance history, the various forest types are mixed on the landscape and with other cover types like grassland, shrubland, rocks, and cliffs. The Colorado Gap Analysis Project (Schrupp et al. 2000) identifies several forest types across the state:

- *Evergreen forests* (e.g., Engelmann spruce, subalpine fir, lodgepole pine, bristlecone pine, limber pine, Douglas-fir, ponderosa pine, blue spruce, white fir, and "mixed-conifer" forests; this category also includes woodlands that typically have a moderate to low tree density such as pinyon pine and juniper);
- *Deciduous forest* (i.e., aspen);
- *Forest-dominated wetland/riparian land* (e.g., cottonwood, aspen, boxelder, willow trees, conifers in wetlands)

Tree snag used as a maternity roost by bats. Photo by D. Neubaum.

Bats occupy all of these forest types, and exploit the resources within them in a variety of ways. At least 9 species of Colorado bats typically use forest and woodland ecosystems for roosting and foraging habitat, including the western small-footed myotis (*Myotis ciliolabrum*), long-eared myotis (*M. evotis*), fringed myotis (*M. thysanodes*), long-legged myotis (*M. volans*), little brown bat (*M. lucifugus*), big brown bat (*Eptesicus fuscus*), eastern red bat (*Lasiurus borealis*), hoary bat (*L. cinereus*), and silver-haired bat (*Lasionycteris noctivagans*). Other species that typically use non-tree roosts but forage in forests and woodlands include Townsend's big-eared bat (*Corynorhinus townsendii*), pallid bat (*Antrozous pallidus*), spotted bat (*Euderma maculatum*), Allen's lappet-browed bat (*Idionycteris phyllotis*), canyon bat (*Parastrellus hesperus*), California myotis (*M. californicus*), and Yuma myotis (*M. yumanensis*). The big free-tailed bat (*Nyctinomops macrotis*) and Brazilian free-tailed bat (*Tadarida brasiliensis*) are known to forage above forests and woodlands in Colorado, but their distribution is restricted to warmer regions of the state and driven by availability of high cliffs or large caves/mines for roosting. Several species do not occur at high elevations, others do not occur at low elevations, and some may be found in every forest type in the state. See the Introduction and Species Accounts for more details for species occurrence and habitat needs.

HOW BATS USE FORESTS AND WOODLANDS

Four ecological factors are important in shaping habitat suitability for bats in forests: characteristics and abundance of roost sites, amount of clutter, availability of water, and availability of prey (Hayes and Loeb 2007).

ROOSTS

Bat roost under sloughing bark of pinyon pine snag. Photo by D. Neubaum.

During the active season in Colorado (i.e., spring, summer, and fall), forest-dwelling bats can be found roosting in a variety of locations, including live trees, snags, and non-tree sites (e.g., caves, mines, rock crevices, bridges, buildings). These sites may be used by females with non-volant young, colonies of adults and juveniles, or single bats. Some species are strongly colonial or solitary roosters, and others are more flexible in their roosting habits. Bats roost in the crevices and cavities of live trees and snags, under exfoliating bark, and in the foliage of live trees. Hoary bats, red bats, and sometimes silver-haired bats will roost on the trunk or in the foliage of trees where their thick camouflaged coats help protect them from weather and predators. In addition to the natural folds and crevices of bark and branches, lightning strikes, fungal growth, fire scars, insect attacks, and broken tops and branches are all potential sources of decay that can make trees suitable roost sites for many species. In general, larger trees and snags provide more roosting surface and persist on the landscape longer than smaller trees, enabling them be reused for several years. Snags in middle decay classes are the most useful because they have more loose bark and cavities than those in very early or late decay classes. One highly suitable snag can house hundreds of bats and be very important to the local bat population (Taylor 2006; Hayes and Loeb 2007).

Tree snag used as a bat roost. Photo by K. Navo.

Factors such as roost microsite conditions and availability of alternate sites affect roost selection. Optimal thermal conditions at roosts vary by bat species, sex, reproductive status, age, and with the weather and time of year. Thermal and humidity conditions of potential roost trees and snags are affected by the surrounding forest and topographic position; ambient temperature, humidity, shade, sun, and wind exposure are all important factors affecting suitability of roost sites within a stand. Clumps of snags, or stands with higher snag densities, provide more

Exit point from a bat roost in a juniper tree snag. Photo by D. Neubaum.

options for roost-switching and create roost space for bat colonies that may not all fit in one snag. Individuals may also frequently switch to a different roost tree daily or every few days. The same collection of trees may be reused repeatedly during the summer and between years, or individuals may continually find new roosts. Due to the ephemeral nature of tree and snag roosts, and the variety of thermal requirements within bat communities, forest management should allow for a diversity of roost trees and snags situated in a variety of topographic and ecological settings to meet bat habitat needs across the seasons in perpetuity (Willis et al. 2006; Hayes and Loeb 2007; Chung-MacCoubrey unpublished).

Forest structure and juxtaposition around non-tree roosts (e.g., rocks, cliffs, caves, mines, bridges, and buildings) may have an influence on roost suitability for different bats, but specific effects are poorly understood (Hayes and Loeb 2007). Some species commonly select day roosts in non-tree sites despite availability of trees and snags in or near their foraging areas (Rabe et al. 1998; Ives et al. 2006; O'Shea et al. 2011; Schorr and Siemers 2013). Others may choose rock and cliff roosts where those resources are available, but will use trees and snags occasionally where rocks and cliffs are limited. This situation seems especially important in pinyon-juniper woodlands (Chung-MacCoubrey 2003; Siders and Jolly 2009; Solvesky and Chambers 2009; Snider et al. 2013).

CLUTTER

The amount and size of obstacles a bat must detect and avoid in a given area is referred to as clutter. The space within a dense forest canopy is highly cluttered, whereas the space in a meadow, over a lake, or above the forest canopy is uncluttered. Within a forest, the degree of clutter varies with the density of trees and shrubs in the overstory and understory. Bat species differ in body size and wing shape, which affect their ability to maneuver in cluttered environments. Those with small bodies and low wing loading are able to exploit more cluttered habitats, whereas those with larger bodies and high wing loads are less tolerant of highly cluttered habitats (Hayes and Loeb 2007). Echolocation calls can also differ among species, with some calls better suited to cluttered environments and others suited to open environments (Schnitzler and Kalko 2001). However, most bats are able to use a range of open and cluttered environments. Bats frequently use edge habitat for commuting and foraging, and will target prey according to the species' clutter tolerance and foraging strategy (e.g., gleaning or aerial hawking). Some species focus their foraging efforts in open areas within a few meters of the forest edge, others forage further out into the open or above the canopy, and still others remain primarily within the more dense forest (Jantzen and Fenton 2013). Thus, the ratio and arrangement of trees and openings on the landscape will influence the assemblage of bats in any given area. Natural disturbances and forest management activities that alter tree density and forest structure influence the degree of vegetation clutter and the bat community in turn.

WATER

Aquatic habitats play a critical role in bat ecology, as both a source of drinking water and insect prey. They are particularly important in arid environments, where water can be a limiting resource influencing the presence of bats. Active insectivorous bats have relatively high rates of evaporative water loss and consequently require surface water, which they consume in flight, to maintain their internal water balance (Hayes and Loeb 2007). Lactation can further increase drinking water requirements of reproductive females (Adams and Hayes 2008), and overall productive output of a population can be negatively affected in part by drought (Adams 2010). Riparian areas and open surface water are also important foraging areas where insect densities are often higher and insect communities are different than surrounding uplands (Bell 1980; Fukui et al. 2006). In densely forested landscapes, streams and lakes can provide open commuting paths, and in arid rangelands the cottonwood forests associated with surface water can provide the only tree and snag roosts for several miles (see section V. Rangeland Management Practices).

Not all surface water is equally beneficial to bats; a site's suitability is influenced by the presence of flat water, the amount of surface area, and the arrangement of overhanging clutter. The sound of rough water can interfere with echolocation, and the shape and movement of waves make it difficult for bats to safely get very close to the water surface. Large water sources with greater open surface area are useful for larger bats that can't maneuver over small and/or cluttered water sources, whereas smaller bats can take advantage of smaller sites, even puddles. Artificial water impoundments (e.g., troughs and stock ponds) in upland habitats can provide valuable sources of drinking water in otherwise arid lands, but they likely contribute little to prey abundance and can be death traps if they don't have a clear flight path, are filled with floating algae, or don't have functional escape ramps (Hayes and Loeb 2007; Taylor and Tuttle 2007).

PREY

Forest vegetation and aquatic habitats provide resources not only for bats, but habitat for insects that the bats prey on. Bats consume large quantities of many types of insects in the air, from foliage, and on the ground. Bat body size, dentition, call structure, and wing morphology all affect the type of prey a bat may select (e.g., gnats vs. June beetles vs. moths), and many species have flexible and overlapping diets. Insect species composition and abundance differ across forested landscapes and over time with changes in the vegetation cover, which in turn can affect forest bats. Natural and anthropogenic disturbances are expected to alter prey availability, but the specific differences are difficult to generalize and not fully understood (Hayes and Loeb 2007; Snider 2009). For example, converting forest or woodland to another cover type by fire or mechanical means may make prey more available to some species and less available to others, or generally less (or more) available to all bats. The type, timing, severity, and extent of disturbance (e.g., fire, insect outbreak, or mechanical tree removal) also likely play a role in prey availability. The effect of such changes on prey availability in all forest and woodland types is in need of further research. Although typically used sparingly in forested landscapes, pesticides sprayed to thwart insect infestations in green stands could be directly or indirectly deleterious to forest bats, especially those roosting in the foliage of sprayed trees.

FOREST MANAGEMENT CONSIDERATIONS

Forest and woodland conditions are affected by anthropogenic and natural disturbances, which vary widely in type and scale. Generally, a forested landscape with an adequate amount of heterogeneity in stand structure and species composition will provide the habitat components for roosting and foraging that are required to maintain a diverse bat community in forests. Forest and woodland management actions should be informed by the natural range of variability of each ecosystem. There are some key characteristics that should be considered for bats when designing projects that alter forest and woodland conditions.

PATCH SIZE AND STAND STRUCTURE

Management actions should reference the natural range of variation within a specific forest ecosystem to derive appropriate stand structure and patch size. Given that, the extremes of very dense forest and vast treeless areas without shrubs or water are less useful to many forest bats than some intermediate mixture of trees and openings. The species composition of a bat community will adjust to the available habitat. Landscapes with more dense multi-layered forest will favor highly-maneuverable bats, whereas landscapes with lower tree density and/or a greater amount of open habitat next to forested habitat will favor those that can't navigate highly cluttered spaces (Figure 4.1). Landscapes with a range of tree densities and ages in a heterogeneous distribution will likely meet the needs of the most forest bat species.

Figure 4.1. Aerial photos of Pike National Forest demonstrating different levels of dense, mixed and sparse forest clutter. The dense forest is a stand of Engelmann spruce and subalpine fir; the mixed forest is a mixture of ponderosa pine, Douglas-fir, and aspen forest 8 years after the Hayman fire where some trees survived and some became snags; the sparse forest is a stand of ponderosa pine. Photos provided by M. Painter.

SNAGS AS ROOST TREES

Forest stands composed of mostly younger, smaller trees and no snags are less valuable for roosting than stands with larger live trees with some damage or deformity and more numerous and larger snags. Clumps and groups of snags within a stand may also be more useful than single snags. Exposed snags in the open or on the windward side of a hill are more likely to fall due to wind. Single live trees or snags isolated in the open are also less likely to be used as roost sites since they offer only modest shelter from the elements in comparison to a secure stand of trees. Larger-diameter snags and trees with some damage or deformity are more valuable as roost sites for most forest bats than smaller-diameter trees. These trees and snags may be taller than the surrounding canopy, but not always.

SURFACE WATER

In most of Colorado's forest ecosystems surface water does not need augmentation for bats. Good water quality and adequate flow is important not only for the bats to drink, but to support healthy aquatic insect populations and riparian areas. Bats in arid pinyon-juniper woodlands may benefit from constructed water sources. No matter where they are located, these resources must be kept safe for bats to access; otherwise they can become a significant cause of bat mortality (e.g., stuck on barbed wire, trapped in floating algae, or drowned without a sufficient escape ramp). See Taylor and Tuttle (2007) for a thorough description of waters for wildlife.

All of these habitat components work together and must be replaced over time, so land managers should plan into the future to ensure the continued presence of these forest and woodland features as stands age, are disturbed, and regenerate across the landscape. Each disturbance or management action, such as widespread natural disturbance, timber harvest, or wildfire fuel reduction, does not inherently pose a threat to all bats in forests and woodlands. However, care must be taken to ensure the type and degree of natural and anthropogenic disturbances across a landscape do not overwhelm the ability of bat communities to compensate and persist.

In this chapter we address three broad categories of issues for rock crevice and cavity roosting bats: Forest and woodland management actions; insect outbreaks, tree disease, and wildfire; and Fuel reduction, rangeland improvement, and ecosystem restoration.

FOREST AND WOODLAND MANAGEMENT ACTIONS IN COLORADO

Federal land accounts for 67 percent of all forest types in Colorado, 29 percent is under private ownership, and the remainder is divided between state and tribal lands. It is important to note that 80 percent of forested wetlands are privately owned, and approximately half of ponderosa pine, juniper woodlands, and mixed conifer forests are also privately owned and managed (Schrupp et al. 2000). There is some level of management consistency among federal land management agencies, but forest management actions on private lands vary widely depending on the land management goals of the individual owners.

Forests and woodlands are naturally dynamic, and various disturbances act at multiple spatial and temporal scales to change or maintain forest conditions. Individual trees and whole stands commonly die or are damaged by insects, disease, fire, windthrow, and drought, and then are recolonized when conditions are favorable. Bats are adapted to the dynamic nature of forest ecosystems, as well as the balance of disturbance and stability within a landscape. Humans remove both live and dead trees by cutting, burning, dozing, or drowning. In Colorado the primary forest and woodland management issues include insect outbreaks, wildfire, fuel reduction, salvage and timber sales, rangeland improvement, and ecosystem restoration. Forest removal for such things as reservoir expansion, infrastructure, and other development needs occur across the state, but are generally localized. In contrast to some forested landscapes in other parts of the US like the Pacific Northwest and southeastern states, intensively managed commercial forests are not currently a part of the Colorado landscape.

GOAL

MANGE COLORADO'S DIVERSE FOREST RESOURCES TO PROMOTE STABLE OR INCREASING BAT POPULATIONS FOR THE SPECIES KNOWN TO USE THEM.

Objective 1: Encourage public and private land managers to actively and objectively consider bats in management decisions that involve forests and woodlands.

Objective 2: Encourage all land managers to communicate and work cooperatively across ownership boundaries to promote positive bat habitat management over broad spatial scales.

Objective 3: Assess bat populations in Colorado forests to determine population trends and refine species' ranges by participating in established national efforts such as NABat (Loeb et al. 2015) or developing state and local level designs.

MANAGEMENT RECOMMENDATIONS

- Consider landscape-scale management of mature forests for bat populations when developing forest management plans.
- Protect an adequate density of large diameter and/or tall snags and live trees with cavities within forest stands. Trees with the following characteristics should be favored for retention: loose bark, dead or broken tops, lightning strikes, natural cavities, or woodpecker cavities.
- Provide snags in clumped or clustered patterns across the landscape in all forest types, to address frequent roost switching that occurs with many forest-dwelling bats. Avoid leaving potential roost trees isolated as individuals within large clearcut blocks.
- If natural snag density and conditions are severely lacking across a large focal area where green trees are abundant, replacement snags may be created by girdling or topping a selection of large live trees. However, artificially created snags are less useful to bats because they do not readily develop the loose bark and cavity features that occur in trees that die naturally from pathogens or trauma.
- Provide land managers with up-to-date information on bat ecology and management recommendations for incorporation into agency plans.
- Provide county extension agents and the Colorado State Forest Service information to assist private landowners with the protection and development of roost trees. Make private

landowners aware of the value of snags and live cavity trees. Where possible, roost trees should not be removed if private lands must be cleared for development.

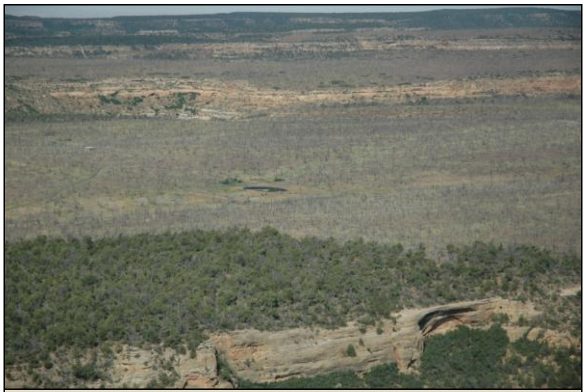
RESEARCH NEEDS

- Identify the timing of seasonal behaviors (i.e., hibernation, migration, reproductive stages) across the range of elevations and latitudes in Colorado for the various bat species that reside in or migrate through the state.
- Collect basic data on bat activity in higher-elevation forests like lodgepole pine, bristlecone pine, and spruce-fir. The abundance of higher-elevation/lower-latitude forests in the southern Rocky Mountains is considerably different than surrounding regions.
- Determine relative importance of aspen to bats. Do bat communities differ in forests where aspen is a major component compared to stands with little to no aspen?
- Characterize bat activity in the many configurations and locations of the state's broadly defined forest and woodland types.
- Tree mortality is an important process in any forest or woodland ecosystem, but how do the different types and scales of tree mortality events compare in terms of bat activity and community responses? Consider natural and anthropogenic disturbances that result in tree mortality or removal. Are there thresholds for one event or an accumulation of events in a given landscape?
- Investigate bat habitat use and the relationship of forest/woodland structure near non-tree roost sites such as urban areas or rock crevices, particularly for species that use both.
- Conduct targeted observations to determine the extent of eastern red bat occurrence in the state; consider historic trends and the importance of riparian forests and woodlands in relation to the species.

INSECT OUTBREAKS, TREE DISEASES, AND WILDFIRE

In Colorado forests, fire, insects, and disease are among the major disturbance agents for changing forest composition and structure at both fine and broad scales. Insects such as wood borers, defoliators, and bark beetles typically exist at low levels, but can occasionally form significant outbreaks that can quickly cause widespread tree mortality (RMRFHP 2010). Since the late 1990's, native bark beetle outbreaks in conifer forests and woodlands have been observed on a broad scale in the state, and the effects on bats are largely unknown. The adult beetles in flight may be an opportunistic source of prey for forest bats (similar to outbreaks of spruce budworm larvae; see Wilson and Barclay 2006), but their overall dietary significance is likely minimal. Disease and environmental stressors are also causing widespread decline of many aspen stands in Colorado (Worrall et al. 2010; Marchetti et al. 2011), which could alter bat foraging conditions and roosting habitat. After a severe insect or disease outbreak has passed and a forest stand is composed of mostly dead trees, the effects on insect and bat populations have not been thoroughly studied. Some land managers may choose to salvage dead trees, which is an additional factor of disturbance that should be investigated as it pertains to bats. After trees have died or been removed there are numerous possible stand regeneration outcomes that would influence bat habitat suitability and bat communities. The stand may be more accessible to clutter-intolerant bats, roost sites may temporarily be unlimited or eliminated, the bat community could switch to insects that respond to a rejuvenated understory and aspen regeneration, or overall prey availability could drop and cause bats to forage or roost elsewhere. Further study is needed to validate these possibilities.

Like insects and disease, fire is a natural process that most forests in Colorado evolved with. However, massive high-severity wildfires appear to be occurring more often and have become a concern to forest managers and residents in the state (e.g., 2000 Bircher Fire, 2002 Hayman Fire, 2002 Mount Zirkel Complex, 2012 High Park Fire, 2013 Black Forest Fire, 2013 West Fork Complex; Makings 2013). Researchers are beginning to investigate the effects of forest fire on bats, and so far the results appear to be mixed. Some studies have found bats to selectively forage and/or roost in burned areas (e.g., Lacki et al. 2009, Buchalski et al. 2013), while others found bats foraging away from burned areas (e.g., Chambers and Saunders 2013, Snider et al. 2013). Fires may also remove important vegetation that releases large amounts of sediment which may inundate small water sources. O'Shea et al. (2011) found that the abundance of some species may have been altered in post fire surveys of Mesa Verde National Park due to the loss of ephemeral water sources from siltation. Other studies in Colorado have shown the importance of ephemeral water sources for a number of bat species and suggest that climate change and wildfire may threaten these resources (Adams et al. 2003; Neubaum 2017). Some fires may be beneficial for roosting or foraging, but not both. Like insect- and disease-killed stands, land managers may choose to salvage stands heavily impacted by fire. Fire severity, extent, forest type, and post-fire vegetation and management responses are all interacting factors that likely influence post-fire habitat suitability and bat communities.



Large wildfires are capable of altering landscapes used by bats quickly. Wildfire has burned 73% of the pinyon-juniper woodland on Mesa Verde in the last two decades alone. Photo by D. Neubaum.

GOAL

MANAGE FOREST AND WOODLAND LANDSCAPES IN A MANNER THAT PROMOTES DYNAMIC, RESILIENT SYSTEMS THAT CONTINUE TO PROVIDE FORAGING AND ROOSTING HABITAT FOR BATS AFTER LARGE SCALE ALTERATION FROM DISEASE AND WILDFIRE HAS OCCURRED.

Objective 1: Utilize long-term monitoring of bat use in forests and woodlands heavily altered by disease, insects, or wildfire to document the subsequent decline or rebound of populations, and the timelines on which they act to identify trends and inform future management decisions.

MANAGEMENT RECOMMENDATIONS

- Develop management plans with bat species in mind that consider multi-district landscape scales that account for landscape-scale disturbances.
- Restore fire to forest stands to meet management objectives. Periodic low intensity burning in some forest systems could help maintain a more open understory and reduce clutter that impedes bat flight. Incorporate snag protection measures within burn plans.

RESEARCH NEEDS

- Investigate how bat populations are impacted pre and post large scale forest replacement events caused by insect outbreaks or wildfires.
- Investigate bat population responses to timber salvage in comparison to non-salvaged stands that have been severely impacted by insects or fire.

FUEL REDUCTION, RANGELAND IMPROVEMENT, AND ECOSYSTEM RESTORATION

Land managers in Colorado intentionally manipulate forests and woodlands to meet a variety of goals (e.g., reduce fire hazard, ecosystem restoration, improve grazing opportunities, or timber sales), but most goals are accomplished with similar tools. Generally they include prescribed fire, tree removal with heavy equipment or chainsaws, and tree planting. Tree planting is not typically considered an issue for bat habitat management and will not be addressed further. More frequently, management questions involve the specifics of removing trees in bat habitat. Tree removal techniques differ among forest types, which may or may not have beneficial results for bat habitat. In lower montane forests like ponderosa pine, Douglas-fir, and mixed conifer, stands are cut or masticated to meet fuel reduction and ecosystem restoration goals. These mechanically treated areas may be thinned by size class and/or removed by group selection; often a more desirable species (e.g., ponderosa pine) is favored for retention. Prescribed fire is also used to maintain lower tree densities and rejuvenate the herbaceous understory. In upper montane and subalpine forests like lodgepole pine and spruce-fir, stands are more often cut by group selection or in larger patches that can cover tens or hundreds of acres, which also reduce fuel loads and can mimic some aspects of natural fire disturbances. In some locations, conifer stands are cut for merchantable timber or biomass production. Aspen are frequently favored for retention to enhance biodiversity, but some stands may be cut specifically for aspen logs or to encourage regeneration if the stand is deemed too decadent to persist without disturbance. At lower elevations, pinyon pine and juniper trees are removed singly or in patches by mulching, cutting, or burning to restore grassland and shrubland habitats for wildlife like sage grouse, pronghorn, and mule deer; to enhance growth of herbaceous and shrubby forage for livestock; and specifically for firewood sales.

GOAL

ENABLE HABITAT MANAGEMENT THAT PROMOTES BAT OCCUPANCY AND COMMUNITY DIVERSITY IN FORESTS AND WOODLANDS WHERE APPROPRIATE.

Objective 1: Utilize forest management practices that promote or mimic natural forest disturbance regimes, both temporally and spatially.

Objective 2: Focus research activities on bat habitat issues that are widespread within, or particular to forest and woodland types of Colorado.

MANAGEMENT RECOMMENDATIONS

- Encourage native tree species diversity within and among stands, where appropriate. Diverse stands support a wider variety of insect species, and are less susceptible to widespread insect and disease outbreaks.
- Stagger harvest and fuels treatments through time across the landscape, and apply prescriptions that are informed by the natural disturbance regime of the local and desired forest type.
- Plan for future bat roosting habitat on the landscape by identifying large-diameter live trees to retain during harvest activities. These trees should be protected during subsequent harvest entries as well.
- Develop firewood guidelines to ensure retention of adequate snag densities in fuelwood units.
- For larger land parcels (i.e., tens of acres or more), develop forest management plans that promote an appropriate balance of open, cluttered, and edge habitat suitable for the variety of bat species that are expected to use the area.
- Maintain edge habitat, areas where treatments are excluded, and riparian corridors to promote roosting and foraging opportunities.

RESEARCH NEEDS

- Monitor bat community responses to changes in forests and woodlands triggered by shifting climate conditions.
- Monitor bat community responses to mechanical and/or prescribed fire management of forests and woodlands and compare to unmanipulated forests and woodlands.

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