Issues and Perspectives

Guidelines for Defining Biologically Important Bat Roosts: A Case Study from Colorado

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Abstract

Conservation of roosts is regularly recommended as a strategy to decrease the risk of threats to local bat populations (e.g., white-nose syndrome). Determining whether a roost site plays a meaningful role in maintaining a local bat population can be difficult given the variability found in roost structure type, and use by season, duration, and sex. Here we provide land managers and biologists with guidelines to aid in the decision process for determining which roosts are biologically important in maintaining healthy bat populations at a local scale. We define methods for determining biologically important roost sites and provide a case study of their use on bat roosts in Colorado. To be considered biologically important, we suggest that a roost meet two primary criteria: 1) it is considered a hibernaculum, maternity roost, transient roost, colonial bachelor roost, or fall swarming site used by bat species that are gregarious roosters, hibernators, or are known to swarm, and 2) if the site is disturbed or lost, it could affect 5% or more of the local population of the species, as defined by the investigator. Additive measures to further evaluate the importance of the roost and assign higher conservation value include: 1) a roost used by a special status species and 2) large aggregations of bats where an estimated 20% or more of the local population is roosting or swarming at the site. We also provide definitions for the seasonality of roost types, examples of several real-life scenarios where management decisions have been made for roosts, and a worksheet that helps guide users through the process.

Keywords: bat; biologically important; local population; cave; roost; scope of roost; white-nose syndrome

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Introduction

Roosting strategies and associated habitats used by bats have long been recognized as important components for their survival and emphasized when considering conservation efforts (Sheffield et al. 1992; Bogan et al. 1996; Pierson 1998; O'Shea and Bogan 2003). Bats use roosts during all seasons, serving functions such as maternity wards (summer colonies where pups are born and reared), mating sites (where swarming behavior and mating may occur), migratory stopovers (resting spots), and hibernacula (winter roosts where extended bouts of torpor are used). Roosts are often the location where bats are most vulnerable to disturbances, where conflicts with humans most often arise, and in some cases are limiting resources (Pierson 1998). Worldwide, over 1,000 multiple mortality events or "die-offs," falling into nine categories, were tabulated by O'Shea et al. (2016), suggesting several challenges to bat conservation. Included among these threats is white-nose syndrome (WNS), considered to be one of the most significant mortality events affecting bats at their roosts in North America to date (Lorch et al. 2016). To understand the implications of how some of these threats affect local bat populations (individuals within an area smaller than the range of the species) in North America and to formulate better decisions on how to mitigate them, baseline information on the biological importance of individual roosts is needed. The term "biologically important," as we use it in this document, refers to roosts that play a crucial role in the persistence of local bat populations.

We consider the ability of biologists and land managers to determine which roost sites are biologically important for a local population necessary for several reasons. Determination of biological importance would provide consistency of roost management decisions across agencies, while offering transparency and standardization to the evaluation process. Currently, the method of operating is often to set cutoffs of numbers of bats without following a guiding framework that communicates how these numbers relate to local populations of bats. Decisions on how to set these cutoffs, such as those related to WNS, can be inconsistent, lack clear definitions for how they were derived, and can falter when applied to a different species or broad-scale management strategy. For example, across portions of the western United States, federal agencies such as the U.S. Bureau of Land Management (USBLM) and U.S. Forest Service (USFS) have created WNS management plans where the management of individual roosts such as caves and their continued access by the public is weighed against the potential for accidental introduction of the fungus *Pseudogymnoascus destructans*, which causes WNS. The approaches taken by western land agencies to manage roosts where WNS currently does not exist, but could be introduced in the near future, have varied widely and include: closing all caves (USFS 2010), closing select caves where use by bats has been confirmed (USFS 2013), setting numeric cutoffs for numbers of bats using a roost on the basis of biological information and expert opinion (USBLM 2010), and leaving all caves open until the disease reaches a set geographic distance or buffer from a known site (USBLM 2014). During the 2011 National Speleological Society's annual convention in Colorado (Reames 2011), concerns about recreational caving introducing WNS to an uninfected western state brought roost management for caves to the forefront for land management agencies, thus forcing difficult decisions. At the same time, all caves were closed across the Forest Service's Rocky Mountain Region (USFS 2010), a decision that posed serious constraints on caving access by the public and convention attendees. Circumstances such as these leave land managers and biologists with limited time to make difficult decisions that have significant ramifications.

With the continued spread of WNS in North America (Lorch et al. 2016) as well as ever-increasing threats to bats (O'Shea et al. 2016), the need for guidelines that help land managers and biologists determine biological importance of bat roosts has never been greater. Such guidelines would further bat conservation by protecting roosts that are more important to local bat populations and focus efforts of land managers and biologists. The intent of this document is to provide land managers and biologists with guidelines that aid in the decision process for determining which roosts affect local population persistence and support the investment of time and limited resources. We describe methods for defining biologically important roosts, sites that play a crucial role in maintaining user-delimited local populations of bats, by providing a series of guidelines that consider how the site is used by bats, the scope of the roost (percentage of individuals from the local population using the roost), and species status. We use roost scenarios that we have encountered in Colorado as a case study to show how the guidelines can be applied. We also provide definitions for the seasonality of roost types, use of roosts by species, and a worksheet to help guide the user through the evaluation process.

Roost Characteristics and Local Population Estimates

Determining the biological importance of bat roost sites can be difficult given the variability found in roost site characteristics, and use by season, duration, and sex. Numerous studies have shown or suggest that variables such as roost structure, availability, surface disturbances (Sherwin et al. 2003; O'Shea et al. 2011b), and recreational pressure (O'Shea and Vaughan 1999) can affect where bats roost from year to year. The plasticity in roost selection that bats exhibit in relation to many of these variables makes management decisions difficult.

We define different types of roosts by the specific role they play in terms of seasonal requirements for a given bat species (Figure 1). Consequently, management of a roost may vary depending on how the roost functions. Hibernacula have stable microclimates that limit freezing temperatures but stay cold enough for a bat to utilize prolonged bouts of torpor during the time of year when food resources are not available (Ransome 1990). Maternity roosts provide warm microclimates for raising young during early summer and can have large numbers of adult females depending on the species (Neubaum et al. 2007). Transient roosts are sites bats use in spring and fall when moving between hibernacula and maternity colonies. Transient roosts are used for shorter periods of time and tend to have microclimates that are warmer than hibernacula but cooler than maternity roosts, thus allowing daily bouts of torpor (Ransome 1990; Speakman and Thomas 2003; Neubaum et al. 2006). Numbers of bats at transient roosts range widely and such roosts may be used sporadically, making use more difficult to confirm (Ingersoll et al. 2010). Colonial bachelor roost sites are used in summer by aggregations of primarily male bats (Safi 2008). Male bats of most species in North America tend to roost alone or in small groups, but some species, such as the Brazilian free-tailed bat *Tadarida brasiliensis*, may form bachelor colonies (Harvey et al. 2011). A good example of such a roost is the Orient Mine

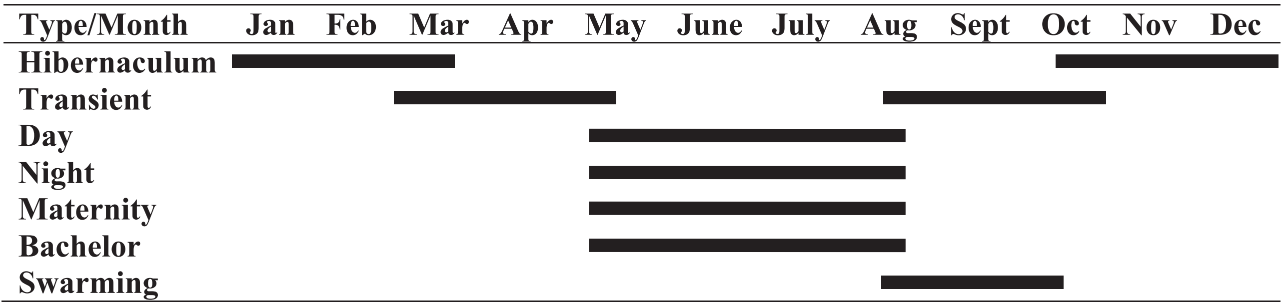

Figure 1. Approximate seasonality of roost use and gathering activity for bat species from families Vespertilionidae and Molossidae in Colorado (Table 2) as of 2016 (Armstrong et al. 2011). Seasonal roost use and gathering activity by bats may overlap with each other and change from one year to the next. Consequently, seasonal ranges of use and activity depicted here are liberal in their approximate timing extents to account for this variation.

in Colorado, which houses an estimated 100,000 male free-tailed bats throughout the summer (Svoboda and Choate 1987). Swarming in bats is thought to occur in autumn when large numbers of individuals aggregate at caves, mines, or other locations, and interact through repeated circling, diving, chasing, and landing events (Veith et al. 2004). However, smaller numbers of bats than associated with swarming may use the behavior in preparation for hibernation (Ingersoll et al. 2010). Swarming behavior could serve multiple social purposes, including mating and orientation of young bats for either migration or with potential hibernacula. For the purposes of this document we refer to sites where swarming is observed as a roost despite the multiple behaviors observed during such events.

When possible, we encourage those determining biological importance of roosts to incorporate local population data. Approaches to estimating local populations such as mark–recapture, although preferable, are not always available, or even possible to collect for bats because of the difficulty in meeting assumptions for these techniques as well as the resources needed to collect such data (Kunz 2003; Weller 2007). Given these limitations, we encourage users of these guidelines to first review local information and consult local experts to gain an understanding of the threat to the roost(s), and to determine which species might be affected. Such information will help the user gain a better overview of the management situation at hand and provide additional reasoning for final decisions.

As a framework to estimate the size of a roost in relation to its local population, we modified the ranking system presented by Master et al. (2012) that scores the proportion of a species affected by a threat, or "scope." We defined scope for purposes of this tool as the proportion of a bat species' local population that is observed, inferred, or suspected to be present at a particular roost during some point of the bat's roosting cycle. The proportions range from insignificant ($<$ 5%) to high ($>$ 60%) and refer to how much of the local population is accounted for by the number of bats using a given roost (see scope of roost, Figure 2). The thresholds for the scope of roost values were modified through several deliberations by Colorado bat experts while preparing the Colorado Bat Matrix (CBWG 2010), which addresses threats to bats. We believe that the ability of a biologist or land manager to determine that the loss of a given roost will have an insignificant impact because it affects $<$ 5% of the local bat population provides a decision-making process based on a structured, transparent, and standardized methodology that is easy to follow and explain. At the same time, we acknowledge that these guidelines only address issues related to the degree to which bats utilize these resources and do not provide a blanket fix for all management concerns tied to them.

We recommend starting a roost evaluation by defining the local population of interest because of its influence on the value of scope. Local populations are defined by Wells and Richmond (1995) as "a group of individuals within an investigator-delimited area smaller than the geographic range of the species and often within a population" but "could be a disjunct population as well." Local populations are often a more practical or feasible portion of the larger demographically, genetically, or spatially disjunct population that land managers and biologists work with. The scale at which the threat is acting upon a roost type or managerial boundary may dictate the extent of a local population, and thus scope, depending on how the tool is to be applied. In this application, a local population could be defined by the species of interest's habitat, such as any suitable coniferous forest, or by a political boundary such as a specific national forest district. The local population could also be disjunct from the core of the overall population. Although this definition allows the user to determine what the local population of interest is, we recommend that the area under consideration be kept as biologically meaningful as possible.

In cases where local population data are absent, other types of data may act as a surrogate from which to determine scope of the roost (i.e., percentage of local population using the roost). Variables discussed previously, such as the number of roosts available within the local population, may provide the user with an idea of how many other options the bat(s) will have if a given roost(s) is lost. We recommend reviewing and accounting for the questions posed previously, such as: "Is the species a roost specialist or generalist and in what season is the roost used?" For example, if the roost in question

Roost Worksheet

Site Name__________________________________ **Date**_______ **Biologically Important?** ☐ **Yes** ☐ **No**

Is this site biologically important to a local population of bats in Colorado?

Biologically important if the roost meets **both** components of the **Primary** criterion.

1. Site is a hibernaculum, roost (maternity, transient, colonial bachelor, day), or fall swarming site used consistently by gregarious roosters (> 1 individual), hibernators, or species known to swarm in CO.
☐ Yes ☐ No

2. Loss of or impacts to the roost from disturbance has a Scope of Roost ranking of at least "Low."* **OR**
Low ranking can be inferred due to the availability of the roost type, reference of available matrices, or consultation of bat experts.
☐ Yes ☐ No

Additional conservation value if the site meets one or both of the **Additive** measures.

A. Site is used by special status species.**
☐ Yes ☐ No
Species: _______________________

B. At least a "Moderate" Scope of Roost.*
☐ Yes ☐ No

Local population defined as: ____
____ **(Use back if needed)**

Estimate of density for available roosts within the area of local population: High Medium Low
Matrix referenced ____
Bat expert(s)/sources referenced ____
Estimated Scope: ______% of local bat population using roost (justify calculation on back of worksheet).

Scope of Roost*

Ranking	% of local bat population affected
High	> 60%
Moderate	21-60%
Low	5-20%
Insignificant	< 5%

Special Status Species**

Scientific name	Common name
Corynorhinus townsendii	Townsend's big-eared bat
Euderma maculatum	Big brown bat
Idionycteris phyllotus	Allen's big-eared bat
Lasiurus cinereus	Hoary bat
Myotis ciliolabrum	Western small-footed myotis
Myotis evotis	Western long-eared myotis
Myotis lucifugus	Little brown myotis
Myotis thysanodes	Fringed myotis
Myotis volans	Long-legged myotis
Myotis yumanensis	Yuma myotis
Nyctinomops macrotis	Big free-tailed bat

No criteria met?
Continue to consider:

- Use principle of do no harm when possible
- Cumulative impacts of eliminating roosts
- Design criteria or mitigations
- Current & future information needs

Figure 2. Worksheet of primary criteria and additive measures that assist in determining if a roost is biologically important for local bat populations. Domain categories (*) with associated thresholds used to determine scope of roost, as defined by the Colorado Bat Matrix (CBWG 2010) and adapted here for use in determining biological importance of roosts to local bat populations, and special status species (**) used to determine additive measures, are provided.

is a cave (roost type) within a local population (defined by the user) of Townsend's big-eared bat *Corynorhinus townsendii* (a cave-roosting specialist), the user may know how many other caves exist within that defined area. Consider if the species of bat can use roost structures other than caves (e.g., mines) and their availability. In addition, referencing threat matrices, when available, will help users gain a better understanding of the cumulative picture of threats acting on a species. By asking these questions, one may reduce the uncertainty related to percentage of the local population being affected. Consequently, the flexibility of the guidelines in defining scope continues to allow them to be usable even when local population data are not available.

We remind those using these guidelines to exercise caution when using surrogate data because not all roosts are created equal. Just because a cave exists does not automatically make it suitable for use by bats. We feel that use of this tool for determining the biological importance of bat roosts, while creating some ambiguity when determining scope of roost in the absence of local population abundance data, is more accurate when incorporating expert input and additional data like roost type and availability than setting cutoffs of number of bats that are not guided by a consistent, transparent framework. A more in-depth discussion of roost management and population monitoring can be found in O'Shea and Bogan (2003).

Defining Biologically Important Roosts for Bat Species—A Colorado Case Study

In Colorado, conflicts between humans, bats, and their roosts arise for several direct and indirect reasons. Examples of direct conflicts include the closure of inactive mines related to public safety (Navo 2001) and extirpation or exclusion of bats from anthropogenic structures due to concerns related to rabies (Neubaum et al. 2007; O'Shea et al. 2011a). An indirect example is recreational caving acting as a potential source for introducing the disease WNS to the state (USFS 2013). At the request of the Colorado White-Nose Committee, which was struggling with identifying appropriate roosts to focus surveillance and monitoring efforts before the arrival of WNS in the state, we developed guidelines for determining biological importance of roosts. We emphasize criteria for roosts in these guidelines that are biologically important to Colorado bats and have the greatest potential of being affected by any threat, not just WNS. However, these guidelines could easily be adapted to bat communities elsewhere in North America and beyond by amending the bat species and threats considered.

We propose that for a bat roost to be considered biologically important in relation to the species' local population in Colorado that we delimit, it meet the primary criteria detailed below. A rationale and qualifying species are provided here on the basis of our knowledge of bat roosts in Colorado and are likely to vary elsewhere. Additional significance is given to roosts if they meet either of the additive measures addressed in the following section. We also consider roosts for species that are federally listed as threatened or endangered pursuant to the U.S. Endangered Species Act (ESA 1973, as amended) to be biologically important regardless of scope of roost.

Primary criteria

A biologically important bat roost includes any hibernaculum, maternity roost, transient roost, colonial bachelor roost, or fall swarming site used by bat species that are one or more of the following: gregarious roosters, hibernators, or are known to swarm in Colorado. Loss of, or impacts to, the roost from disturbance(s) or disease, in addition to other known losses to the local population as defined by the user, have the potential to affect 5% or greater of the local population defined by the user (See scope of roost, Figure 2). The loss of a roost assigned a scope of insignificant ($<$ 5%) for a local population would be thought to have minimal impact on the persistence of that local population.

The types of bat roosts we noted in the primary criteria have been shown to influence the survival of local bat populations (Sheffield et al. 1992; Altenbach and Pierson 1995; Pierson 1998; O'Shea et al. 2003), providing shelter used by bat species on a consistent seasonal and sometimes year-round basis free from direct or indirect disturbances (Siemers 2002; Ellison et al. 2003; Ingersoll et al. 2010; Hayes et al. 2011). A good example of how a disturbance to a roost could be direct, indirect, or both, and thus affect how scope is determined, is the potential introduction of WNS. Since its first confirmation in early 2007, WNS has been an emerging disease of gregarious, hibernating bat species. As of May 2016, seven species of hibernating bats in the eastern United States have been affected (USFWS 2016), and of these, five (the same species or a close counterpart) occur in Colorado. White-nose syndrome is associated with cave and mine roosts because the fungus *P. destructans* thrives in conditions associated with characteristics found in these sites such as darkness, low temperatures, and high humidity (Hayes 2012). However, this criterion also applies to roosts other than caves or mines (e.g., buildings) because one bat could pick up WNS spores while using a cave during one season and potentially transmit it to a colony during a different season at a different roost type. To date, we know little about WNS's ability to persist and spread in rock crevices that are used as hibernacula in Colorado (Neubaum et al. 2006). Roosts used by bats that are not gregarious pose little to no risk of acting as a reservoir for WNS. For example, a hibernaculum used by a lone female bat is not biologically important in relation to the persistence of that species' local population. However, that same roost used by gregarious bats, even if the number of individuals is as low as two, has potential to spread WNS. The direct impact of WNS killing bats in a hibernaculum or indirect effects of *P. destructans* spores being transferred from one roost to another (e.g.,

Table 1. Bat species known to use roosts in Colorado on at least a seasonal basis and their gregarious roosting, hibernating, and swarming tendencies as noted in the western United States as of 2016. Taxonomy follows Armstrong et al. (2011) for species where roosting in Colorado has been documented. Gregarious roosting habits documented in Colorado include maternity roosts (M), colonial bachelor roosts (CB), transition roosts (T), and hibernacula (H).

Scientific name	Common name	Gregarious roosting	Obligatory hibernator	Swarming
Antrozous pallidus	Pallid bat	Yes (M)	Yes	Yes
Corynorhinus townsendii	Townsend's big-eared bat	Yes (M, H)	Yes	Yes
Eptesicus fuscus	Big brown bat	Yes (M)	Yes	Yes
Euderma maculatum	Spotted bat	Yes (M)	Unknown	Unknown
Lasiurus borealis	Eastern red bat	No	No	No
Lasiurus cinereus	Hoary bat	No	No	No
Lasionycteris noctivagans	Silver-haired bat	No	No	No
Myotis californicus	California myotis	Yes (M, H)	Yes	Yes
Myotis ciliolabrum	Western small-footed myotis	Yes (M, H)	Yes	Yes
Myotis evotis	Western long-eared myotis	Yes (M)	Yes	Yes
Myotis lucifugus	Little brown myotis	Yes (M, T)	Yes	Yes
Myotis thysanodes	Fringed myotis	Yes (M)	Yes	Yes
Myotis volans	Long-legged myotis	Yes (M)	Yes	Yes
Myotis yumanensis	Yuma myotis	Yes (M)	Yes	Yes
Nyctinomops macrotis	Big free-tailed bat	Yes (M)	No	No
Parastrellus hesperus	Canyon bat	Yes (M)	Yes	Yes
Perimyotis subflavus	Tricolored bat	Unknown	Yes	Unknown
Tadarida brasiliensis	Mexican free-tailed bat	Yes (M, CB)	No	No

maternity roost) could both occur. Consequently, the user will need to consider how a threat is acting on a roost, direct or indirectly. We suggest that the user determine seasonality of roost use when deciding to restrict access to a site being managed for WNS. Use of a roost by bats during only one season may allow for managed access during other times of the year.

We note that determining if the roost meets the primary criteria for being biologically important is still made on a case-by-case basis. Roost types not considered as biologically important for most bat species under the primary criteria, or that lack enough data to suggest otherwise, include night roosts, transient spring and fall roosts that are thought to be used only once or for short periods of time, roosts that are more exposed to the elements, and roosts that are used by lone individuals. The seasonality of how these roosts are used varies year to year and overlap may be expected (Figure 1). If a roost is used for more than one of these roost types we recommend that it be considered to have a higher biological significance.

Table 2. Bat species occurring in Colorado known to aggregate in colonies or gatherings that have the potential to support moderate proportions of the local population (scope of 20–60%) as of 2016 (CBWG 2010).

Scientific name	Biological activity
Antrozous pallidus	Maternity[a]
Corynorhinus townsendii	Maternity[b], hibernation[c,d], swarming[d]
Eptesicus fuscus	Maternity[e]
Euderma maculatum	Maternity[f]
Myotis evotis	Swarming[g]
Myotis lucifugus	Maternity[f, h], swarming[g]
Myotis thysanodes	Maternity[i]
Myotis volans	Maternity[f], swarming[g]
Myotis yumanensis	Maternity[h], swarming[g]
Nyctinomops macrotis	Maternity[j]
Tadarida brasiliensis	Bachelor colony[k], maternity[h]

[a] Ellinwood 1978.
[b] Armstrong 1972.
[c] Hayes et al. 2011.
[d] Ingersoll et al. 2010.
[e] Neubaum et al. 2007.
[f] O'Shea et al. 2011b.
[g] Navo et al. 2002.
[h] Armstrong et al. 2011.
[i] Hayes and Adams 2015.
[j] Navo and Gore 2001.
[k] Svoboda and Choate 1987.

Qualifying species. A total of 18 bat species has been documented using some type of roost during one or more seasons in Colorado (Table 1; Armstrong et al. 2011). Information on roost use by bats in Colorado has improved greatly over the last 2 decades, due in part to the application of miniature radiotransmitters. Data supporting gregarious roost use, mainly in the summer, have been collected by several studies in the state (Svoboda and Choate 1987; Navo and Gore 2001; Neubaum et al. 2007; Adams 2010; Hayes et al. 2011; O'Shea et al. 2011b; Hayes and Adams 2015) and additional work can be drawn upon from states adjacent to Colorado (Table 2).

Specific knowledge of hibernaculum use and locations vary by roost site type in Colorado, with documentation of bats using rock crevices, mines, and caves (Finley et al. 1983; Neubaum et al. 2006; Ingersoll et al. 2010; Hayes et al. 2011). Data tied to swarming activity are also somewhat limited because the behavior has not been well studied across these species' ranges. Efforts by Navo et al. (2002), Englert (2008), Siemers and Neubaum (2013), and others have focused on the national forest in north-central Colorado where karst resources exist and account for the majority of work documenting swarming in the state.

Table 3. Status of roosting bat species occurring in Colorado for former category-2 candidates (USFWS 1994), sensitive species for U.S. Forest Service (USFS 2015), Bureau of Land Management (USBLM 2015), and Western Bat Working Group (WBWG 2016), and species of conservation priority for Colorado Parks and Wildlife (CPW 2015) as of 2016.

Scientific name	USFWS	USFS	BLM	WBWG	CPW
Corynorhinus townsendii	X	X	X	X	X
Euderma maculatum	X	X	X	X	X
Idionycteris phyllotus	X	—	—	X	—
Lasiurus cinereus	—	X	—	—	—
Myotis ciliolabrum	X	—	—	—	—
Myotis evotis	X	—	—	—	—
Myotis lucifugus	—	—	—	—	X
Myotis thysanodes	X	X	X	X	X
Myotis volans	X	—	—	—	—
Myotis yumanensis	X	—	—	—	—
Nyctinomops macrotis	X	—	X	X	X

Additive Measures: Special Status Species and Large Aggregations

Because of the special status assigned at the state and federal level to some bat species and the magnified importance of roosts with large numbers of individuals, we discuss two additive measures that will help biologists and land managers emphasize an increased level of biological importance for applicable roosts. An additional level of biological importance is warranted for the roost for each additive measure that is met. We note that the presence of a special status species (additive measure A) alone does not guarantee that a site will be considered biologically important because the scope of the local population affected by the roost must extend to 5% or greater of the local population as stated in the primary criteria (Figure 2). A good example of this scenario would be finding a solitary Townsend's big-eared bat roosting in a cave. Although this bat is a state species of concern and federal sensitive species, the presence of only one individual would not meet the gregarious or scope of roost requirements. In cases outside of Colorado where species are federally listed as threatened or endangered, we suggest that these roosts be considered biologically important regardless of scope. Likewise, all roosts that have a moderate scope of threat as defined below will be biologically important.

Additive measure A—special status species

Bat species occurring in Colorado that face multiple conservation threats have been classified as former USFWS category-2 candidates (USFWS 1994), federally sensitive (USBLM 2015, USFS 2015), state species of conservation priority (CPW 2015), or ranked "high" on Western Bat Working Group's (WBWG 2014) Regional Bat Species Priority Matrix (Table 3, Figure 2). We suggest that listed species (USFWS 1994) and species of concern (e.g., USFS 2015) be included under an additive measure because these bat species are considered by various entities as vulnerable or threatened, or are already in need of specific conservation actions separate from roost disturbance alone (O'Shea et al. 2016). If a biologically important roost is compromised, these local populations may be at additional risk of decline.

Nine of the 18 bat species known to roost in Colorado (Table 1) are former USFWS category-2 candidates (nine species), USFS and USBLM federally sensitive (five species), Colorado Parks and Wildlife state species of conservation priority (five species), or ranked high on Western Bat Working Group's species matrix (five species, Table 3). Townsend's big-eared bats and fringed myotis *Myotis thysanodes* are known to roost gregariously and hibernate. Spotted bats *Euderma maculatum*, western small-footed myotis *Myotis ciliolabrum*, western long-eared myotis *Myotis evotis*, long-legged myotis *Myotis volans*, and Yuma myotis *Myotis yumanensis* are known to roost gregariously during the summer, but winter behavior is unknown. Big free-tailed bats *Nyctinomops macrotis* roost gregariously in summer but are thought to be migratory. Hoary bats *Lasiurus cinereus* have not been confirmed to be gregarious and are migratory. Roosts for species that are federally listed as threatened or endangered occur in many states and we recommend that they be considered biologically important regardless of scope.

Additive measure B—large aggregations

We suggest that roosts where an estimated $> 20\%$ (medium to large scope) of the local population (See moderate scope of roost, Figure 2) is roosting or swarming warrant an additional level of biological importance. Colonies under this additive measure and swarming groups are consistently larger than those at most roosts that will meet the primary criteria of a biologically important roost. Medium to large roosts are vulnerable to human disturbance and persecution because of the higher percentages of the local population they contain (Sheffield et al. 1992; Hayes and Loeb 2007; Neubaum et al. 2007). Many caves that were once known to house large concentrations of bats are no longer used by bats because of disturbance (Tuttle and Moreno 2005). Bats are especially vulnerable to local population declines because they exhibit slow population growth, giving birth to one or two offspring once per year. In addition, roosts where swarming activity occurs may provide atypical situations where large numbers of bats composed of multiple species can interact during a short period of time. In Colorado, swarming has been documented at several roosts for multiple species (Navo et al. 2002; Englert 2008; Siemers and Neubaum 2013). Nine of the 18 bat species occurring in Colorado (Table 1) are known or thought to form roosts, meeting a medium scope ($\geq 20\%$ of the local population, Figure 2) and 5 have been documented swarming (Table 2).

We provide examples for several scenarios that we encountered in Colorado that may be applicable elsewhere for determining biological importance of bat roosts in Text S1, *Supplemental Material*. A summary of this tool is captured in a worksheet that steps the user through an easy series of questions regarding the primary criteria and additive measures (Figure 2). We recommend that the worksheet be filed with additional information pertaining to the roost under consideration to help explain how the final management decision was made.

Conclusions and Recommendations

Land managers and biologists are regularly required to make management decisions that affect use and persistence of bat roosts. In general, we recommend following the principal of do no harm when making decisions regarding roosts (e.g., determining the need to gate a cave). Conserve roosts and the surrounding habitat that may affect them when possible. Whereas protecting every roost would be one solution, in practice such broad-reaching actions are rarely feasible. Consequently, decisions regarding which roosts warrant protection may carry significant impacts to a local bat population (Sheffield et al. 1992). Use of roosts by bats can vary by season, location, sex, and species (Sherwin et al. 2003; O'Shea et al. 2011b). Here we have provided guidelines to assist land managers and biologists in making such decisions by incorporating several biological metrics and providing examples of how these metrics are used.

We designed these guidelines to offer flexibility to the user, and they depend heavily on how the local population under consideration is defined. Consequently, we advise basing these extents on biologically meaningful information as much as possible. Judgment calls regarding local bat populations can be informed by some basic information like habitat and roost type, and range of the species (O'Shea and Bogan 2003). We caution that although these guidelines include flexibility for the user, those same judgments can substantially alter the management decision outcome. Although we urge users to define a biologically meaningful and reasonable extent for the local population that best addresses the conservation of bats at an appropriate level to the threat under consideration, the smaller the geographic area considered as the local population, the less meaningful the application of this process will be to the species and its larger population. Thus, users can apply these guidelines to many different geographic or political extents depending on the project, which underscores the importance of documenting how the local population was delimited. This flexibility also heightens the need for users to document in detail the context of each situation, specific assumptions about local populations, and why various choices are made. We provide a worksheet (Figure 2) that offers a simple method of capturing these decisions for future reference. As better local population data become available, we recommend that it be taken into consideration with decisions reevaluated as part of an adaptive plan.

Roosts inhabited by large numbers of individuals tend to be given more attention for most threats because the impact on the local population is greater (Sheffield et al. 1992; Tuttle and Moreno 2005). While assessing the functionality of these guidelines on various roost scenarios, we found that WNS provides a unique example where small numbers of gregarious individuals (one or two) can have a large influence in terms of the threat for some scenarios (direct vs. indirect disturbances) despite not meeting the required scope for a roost to be considered biologically important. Decisions regarding roost management were more difficult when considering WNS because we had to account for its ability to potentially spread from roost to roost even when used by low numbers of bats (Ihlo 2013). These guidelines will need to evolve in how they account for WNS as new knowledge is gained regarding the spread of the disease.

We believe that use of local population abundance estimates will provide the most robust method for determining scope of roost. Local working groups can often put users in touch with bat experts who may have data for local populations and who can assist in determining suitable values for scope of roost on the basis of their knowledge of the species. Some working groups have other resources available to assist users including natural history accounts of species, conservation plans, and threat matrices (Ellison et al. 2003; CBWG 2010; WBWG 2014). We encourage referencing these resources when using these guidelines and developing management plans related to bat roosts. In instances where such data are limited or not available, additional sources of data such as roost availability may act as suitable surrogates that aid in making educated decisions. Biologists and land managers may have data on resources (e.g., number of caves) rather than local population abundance estimates on bats using those resources. We caution that although data related to roost density may be readily available in some cases, it should be used carefully because not all potential roosts may be suitable for or will be used by bats. A wide host of variables such as microclimate, exit height to the ground, and aspect of the roost exit were shown to influence whether a site is used by bats in Colorado (Neubaum et al. 2006; Schorr and Siemers 2013; Snider et al. 2013). Another characteristic for consideration is seasonality of roost use. For example, signs of use by bats such as guano droppings and presence of bats themselves may not be detected during a summer visit despite bats using the site in winter. Thus, visits to a potential roost during multiple seasons may be necessary to fully evaluate use of a given site.

Our guidelines rely partly on the premise that the loss of a roost assigned a scope of insignificant (contains $<$ 5% of the local population, Figure 2) would have minimal impact on the persistence of that local population. The scope of roost thresholds we implemented for these guidelines was modified from Master et al. (2012) through a number of deliberations by Colorado bat experts while preparing the Colorado Bat Matrix (CBWG 2010), which addresses threats to bats. Future use of these guidelines may determine that this scope threshold ($<$ 5%) needs to be adjusted. Consequently, adapting use of this modified scope of roost for use on individual roosts rather than broad threats may necessitate further modification if users are finding that the domains are not sensitive enough to capture percentages of bats that alter local populations. Although we acknowledge that scope-of-roost domains are likely to evolve as knowledge about local bat populations is gained, we feel that use of these guidelines as presented here will provide a consistent approach to determining biological significance of roosts. These guidelines can move users away from problematic numeric cutoffs related to a single roost that do not reference structured, transparent guidelines toward vetted scope-of-roost domains that do reference such methods and relate directly to local population persistence (CBWG 2010; Master et al. 2012).

This document is not intended to be used for resource planning applications in regard to bat conservation beyond those related to roosts. For example, limitations of this tool may arise when considering tree bats, or lasiurines, which are not considered to be gregarious roosters, and would not meet the primary criteria under this process. An exception may be where the user defines a stand of trees, such as a cottonwood gallery, to be the roost rather than an individual tree (examples 3A and 3B, Text S1, *Supplemental Material*). We recommend that resource planning for forest management activities, or others, give consideration of potential impacts from such a threat to these species when possible because special exceptions do arise. Rather, we suggest that these situations be considered in the aggregate, and from both cumulative and landscape level perspectives, with additional tools such as local conservation plans or matrices (CBWG 2010; WBWG 2014) being referenced.

Supplemental Material

Please note: The *Journal of Fish and Wildlife Management* is not responsible for the content or functionality of any supplemental material. Queries should be directed to the corresponding author for the article.

Text S1. Example scenarios encountered in Colorado where guidelines for determining biological importance of bat roosts have been applied as part of a Colorado case study. Found at DOI: http://dx.doi.org/10.3996/102015-JFWM-107.S1 (17 KB DOCX).

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