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Bat Conservation Plan

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Washington Department of Fish and Wildlife
Wildlife Diversity Division
Wildlife Program

This is the Washington State Bat Conservation Plan. It gives an overview of bat biology, habitat requirements, relationships to public health, legal and conservation status, conservation and management activities, and known or potential threats to bats. The plan summarizes the historical and current distribution and abundance of each of the 15 bat species found in Washington, with information also provided on identification, taxonomy, habitat, natural history, threats, and conservation measures. The plan also outlines strategies and tasks needed to implement conservation and protection of bats in Washington.

The draft conservation plan was reviewed by researchers and technical staff from state and federal agencies, and regional experts. This review was followed by a 30-day public comment period. All comments received were considered in preparation of the final conservation plan. For more information about bats, check the Washington Department of Fish and Wildlife's web site (http://wdfw.wa.gov/) or email the Department at wildthing@dfw.wa.gov.

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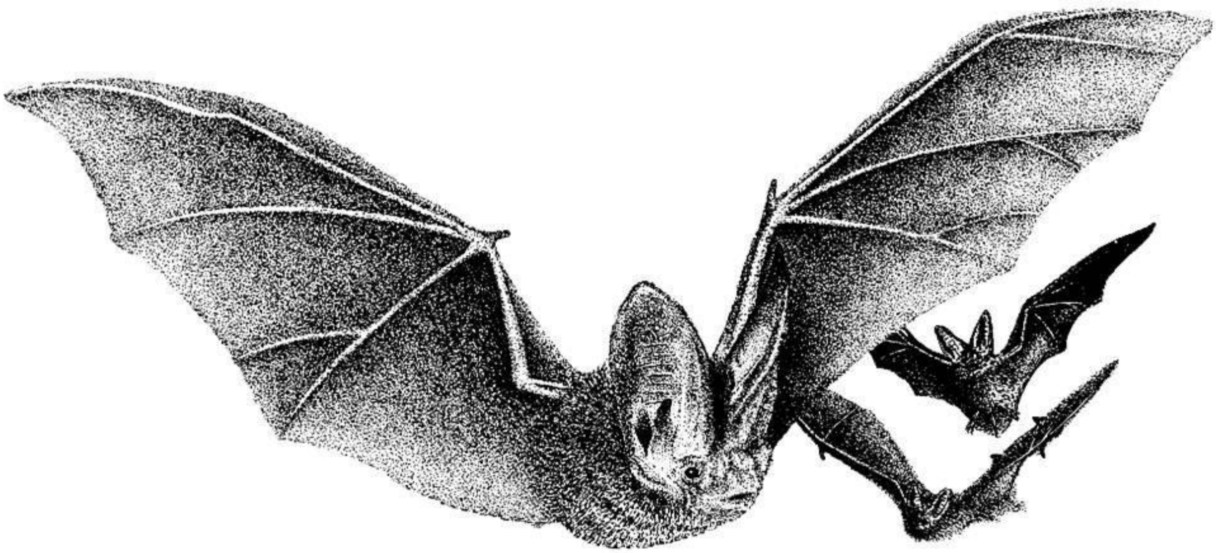
WASHINGTON STATE BAT CONSERVATION PLAN



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EXECUTIVE SUMMARY

Bats are the only mammals capable of true flight, and are second only to rodents in the number of species worldwide. They are found on every continent except Antarctica, with 47 species present in the United States. Washington is home to 15 bat species: the big brown bat, California myotis, canyon bat, fringed myotis, hoary bat, Keen's myotis, little brown myotis, long-legged myotis, pallid bat, silver-haired bat, spotted bat, Townsend's big-eared bat, western long-eared myotis, western small-footed myotis, and Yuma myotis.

Bats are the primary vertebrate predators of night flying insects and play an essential role in ecosystem function and human economies. In North America, bats provide an estimated benefit of nearly $4 billion annually to the agricultural industry by preying on agricultural pests. None of the bat species that occur in Washington are listed as endangered or threatened under federal or state law, but two species, Keen's myotis and Townsend's big-eared bat, are classified as state candidate species. They will be reviewed in the future for potential state listing as endangered, threatened or sensitive. Significant information gaps on population status and trends exist for most of the 15 species that occur in the state.

This is the first conservation plan written for the bats of Washington. It summarizes information on the biology and habitat requirements of the species present, discusses factors affecting populations, and outlines conservation activities for maintaining viable bat populations in the state. Brief accounts with background information, photos, and distribution maps are provided for each species.

All 15 bat species in the state have largely insectivorous diets and forage at dusk, night, and dawn. Echolocation is used to capture prey and navigate. All species give birth once per year in the summer, with most having a litter size of one pup. Most species make use of torpor (i.e., the body temperature and metabolic rate are greatly reduced, allowing animals to become inactive during periods of harsh weather and food shortage) during winter hibernation or on a daily basis during other seasons. Two species, the hoary bat and silver-haired bat, are long-distance migrants that overwinter in southern North America, although some silver-haired bats remain in Washington year-round. A number of other species are believed to be short-distance migrants that change elevations as they move to winter roosts with temperatures suitable for hibernation.

The most important habitats for Washington's bats are those used for roosting and foraging. A variety of roost types are occupied to meet daily and seasonal needs, including trees, snags, caves, mines, cliffs, talus, buildings, and bridges. While hoary bats roost almost exclusively in trees, nearly all other bat species in Washington use a variety of roost structures. Some of the state's bat populations make widespread use of cavities and crevices in trees and snags as roosts, with a strong preference for large trees and snags in the early to intermediate stages of decay. Microclimate plays a large role in roost selection, with bats seeking locations having optimal temperatures for saving energy, development of fetuses, and rearing young. Suitable densities of roost sites, especially snags and trees, are important for maintaining viable bat populations.

Adequate foraging habitat is a second primary requirement of bat populations. A number of bat species in Washington concentrate their feeding near fresh water (especially in riparian areas) and along edge habitats, where insect availability is commonly high and vegetational clutter is reduced. Overall activity is typically higher in open sites, including clearcuts, meadows, and forest gaps, than in dense forest. Most of the bat species in Washington make greater use of older, more open forests for foraging than younger forests with denser vegetation. In shrub-steppe and grassland habitats, some bat species favor foraging in riparian zones, while others feed more broadly across both habitats. Availability of drinking sites is another key component of bat foraging habitat, especially in drier regions of the state where water sources may be limited.

Habitat loss and human disturbance are two of the main factors that can negatively impact bat populations in Washington. Habitat loss and alteration affect the availability of both roosting and foraging habitat of bats in the state. Logging and other forest management practices have resulted in younger and often denser forests across the state, causing a general decline in the number of large snags and decadent trees for roosts and also negatively impacting foraging habitat. Regulations requiring the retention of some snags and trees, and buffers around riparian zones have helped reduce this threat, but the issue remains an important concern for forest-dwelling bat species. Agricultural land conversion, urbanization, and mine closures have also reduced roosting and foraging habitat for bats. Human disturbance of bats roosting in caves and other structures is a concern at some sites, but overall is not considered a major threat to most species in the state. Various environmental contaminants also potentially impact some bat populations in the state.

Three additional factors (wind energy, disease, and climate change) may increase in importance in the future. Bats are susceptible to being killed at wind energy facilities. Hoary bats and silver-haired bats comprise almost 98% of the bats killed by wind turbines since commercial wind energy production began in Washington in 2001. In 2011, an estimated minimum of 2,419 bats were killed at operational wind projects in the state. Significant expansion of this industry is expected in Washington in the coming decades and even with pre-construction surveys and proper siting, will likely continue to cause mortality to bats. A fungal disease, white-nose syndrome, has recently emerged as a major killer of cave-hibernating bats in eastern North America and is spreading westward. An estimated minimum of 5.7 to 6.7 million bats have died from white-nose syndrome. It is unknown whether the disease will reach Washington or what impacts it may have on bat populations in the state. Species that form tight clusters during hibernation are usually the most vulnerable. Lastly, climate change is likely to alter the future availability of roosting, foraging, and drinking resources for bats, and may have other unforeseen impacts.

The bat conservation plan identifies seven conservation objectives, with strategies and tasks to achieve those objectives. Objectives are:

- Collect baseline inventory data and monitor bat populations to assess trends.
- Safeguard bats from sources of mortality and disturbance.
- Manage habitat to maintain and enhance bat species diversity and abundance.
- Conduct research to determine requirements for bat populations.
- Conduct conservation planning to benefit bats.
- Establish partnerships with agencies, landowners, and other groups to achieve bat conservation.
- Develop and implement public outreach and education programs for bats.

Obtaining basic information on distribution, abundance, and ecological requirements is one of the primary needs for bat conservation in Washington. This information will contribute to an improved understanding of the conservation needs for the 15 species of bats in the state. Addressing threats and maintaining healthy populations of bats will require cooperation and partnerships among government agencies, private resource management entities, non-governmental organizations, tribes, and the public. Partners can also work together to secure funding for implementing priority bat conservation strategies and tasks identified in the plan.

INTRODUCTION

Bats have long captured the imagination of humans in cultures around the world. With greater knowledge about bats and expanded education by conservation organizations and governments in recent decades, age old fears have begun to give way to increased public interest and fascination in bats, especially in North America. Bats are the primary vertebrate predators of night flying insects, including forest and agricultural pests, and therefore play essential functions in ecosystems and human economies (Boyles et al. 2011, Kunz et al. 2011). In North America, bats provide an estimated benefit of nearly $4 billion annually to the agricultural industry (Boyles et al. 2011). As such, bats may be sensitive indicators of ecosystem function and environmental threats (Jones et al. 2009). Bats also serve as prey for other vertebrates and as agents of nutrient transport from riparian to upland areas (Aubry et al. 2003).

Bats are one of the most diverse groups of mammals in Washington, with 15 species confirmed present in the state (Table 1). Despite the extensive distribution of bats in the state, much remains unknown about basic aspects of their status and ecology (Johnson and Cassidy 1997).

For all species, adequate information is lacking on ranges, population sizes and trends, characteristics of roosts and foraging habitat, seasonal behaviors, and factors limiting populations. The purpose of this document is to compile and summarize information on the biology of Washington's bats, discuss factors affecting bat populations, and identify management actions to conserve bat populations in the state.

The conservation plan is divided into three chapters: (1) Natural History and Status, (2) Species Accounts, and (3) Conservation Strategies and Tasks. Chapter 1 gives an overview of bat biology, habitat requirements, relationships to public health, legal and conservation status, conservation and management activities, and known or potential threats to bats. Chapter 2 provides individual accounts for each of the 15 bat species found in Washington, with information on identification, distribution and population status in the state, natural history, threats, and conservation measures. Chapter 3 provides a step-down outline of strategies and tasks needed to implement conservation and protection of bats in Washington.

Table 1. Bat species documented in Washington.

Species	**Scientific Name**
Big brown bat	*Eptesicus fuscus*
California myotis	*Myotis californicus*
Canyon bat	*Parastrellus hesperus*
Fringed myotis	*Myotis thysanodes*
Hoary bat	*Lasiurus cinereus*
Keen's myotis	*Myotis keenii*
Little brown myotis	*Myotis lucifugus*
Long-legged myotis	*Myotis volans*
Pallid bat	*Antrozous pallidus*
Silver-haired bat	*Lasionycteris noctivagans*
Spotted bat	*Euderma maculatum*
Townsend's big-eared bat	*Corynorhinus townsendii*
Western long-eared myotis	*Myotis evotis*
Western small-footed myotis	*Myotis ciliolabrum*
Yuma myotis	*Myotis yumanensis*

CHAPTER 1: NATURAL HISTORY AND STATUS

Bats belong to the order Chiroptera and have characteristics that make them unique among mammals. They are the only mammals capable of true flight, are second only to rodents (order Rodentia) in number of known species worldwide (about 1,230 species known as of 2011), and as a group have one of the widest geographical distributions among mammals (Hill and Smith 1984, van Zyll de Jong 1985, Findley 1993, Altringham 1996; N. Simmons, unpubl. data). Bats are found on every continent except Antarctica and occur on many isolated oceanic islands. There are 148 bat species in North America, with 47 species present in the U.S. (Simmons 2005) and 15 confirmed in Washington (Table 1). All bat species in Washington belong to the family Vespertilionidae, which is part of the suborder Microchiroptera. Microchiropterans in North America rely primarily on acoustic orientation and prey mainly on insects (Hill and Smith 1984, Altringham 1996).

NATURAL HISTORY

Reproduction and Longevity

Most North American bats mate between late summer and early winter before hibernation (Barbour and Davis 1969, Racey and Entwistle 2000, Cryan et al. 2012). In many species, adults of both sexes come together in "swarming flights" at the entrances of autumn roosts or hibernacula, where mating occurs (e.g., Thomas et al. 1979). Copulations also occur throughout winter when bats periodically arouse from hibernation. Mating involves little, if any, courtship behavior. Following mating and during winter, sperm are stored in the female reproductive tract. In most species, ovulation and fertilization are delayed until spring, after arousal from hibernation (Racey and Entwistle 2000). Gestation normally lasts 40-60 days, but can extend well beyond in a few species such as hoary bats (90 days) and Townsend's big-eared bats (up to 100 days).

Bat species in the Pacific Northwest produce one litter per year. Births normally occur in June or July when food abundance is highest, but can be earlier or later depending on the species, environmental conditions, and location. Cooler temperatures associated with higher elevations, higher latitude, or unfavorable spring weather can prolong pregnancies by up to a month or more because of females using torpor more frequently (Racey 1982, Grindal et al. 1992). Most species in Washington give birth to a single young, except for hoary bats (average litter size = 2, range = 1-4), canyon bats (litter size = 2), silver-haired bats (average litter size = 2, range = 1-2), and pallid bats (litter size = 2 in older females).

Newborns are about 20% of adult weight, naked, and pink-skinned (Kurta and Kunz 1987). After several days, their skin becomes pigmented, hair begins to grow, and the ears become sensitive to auditory stimuli. Young are dependent on their mother for care and nourishment. Females generally leave their young in the nursery roost while they forage. Juveniles usually can fly at 2.5 to 4 weeks of age and are weaned at 1 to 2 months of age. In most species found in Washington, some or most juvenile females and males are capable of breeding by their first autumn (e.g., O'Shea et al. 2010, Cryan et al. 2012).

Despite their small size, microchiropteran bats are relatively long-lived, with some species known to live 15 to more than 30 years of age (Tuttle and Stevenson 1982, Wilkinson and South 2002, Podlutsky et al. 2005). Accurate information on survival rates is lacking for most species. A number of survival studies conducted for North American bats in the 1960s and 1970s were biased by additive mortality associated with banding, band loss, or other problems, and were further hindered by inadequate statistical techniques (O'Shea et al. 2004, O'Donnell 2009). More recent studies using improved methods do however confirm earlier findings showing that annual survival rates are lower in juveniles (23-80%) than in adults (63-90%) (Tuttle and Stevenson 1982, Frick et al. 2007, 2010a, O'Shea et al. 2010, 2011).

Echolocation

Bats are able to be active at night and inside dark roosts because of their ability to echolocate. Echolocating animals process the echoes of their own emitted sound waves to find and identify objects in their immediate environment (Altringham 1996). Bats, whales, dolphins, and some shrews are among the species groups that use echolocation. Within bats, echolocation is found almost exclusively among microchiropterans. Bats use echolocation for navigation and to detect, classify, and capture prey (Altringham 1996, Schnitzler and Kalko 2001).

Most microchiropterans produce short pulses of sound separated by longer periods of silence (Arita and Fenton 1997). Bats generate their echolocation calls in the larynx and emit them through the mouth or nostrils. Large external ears allow bats to hear and localize the returning echoes. Most bats echolocate between 20 kHz and 120 kHz, which is above the range of human hearing (about 20 Hz up to 20 kHz). High frequency sounds have short wavelengths, which are best suited for detecting small objects such as insect prey, and don't travel far in air before becoming quiet, which may allow bats to avoid interfering with each other's echolocation.

The acoustical structure of bat echolocation calls is generally species-specific (Schnitzler and Kalko 1998), with considerable variation in absolute frequency, range of frequencies (bandwidth), harmonic structure, duration, and intensity (Neuweiler 1989, Fenton 1990). Within a species, variation in calls occur among individuals, populations, and geographic areas, as well as with the type of environment (open vs. cluttered) being used (Barclay 1999, O'Farrell et al. 1999a, 1999b).

A bat emits short pulses of sound, waits for the returning echoes, calculates the distance to a prey object, and then emits additional short pulses to track the movement of the prey. Its echolocation pulses undergo changes in structure as the bat transitions through the searching, approach, and terminal phases associated with prey capture. As a bat approaches its target, pulses become shorter to avoid pulse/echo overlap and the bandwidth increases to provide the bat with more detailed information on target position.

The echolocation calls of bats can be broadly categorized as consisting of broadband (= FM, frequency modulated) or narrowband (= CF, constant frequency) components, or combinations of these. A broadband FM pulse is a short downward sweep through multiple frequencies, whereas a narrowband CF pulse is longer in duration, and more or less constant in frequency. Broadband FM pulses are used to detect close objects and to avoid pulse/echo overlap. Narrowband CF pulses are of lower frequency and are used to detect objects farther away. Narrowband CF calls are good for detecting targets, but less well suited for localizing targets and discriminating their features. Broadband FM calls, however, are good for localization and recognition of targets, but less well suited for target detection. Because of this trade-off between detectability and accuracy of localization, most microchiropteran foraging calls include both broadband and narrowband components (Altringham 1996, Schnitzler and Kalko 2001).

Some bat species can be recognized by their echolocation characteristics (i.e., call frequency, duration, intensity, shape, and harmonics), but for others there is much overlap in call features, making identification uncertain. Much of the interpretation of bat calls has been based on their time-frequency character, but the recent availability of technology employing full-spectrum processing allows greater recognition of species-specific characteristics to determine identification. Modern bat detectors and software programs allow the recording, analysis, and identification of bat vocalizations, making them an important component of bat survey work.

Foraging Behavior and Diet

Foraging behavior. Insectivorous bats capture their prey aerially or by gleaning them from foliage, the ground, or the surface of water (Hill and Smith 1984). In many species, feeding activity is often most intense in the first 2-3 hours after sunset, continues in bouts throughout the night, and increases again for a short time just before sunrise. Individuals roost between foraging forays to rest and digest their prey. North American bats often concentrate their foraging efforts among trees in the forest canopy or above the canopy, along forest edges, over clearings or other open habitats, over lakes and streams, and along cliff faces. In the Pacific Northwest, bats forage in nearly all natural and human-created habitats (e.g., Whitaker et al. 1977, 1981a, Hayes and Gruver 2000, Waldien and Hayes 2001, Ober and Hayes 2008a, 2008b). The only habitats not used are probably high-elevation alpine areas with year-round snow cover and offshore marine waters.

Echolocation characteristics are an important factor affecting the foraging behavior of bats (Fenton 1982). Foraging bats must discriminate between echoes of prey and echoes of interfering objects, such as twigs and leaves, referred to as "clutter." Clutter conditions present both perceptual and mechanical challenges (Fenton 1990). Bats that forage in open areas with few obstacles experience different navigational challenges than bats foraging in areas with dense vegetation and large amounts of clutter. Generally, species that forage in cluttered habitats tend to possess lower intensity calls that are of short duration, high peak frequency, and cover a wide range of frequencies (Schnitzler and Kalko 1998, Lacki et al. 2007a). Those that feed in more open locations often have calls that are more intense, longer in duration, lower in frequency, and cover a narrower range of frequencies. Bat species that capture some of their prey by gleaning depend more on vision and hearing and less on echolocation for detecting prey (Bell 1985, Faure and Barclay 1992).

Foraging behavior and diet are also influenced by a number of physical features, including body weight and size, and shape of the wing, head, and teeth (Lacki et al. 2007a). Species with smaller heads and teeth typically feed on smaller or soft-bodied prey. Wing morphology, including the shape of the wing tip, aspect ratio (square of the wingspan length divided by the surface area of the wing), and wing loading (mass of the bat divided by its total wing area) affect the flight speed and maneuverability of bats (Norberg and Rayner 1987, Norberg 1990). Species with short broad wings and/or low wing loading are highly maneuverable and adept at flying in structurally cluttered environments like forest, whereas bats with higher wing loading and aspect ratios fly at faster speeds, are less maneuverable, and typically forage in more open, uncluttered areas, including above the forest canopy. Thus, co-occurring species often stratify their overlapping foraging areas.

Most of Washington's bat species have either moderate aspect ratios and low wing loading (e.g., fringed myotis, silver-haired bat, big brown bat, pallid bat) or low aspect ratios and moderate wing loading (e.g., Keen's myotis, western long-eared myotis, little brown myotis, Townsend's big-eared bat) (Lacki et al. 2007a). Two species (California myotis, long-legged myotis) have low aspect ratios and low wing loading, and only the hoary bat has a high aspect ratio and high wing loading.

Diet. All bat species in Washington are largely insectivorous. Insectivorous bats consume up to half or more of their body weight in insects and other arthropods each night (Hill and Smith 1984, Kurta et al. 1989, 1990, Kunz et al. 1995). Beetles (Coleoptera), moths (Lepidoptera), and flies (Diptera) are among the most widely eaten prey groups (Lacki et al. 2007a). Most North American bats are flexible in their prey selection and feed on multiple insect orders, although many can show moderate dietary specialization on certain insect prey in some localities (Lacki et al. 2007a).

At least 18 dietary studies of bats have been done in the Pacific Northwest. Most were conducted in Oregon (Whitaker et al. 1977, 1981a, 1981b, Henny et al. 1982, Verts et al. 1999, Ober and Hayes 2008a), British Columbia (Woodsworth 1981, Herd and Fenton 1983, Wai Ping and Fenton 1989, Brigham 1990, Brigham et al. 1992, Kellner and Harestad 2005, Burles et al. 2008, Rambaldini and Brigham 2011), or Idaho (Johnson et al. 2007, Lacki et al. 2007b). Only two minor diet studies have been completed thus far in Washington (Wunder et al. 1992, Rambaldini 2006). From this body of research, it is apparent that most bat species in the region are prey generalists, with the exception of Townsend's big-eared bats, spotted bats, and sometimes long-legged myotis, which mainly consume moths (Whitaker et al. 1977, 1981a, WBWG 2005, Lacki et al. 2007a, Ober and Hayes 2008a). Among the generalist species, hoary bats, western long-eared myotis, fringed myotis, and big brown bats forage primarily on terrestrial-derived insects, whereas California myotis, little brown myotis, and Yuma myotis feed mainly on aquatic-related insects (Ober and Hayes 2008a).

Torpor

Temperate-zone bats, including all species found in Washington, are capable of greatly lowering their body temperature and metabolic rate, which allows them to become inactive during periods of harsh weather and food shortage. This physiological process is known as torpor (or heterothermy) and comes in two forms: hibernation and daily torpor. Hibernation extends for prolonged periods (i.e., multiple days or weeks) during the colder months of the year, whereas daily torpor lasts for hours and may be used on a daily basis during the active season (Altringham 1996, Geiser 2004, 2010, 2011, Willis 2006). During torpor, body temperature is reduced to near ambient temperature (but does not go below freezing), heart rate and respiration decrease greatly, metabolic rate falls to 5-30% of normal, and other physiological changes occur (Altringham 1996, Geiser 2004, 2010, 2011). Greater declines in body temperature and metabolic rate occur during hibernation than in daily torpor.

Use of torpor results in substantial energy savings for bats during unproductive foraging conditions (Altringham 1996, Willis 2006). It also allows bats to occupy certain habitats (e.g., arid areas, higher altitudes) or geographic regions (e.g., more northerly latitudes) that would otherwise be too harsh to inhabit (Bell et al. 1986, Chruszcz and Barclay 2002, Rambaldini and Brigham 2008). In maritime environments with mild winter conditions, such as the lowlands of western Washington, some bats may use daily torpor, intermittent hibernation, or possibly a combination of the two during winter and continue to forage on nights when insects are available (Falxa 2007a, Turbill and Geiser 2008).

Hibernation. Hibernation in North American bats lasts 3-7 months, usually beginning in October or November and extending until March or April. Declining food availability, rather than cold weather, appears to be the primary stimulus for entering hibernation (Geiser 2010). Bats must accumulate up to 40% of their summer weight in body fat before hibernating (e.g., Ewing et al. 1970, Kunz et al. 1998). This fat is then slowly metabolized for energy over the course of hibernation (Jonasson and Willis 2012). If stored fat is depleted before hibernation ends, it results in the death of the bat. Like all hibernating mammals, bats periodically arouse to warm themselves back to normal body temperatures and to reestablish other physiological functions for usually less than a day (Altringham 1996, Geiser 2004). Average time between arousals is typically 10-25 days, but can be more or less frequent depending on ambient temperatures (e.g., Brack and Twente 1985, Jonasson and Willis 2012). Arousals during hibernation are energetically costly and consume much of an animal's energy reserves (Thomas et al. 1990). During arousals, bats may remain inactive, change roost locations, drink, groom, mate, or forage outside the roost. In spring, warmer ambient temperatures trigger bats to end hibernation and become active (Hill and Smith 1984), although some bats (including pregnant females; Willis et al. 2006b) may resume short periods of hibernation if harsh weather is encountered.

Daily torpor. Bats may use daily torpor during day roosting or night roosting. How often it is used (daily or less often) depends on food availability, weather, roosting conditions, and the sex and reproductive status of the bats (Grinevitch et al. 1995, Geiser 2004, Willis 2006, Klug and Barclay 2013). Males and nonreproductive females in some species appear to use daily torpor more frequently than reproductive females (Hamilton and Barclay 1994, Grinevitch et al. 1995). Because of the energetic costs associated with arousal from daily torpor, males and nonreproductive females commonly seek day roosts with both cool microclimates during the morning and midday, and warmer conditions later in the day (Hamilton and Barclay 1994, Willis 2006, Rambaldini and Brigham 2008). These traits maximize energy savings in the bats by facilitating the use of deeper daily torpor during the cooler periods and enhancing passive rewarming as animals arouse before evening emergence. Males and nonreproductive females may also routinely reduce or forego foraging and enter torpor on cool nights when foraging is unproductive (Grinevitch et al. 1995).

In contrast, reproductive females must balance the energetic benefits of daily torpor against impacts to reproduction through reduced fetal and juvenile growth rates and lowered milk production (Tuttle 1976, Racey and Swift 1981, Audet and Fenton 1988, Lewis 1993). Studies indicate that reproductive females of most species employ daily torpor more frequently or for longer duration during pregnancy than when nursing (Audet and Fenton 1988, Grinevitch et al. 1995, Chruszcz and Barclay 2002, Lausen and Barclay 2006, Willis 2006). This may be due to the lower ambient temperatures, lower insect availability, and higher wing loading that females encounter during pregnancy. Reproductive females may choose different roost structures and roosting behavior (e.g., clustering) to meet their energy and safety needs, which influences their use of daily torpor (Hamilton and Barclay 1994, Chruszcz and Barclay 2002, Lausen and Barclay 2006, Willis et al. 2006a). Juveniles of some species also use torpor (e.g., hoary bats, Klug and Barclay 2013).

Roosting Behavior

Roosts provide many critical benefits to bats including: suitable locations for sleeping and rearing young; shelter from weather; protection from predators; energetic savings through improved thermoregulation and reduced commuting distances to feeding sites; and improved mating opportunities (Kunz 1982a, Altringham 1996). Roosting behavior varies with species, sex, season, and reproductive activity. Multiple species of bats sometimes share roosts (Kunz 1982a). Roosts can be broadly categorized as day roosts, night roosts, and hibernacula.

Day roosts. Bats use day roosts during daylight hours in spring, summer, fall, and, in some locations, winter. Most species occurring in Washington use a variety of structures as day roosts, which can include caves, mines, buildings, bridges, bat houses, crevices or cavities in rocks and trees, space beneath loose tree bark and tree branches, and the foliage of trees (Kunz 1982a, Hayes 2003). Day roosts of hoary are almost exclusively in trees.

Most of the state's bat species segregate by sex and reproductive status when day roosting during the warmer months. Reproductive females often establish communal day roosts, known as maternity or nursery colonies, where young are born and cared for. These females have different physiological needs than males and nonreproductive females due to the demands of pregnancy and nursing (Altringham 1996, Chruszcz and Barclay 2002, Lausen and Barclay 2003). Maternity roosts are therefore often in warm locations, which promote fetal development and the growth of young, and reduce thermoregulatory costs. The large number of individuals in some maternity colonies can also raise roost temperatures to levels more desirable for raising young. In some species, females and their young roost in tight clusters to conserve energy. Warm roost conditions also benefit juveniles left alone at night that are too young to sufficiently thermoregulate on their own.

Most known maternity colonies in Washington contain a few to several hundred adult females, although a few hold as many as 1,500-4,100 adult females (WDFW WSDM database). Hoary bats and possibly spotted bats are the only species in which all reproductive females roost solitarily. Depending on species and location, maternity colonies in the Pacific Northwest usually form in April or May and disband in August or September, but occupation of sites can begin as early as late March or extend until October in a few species. Males and non-reproductive females of most species roost singly or in small groups during the day, but may sometimes join maternity colonies.

The terms "transient roost" and "interim roost" are sometimes applied to day roosts that are temporarily occupied in spring or fall as bats move between summer roosts and hibernacula (Dobkin et al. 1995). "Migratory roosts" are those used by species migrating between their summer and winter ranges (Sherwin et al. 2009).

Night roosts. Night roosts are used nocturnally between bouts of foraging and usually are located away from day roosts. Most are occupied for relatively short periods of time ranging from less than a minute to a few hours. Night roosts allow bats to rest, save energy (especially on nights of low foraging success), digest, find protection from poor weather and predators, socialize with other individuals, and possibly learn the locations of prey-rich feeding sites from roost mates (Kunz 1982a, Hayes 2003, Ormsbee et al. 2007). Some species (e.g., pallid bats, Townsend's big-eared bat) also visit night roosts to consume prey. Conservation of energy at night roosts is achieved through the use of torpor, clustering with roost mates, or selection of sites with warmer ambient temperatures.

Mines, caves, buildings, trees, tree hollows, rock crevices, bridges, and shrubs are among the most common types of night roosts (Lewis 1994, Perlmeter 1996, Pierson et al. 1996, Adam and Hayes 2000, Hayes 2003, Ormsbee et al. 2007). In the Pacific Northwest, group sizes of one to nearly 300 bats and multi-species aggregations have been reported at night roosts (Perlmeter 1996, Adam and Hayes 2000). Males of some species generally roost solitarily at night roosts, whereas females roost in clusters or alone (Perlmeter 1996). Reproductive condition can influence the use of these roosts (Barclay 1982, Perlmeter 1996).

Hibernacula and other winter roosts. Hibernacula are roosts that are used for hibernation during fall, winter, and early spring. Caves, lava tubes, mines, rock crevices, and buildings are commonly occupied locations (Kunz 1982a, Hayes 2003, Sherwin et al. 2009). Relatively limited information is available on the winter roosting habits of most bat species in the Pacific Northwest. In eastern North America, some species gather in huge numbers (thousands to hundreds of thousands) at hibernacula, but in the Pacific Northwest, bats generally appear to hibernate alone or in small groups of fewer than 25 bats (e.g., Senger et al. 1974, Perkins et al. 1990, Nagorsen and Brigham 1993, Hendricks 2012). In Washington, the largest known wintering aggregations – about 300 bats – involve Townsend's big-eared bat (WDFW WSDM database). The region's small groups of hibernating bats do not account for the much larger numbers of bats present in summer. One explanation for this is that many species may rely predominantly on undiscovered hibernation sites in rock crevices, caves, and trees at higher elevations (Barclay 1991, Cryan et al. 2000, Neubaum et al. 2006).

Both sexes hibernate together because of similar thermoregulatory strategies at this time of the year. Some species (e.g., Townsend's big-eared bat, long-legged myotis) commonly hibernate in tightly packed clusters to conserve body energy (Adler 1977, Perkins et al. 1990). During hibernation, bats occasionally shift locations within a roost or move to a different roost to seek suitable temperatures or to avoid disturbance (e.g., Pearson et al. 1952, Adler 1977).

In parts of Washington with mild winter conditions, such as the Puget Sound lowlands, California myotis, silver-haired bats, and perhaps other species regularly emerge to forage at night, switch roosts, or possibly drink (Nagorsen and Brigham 1993, Hayes 2003, Falxa 2007a; G. Green, pers. comm.). These bats presumably use daily torpor during parts of the winter rather than hibernation, and their winter roosts may resemble summer roosts. In Spokane County, the echolocation calls of California myotis and silver-haired bats have been recorded throughout winter on warmer nights, although activity levels are much lower than in summer (N. Williams, pers. comm.).

Roost site fidelity and roost switching. Bats return to or change roost sites for a number of reasons. These relate to the availability and permanence of roosts, changes in microclimate within roosts, changes in food availability, disturbance, predation, maintenance of cohesive social groups, and avoidance of ectoparasites (Kunz 1982a, Lewis 1995). Sex, age, reproductive status, season, and social organization can also influence roost fidelity. Fidelity to specific roost locations is often higher during the maternity period for reproductive females and during winter for hibernating bats. Bats occupying more permanent structures, such as caves, mines, buildings, and tree cavities, typically remain at these types of sites for periods of weeks or months before changing to another roost and often return to the same locations year after year. In contrast, bats using tree bark, foliage, and crevices in trees and rocks may switch sites every one to several days (e.g., Lausen and Barclay 2002, Willis and Brigham 2004, Baker and Lacki 2006, Lacki and Baker 2007, Barclay and Kurta 2007, Arnett and Hayes 2009, Nixon et al. 2009). Bats in less stable roosts commonly exhibit fidelity to a general area rather than specific roosts (Lewis 1995, Mattson et al. 1996, Ormsbee 1996, Barclay and Kurta 2007). Both patterns may be present within a species.

Movements and Migration

Nightly movements. Considerable variation exists in the nightly movements of different insectivorous bat species, as well as within species, depending on proximity of foraging habitat, sex, season, and reproductive condition (Fellers and Pierson 2002). Radio-tracking studies reveal that most North American bats move relatively short distances (generally 0.5-10 km) between day roosts and foraging areas, although some species may commute considerably farther (e.g., spotted bats, up to 39 km, Rabe et al. 1998b; Yuma myotis, up to 13 km, Falxa 2008b). Reproductive females typically return to maternity roosts to nurse their young one or more times per night and therefore may forage closer to their day roosts than males and females without young. Bats may travel directly to foraging sites without feeding along the way and may follow similar commuting routes night after night (e.g., Falxa 2007b, Hillen et al. 2010). Bats demonstrate fidelity between years to their annual home ranges and to core areas within home ranges (Hillen et al. 2009, Perry 2011), suggesting there are benefits to foraging or drinking in familiar areas.

Seasonal migration. Many North American bat species migrate between wintering and summering areas in response to seasonal changes in food availability (Fenton 1997, Fleming and Eby 2003, Cryan and Veilleux 2007). In most of these species, movements of this type cover relatively small distances ranging from tens of kilometers to more than 500 km (e.g., Norquay et al. 2013). In the West, migration of this type often involves elevation changes as bats seek areas with suitable temperatures for hibernating, raising young, or conserving energy through daily torpor. Thus, reproductive females commonly move from cold hibernacula to lower elevations with warmer temperatures during spring and summer, whereas males and non-reproductive females may move from hibernacula to higher elevations during this time of year to enhance their use of daily torpor (Hill and Smith 1984, Barclay 1991, Grindal et al. 1999, Cryan et al. 2000, Neubaum et al. 2006). The extent of short-distance migration movements among bats in the Pacific Northwest is unknown because no studies of seasonal movements have been conducted.

Hoary bats and silver-haired bats are generally considered to be long-distance migrants because they undertake continent-wide migration movements of several thousand kilometers or more, although the details of timing and routes of migration and locations of winter habitat are poorly known (Cryan 2003). The greatest wintering concentrations of hoary bats occur in southern California and Mexico, with sizable numbers also present in the eastern U.S. and smaller numbers elsewhere on the continent (Shump and Shump 1982a, Cryan 2003, Cryan and Veilleux 2007). During spring, large numbers of hoary bats move through the southwestern states and northern Mexico on their way to summer ranges in more northerly regions. Females wintering in California appear to disperse primarily to eastern North America in summer, whereas most males over-summer in western North America (Cryan 2003). Silver-haired bats spend the winter in the mid-latitude eastern states, Pacific Northwest, and Southwest (Cryan 2003, Cryan and Veilleux 2007). In the eastern U.S. during spring, dispersal from wintering sites is northward and eastward toward summering sites, whereas in the western U.S., spring migration is northward. Some males appear to remain in parts of their winter range as females disperse northward. During late summer and early fall, the sexes overlap as females move south, and as fall progresses the ranges of both sexes continue to shift south (Cryan 2003). Captures of hoary bats and silver-haired bats during winter months at some northern latitudes indicates that some individuals do not migrate or that migrations are overlapping north-south shifts (Dalquest 1938, Nagorsen et al. 1993, Verts and Carraway 1998).

Some bat populations in Washington appear to reside year-round in one area and thus do not migrate. This includes some species using lowland areas of Washington as well as other species that hibernate in their summering areas.

HABITAT REQUIREMENTS

Roosting Habitat

Roost sites are a crucial habitat requirement and often a limiting resource for bats, and are therefore a primary factor affecting the localized diversity of bat faunas and abundance of species. Bats occupy a variety of roost structures to meet their daily and seasonal needs. Roosting can occur in cavernous structures, such as caves, mines, and buildings; in and under bridges; in crevices of rocks, trees, and under loose bark; and in tree hollows and foliage (Table 2). Because of the different physiological requirements associated with pregnancy and rearing young, reproductive females often select different roost types and microclimates than males and nonreproductive females (Altringham 1996, Chruszcz and Barclay 2002, Lausen and Barclay 2003, Barclay and Kurta 2007). Proximity to foraging sites and water and levels of human disturbance are among the many other factors influencing roost selection in bats. Many bat species demonstrate strong fidelity to their roosts, especially those located in caves, mines, buildings, and tree cavities, indicating the importance of such sites for raising young, maintaining social contacts, and offering suitable conditions for hibernation (Kunz 1982a, Lewis 1995).

Female bats of many species generally prefer ambient roost temperatures between 21-32°C (70-90°F) for raising young, although Townsend's big-eared bats can use sites averaging as low as 15.7°C (60°F) (Reid et al. 2010). Hibernacula temperatures of vespertilionid bats in winter typically occur between 1-11°C (32-52°F), although temperatures several degrees below 0°C (about 27°F) may be tolerated for short periods by some species (Webb et al. 1996). Some bat species, such as those found in milder coastal areas where foraging and hibernation may be interspersed, occupy warmer hibernacula with temperatures reaching 15°C (59°F) or more (Pierson 1988, Webb et al. 1996). High humidity levels are another desirable feature of hibernacula and help prevent dehydration in roosting bats (Altringham 1996).

<u>Caves and Mines</u>

In many parts of North America, caves and mines are used by bats for hibernation and raising young, as well as for night and transient roosts (Barbour and Davis 1969, van Zyll de Jong 1985). Fourteen of the 15 bat species in Washington have been found using caves and mines for roosting during some part of their annual cycle (Table 2). In the Pacific Northwest, Townsend's big-eared bats comprise most of the bats found in caves and mines. However, their colonies are small (in the low hundreds) relative to those of other species occupying caves elsewhere in North America, which can reach in the thousands or tens of thousands. For species such as Townsend's big-eared bat, a population may use a cave complex that includes hibernacula, spring and fall staging sites, and maternity roosts (Senger and Crawford 1984, Dobkin et al. 1995, Tuttle and Taylor 1998).

Caves and mines vary greatly in size and spatial complexity (Figure 1). Many are relatively simple, with a single entrance and only one or a few rooms, or chambers, laid out on a single level (Halliday 1963, Sherwin et al. 2009). Others are considerably

Figure 1. Entrance of a cave used by bats in Washington (photo by Theresa Baker).

Table 2. Types of roosts used by bat species found in Washington (adapted from Hayes 2003).

Species	Roost structure: Caves and mines	Cliffs, talus, and boulders	Buildings and bridges	Trees
Big brown bat	X	X	X	X
California myotis	X	X	X	X
Canyon bat	X	X	X	
Fringed myotis	X	X	X	X
Hoary bat				X
Keen's myotis	X	X	X	X
Little brown myotis	X	X	X	X
Long-legged myotis	X	X	X	X
Pallid bat	X	X	X	X
Silver-haired bat			X	X
Spotted bat	X	X	X	
Townsend's big-eared bat	X	X	X	X
Western long-eared myotis	X	X	X	X
Western small-footed myotis	X	X	X	X
Yuma myotis	X	X	X	X

more complex with more than one entrance and numerous rooms, tunnels, shafts, and cracks on multiple levels. Only a fraction of available caves and mines provide suitable microclimates for bat occupancy during different stages of the annual cycle (Tuttle and Taylor 1998). Size, configuration, and complexity of the cave or mine influence microclimate by affecting airflow, air temperature, and humidity (Altringham 1996, Tuttle and Taylor 1998, Sherwin et al. 2009). Differences in internal and external air temperatures and barometric pressure determine airflow, which may change daily and seasonally through an underground structure (Doering 1996, Sherwin et al. 2009). Dense, cool air sinks and light, warm air rises, which can result in cool air pockets in lower sections of caves and mines and warm air pockets at higher locations. Chimney-effect air movement may also occur in caves or mines with two or more entrances existing at different elevations (Sherwin et al. 2009).

There are an estimated 400 caves in Washington (J. Nieland, pers. comm.), some of which are described in Halliday (1963). Six types of caves occur in the state: lava tube, erosional, limestone, littoral, talus, and glacial (Halliday 1963, WDFW 1994). Most of Washington's caves are lava tubes formed of pahoehoe basalt or solution caves formed in limestone (Halliday 1963). Most lava and erosional caves are found in the Mt. St. Helens and Mt. Adams areas of Skamania County (see Appendix B for a map of Washington counties). Limestone caves primarily occur in the San Juan Islands, the northern and central Cascades (mainly King, Skagit, and Whatcom counties), and the Okanogan Highlands. Littoral caves are created by tidal action and are mostly present along the northern outer coast and Strait of Juan de Fuca. Talus caves occur throughout mountainous and hilly areas of Washington. Glacial caves are rare in the state and occur only on mountain glaciers. Many counties in Washington have few or no caves (Halliday 1963).

Mines may be especially important to bats in areas without caves. An estimated 3,400 underground mines exist in Washington (McFaul et al. 2000, Fleckenstein 2002), located primarily in the Cascades and Okanogan Highlands. Nearly 50 of these are known to support bats (WDFW WSDM database), but the vast majority remain unsurveyed (Fleckenstein 2002; J. Fleckenstein, pers. comm.). The Geology and Earth Resources Division of the Washington Department of Natural Resources, in conjunction with the U.S. Environmental Protection Agency, U.S. Forest Service, Bureau of Land Management, and Bat Conservation International, has produced a database and GIS coverage of mines for use in surveys to assess human hazards and bat habitat.

Cliffs, Talus, and Boulders

Nearly all of the bat species found in Washington roost at least occasionally in crevices between rocks, such as in talus at the base of cliffs or in horizontal or vertical rock fractures on cliff faces (Table 2). Temperature, access by predators, and proximity to foraging habitat and water are some of the factors determining the selection of roosts in rock crevices (Altringham 1996, Rancourt et al. 2005). Relatively few studies have focused on the ecology of bats occupying crevices because their tendency to roost in small groups makes detection difficult.

Crevice roosting has been fairly well described for reproductive female western long-eared myotis in the Channeled Scablands of eastern Washington (Rancourt et al. 2005) and parts of Alberta (Chruszcz and Barclay 2002), for fringed myotis in the eastern Cascades of Washington and Oregon (Lacki and Baker 2007), for pallid bats in Oregon (Lewis 1996), and for big brown bats in Alberta (Lausen and Barclay 2002). In most of these locations, crevice selection was potentially based on microclimate differences, with avoidance of predators being a possible factor at some sites. In Colorado, big brown bats of both sexes use rock crevices as autumn roosts and presumably hibernacula (Neubaum et al. 2006). Higher entrance heights above the ground and microclimate were important traits in selection of crevice roosts in this region, with deeper crevices providing more stable conditions. Two other species occurring in Washington, spotted bats and canyon bats, also roost extensively in crevices (Wilson and Ruff 1999, WBWG 2005, Luce and Keinath 2007).

Buildings and Bridges

Fourteen of the 15 bat species present in Washington are known to roost in buildings or under bridges (Table 2). Both types of structures substitute for natural roosts found in trees and caves. The construction of buildings in North America during the past few centuries has allowed a few bat species to increase in number and distribution (Kunz and Reynolds 2004).

Buildings. Houses, garages, barns, churches, and other buildings provide a range of suitable roosting conditions for many bat species (Kunz and Reynolds 2004). Buildings serve as maternity roosts, night roosts, and transient roosts, but are used less often as hibernacula. The exteriors of buildings offer many potential roost sites, including the spaces beneath tile, corrugated metal, wood shingles, shutters, and other trimming; inside crevices behind wooden siding, bricks, and stones; underneath eves and porches; and inside chimneys. Internal roost sites include attics, walls, inside insulation, and underneath floor boards. Internal roosts are usually accessed through gaps as narrow as 0.4 in (9.5 mm) or holes as small as 0.7 in (1.8 cm) in diameter in a building's exterior (Greenhall 1982). Older buildings are especially attractive to bats because they often possess many entry points. Bat colonies in buildings are eventually displaced over time as structures are renovated, demolished, or deteriorate (Kunz and Reynolds 2004). In Washington, big brown bats, Townsend's big-eared bats, little brown myotis, Yuma myotis, California myotis, silver-haired bats, and western long-eared myotis are among the species that most commonly use buildings as roost sites (Wunder et al. 1992; G. Falxa, pers. comm.; H. Ferguson, pers. comm.).

Bridges. Bats use bridges as day roosts (including maternity sites), night roosts during summer, and hibernation sites (Keeley and Tuttle 1999). Bridges of all types are used, but large concrete bridges are particularly effective in offering the desirable microclimates and protection from predators that bats seek. Large concrete bridges provide a thermal buffering effect and shelter from winds, with stable, cooler temperatures during the day relative to ambient temperature and stable, warmer temperatures during the night (Perlmeter 1996, Pierson et al. 1996, Keeley and Tuttle 1999). Wooden bridges Usually receive low use by bats, perhaps because they are frequently coated with creosote, an oily liquid with a pungent odor. Metal bridges do not provide suitable temperatures for bats and, as a result, are not often used. Bridges of all types can be retrofitted with artificial roost structures to accommodate bats (Keeley and Tuttle 1999, Arnett and Hayes 2000).

During the day, bats will roost in the expansion joints and other crevices of bridges (Keeley and Tuttle 1999). Characteristics of bridges used during the day are: 1) full sun exposure during most of the day, 2) concrete construction, 3) vertical crevices 1.3-3 cm (0.5–1.25 in) wide and 30 cm (12 in) deep to promote bat entry, 4) sealing at the top to prevent rainwater seepage, 5) roost heights of >3.0 m (>10 ft) above the ground, and 6) placement over water or roads with less traffic. In some locations, parallel box beam bridges are most preferred as day roosts, with concrete cast-in-place and pre-stressed concrete girder span bridges also favored (Keeley and Tuttle 1999). In Washington, parallel box beam bridges made of steel are usually avoided (M. MacDonald, pers. comm.).

Bats commonly select night roosts under bridges during spring, summer, and fall (Perlmeter 1996, Pierson et al. 1996, Adam and Hayes 2000, Ormsbee et al. 2007). Bridges made of pre-stressed concrete girder spans, cast-in-place spans, and steel I-beams are most often used for this purpose (Keeley and Tuttle 1999, Adam and Hayes 2000). Large bridges with chambers underneath are preferred for night roosts, probably because these provide more space for roosting and better access, retain more heat from daytime solar radiation, and offer better protection from predators (Pierson et al. 1996, Keeley and Tuttle 1999, Adam and Hayes 2000). Bats typically roost on the vertical concrete surfaces and corners located between beams, where there is better protection from airflow and heat loss, and generally make minor use of or avoid wooden and flat-bottom bridges (Adam and Hayes 2000). Center chambers near the ends of bridges are often used more than mid-span chambers for night roosting (Adam and Hayes 2000; M. MacDonald, pers. comm.).

In Washington, Fursman and Aluzas (2005) documented bats day roosting under 19 of 83 bridges in Olympic National Forest, most of which were used by one or several Townsend's big-eared bats. Other examples of bridge use in the state include a highway bridge used as a maternity roost by big brown bats (M. MacDonald, pers. comm.), several highway bridges used as maternity roosts by Yuma myotis in eastern Washington (H. Ferguson, pers. comm.), an old abandoned wooden railroad trestle over water used as maternity roosts by a combined colony of Yuma myotis and little brown myotis (Falxa 2007b, 2008b), and various bridges used as night roosts (Perkins 1988, Perkins and Peterson 1996, Keeley and Tuttle 1999, Fursman and Aluzas 2005; M. MacDonald, pers. comm.) and winter roosts (G. Falxa, pers. comm.). Pallid bats make frequent use of bridges as night roosts in eastern Washington (J. Fleckenstein, pers. comm.).

<u>Trees</u>

Thirteen of the 15 bat species found in Washington make widespread use of cavities, crevices, and foliage in trees or tree snags as day, night, or winter roosts (Table 2, Figure 2). Recent advances in radio transmitter technology have resulted in much improved knowledge of the roost selection of tree-dwelling bats in the Pacific Northwest (Hayes 2003, Barclay and Kurta 2007).

As day roosts for bats, tree crevices and cavities provide protection from predators and adverse weather and suitable microclimates for resting and maternity sites (Kunz 1982a, Kunz and Lumsden 2003). Crevices beneath loose bark can be efficient in trapping heat and offer large spaces for rearing young, whereas cavities provide more stable temperatures and humidity. Crevices used by bats are typically beneath sloughing tree bark or exist as cracks or breaks in tree trunks and limbs (e.g., Mattson et al. 1996, Brigham et al. 1997, Rabe et al. 1998a, Weller and Zabel 2001, Rancourt et al. 2007, Vonhof and Gwilliam 2007). Woodpecker abundance and excavation preferences are often important factors in the creation of cavities for bats (Kalcounis and Hecker 1996, Mattson et al. 1996, Vonhof and Barclay 1996, Betts 1998a, Kalcounis and Brigham 1998, Rancourt et al. 2007). Roost

Figure 2. A snag occupied by bats in Washington (photo by Michael Baker).

cavities also commonly occur as broken tops in trees (Betts 1996, Campbell et al. 1996, Waldien et al. 2000, Weller and Zabel 2001), exist as naturally formed cavities (Vonhof and Barclay 1996, Kalcounis and Brigham 1998), or occur as basal hollows in large trees (Gellman and Zielinski 1996, Ormsbee 1996). Evidence is lacking on whether deep fissures in the bark of old trees are also widely occupied (Hayes 2003). Many studies have found snags to be particularly favored as roosts (Table 3). At least one species, the western long-eared myotis, regularly roosts in the crevices of stumps (Vonhof and Barclay 1997, Waldien et al. 2000). Hoary bats use the foliage of trees almost exclusively as day roosts (Shump and Shump 1982a, Willis and Brigham 2005).

Trees, snags, tree hollows, and large logs (particularly those over streams) are probably common night roosts (Ormsbee et al. 2007). Little information is available on the extent of use, typical types, and locations of tree roosts used in fall, winter, and spring in the Pacific Northwest, although some bats have been observed hibernating under the bark of conifers (Nagorsen et al. 1993). Additional studies are needed to clarify the extent of tree use by bats during these seasons. Tree hollows may provide important hibernacula or other winter roosts for bats in some areas (Gellman and Zielinski 1996).

Tree size, height, and decadence. Snags and trees used by crevice- and cavity-roosting bats in western forests are generally large in diameter (≥50 cm), height (≥18 m), or both, and in the early to intermediate stages of decay (Table 3 and references within; Hayes 2003, Kalcounis-Rüppell et al. 2005, Barclay and Kurta 2007, Arnett and Hayes 2009, Lacki et al. 2010). Trees and snags used as day roosts are often taller than the surrounding tree canopy (e.g., Brigham et al. 1997, Betts 1998a, Ormsbee and McComb 1998, Weller and Zabel 2001) or occur in forest gaps, along forest edges, or in areas with low tree canopy cover where there is reduced vegetative clutter near entrances to roosts (e.g., Campbell et al. 1996, Vonhof and Barclay 1996, Brigham et al. 1997, Waldien et al. 2000).

Large trees may be selected as roost sites because they provide more roosting options and bigger cavities or greater space beneath bark, or because their occurrence in open areas or extension above the forest canopy perhaps makes them more easily detected, easier to access, gives them a warmer microclimate due to greater solar heating, or minimizes predation risk from ground predators (Vonhof and Barclay 1996, Betts 1998a, Crampton and Barclay 1998, Barclay and Kurta 2007, Vonhof and Gwilliam 2007, Lacki et al. 2010). Roost locations in more open locations may be important for young bats learning to fly (Campbell et al. 1996). Vonhof and Barclay (1996) reported a positive correlation between tree height and height of bat roost entrances.

Size of the roost site may also influence colony size. Cavity volume in roost trees is positively correlated with emergence counts of reproductive female big brown bats (Willis et al. 2006a). Baker and Lacki (2006) found that larger colonies of long-legged myotis occupied larger-diameter snags (82.3 ± 3.6 [SE] cm in dbh) than smaller colonies (60.9 ± 1.9 cm) and random snags (54.0 ± 1.7 cm). Roost trees/snags used by larger colonies also retained more total bark and exfoliating bark and were taller than those of smaller colonies and random snags in the forest patch.

As with foliage-roosting bat species in eastern North America, which frequently select tall, large-diameter trees (Menzel et al. 1998, Hutchinson and Lacki 2000), hoary bats in the West may also prefer roosting in large trees. Perkins and Cross (1988) captured hoary bats only in mature and old-growth forests of southwestern Oregon and suggested that the crown structure of old trees may be most suitable for this species. However, in Saskatchewan, hoary bats roost in trees that are typically equal in height to the surrounding forest canopy (Willis and Brigham 2005).

Tree species. Tree-dwelling bats roost in many tree species across the West, but often make greater use of one or several primary species at particular locations (Table 3 and references within; Hayes 2003, Barclay and Kurta 2007). Geographic variation of this type is demonstrated by big brown bats. At Turnbull National Wildlife Refuge in northeastern Washington, they roost mostly in ponderosa pine (*Pinus ponderosa*) but also in quaking aspen (*Populus tremuloides*; Rancourt et al. 2007); in coastal Oregon, they use mostly Douglas-fir (*Pseudotsuga menziesii*; Arnett and Hayes 2009); at two locations in southern British Columbia, they roost in ponderosa pine (Brigham 1991) or primarily in aspen (Vonhof and Gwilliam 2007); in southwestern Saskatchewan, they occupy only aspen (Kalcounis and Brigham 1998); and in northern Arizona, they use only ponderosa pine (Rabe et al. 1998a). Tree species selection may vary with availability, as well as a bat's sex and reproductive status.

The species of a tree appears to be important only as it relates to decay characteristics, which affect both the amount of loose bark present and formation of cavities through natural processes or excavation by birds, and the presence of trunk furrows. As the primary excavators of cavities used by bats, woodpeckers generally prefer trees with decayed heartwood but relatively hard sapwood (Harestad and Keisker 1989, Lundquist and Mariani 1991).

Influence of microclimate on roost selection. As with other types of roosts, microclimate appears to play a major role in the selection of tree roosts by bats because of its influence on thermoregulation (Hayes 2003, Barclay and Kurta 2007). Thus, reproductive females seek warmer sites that promote optimal growth of fetuses and young, whereas males and nonreproductive females generally occupy cooler roosts that enhance the use of torpor for maximum energy savings (Barclay and Kurta 2007). For most bat species, roost trees that are taller than the surrounding forest canopy or occur in canopy gaps, along forest edges, or in areas of reduced forest cover likely provide warmer roost temperatures due to increased exposure to sunlight compared to smaller trees in closed forest (Campbell et al. 1996, Vonhof and Barclay 1996, 1997, Brigham et al. 1997, Frazier 1997, Betts 1998a, Ormsbee and McComb 1998, Waldien et al. 2000, Weller and Zabel 2001, Barclay and Kurta 2007). In contrast, the stump roosts of western long-eared myotis in clearcuts have intermediate temperatures that appear to offer some of the benefits of solar warming while avoiding the risk of heat stress (Vonhof and Barclay 1997).

Temperatures of tree roosts can be affected by other factors as well. Several studies have reported cavity openings of maternity and solitary bat roosts being located more frequently on the south side of tree trunks, where solar exposure is greater (Mattson et al. 1996, Vonhof and Barclay 1997, Kalcounis and Brigham 1998, Rancourt et al. 2007). Bats may select roost trees in the early stages of decay because firm wood is a better insulator than rotten wood. Live and newly dead trees retain most of their bark, which also helps maintain suitable temperatures (Crampton and Barclay 1998). Vonhof and Barclay (1997) reported that western long-eared myotis often roosted under the loose bark of stumps blackened by fire, which appeared to enhance solar warming. Baker and Lacki (2006) found nursing female long-legged myotis roosting more often in snags with thick bark, which probably offer better insulation and more stable temperatures than thin-bark roosts. Among foliage-roosting hoary bats, reproductive females consistently roost at southward-facing locations that provide increased sun exposure and greater protection from wind (Willis and Brigham 2005, Klug et al. 2012).

Roost site distribution and numbers. Tree-roosting bats routinely travel up to several hundred meters when switching between day roosts, but

Table 3. Characteristics of trees used as day roosts by bat species in western forests (modified from Hayes 2003).

Species	Primary roost structure	Diameter (cm) Mean (SD)	Diameter (cm) Range	Height (m) Mean (SD)	Height (m) Range	Primary decay stage	N[a]	Source[b]
Big-brown bat	Live ponderosa pine or snags	76.3 (12.2)	-	18.0 (6.5)	-	-	7	2
	Quaking aspen snags	49.0 (15.6)	-	29.4 (9.0)	-	Early	46	14
	Douglas-fir snags	121.6 (42.8)	-	24.3 (9.1)	-	-	42	15
	Live ponderosa pine	53.4 (-)	-	18.3 (-)	-	Intermediate, late	34	16
California myotis	Conifer snags	56.0 (16.8)	-	27.0 (7.9)	-	Intermediate	19	3
	Douglas-fir snags	55.8 (14.2)	-	29.3 (6.7)	-	Intermediate	20	14
Fringed myotis	Douglas-fir snags	120.8 (24.9)	58.5-167.0	40.5 (13.6)	15.8-57.5	Intermediate	23	6
Hoary bat	Live white spruce	43.5 (11.2)	-	21.6 (4.8)	-	-	19	22
	Live deciduous trees	43.0 (10.4)	-	16.1 (4.2)	-	-	19	23
Keen's myotis	Live western redcedar with defects, snags	106.5 (34.6)[c]	-	27.2 (-)[c]	-	Live with defects, early	62	12,13
	Western redcedar and western hemlock snags	65.6 (34.8)[d]	-	22.2 (-)[d]	-	Intermediate, late	24	12,13
Little brown myotis	Live quaking aspen	41.0 (-)	-	22.3 (-)	-	Early	16	17
Long-legged myotis	Douglas-fir snags	100.0 (41.4)	34-172	40.0 (17.8)	13-72	Early, intermediate	40	8
	Douglas-fir snags	91.1 (49.2)	-	22.8 (9.2)	-	-	105	15
	Ponderosa pine and fir snags	64.0 (-)	-	27.4 (-)	-	Early, intermediate	192	7
	Grand fir snags	50.3 (20.5)	22.8-114.7	27.6 (10.3)	9.4-48.5	Loose bark	28	11
	Grand fir snags	35.2, 16.5[e]	-	71.1, 45.5[e]	-	Early, intermediate	31,33[e]	19
	Conifer snags	54.0 (12.8)	-	-	-	-	100	20
Pallid bat	Snags and live trees	104 (32), 109 (66)[f]	-	25 (13), 32 (13)[f]		-	4, 4[f]	21
Silver-haired bat	Ponderosa pine and grand fir snags	59.8 (14.2)	-	26.7 (7.8)	-	Early, intermediate	17	1,2
	Quaking aspen snags	40.0 (13.4)	-	23.7 (8.4)	-	Early, intermediate	46	14
	Ponderosa pine snags	39.0 (-)	13-63	14.2 (-)	3.7-24.1	Intermediate, late	39	4
	Conifer snags	47.0	20-74	-	6.9-61.5	Intermediate	15	9,10
	Live quaking aspen	42.5 (-)	-	22.1 (-)	-	Early	11	17
Western long-eared	Douglas-fir snags	93.0 (52.3)	-	34.0 (21.8)	-	Intermediate	20	5
myotis	Douglas-fir snags	62.4 (37.2)[c]	-	17.7 (10.8)[c]	-	-	24	15
	Douglas-fir snags	42.9 (35.2)[d]	-	14.6 (11.7)[d]	-	-	22	15
Multiple species[g]	Ponderosa pine snags	69.2, 66.0[e]	31.2-101.6	17.8, 18.8[e]	2.8-36.5	Loose bark	54, 43[e]	18

[a] Number of trees sampled.
[b] Sources: 1, Betts 1998a; 2, Betts 1996; 3, Brigham et al. 1997; 4, Mattson et al. 1996; 5, Waldien et al. 2000; 6, Weller and Zabel 2001; 7, Baker and Lacki 2006; 8, Ormsbee and McComb 1998; 9, Campbell et al. 1996; 10, Campbell 1993; 11, Frazier 1997; 12, Boland 2007; 13, Boland et al. 2009a; 14, Vonhof and Gwilliam 2007; 15, Arnett 2007; 16, Rancourt et al. 2007; 17, Crampton and Barclay 1998; 18, Rabe et al. 1998a; 19, Taylor 1999; 20, Johnson et al. 2007; 21, Baker et al. 2008; 22, Willis and Brigham 2005; 23, Klug et al. 2012.
[c] Females.
[d] Males.
[e] Values reported separately for two study areas.
[f] Values reported for snags and live trees, respectively.
[g] Results combined for pallid bats, big brown bats, Allen's big-eared bats (*Idionycteris phyllotis*), long-eared myotis, fringed myotis, long-legged myotis, and little brown myotis.

may go as far as several kilometers (Betts 1996, 1998b, Mattson et al. 1996, Ormsbee 1996, Vonhof and Barclay 1996, Brigham et al. 1997, Rabe et al. 1998a, Weller and Zabel 2001, Baker and Lacki 2006). Despite regular movements of this type, bats may demonstrate a high degree of fidelity to a set of tree roosts within an area, although use of individual snags declines in subsequent years as bark, cavities, and trunks are lost through ongoing decay (Barclay and Brigham 2001, Hayes 2003, Veilleux and Veilleux 2004, Barclay and Kurta 2007, Hillen et al. 2010, Lacki et al. 2012). Baker and Lacki (2006) noted that only half of the tree roosts used by large numbers of long-legged myotis in ponderosa pine forests in eastern Washington and Oregon were reused by bats the following year and that only a third were reused by large numbers of bats. Lacki et al. (2012) reported that less than half of all snags occupied by long-legged myotis in Washington remained standing after 3 years and that only 4.3% remained after 10 years.

The number of trees used by a bat or an entire maternity colony during a season has not been well documented in the West, but in eastern North America, numbers of 1-6 trees per bat and 8-25 trees per colony have been reported (Barclay and Kurta 2007). Numbers of tree roosts occupied varies with roost availability and the rates of switching and reuse within a species (Barclay and Kurta 2007). Baker and Lacki (2006) suggested that multiple roosts capable of housing large numbers of bats were required per watershed by colonies of female long-legged myotis in eastern Washington and eastern Oregon.

Influence of forest stand age and structure on roosting activity. Bats commonly roost in forest stands with higher snag densities, snag basal areas, or live tree basal areas (Campbell et al. 1996, Mattson et al. 1996, Rabe et al. 1998a, Waldien et al. 2000, Cryan et al. 2001, Weller and Zabel 2001, Kalcounis-Rüppell et al. 2005). For example, in ponderosa pine forests in eastern Washington and Oregon, large and small colonies of long-legged myotis roosted in stands with significantly greater snag densities (41.2 ± 15.4 [SE] and 42.7 ± 3.6 snags/ha, respectively) than random patches (16.6 ± 1.8 snags/ha) (Baker and Lacki 2006). Greater snag densities and basal areas of snags and live trees are commonly indicative of older forest stands (Betts 1998a, Crampton and Barclay 1998, Boland et al. 2009a). However, in western Oregon, Arnett and Hayes (2009) found considerable variation in the ages of forest stands used for roosting by three bat species, with big brown bats preferring 81-200-year-old stands, long-legged myotis preferring 41-80-year-old stands, and western long-eared myotis showing no preference. Taylor (1999) reported long-legged myotis using the most mature stands available at study sites in the southern Cascades of Washington. Nevertheless, bats sometimes occupy younger stands where suitable roost sites are present (Ormsbee and McComb 1998, Taylor 1999, Arnett and Hayes 2009).

In terms of stand structure, some studies have reported bats roosting in more open forest patches with lower tree density (Campbell et al. 1996, Vonhof and Barclay 1996, Brigham et al. 1997, Cryan et al. 2001, Kalcounis-Rüppell et al. 2005, Rancourt et al. 2007, Vonhof and Gwilliam 2007), while others have found bats roosting more often in areas of higher tree density (Mattson et al. 1996, Rabe et al. 1998a, Baker and Lacki 2006).

Influence of landscape characteristics on roosting activity. Proximity of tree roosts to foraging and drinking areas can reduce energy costs associated with commuting, particularly for reproductive females, which have higher energy demands than males and nonreproductive females. However, research has yielded differing results regarding the spatial relationships between day roosts and lakes, ponds, rivers, and streams, which are important feeding and drinking sites for bats in western coniferous forests. Some studies indicate that bats may choose day roosts closer to water (Gellman and Zielinski 1996, Ormsbee and McComb 1998, Rabe et al. 1998a, Weller and Zabel 2001, Kalcounis-Rüppell et al. 2005), whereas others have found no relationship (Betts 1998a, Waldien et al. 2000, Lacki et al. 2010) or negative relationships (Mattson et al. 1996, Rancourt et al. 2007). This caused Barclay and Kurta (2007) to conclude that the availability of suitable tree roosts was more important to bats than access to other resources.

Elevation may be another significant influence on roost selection by bats in some locations. In mountainous or hilly regions, studies have variously found a preference for roosting on higher slopes (Betts 1996, 1998a, Campbell et al. 1996, Mattson et al. 1996, Ormsbee and McComb 1998, Rabe et al. 1998a, Waldien et al. 2000) or lower slopes (Baker and Lacki 2006, Arnett and Hayes 2009). In watersheds dominated by ponderosa pine forests in the eastern Cascades of Washington and Oregon, pregnant long-legged myotis roosted about equally in upslope and riparian areas, whereas nursing females spent more time roosting in upslope locations (Baker and Lacki 2006).

Bat Houses and Other Artificial Roosts

A number of bat species are known to occupy artificial roosting structures made specifically for bats. These range in size from small bat houses mounted on the sides of buildings and tree trunks or atop single poles, and which typically hold small numbers of bats, to much larger free-standing "bat condos" that may be erected on utility poles and can house thousands of bats. Bat houses have become increasingly popular with the public since the 1980s, and are widely available for purchase or can be self-made using instructions provided by various conservation organizations and wildlife agencies. Many factors affect the likelihood of use of bat houses by bats, including placement, design, and construction (Kiser and Kiser 2004, Bats Northwest 2011). Bat houses that are poorly placed or improperly designed or built generally have low success in attracting bats. In Washington, bat houses are primarily used during the non-winter seasons, with the largest known colony totaling about 1,100 adult female Yuma myotis (in San Juan County; WDFW WSDM database). Although bat houses sometimes act as alternative roosts for bats evicted from buildings or other human-made structures, they should not be considered a primary mitigation measure for replacing the loss of natural roost sites. However, under some circumstances, artificial bat roosts may provide supplemental roosting opportunities for bats, including in forests (Mering and Chambers 2012).

Foraging and Commuting Habitat

Bats forage in nearly all of Washington's habitats, with the exception of high-elevation alpine areas with year-round snow cover and offshore marine waters. Use of particular foraging locations depends on a number of factors, including vegetation structure of the site; quality of the prey base, both in terms of insect abundance and distribution; and proximity to roost sites and water sources (Grindal and Brigham 1999, Hayes 2003, Hayes and Loeb 2007, Ober and Hayes 2008b). Bats often display complex and variable patterns of habitat use while foraging and commuting between sites (Hayes 2003), with a number of species being fairly broad in their selection (e.g., Johnson et al. 2007).

Wing and echolocation characteristics influence a bat species' ability to exploit different habitats and capture prey. Slow maneuverable species with short broad wings and low intensity echolocation usually prefer forest cover and avoid large openings, whereas faster flying and less maneuverable species with longer and narrower wings and louder calls forage more often in or above the upper forest canopy or in other open habitats (see Foraging Behavior and Diet).

Many bat species in North America concentrate their feeding and other activity near fresh water (especially in riparian areas) and along edge habitats, where insect availability is commonly high and there is less vegetational clutter than in forest (Lunde and Harestad 1986, Thomas 1988, Brigham 1991, Parker et al. 1996, Grindal and Brigham 1999, Grindal et al. 1999, Seidman and Zabel 2001, Waldien and Hayes 2001, Hogberg et al. 2002, Hayes 2003, Rogers et al. 2006, Ober and Hayes 2008a, 2008b, 2008c, Rosier 2008, Hagen and Sabo 2011). Overall activity is typically higher in open sites such as clearcuts, meadows, and forest gaps, than in dense forest (Brigham et al. 1992, Erickson 1993, Erickson and West 1996, Adams 1997, Grindal and Brigham 1998, Hayes 2003). Greater use of older forests than younger forests (i.e., those usually between 10 and 100 years old) has been widely reported (Perkins and Cross 1988, Thomas 1988, Parker et al. 1996, Crampton and Barclay 1998, Humes et al. 1999, Jung et al.

1999), although at least one study (involving long-legged myotis, which have broader echolocation capabilities) has reported extensive use of younger forests (Johnson et al. 2007). Greater use of older forest stands likely results, in part, from the greater availability of suitable roosts, especially large snags, whereas younger forests typically have more clutter and fewer available roosts (Perkins and Cross 1988, Thomas 1988, Thomas and West 1991, Crampton and Barclay 1998, Humes et al. 1999, Jung et al. 1999, Kalcounis et al. 1999). However, in some situations, thinning of younger forests can increase their use to levels comparable for old-growth forests (Humes et al. 1999). A number of forest-dwelling bat species also respond positively to the creation of early successional habitats caused by forest fires (Malison and Baxter 2010, Buchalski et al. 2013).

Bat activity also varies among vertical strata in forests, based in part on species differences in foraging behavior and flight characteristics (Bradshaw 1996, Jung et al. 1999, Kalcounis et al. 1999, Hayes and Gruver 2000). In an old-growth forest in western Washington, myotis bats were most active beneath the forest canopy, while larger bats (i.e., big brown bats, silver-haired bats, Townsend's big-eared bats, and hoary bats) used upper level vertical strata most frequently (Hayes and Gruver 2000). Vertical partitioning of habitat by bats suggests that multi-layered forest stands may provide greater foraging opportunities, which may partially account for higher levels of activity in old forests. In contrast, young stands with relatively simple vertical structure may not provide a diversity of foraging niches for bats. Levels of activity above the canopy have been variously reported as low in an old-growth Douglas-fir forest (Hayes and Gruver 2000) or substantial above aspen and conifer forest types (Kalcounis et al. 1999).

Forest structure and plant species composition affects the abundance and species richness of moths, an important prey base for many bat species (Burford et al. 1999). Many of the Pacific Northwest's most common moth species consume deciduous plants rather than conifers, thus the extent of hardwood tree and shrub cover within different forest types is a major factor in moth production and diversity in the region (Hammond and Miller 1998, Muir et al. 2002, Ober and Hayes 2010). Deciduous vegetation cover is also an important habitat component for a variety of other nocturnal flying insects (Ober and Hayes 2008c). In a comparison among old-growth, young-growth, and clearcut stands in Douglas-fir forests, Muir et al. (2002) reported moth abundance to be highest in old-growth and lowest in clearcuts.

Less information exists on the foraging activity of bats in shrub-steppe and grasslands. Habitat use appears to vary among species, with some favoring riparian zones associated with open habitats, while others feed more broadly across both shrub-steppe and grasslands (Holloway and Barclay 2000, Everette et al. 2001, Rosier 2008). Differences in insect prey abundance and water availability may be important factors determining selection of these habitats in some locations (Grindal et al. 1999, Adams 2003), but not at others (Rosier 2008).

Landscape level habitat features can also influence foraging and commuting activity, and thus can affect habitat use and abundance of bats (Lacki et al. 2007a). The amount of area comprised of different habitat types may influence the number and species composition of bats that an area can support, whereas location of those habitat types in relation to one another may determine the amount of edge habitat and level of fragmentation of sites (Hayes 2003). However, in western Oregon, Ober and Hayes (2008b) found that species richness, percent cover, and species composition of riparian vegetation at the stand scale explained more variation in bat activity than did vegetation characteristics at broader spatial scales. An analysis of forest structure in 100-ha landscapes surrounding 70 to >200 year-old Douglas-fir-dominated stands in western Oregon and Washington found no landscape-level influence on bat activity (Erickson and West 2003). Linear landscape features, such as tree-lines, appear to be important as corridors for at least some bat species when commuting between roost sites and foraging habitats (Lacki et al. 2007a).

PUBLIC HEALTH

From a public health perspective, rabies and histoplasmosis are the two diseases most commonly associated with bats in North America that are transmissible to people.

Rabies

Rabies is a viral infection of the central nervous system and is typically fatal in humans unless early treatment is received (Brass 1994). Because rabies viruses are not known to penetrate intact skin, infections depend on the virus accessing deeper tissues through bites and scratches from infected animals. Other routes of exposure, such as inhalation of aerosolized virus while in roosts or via virus-laden saliva coming into contact with mucous membranes (i.e., eyes, nose, and mouth), are extremely rare or have been documented only under laboratory conditions (Brass 1994). Although human deaths from rabies have become very rare, the disease remains a threat to human health.

Raccoons, skunks, bats, and foxes are important reservoirs of rabies virus in the U.S. (Brass 1994, Rupprecht et al. 2001). Bats are the only known reservoir of rabies virus in Washington (WSDH 2007), but numerous other mammal species may be able to acquire and spread the virus. The rabies virus variant associated with silver-haired bats may be the most significant variant in the northwestern U.S. (Messenger et al. 2002, 2003). Prevalence of rabies varies with bat species, colony, and location, and is typically very low in most wild populations (<1%; Brass 1994, Klug et al. 2011). Bat bites have accounted for an increasing proportion of rabies cases in people in the U.S. in recent years (Rupprecht et al. 2001) and most deaths from rabies are now attributed to unrecognized exposures to animals infected with bat-variant rabies (Messenger et al. 2003). Between 1951 and 2006, 51 rabies cases in the U.S. and Canada were attributed to bat variants of the virus, including two deaths in Washington in 1995 and 1997 (Constantine 1993, 2009, Messenger et al. 2002, De Serres et al. 2008). On average, one to two people acquire rabies in the U.S. per year, with the species of animal causing the infection not known in the majority of cases. In some cases, intermediate species (e.g., raccoons, skunks, foxes) may have been bitten by or eaten an infected bat, allowing them to spread the disease to people.

Vaccination of dogs has led to a dramatic decline of human rabies cases in the U.S. since the 1940s (Brass 1994). Most human deaths from rabies in the U.S. occur because people are unaware of their exposure and therefore do not seek post-exposure treatment. People can minimize their chances of rabies infection by taking precautionary measures, including not handling wildlife and ensuring that dogs and cats are vaccinated against rabies. Cats account for the majority of contact between humans and sick bats when they bring bats home to their owners (Constantine 2009). Bats should not be allowed to inhabit human living quarters. The most effective means of preventing bats from roosting in buildings is to prohibit their reentry by bat-proofing the premises (see WDFW's *Living with Wildlife* webpage [http://wdfw.wa.gov/wlm/living/index.htm] and Link [2004]). This is preferable to the use of chemical poisons, which (1) are inhumane, (2) may not solve the problem if bats regain entry through unsealed openings, (3) kill or sicken the bats and leave carcasses to rot in interior walls or ceilings, (4) can cause secondary poisoning of other species (including pets) that consume poisoned bats, and (5) can create additional exposure to rabies among residents and unvaccinated pets of the home and the general public by creating further opportunities to encounter sick bats on the ground (Brass 1994). If a person thinks he or she may have been exposed to a bat or has an animal bite, the person's doctor and local health department should be contacted for instruction.

Histoplasmosis

Histoplasmosis is a disease of humans and other mammals and is caused by the fungus *Histoplasma capsulatum*, a soil saprophyte that occurs in warm humid areas worldwide (Constantine 1993). The fungus can grow in soil with a high organic content from bird or bat feces, and if aerosolized and enough is inhaled, could produce infection. Infected humans usually develop flu-like symptoms, but the disease may be fatal to people already immunocompromised or those receiving high doses of the fungus, such as guano miners. To minimize exposure to histoplasmosis, people working near bat roosts and large quantities of guano should wear a well-fitting respirator capable of filtering particles 2 microns in diameter (Constantine 1993) and properly sanitize their clothing after leaving the site. Histoplasmosis is quite rare in Washington (R. Worhle, pers. comm.) and elsewhere in the Pacific Northwest (Nagorsen and Brigham 1993).

LEGAL AND CONSERVATION STATUS

Federal

None of the 15 bat species in Washington are federally listed as endangered or threatened, or proposed for listing by the U.S. Fish and Wildlife Service. One species (little brown myotis) is currently being reviewed for listing under the Endangered Species Act (Kunz and Reichard 2010) and five others are considered federal species of concern by the agency (Table 4). Federal species of concern are those whose conservation status is of concern, but for which additional information is needed on abundance, population trends, and impacts of threats. Conservation measures for these species are voluntary but recommended by the U.S. Fish and Wildlife Service.

The U.S. Forest Service maintains a list of sensitive species for Region 6 (Pacific Northwest) to meet its obligations under the Endangered Species Act and National Forest Management Act. Sensitive species are defined as "those identified by a regional forester for which population viability is a concern." Three species (Keen's myotis, pallid bat, Townsend's big-eared bat) are managed as sensitive species on national forests in Washington (Table 4).

The Bureau of Land Management (BLM) has established rankings for species management on its lands in Washington, with two bat species (pallid bat, Townsend's big-eared bat) assigned sensitive status (Table 4). BLM policy is to initiate proactive conservation measures that reduce or eliminate threats to BLM sensitive species to minimize the need for listing under the Endangered Species Act.

Federal agencies are required by the Federal Cave Resources Protection Act (FCRPA) of 1988 to protect and maintain significant caves on federal lands to the extent practical. A significant cave is defined as having biological, geological, mineralogical, paleontological, hydrologic, cultural, recreational, educational, or scientific components. Nearly all caves on federal land are expected to meet this definition of significance and therefore warrant protection under the FCRPA. Cave locations are afforded confidential status, including exemption from the Freedom of Information Act. Under the FCRPA, federal land managers are responsible for cave-resource protection when planning activities and developing management strategies.

State

All bats are classified as protected wildlife in Washington, except when found in or immediately adjacent to dwellings or other human-occupied buildings (WAC 232-12-011, Appendix C). Protected wildlife cannot be hunted, possessed, or maliciously killed (RCW 77.15.130, Appendix C), with violation of the law being a misdemeanor. None of the bat species in Washington are currently listed as state endangered, threatened, or sensitive by WDFW. Keen's myotis and Townsend's big-eared bat are state candidate species (Table 4), meaning they will be reviewed by WDFW for possible listing as state endangered, threatened, or sensitive species. Designation as a state candidate species occurs when preliminary evidence suggests that a species may meet listing criteria (WDFW Policy 5301, Appendix C). Keen's myotis and Townsend's big-eared bat are also identified as "species of greatest conservation need (SCGN)" in *Washington's Comprehensive Wildlife Conservation Strategy* (WDFW 2005). Seven bat species are state "monitor" species that require management, survey, or data emphasis (Table 4).

The WDFW Priority Habitats and Species Program (PHS) recognizes species and habitats as priorities for conservation and management based on the following criteria: (1) the species is state-listed

Table 4. Federal and state conservation status of bat species in Washington.

Species	Federal			State	
	USFWS[a]	USFS[b]	BLM[c]	WDFW[d]	WDNR Natural Heritage[e]
Big brown bat				PHS	G5, S5
California myotis				PHS	G5, S3S4
Canyon bat				SM	G5, S3
Fringed myotis	SOCW			SM, PHS	G4, S3
Hoary bat					G5, S3
Keen's myotis		S		SC, PHS, SGCN	G2G3, S1
Little brown myotis				PHS	G3, S3
Long-legged myotis	SOCW			SM, PHS	G5, S3S4
Pallid bat		S	S	SM, PHS	G5, S2S3
Silver-haired bat					G5, S3
Spotted bat				SM	G3G4, S3
Townsend's big-eared bat	SOCS	S	S	SC, PHS, SGCN	G4, S2S3
Western small-footed myotis	SOCW			SM, PHS	G5, S4
Western long-eared myotis	SOCS			SM, PHS	G5, S4
Yuma myotis				PHS	G5, S5

[a] U.S. Fish and Wildlife Service: SOCW = species of concern in western Washington only, SOCS = species of concern statewide.
[b] U.S. Forest Service: S = sensitive.
[c] Bureau of Land Management: S = sensitive.
[d] Washington Department of Fish and Wildlife: SC = state candidate species, SM = state monitor species, PHS = priority habitats and species, SGCN = species of greatest conservation need.
[e] NatureServe: G = global, S = state, 1 = critically imperiled, 2 = imperiled, 3 = vulnerable to extirpation or extinction, 4 = apparently secure, 5 = demonstrably widespread, abundant, and secure.

or a candidate, (2) the species or species group forms vulnerable aggregations, or (3) the species or species group has recreational, commercial, or tribal importance but is vulnerable to habitat loss or degradation. The two state candidate bat species and those that form large roosting concentrations (big brown bats, pallid bats, and species of *Myotis*) are designated priority species, with locations of communal roosts classified as priority habitats under the PHS program (Table 4). Caves, cliffs (greater than 7.6 m tall and occurring below 1,524 m elevation), snags (greater than 2 m in height with diameters exceeding 51 cm in western Washington and 30 cm in eastern Washington), and talus are identified as Priority Habitats under this same program.

The Washington Natural Heritage Program of the Washington Department of Natural Resources identifies the global and state conservation ranks of all bat species in the state according to criteria established under NatureServe. Current ranks under this program are given in Table 4.

CONSERVATION AND MANAGEMENT ACTIVITIES

Surveys and Research

Historical surveys and accounts. Few important investigations of bats were made in Washington before 1980. Taylor and Shaw (1927) provided an early report of the bats at Mount Rainier National Park, with supplementary information appearing in Schamberger (1970). Taylor and Shaw (1929) compiled the first list of the state's bats, which included all species currently known for Washington except the spotted bat, and contained subspecies designations and remarks on distribution. Dalquest

(1938) updated the state species list with additional information on occurrence. Accounts on the bats of the San Juan Islands and the Olympic Peninsula appeared in Dalquest (1940) and belatedly in Scheffer (1995), respectively. Booth (1947) and Dalquest (1948) gave expanded reviews of the state's bat fauna, with information on taxonomy, physical appearance and size, identification, distribution, and natural history. Ingles (1965) provided an identification key and range maps for bats occurring in Washington.

Extensive surveys made primarily for Townsend's big-eared bat took place during the 1980s at Mt. St. Helens National Volcanic Monument (Senger and Crawford 1984); in the Mt. Adams and Wind River ranger districts on Gifford Pinchot National Forest (Perkins 1985, 1990b); and on Olympic, Mt. Baker/Snoqualmie, Wenatchee, Okanogan, and Colville national forests (Perkins 1988, 1990a). Survey results for fringed myotis were also presented in Perkins (1988, 1990a). Perkins et al. (1990) reported on hibernacula surveys in Klickitat County during 1982-1989 for species other than Townsend's big-eared bat. West et al. (1984) and Thomas (1988) described samples of bats captured on Gifford Pinchot National Forest.

Recent surveys and accounts. Inventories of Washington's bat fauna have greatly expanded since about 1990. In the eastern half of the state, survey findings have been compiled for the Callispell basin in Pend Oreille and Stevens counties (Campbell 1993); the Yakima Training Center in Yakima and Kittitas counties (Christy et al. 1995); the Teanaway River valley in Kittitas County (Frazier 1997); the Trout Lake area in Skamania and Yakima counties (Taylor 1999); the Columbia River corridor in Benton and Klickitat counties (Perkins and Peterson 1996); the Hanford Site in Franklin, Benton, and southern Grant counties (Gitzen et al. 2002, Lindsey et al. 2012); Nature Conservancy lands and adjoining areas at Moses Coulee in Douglas County, Badger Gulch in Klickitat County, and Barker Mountain in Okanogan County (Fleckenstein 2000, 2001a, Rosier and Rosenberg 2006); the Rock Creek and Oak Creek drainages in Yakima and Kittitas counties (Baker and Lacki 2004); the Pend Oreille River in northern Pend Oreille County (Green et al. 2009); and several drainages in eastern Grant and northwestern Adams counties (Wisniewski et al. 2010). Surveys for spotted bats and other relatively rare bat species were made for six north-central counties (Sarell and McGuinness 1993) and Crescent Bar, Grant County (Gitzen et al. 2001). Reports have also appeared on specific colonies of Townsend's big-eared bat (Woodruff 1999, 2000, Mathis 2005) and Yuma myotis (Gano et al. 2009, Lucas 2011, West et al. 2011). Johnson and Erickson (2011) summarized bat mortality at wind energy facilities in eastern Washington and eastern Oregon.

In western Washington, bat surveys have been conducted for Joint Base Lewis-McChord in Pierce and Thurston counties (Wunder et al. 1992, Falxa 2005, 2006, 2008a, Freed and McAllister 2008); Long Island in Pacific County (Christy 1993); Olympic National Forest (Fursman and Aluzas 2005); and Olympic, North Cascades, and Mount Rainier National Parks (Erickson et al. 1998, Jenkins et al. 1999, Petterson 2001, Christophersen and Kuntz 2003, West et al. 2004). Falxa (2007b, 2008b) reported on a colony of Yuma myotis and little brown myotis. Falxa (2007a) described winter foraging by silver-haired bats and California myotis.

Statewide, Johnson and Cassidy (1997) provided updated and projected distributional information for all bat species. Compilations of winter bat records were given by Senger et al. (1974) and Perkins et al. (1990). Fleckenstein (1998, 2001b, 2002) made preliminary evaluations of mines to determine suitability for bats. From 2004 to 2011, the U.S. Forest Service, Bureau of Land Management, and others conducted Bat Grid surveys in Washington (Ormsbee 2008, Ormsbee and Hohmann 2010, Ormsbee 2011).

Research. A number of bat research projects have been conducted in Washington. From the mid-1960s to 1980, Townsend's big-eared bat was the focus of two hibernation studies (Hughes 1968, Adler 1977) and a long-term banding and recapture project by Clyde Senger that was conducted mainly in Klickitat, Skamania, and Skagit counties, with survival estimates eventually produced (Ellison

2008, 2010). Studies of roost selection and related topics have been made for several species, including silver-haired bats (Campbell 1993, Campbell et al. 1996), long-legged myotis (Frazier 1997, Taylor 1999, Baker and Lacki 2006, Lacki et al. 2010, 2012), western long-eared myotis (Rancourt et al. 2005), fringed myotis (Lacki and Baker 2007), big brown bats (Rancourt et al. 2007), and Townsend's big eared bats (Falxa 2009). Several studies have examined patterns of habitat use by foraging bats in forest (Thomas 1988, Thomas and West 1991, Erickson 1993, Erickson and West 1996, Hayes and Gruver 2000, Erickson and Adams 2003) and shrub-steppe (Rosier and Rosenberg 2006, Rosier 2008). Baker and Lacki (2004) provided information on elevational use and the timing of reproduction at two drainages in the southeastern Cascades. Nuetzmann (2001) compared bat activity in urban and rural areas in Spokane County. Rodhouse et al. (2012) modeled occurrence probabilities for little brown myotis in Washington and Oregon using Bat Grid data.

Protection of Species and Habitats

Of the 11 species of bats currently covered under WDFW's Priority Habitats and Species (PHS) program (Table 4), specific management recommendations have been developed for two: pallid bats and Townsend's big-eared bats (Ferguson and Azerrad 2004, Woodruff and Ferguson 2005). WDFW provides PHS data and maps to county governments for use in comprehensive plans required by the state's Growth Management Act. Protective measures implemented for different habitats and species vary among counties according to the objectives and specific details of their comprehensive plans. No summary of the number of counties covering bats under their critical area ordinances is available. The PHS management recommendations are also available on the WDFW website (http://wdfw.wa.gov/publications/00027/) for landowners, regulators, agencies, and others interested in their conservation.

WDFW maintains data on bat colony locations and species occurrences. To protect roost sites, the agency's sensitive data policy (WDFW Policy 5210) prevents specific location data for 11 bat species from being released to the public, as follows. For big brown bats, Keen's myotis, little brown myotis, Townsend's big-eared bats, and Yuma myotis, locations of aggregations, maternity colonies, and hibernacula (excluding those in privately-owned buildings) can be released only at the township level. For California myotis, canyon bats, fringed myotis, long-legged myotis, western long-eared myotis, and western small-footed myotis, occurrences in caves can be released only at the township level, whereas other location data are not restricted.

Numerous projects to protect and monitor bat roosts and populations have been conducted in Washington by agencies (e.g., WDFW, U.S. Forest Service, Bureau of Land Management, Washington Department of Natural Resources [WDNR], Department of Defense, National Park Service, Department of Energy, U.S. Fish and Wildlife Service, Washington State Department of Transportation, and Washington State Parks and Recreation Commission), organizations (e.g., Bat Conservation International, The Nature Conservancy, Bats Northwest, Center for Natural Land Management, and Cascadia Research), and private landowners and companies (e.g., Iberdrola Renewables, Weyerhaeuser, U.S. Timberlands, Plum Creek Timber Company, and Tacoma Power).

Habitat conservation plans. In general, habitat conservation plans and other conservation measures implemented by timber companies and natural resource agencies to protect northern spotted owls (*Strix occidentalis caurina*), marbled murrelets (*Brachyramphus marmoratus*), and other federally listed species have benefited tree-dwelling bats through the recruitment and retention of large-diameter trees and snags, thereby enhancing roosting opportunities for bats. Five habitat conservation plans with the U.S. Fish and Wildlife Service have been developed in Washington that specifically include various species of bats as other "species of concern." These plans cover lands owned by West Fork Timber Company in Lewis County (Beak Consultants 1993), Port Blakely Tree Farms in Pacific and Grays Harbor counties (Port Blakely Tree Farms 1996), and Plum Creek Timber Company in the central Cascades

(Plum Creek Timber Company 2000), as well as WDNR's forested state trust lands (WDNR 1997) and the city of Seattle's Cedar River watershed (City of Seattle 2000). The plans call for many conservation measures that are advantageous to bats, such as management for older forests; creation of large snags; and various types of protection (e.g., retention of buffers, controlled public access) for riparian zones, wetlands, snags, live trees, caves, cliffs, and talus fields.

WDFW is currently preparing a habitat conservation plan to address activities affecting federally listed species and some species of concern on state wildlife areas. Conservation measures specific to Townsend's big eared bats will be included in the plan. Other management activities covered under the plan should benefit bats in general as well.

Bat Conservation Organizations and Conservation Planning for Bats

Bat conservation organizations and groups, with extensive partnerships, have been formed at the international, national, regional, and state levels to address bat conservation, management, education, and research needs. Several of these organizations are active in Washington, and their activities are described below.

National. Bat Conservation International has conducted numerous conservation, education, and research projects involving bats in the U.S. since the early 1980s. Major projects since 2000 include protection of endangered and threatened bats, investigation of and response planning for white-nose syndrome, research and mitigating impacts of wind energy on bats, management of bridges and abandoned mines with bats, providing safer water sources for bats in the western U.S., and improving public awareness of bats.

Regional. The Western Bat Working Group was established as a coalition of bat working groups from 14 western states, five Canadian provinces, and northern Mexico. Its goals are to (1) facilitate communication among interested parties and to reduce the risk of species decline or extinction, (2) provide a mechanism by which current information regarding bat ecology, distribution, and research techniques can be readily accessed, and (3) develop a forum in which conservation strategies can be discussed, technical assistance provided, and education programs developed (WBWG 2008). One of the Working Group's first accomplishments was to facilitate a memorandum of understanding between the members of the Western Association of Fish and Wildlife Agencies to implement conservation actions for Townsend's big-eared bats (Pierson et al. 1999).

Bats Northwest is a non-profit organization that formed in 1996 and is devoted to the study and preservation of bats in the Pacific Northwest through conservation, education, and research. The group works to educate the general public, media, and others about the importance of bats and bat conservation, conducts and supports surveys and research on bats, serves as a clearinghouse to those seeking information on bats, and provides information on appropriate methods for excluding bats from buildings and placing gates on mines and caves.

State. The Washington Bat Working Group was established in 1998 as a subgroup of the Western Bat Working Group. Membership includes bat researchers, biologists, and bat enthusiasts in the state. The group holds an annual meeting and maintains a listserve (http://tech.groups.yahoo.com/group/WABWOG/).

Other conservation planning. Some conservation planning for bats in Washington is integrated with planning for other wildlife at state and national levels. In 2005, WDFW developed a Comprehensive Wildlife Conservation Strategy (CWCS) in response to a requirement by Congress for each of the states to develop strategies, now known as Wildlife Action Plans, as a condition for obtaining funding from the State Wildlife Grants program under the U.S. Fish and Wildlife Service (WDFW 2005). Guiding principles for Washington's CWCS include conservation of species and habitats of greatest conservation need, recognizing the importance of maintaining the healthy status of common species, and building and strengthening partnerships and communication with other agencies, tribes, local governments, non-governmental organizations, and various interest groups to achieve conservation goals. Townsend's big-eared bat and Keen's myotis are currently the only bats identified as species of greatest conservation need in Washington's CWCS. Periodic updates are made to the list of species of greatest conservation need, and it is likely that more bat species will be proposed for addition to the list during the next update in 2015 (see Chapter 3, Task 6.2).

CONSERVATION ISSUES

Habitat Loss and Alteration

<u>Forest Management</u>

In the Pacific Northwest, some bat species are primarily associated with forests (Keen's myotis, long-legged myotis, western long-eared myotis, silver-haired bat, hoary bat), while others inhabit both forests and non-forested habitats (big brown bat, California myotis, fringed myotis, little brown myotis, pallid bat, spotted bat, Townsend's big-eared bat, western long-eared myotis, western small-footed myotis, Yuma myotis), or rarely occur in forests (canyon bat) (Hayes 2003). For those species regularly present in forests, forest management practices can be a major influence on local and regional abundance.

Washington has nearly 22.4 million acres of forest (about 49% of the state's land area) with ownership divided between public (55%) and private (43%) (Smith et al. 2009, Campbell et al. 2010). Ownership of forests typically determines how forests are managed. Federal agencies manage about 9.9 million acres (44%) of the state's forests, with 6.1 million acres classified as timberland and 3.5 million acres held in reserve areas excluded from timber harvest (Campbell et al. 2010). The Washington Department of Natural Resources (WDNR) manages about 2.5 million acres of forests, with the majority (92%) classified as timberland. WDFW manages 813,000 acres of land, of which about 25% is forested. WDFW thins or salvage logs only a small portion (usually <1,000 acres) of its forestland annually, largely to enhance wildlife habitat or to reduce the threat of fires.

Federally-owned forests are managed for multiple uses such as wood production, water, wildlife, recreation, conservation, and biological diversity, whereas WDNR-owned timberlands are primarily managed to generate revenue for public schools, universities, and other state institutions while maintaining forest productivity and providing other societal values (Bolsinger et al. 1997, Campbell et al. 2010). Public forestlands provide important bat habitat through preservation of old forests and management practices that retain and recruit large snags and promote diverse forest structure conditions. Most forests over 100 years old in Washington occur in reserved areas on national forests. A substantial amount of the 6.1 million acres of federal timberlands occurs in areas of national forests that may not be available for wood production, including but not limited to riparian areas and late-successional reserves (Bolsinger et al. 1997, Campbell et al. 2010).

Washington has about 9.5 million acres of private timberlands divided about equally between corporate and non-corporate owners (Smith et al. 2009, Campbell et al. 2010). Corporate forest ownership has changed in recent years with an increasing number of investor-owned timber companies transitioning to real estate investment trusts and timber investment management organizations that value forests as investment vehicles (Smith et al. 2009, Campbell et al. 2010). The majority of non-corporate timberlands are owned by private individuals (56% of acreage; these are concentrated in western Washington lowlands), or tribes (39%) (Bolsinger et al. 1997, Campbell et al. 2010). In general, private timberlands in Washington probably support smaller bat populations than public forests because most corporations manage timberlands on short rotation cycles (as short as 45-50 years) that result in young forests with smaller trees, reduced species composition, and simplified forest structure (Bolsinger et al. 1997). An additional concern is that as land values have increased in recent decades, private timberlands have been increasingly converted to other land uses (e.g., housing and other development), especially those located near human population centers.

Many forest management activities have the potential to directly or indirectly impact bats. Direct effects include the cutting down of roost trees and snags, including those occupied by maternity colonies, which can result in immediate mortalities to bats. The extent of this is poorly documented and its effects on bat populations are unknown. Indirect impacts may have much greater effects on some bat populations through the manipulation of vegetation and forest structure, which influences the characteristics and abundance of tree roosts, the amount of vegetative clutter, and the availability of prey and water (Hayes and Loeb 2007). Wildfire control may exert similar impacts (e.g., Malison and Baxter 2010, Buchalski et al. 2013).

Intensive forestry involving short rotation cycles influences roost availability for bats in the short-term by removing existing and potential roost trees during timber harvest and over the long-term by inhibiting recruitment of future roost trees. For example, Arnett (2007) found snags >50 cm dbh to be more than 50 times more abundant in old growth stands than in 21- to 40-year-old managed stands in western Oregon, and Wilhere (2003) demonstrated that for typical timber management prescriptions in western Washington, large-diameter snags of >64 cm dbh can be up to 100 times less abundant than in unmanaged forests.

Forest management practices can also influence the environmental context in which tree roosts occur. For example, manipulation of forest structure and composition can alter the conditions around a roost, thus affecting its thermal characteristics (Hayes and Loeb 2007). Forest management that emphasizes retention and recruitment of roosts in riparian habitats alone may not meet the diverse roost requirements needed to sustain tree-dwelling bat populations (Campbell et al. 1996, Hayes and Loeb 2007, Arnett and Hayes 2009). Additionally, forestry activity and resulting changes in forest structure can change the suitability of bat roosts in closeby rock crevices, caves, mines, and bridges by altering airflow, thermal characteristics, and accessibility.

Forest management activities also impact foraging opportunities for bats by altering the amount of vegetative clutter, tree species composition, and tree density in forests (Humes et al. 1999, Erickson and West 2003, Ober and Hayes 2008b, Betts 2009). At upland sites, use of herbicides (Shepard et al. 2004, Wagner et al. 2004) and narrow spacing of conifer trees can greatly decrease or eliminate shrub and deciduous tree cover during early seral stages and the non-conifer understory strata of mature forests, potentially reducing prey availability for bats. Thinning dense, young-growth stands may increase use by some bat species by opening up the canopy, thereby increasing access for bats (Humes et al. 1999, Betts 2009) and facilitating development of understory shrub and herb layers that provide food plants for insects eaten by bats (e.g., Hammond and Miller 1998). Manipulation and removal of deciduous trees in riparian areas can also substantially alter prey abundance for bats. Prescribed burning in eastern North America has been shown to increase insect availability for bats (Lacki et al. 2009).

The bacteria *Bacillus thuringiensis* (*Bt*) is a microbial pesticide used to control periodic outbreaks of lepidopteran pests such as the gypsy moth (*Lymantria dispar*), western spruce budworm (*Choristoneura occidentalis*), and Douglas-fir tussock moth (*Orgyia pseudotsugata*) in forests. *Bt* is an effective alternative to chemical pesticides and applications can be thousands of acres in size. However, a number of studies have shown that *Bt* spraying reduces the diversity and abundance of non-target moths and other insects (e.g., Miller 1990, 2000, Wagner et al. 1996, Whaley et al. 1998). The extent of such declines is often variable, but can sometimes reach 80-100%, with effects extending multiple years. These impacts could significantly reduce prey abundance for forest bats, especially those that feed extensively on moths such as Townsend's big-eared bat and long-legged myotis. When *Bt* spraying occurs near hibernacula and maternity roosts, bats may be forced to expend more energy foraging longer and traveling farther from roosts to find adequate prey, which could lower their fecundity and survival.

Agricultural Land Use

Agricultural expansion in Washington has resulted in considerable loss or modification of natural habitats, especially shrub-steppe, grasslands, wetlands, and some forest types. Crop production has changed plant communities, soil characteristics, and hydrology, which in turn have caused major impacts to arthropod communities (e.g., Niwa et al. 2001) and thus foraging opportunities for bats. Conversion of natural habitats to crop monocultures lowers insect diversity and the abundance of most insect species, while increasing the abundance of small numbers of crop-related species. Agricultural fragmentation of native habitats also contributes to the decline in arthropod communities. For example, small patches of shrub-steppe bordering crop circles in the Columbia Basin have lower abundances of numerous arthropod groups (including groups eaten by bats) compared to larger patches (Quinn 2004). Use of agricultural pesticides also reduces insect abundances and can result in the accumulation of higher burdens of various harmful chemicals in bats inhabiting farmlands (Gerrell and Lundberg 1993). No studies have assessed the impacts of agriculture on bats in Washington, but in British Columbia, conversion of native shrublands and grasslands to vineyards and other crops is a threat to pallid bats because of resulting differences in prey availability and quality (Rambaldini 2006, Sarell and Rambaldini 2008).

Livestock grazing has impacted rangelands, forests, and riparian habitats by altering vegetation structure and diversity; facilitating invasion of exotic plants, such as cheatgrass (*Bromus tectorum*); increasing the amount of bare ground, soil compaction, and erosion; reducing water quality; changing seasonal water quantity; and leading to more destructive fires (Bock et al. 1993, Belsky and Blumenthal 1997, Finch et al. 1997, Belsky et al. 1999, Vander Haegen et al. 2001). These effects can negatively impact insect populations (Niwa et al. 2001, Kruess and Tscharntke 2002) and hence reduce or alter insect availability for bats. Riparian zones are particularly important to bats as feeding, roosting, and drinking sites, but can be seriously degraded or eliminated by poor grazing practices (Bock et al. 1993, Belsky et al. 1999). In this habitat, grazing can result in higher stream temperatures, lower dissolved oxygen levels, increased sedimentation, and reduced plant detritus, all of which can reduce the availability of aquatic insects (Rinne 1988, Tait et al. 1994, Erman 1996). The herb and grass layer in drier conifer forests is known to support much of the moth biomass and diversity in this habitat (Hammond and Miller 1998), thus degradation of forest floor vegetation by livestock grazing impacts moth availability for bats in this forest type.

Certain aspects of farming and ranching may benefit some bat species under some conditions. Agricultural irrigation, damming for irrigation, and watering of livestock may provide vital water sources to bats in semi-arid environments where water availability is usually highly limited (Adams 2003). However, poorly designed water troughs can contribute to bat mortality when they lack escape devices for bats that have fallen in (Taylor and Tuttle 2012). Calcium-rich water sites can also provide additional minerals for reproductive females and their young (Adams 2003). Trees and buildings associated with farmsteads can provide roosts for bats in areas that previously offered few roosting resources. In addition, species capable of feeding over open farmland may find adequate prey resources (e.g., Whitaker 1995).

Substantial areas of Washington have been used for farming and ranching since the 1800s. In 2007, 35% of Washington, or nearly 15 million acres, was comprised of private agricultural land, including cropland, pasture and rangeland, and non-pastured woodland (NASS 2009). Most agricultural land in the state occurs in eastern Washington, where 52% of all land was farmed or ranched in 2007, compared to just 6% in western Washington. Seven eastern Washington counties had more than 70% of their land area farmed or ranched in 2007 (maximum: Whitman County, 92%), whereas 14 western Washington counties had less than 10% of their land used for those purposes that year (minimum: Skamania County, 0.5%). Amounts of private grazing land and grazing allotments on government lands are also far greater in eastern Washington (NASS 2009, Wiles et al. 2011:173). Conversion of shrub-steppe and grassland to agriculture has been especially severe, with at least 52-59% of shrub-steppe lost (Dobler et al. 1996, Jacobson and Snyder 2000, Vander Haegen et al. 2000, 2001).

Urbanization

Conversion of natural or semi-natural rural lands to urban environments greatly modifies foraging and roosting habitats for bats. Typical changes resulting from this include the reduction, alteration, and fragmentation of habitats used for foraging or drinking; loss of roost sites in trees and old buildings; and contamination of water sources used for drinking. These modifications can significantly reduce overall bat abundance and species diversity compared to the original habitat (Kurta and Teramino 1992, Gaisler et al. 1998, Avila-Flores and Fenton 2005). Although urban habitats can provide increased roosting and feeding opportunities for a few generalist species (e.g., big brown bats, little brown myotis, silver-haired bats), less adaptable species requiring natural habitat features lose important resources needed for their continued presence (Duchamp et al. 2004, Johnson et al. 2008, Loeb et al. 2009, Oprea et al. 2009, Coleman and Barclay 2012, Threlfall et al. 2012).

Urban locations surrounded by cover types such as agriculture, shrub-steppe, and prairie potentially offer improved habitat for some bats through increases in tree cover, buildings, and other resources (Gehrt and Chelsvig 2003, 2004, Neubaum et al. 2007). However, even in this situation, Coleman and Barclay (2012) found that only one species, the little brown myotis, increased in abundance in a city surrounded by Great Plains prairie, while other species declined. Coleman and Barclay (2011) also demonstrated that despite their greater abundance, urban little brown myotis did not show improved reproductive fitness or body condition.

Washington's human population grew from 4.1 million to 6.7 million between 1980 and 2010 and is expected to reach an estimated 8.8 million by 2040 (OFM 2011). This growth has resulted in considerable urban expansion in several areas of the state in recent decades, which will undoubtedly continue in the future. Although anecdotal observations are plentiful, only one study of urban bat communities exists for Washington. Nuetzmann (2001) detected lower bat activity levels and feeding rates at urban locations than in rural and rural-urban interface areas in Spokane County.

Mine Closures and Renewed Mining

Because of human safety concerns, there have been ongoing efforts by federal and state land management agencies and mining companies to close abandoned mines throughout the U.S. in recent decades. This often involves the permanent sealing of mine entrances. Closure of old mines without adequate biological assessment may kill large numbers of bats or eliminate important roosting habitat. An estimated 3,400 underground mines exist in Washington (McFaul et al. 2000, Fleckenstein 2002), located primarily in the Cascades and Okanogan Highlands. Many of these sites have been closed over the years without proper survey for bat use or habitat. Several agencies address abandoned mine lands in the state, including but not limited to the Washington Department of Natural Resources, U.S. Environmental Protection Agency, Bureau of Land Management, National Park Service, and U.S. Forest Service. A number of mines in Washington have been closed with bat gates, stopping human access while allowing bats to continue and even increase their use of the mine. The Bureau of Land Management, U.S. Forest Service, National Park Service, and WDFW are among the public agencies that have protected bat roosts in this manner.

Higher prices for gold and some other minerals have recently spurred the resumption of mining activities at some inactive mines, which can result in bat disturbance and mortality, and the destruction of important roost sites (Tuttle and Taylor 1998). In northeastern Washington, for example, there has been recent interest in reopening a number of abandoned mines for renewed production of gold.

Wind Energy Development

Wind energy production has expanded greatly in the U.S. since the late 1990s and is projected to continue growing over the next few decades. When properly sited, wind energy can be an environmentally friendly source of electricity. However, bat and bird fatalities at some wind energy facilities are a serious concern (Kunz et al. 2007). Bat fatalities at wind facilities in North America primarily involve migratory, tree-roosting species, especially hoary bats, eastern red bats (*Lasiurus borealis*), and silver-haired bats, most of which are killed during migration in late summer and early autumn (Kunz et al. 2007, Arnett et al. 2008, Johnson and Erickson 2011). Fatalities of summer resident or short-distance migrant bats have also been significant at a few locations (Kunz et al. 2007, Arnett et al. 2008, Grodsky et al. 2012).

Recent studies have found no consistent relationships between bat mortality rates and site features or habitat (Arnett et al. 2008, Baerwald and Barclay 2009). Although sites on forested ridges in the eastern U.S. have many of the highest mortality rates reported (15.3 to 41.1 bats killed/megawatt of wind energy capacity/year; Kunz et al. 2007), facilities in prairie and agricultural settings also occasionally experience relatively high mortality (e.g., Baerwald and Barclay 2009, 2011). Bats that travel along linear landscape features (e.g., ridge lines) when migrating or commuting may be at higher risk of encountering wind turbines (Kunz et al. 2007).

Bats are killed at wind energy facilities when they collide with spinning rotor blades, or as they fly near moving blades and experience a sudden reduction in air pressure resulting in hemorrhaging of the lungs, ears, or other tissues (i.e., barotrauma) (Baerwald et al. 2008, Horn et al. 2008, Cryan and Barclay 2009, Grodsky et al. 2011, Rollins et al. 2012). Most bat fatalities at wind facilities occur on nights with low winds and increase with the passage of storm fronts (Arnett 2005, Kerns et al. 2005, Arnett et al. 2008, Horn et al. 2008). Risk is further influenced by height of the structure and dimensions of the rotor-swept area of turbine blades, with taller turbines and greater rotor-swept areas killing more bats (Arnett et al. 2008). As taller wind turbines are constructed, bats that migrate or forage at greater heights may face increased vulnerability (Barclay et al. 2007).

It remains unclear why bats visit wind energy facilities, but a variety of potential reasons exist, including that turbine sites may offer foraging opportunities, turbines may be mistaken as roost sites by tree-roosting species, bats may be attracted to the sounds of moving blades, or bats may be attracted to turbine sites as mating or gathering locations (Cryan and Barclay 2009).

Wind energy production first began in Washington when the Stateline Wind Project entered service in 2001. In 2006, Washington voters approved legislation to require 15% of the electricity sold in the state to be derived from renewable energy resources by 2020 and the reduction of greenhouse gas emissions to 50% below 1990 levels by 2050. As of December 2012, Washington held 1,514 turbines that produced 2,622 megawatts of power at existing wind energy facilities, which ranked the state sixth in the nation in wind power production (AWEA 2012; M. Ritter, pers. comm.). Washington has an estimated potential capacity of 18,479 megawatts (AWEA 2012). At present, nearly all wind facilities occur in shrub-steppe or on agricultural lands in the Columbia Basin, where much of the state's wind resources are located. Specific areas with the greatest potential for utility-scale wind energy production include the Kittitas Valley, ridges in eastern Kittitas and northeastern Yakima counties, parts of the Columbia Gorge, eastern Klickitat and southern Yakima counties, the Horse Heaven Hills in Benton County, northern Columbia and northern Garfield counties, and along the outer coast (Figure 3). Only one wind facility (in Pacific County) exists at a forested site, but several more have been proposed in this cover type (T. Nelson, pers. comm.).

Silver-haired bats and hoary bats are the predominant species of bats killed at wind energy facilities in Washington and Oregon, with both being found in about equal numbers and comprising 97.8% of identified fatalities (n = 525; Johnson and Erickson 2011). Fatalities also include small numbers of little brown myotis and big brown bats. The vast majority of fatalities recorded in the two states have occurred from August to October during the peak of fall migration by silver-haired bats and hoary bats (NWC 2010). An average of 0.94 fatalities/megawatt/year (range = 0.17-2.47 fatalities/megawatt/year) was recorded at 12 wind energy facilities in Washington's Columbia Basin through 2010 (Johnson and Erickson 2011). Based on this rate and total production of 2,573 megawatts in Washington in 2011, a minimum estimate of 2,419

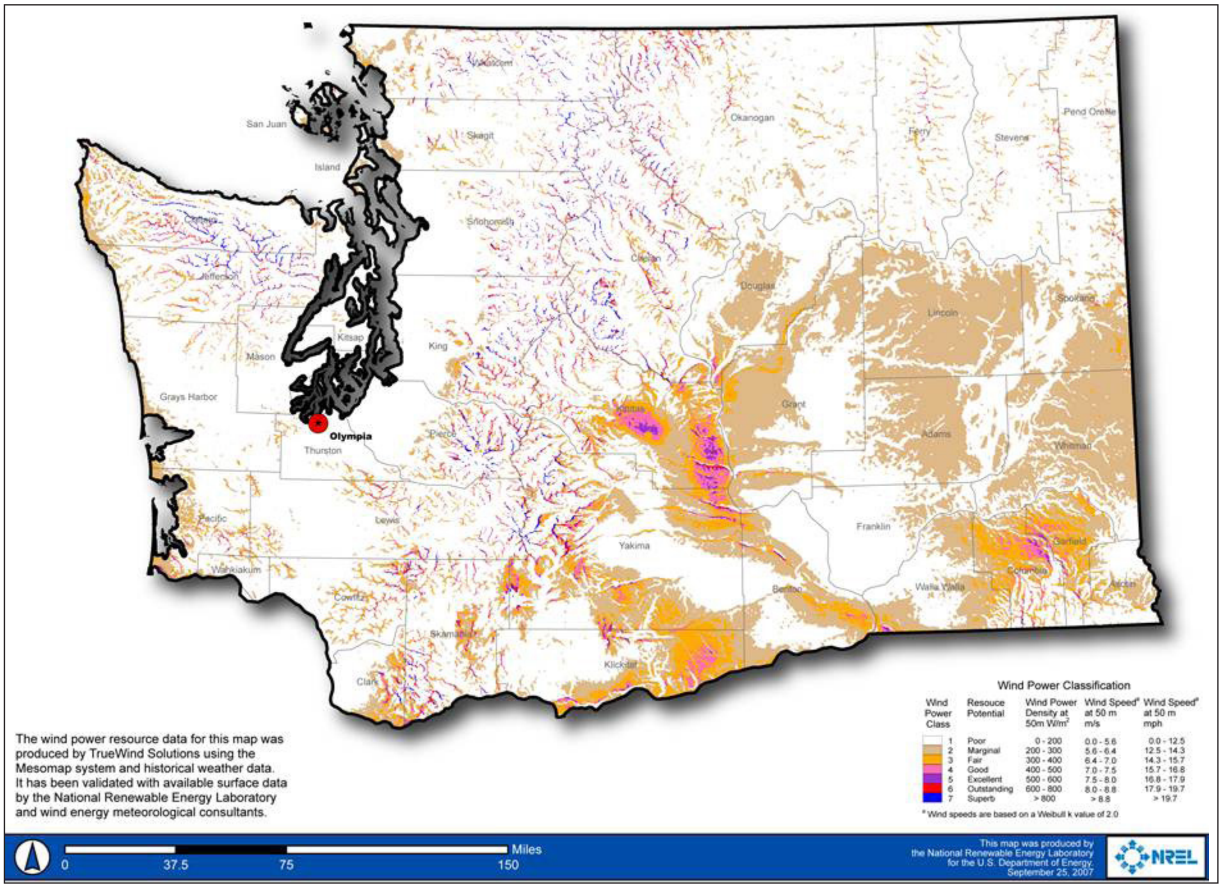

Figure 3. Estimated available wind resources at a height of 50 m above the ground in Washington (source: NREL 2007).

bats (1,161 silver-haired bats, 1,122 hoary bats, and 135 bats other species) were killed that year at wind facilities in the state. The data presented here are taken from publicly available sources and may not be fully representative of mortality patterns at all sites in Washington.

Johnson and Erickson (2011) speculated that detected mortality rates of 1-2 bats/megawatt/year are probably not significant to bat populations. However, mortality rates are likely underestimated because of the difficulty in finding all carcasses. Risk to migratory bat species is further increased because they likely encounter multiple wind power sites when migrating long distances. The cumulative effects of wind power mortalities may have greater consequences for bats because of their low reproductive rates.

In 2009, WDFW updated its guidelines for wind energy development (WDFW 2009). These are intended to provide permitting agencies and wind project developers with an overview of considerations made by WDFW in the review of wind energy project proposals. The guidelines include the opportunity to assess potential impacts to bats by (1) recommending bat surveys in the pre-project phase so that bat-related concerns can be identified and avoided before construction of the facility occurs, (2) recommending bat surveys to monitor fatalities post-construction to estimate direct impacts of the wind facility on bat populations, and (3) recommending additional research studies to assess impacts of the wind facility on bat populations. The guidelines are voluntary; WDFW has no regulatory authority over the wind power industry.

Compliance with the State Environmental Policy Act (SEPA) is required for wind energy proposals. WDFW is considered an agency with environmental expertise through SEPA and provides review and comments on environmental documents. The permitting authority is responsible for SEPA review prior to issuing a project permit. In Washington, the developer of a new wind energy facility has the option of pursuing a permit through either the local jurisdiction (cities and counties) or the state (Energy Facility Site Evaluation Council). The U.S. Fish and Wildlife Service is authorized to review proposed wind energy developments only when they occur on federal lands or impact federally listed wildlife.

Human Disturbance of Roosting Bats

Bats roosting in caves, mines, rock crevices, buildings, bridges, trees, and other structures are highly vulnerable to accidental or deliberate disturbance associated with human visitation and activities (Hutson et al. 2001, Adams 2003). Recreational exploration of caves and mines has become increasingly popular in recent decades and many caves are regularly visited by people during multiple seasons. Additionally, some caves are open to commercial tourism. Roosting bats are sensitive to noise and light (e.g., Thomas 1995, Mann et al. 2002), even when visitors attempt to limit these stimuli. Bats roosting near entrances of sites and within several meters of the floor are most prone to disturbance. Human visitation can unintentionally result in the abandonment of both hibernacula and maternity roosts. Winter visitation, especially when repeated within a single winter, can cause the arousal of hibernating bats, which can lead to their deaths through the premature depletion of critical fat reserves needed to survive hibernation. Summer visitation can result in females abandoning their young. In some cases, vandals have deliberately killed roosting bats. These types of disturbances have resulted in severe long-term impacts to many cave populations of bats in the U.S. and the world (Tuttle 1979, Hutson et al. 2001).

Figure 4. A gated mine entrance on public land in eastern Washington (photo by Theresa Mathis).

Organized caving groups, often known as grottos, frequently promote cave conservation and responsible caving (exploration) activities. To protect bats, many grottos advocate that members avoid entering certain caves or visit them only during certain seasons when colonies should not be present. There are many other people who opportunistically explore caves and mines who do not belong to caving groups and are unaware of the potential disturbance they may cause.

Disturbance of bat colonies from cave and mine visitation has been documented at a few sites in Washington. However, this problem is generally not considered a critical threat to roosting bats in the state and only a modest number of sites have been gated specifically to protect bats (Figure 4; J. Nieland, pers. comm.; M. Wainwright, pers. comm.; J. Fleckenstein, pers. comm.). This is partly because few caves and mines in the state are known to have large bat colonies (this may reflect past human disturbance and abandonment by bats), and many sites are located above snowline, making them inaccessible during winter. Vandals have rarely been found targeting bats in Washington (J. Nieland, pers. comm.; M. Wainwright, pers. comm.; J. Fleckenstein, pers. comm.). One exception was a Townsend's big-eared bat maternity roost in Clallam County, where the killing of bats prompted gating of the site in 1997 and 2001.

Other forms of human disturbance of roosting bats can include that caused by rock climbers on bats roosting in cliffs (Adams 2003), human activity in buildings and at bridges, and mining extraction activities.

White-nose Syndrome

White-nose syndrome (WNS) was first documented in North America at Howes Cave near Albany, New York, during February 2006 (Blehert et al. 2009). Bat researchers conducting routine censuses of bats at this site and three other caves in the area discovered large declines in bat numbers or many dead bats. Both live and dead bats had a characteristic white fungus on their muzzles, ears, and wings, and dead bats were emaciated (Figure 5). The following winter, bat populations in these four caves were reduced by 50-100% and more dead or emaciated bats were found in a larger outward-extending area. Because the white fungus was found at all these locations, the condition was dubbed “white-nose syndrome” (Zimmerman 2009).

A recently described fungus, *Geomyces destructans*, is the causal pathogen of WNS (Blehert et al. 2009, Gargas et al. 2009, Lorch et al. 2011). Not all WNS-infected bats show visible signs of fungal growth on their noses, wings, or tail membranes (Meteyer et al. 2009, Cryan et al. 2010). While damage to the wing membrane, such as depigmentation, holes, and tears, are suggestive of WNS, histopathology is necessary to confirm the disease (Meteyer et al. 2009, Pikula et al. 2012). *Geomyces destructans* colonizes skin on the nose, wing, and ears of bats, then erodes the skin and invades the underlying skin and connective tissue (Meteyer et al. 2009, Blehert et al. 2011). Fungal hyphae can also fill hair follicles and erode skin glands and local tissue. The fungus does not typically lead to inflammation or immune response in the tissue of hibernating bats, but instead causes severe inflammation of tissues upon restoration of immune functions following hibernation (Meteyer et al. 2012). Infected bats also have little or no fat reserves (Blehert et al. 2009, Meteyer et al. 2009).

Figure 5. Bat with white-nose syndrome (photo by Marvin Moriarty, U.S. Fish and Wildlife Service).

WNS appears to occur only in bats, suggesting they have unique traits that predispose them to infection (Blehert et al. 2011). Infected species include the little brown myotis, northern myotis (*Myotis septentrionalis*), eastern small-footed myotis (*M. leibii*), tri-colored bat (*Perimyotis subflavus*), big brown bat, the endangered Indiana myotis (*M. sodalis*), and the endangered gray myotis (*M. grisescens*) (Blehert et al. 2011). All these species are insectivorous and cope with winter food shortages by hibernating in cold and humid environments of caves and mines. While hibernating, these bats dramatically reduce their metabolic rate, lower their body temperature to within a few degrees of ambient temperature in their hibernaculum, and often cluster in large numbers (except tri-colored bats, which hibernate alone or in small groups). Torpid mammals also suppress their immune responses (Prendergast et al. 2002, Carey et al. 2003). These behavioral and physiological adaptations likely predispose bats to infection by *G. destructans* (Blehert et al. 2011), which is a long-lived, cold-loving fungus that can thrive in the 2-14°C (36-57°F) temperature range used by hibernating bats (Gargas et al. 2009, Verant et al. 2012, Lorch et al. 2013).

It is unclear how *G. destructans* kills bats. Fungal infection may disrupt bat behavior during hibernation, leading to more frequent arousals (Reeder et al. 2012) and thus more rapid use of fat reserves. Other aberrant behaviors include relocation from thermally stable microclimates at interior locations in hibernacula to areas near entrances with more variable microclimates, and daytime flights of bats from hibernacula in mid-winter. Fungal infection may disrupt physiological functions, such as maintaining water balance, temperature, blood circulation, and cutaneous respiration (Cryan et al. 2010). Cutaneous infection of bats' wings with *G. destructans* may increase cutaneous evaporative water loss resulting in dehydration. Dehydration could cause mortality directly or indirectly through increased frequency of arousals as bats become dehydrated during hibernation. Affected bats that warm up more frequently to drink would prematurely deplete their fat reserves and risk starvation prior to emergence from hibernacula in spring (Cryan et al. 2010, Willis et al. 2011). Aberrant behaviors of bats with WNS may be strategies to restore water balance (Cryan et al. 2010). The finding that bat species more frequently diagnosed with WNS are those that are most susceptible to evaporative water loss during hibernation is consistent with dehydration being a plausible explanation for mortality of bats from WNS (Cryan et al. 2010, Willis et al. 2011).

Geomyces destructans is widespread in Europe, based on recent survey efforts and the presence of hibernating bats with white muzzles, which have been noted for several decades (Puechmaille et al. 2011, Pikula et al. 2012). However, WNS-caused mortality of bats has not been observed in Europe (Wibbelt et al. 2010, Puechmaille et al. 2011). People likely transported the fungus from Europe to or near Howes Cave, enabling it to establish itself in North America (Blehert et al. 2011). *Geomyces destructans* has been detected in all states and provinces where WNS has been observed, as well as in two states (Iowa, Oklahoma) where WNS has not yet been found affecting bats. The lack of high mortality rates in European bats suggests that they may have coevolved with *G. destructans*, whereas the sudden high mortality in North American species is characteristic of an exotic pathogen introduced into naïve bat populations (Wibbelt et al. 2010).

The rapid spread of WNS in North America is likely the result of hibernaculum-to-bat and bat-to-bat transmission of the fungus (Lorch et al. 2011, Turner et al. 2011). However, the fungus has been found on clothing and gear used at infected hibernacula (Okoniewski et al. 2010), suggesting that people may have assisted the spread of the fungus and disease to new caves, some of which were very distant from known infected sites.

By early 2012, an estimated 5.7 million to 6.7 million bats had died from WNS in North America (U.S. Fish and Wildlife Service, unpubl. data). As of March 2013, WNS had spread to 22 states and five Canadian provinces in eastern North America and biologists expect the disease to continue to spread (Blehert et al. 2011). The little brown myotis has experienced a population collapse in the northeastern U.S., a region where it was once the most common and widely distributed species, and could become regionally extinct by about 2026 due to high mortality from WNS (Frick et al. 2010b). The U.S. Fish and Wildlife Service determined that federal listing may be warranted for the eastern small-footed myotis and northern myotis under the Endangered Species Act and is initiating a status review (USFWS 2011). The U.S. Fish and Wildlife Service was petitioned to list the little brown myotis as federally endangered (Kunz and Reichard 2010). In Canada, the Committee on the Status of Endangered Wildlife in Canada proposed emergency listing of the little brown myotis, tri-colored bat, and northern myotis as endangered under the Species At Risk Act in February 2012 due to unprecedented mortality from *G. destructans* (COSEWIC 2012). Because about half of the 45 bat species in the U.S. are obligate hibernators, an additional 18 bat species may be at risk of infection by *G. destructans* if it spreads beyond its current range.

It remains unknown whether WNS will spread across North America. Modeling indicates that WNS may most likely occur in landscapes that are higher in elevation and topographically diverse, drier and colder in winter, and more seasonally variable than surrounding landscapes (Flory et al. 2012). These general conditions appear to resemble much of the Pacific Northwest. Higher transmission rates occur among species that form tight clusters during hibernation (Langwig et al. 2012). No species of bat in Washington is currently known to roost in this manner during winter, which may suggest lower vulnerability to the disease among many of the state's bat species.

Environmental Contaminants

Bat populations are potentially affected by a wide range of environmental contaminants (Clark and Shore 2001, O'Shea and Johnston 2009), but research on the topic is limited and has in fact declined in recent decades (Weller et al. 2009). Contaminants enter the environment through use as pesticides, release during industrial processes, via the breakdown of manufactured products, from inadequate treatment of wastewater, or through other means. Exposure and accumulation in bats can occur through the diet, drinking, grooming, absorption through the skin, or inhalation. A number of contaminants are fat soluble (lipophilic), which allows them to accumulate in the fatty tissues of bats and to be transferred from mother to young during pregnancy and nursing.

Unique aspects of the life history of bats may make them more susceptible to contaminant poisoning than other small mammals (Clark and Shore 2001, O'Shea and Johnston 2009). These include (1) long life spans, which can allow levels of some compounds to build to toxic levels over time, (2) high metabolic rates, which require greater food consumption, resulting in more exposure to contaminants, (3) mobilization of fat reserves during hibernation, migration, and nursing, which can release toxic levels of stored lipophilic compounds, and (4) low reproductive rates, which reduce the ability of bat populations to withstand stressors (Clark and Shore 2001, O'Shea and Johnston 2009).

High contaminant loads in bats may produce acute symptoms leading to death, or sublethal effects causing chronic health problems or impaired reproduction (Clark and Shore 2001). Elevated contaminant levels have been found in bats with white-nose syndrome, suggesting the possibility that increased exposure could predispose bats to this disease (Kannan et al. 2010).

The following groups of contaminants are of concern for bats (Clark and Shore 2001, O'Shea and Johnston (2009).

- *Organochlorine insecticides* – Heavy, widespread use of these compounds was discontinued in North America by the 1970s and 1980s, but high residual levels often remain in the environment near areas of former industrial contamination and intensive agricultural use. Many organochlorines are neurotoxic and lipophilic. Because they are resistant to metabolic degradation, they commonly bioaccumulate up food webs. These chemicals can be grouped into three subcategories: DDT and metabolites (e.g., DDE); cyclodienes such as aldrin, dieldrin, chlordane, endrin, and hepachlor; and various other compounds including chlorinated camphenes, mirex, and the fungicides PCP and HCB. DDE is the most widely detected of these substances in bats (Clark and Shore 2001). Impacts of organochlorine insecticides on bats have been fairly well studied, with high levels of exposure causing mortality or sublethal effects (Clark and Shore 2001, O'Shea and Clark 2002). Environmental levels of these chemicals have generally declined since their phase-out, meaning that concentrations in bats have also probably decreased over time except near hotspots of contamination.

- *Organophosphate and carbamate insecticides* – These chemicals are widely used and highly toxic, but are not lipophilic, do not accumulate in tissues, and are rapidly metabolized. They act by suppressing cholinesterase activity in the body. Mammals not killed outright by exposure may recover or experience sublethal effects through impaired thermoregulation, reproduction, behavior, and food consumption (Grue et al. 1997). Few studies have been performed on the effects of these compounds on bats. Lethal poisoning of bats likely occurs in the wild, but is poorly documented (Clark and Shore 2001, O'Shea and Clark 2002).

- *Pyrethroid insecticides* – Use of these compounds has grown in recent decades as alternatives to organochlorine insecticides. Pyrethroids are neurotoxic, lipophilic, and some forms likely break down slowly in the environment, but they are quickly metabolized and of low toxicity to lab mammals. Although there is little research on their impacts to bats, they have the potential to adversely affect populations (Clark and Shore 2001).

- *Industrial organochlorines* – This group of chemicals includes polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), and aliphatic hydrocarbons (AHs). PCBs were widely produced for industrial applications in North America until the late 1970s. They are lipohilic, biomagnified up the food chain, and are pervasive in the environment because of their persistence and former widespread use. High concentrations of PCBs can impair reproduction in female mammals and disrupt endocrine function, but studies have not yet confirmed harmful effects in bats. Bats living in urban or industrial areas or feeding over contaminated water sources usually carry the highest loads (Clark and Shore 2001, Kannan et al. 2010).

- *Cyanide poisoning* – This type of poisoning in bats can occur at cyanide-enriched leach waters at gold mines (Clark and Hothem 1991). Cyanide is not persistent and sublethal doses are quickly detoxified and eliminated.

- *Toxic metals* – Lead, mercury, and cadmium are usually the metals of greatest concern to wildlife. Air pollution, industrial causes, and mining are the most frequent sources of exposure. High levels of lead and mercury can produce neurotoxic effects and be harmful to certain organs, whereas cadmium can affect the function of kidneys and other organs (O'Shea and Johnston 2009). Few studies have examined bats for adverse effects.

Numerous new chemicals enter the global environment annually, making it difficult for environmental agencies to monitor levels and sources of all contaminants and to provide effective regulation. These emerging pollutants include pharmaceuticals, flame retardants, surfactants, and others. Little evaluation of the impacts of these compounds on bats has been conducted. Park et al. (2009) documented uptake of endocrine disrupting chemicals by flying insects at sewage treatment facilities, thus posing a potential risk to bats. Kannan et al. (2010) noted high flame retardant levels in little brown myotis.

Only one study has examined contaminant levels in bats in the Pacific Northwest. Henny et al. (1982) reported low levels of DDT, its metabolites, and other organochlorines in five species of bats (big brown bat, California myotis, long-legged myotis, silver-haired bat, and western long-eared myotis) before a single forest spraying with DDT to control larvae of the Douglas-fir tussock moth in northeastern Oregon. Tissue analyses revealed significant increases in the levels of DDT and its metabolites in four of the five species one to two years after spraying, but in only two of the five species after three years. The study did not evaluate whether bats endured any harmful effects from the spraying.

Climate Change

The term "climate change" is generally used to denote a significant change in the statistical properties of climate over long periods of time, regardless of cause. Changes in climate may occur as a result of Earth's natural processes as well as by human activity. As used here, climate change refers to changes in average temperature and precipitation over long periods of time (i.e., decades or longer) caused by human activity (i.e., adding greenhouse gasses to the atmosphere), and in this context "climate change" is synonymous with anthropogenic global warming. Global temperature increased during the 20th century and is projected to continue to increase in the 21st century, with the rate of warming dependent upon the rate of greenhouse gas emissions. In the Pacific Northwest, annual temperature and precipitation increased during the 20th century with the largest increases during winter and spring, respectively (Mote 2003). A recent assessment of climate change in the Pacific

Northwest projects that the region will experience increased warming, decreased precipitation, greater areas burned by fire, changes in natural vegetation, and reduced seasonal streamflow (CIG 2009), all of which are likely to affect Washington's bat populations.

The 21st century is projected to be warmer and warm at a faster rate than the 20th century. Climate models project an increase in average annual temperature of 3.0°C (5.3°F) by the 2080s (or an increase of about 0.4°C [0.7°F] per decade), with increases expected to be greatest during the summer months (Mote and Salathé 2009). Projected changes in average precipitation are equivocal on an annual basis, although most models predict an average decline of 14% during the summer months by the 2080s (Mote and Salathé 2009).

Hotter and drier summers will likely increase the amount of area burned by fire. Regional fire models project an increase in the median area burned annually from about 0.5 million to 0.8 million acres by the 2020s and a doubling or tripling of the acreage burned per year by the 2080s (Littell et al. 2009). By habitat type, the area burned could double in non-forested ecosystems (Columbia Basin, Palouse Prairie) and almost quadruple in forest ecosystems (Western and Eastern Cascades, Okanogan Highlands, Blue Mountains) by the 2040s (Littell et al. 2009). During the summer months, projected increases in temperature and reduced precipitation suggest increases in water deficit that could result in declines in some tree species, such as lodgepole pine. Climate change will also likely cause concentrated mountain pine beetle outbreaks at increasingly higher elevations as the climate conducive to outbreaks shifts to higher elevations. Increasing summer temperatures and evapo-transpiration in forests in western Washington suggest the potential for large disturbances in this sub-region. Climate-driven reductions in precipitation and increased disturbances, such as fire and insect outbreaks, are likely to be the primary mechanisms for change in Washington's forests in the future.

Warmer temperatures and drier conditions are likely to affect the availability of roosting and foraging resources to bats. Future projections of a drier and hotter climate during summer months may reduce coverage of sagebrush (Bradley 2010), as well as increase fire occurrence and subsequent invasion by non-native species in shrub-steppe. This cover type is an important foraging habitat for bats in eastern Washington. Projections of larger areas of forest burned by fire could affect the availability of suitable roost trees and snags for roosting. Decreased precipitation and corresponding availability of water near maternity sites could reduce reproductive output of bats (Adams and Hayes 2008, Jones et al. 2009, Adams 2010). Climate change may result in earlier emergence from hibernation, earlier births, extended foraging seasons, and less time in hibernation during winters of lower cold severity (Jones et al. 2009). Climate change may also cause some bat species to undergo range shifts in elevation or latitude (Humphries et al. 2002, Jones et al. 2009) and may negatively affect migratory bat species due to the loss or degradation of habitat and changes in food availability (Robinson et al. 2009).

CHAPTER 2: SPECIES ACCOUNTS

The following accounts of the 15 bat species known to occur in Washington are arranged in alphabetical order by common name to assist readers in finding the accounts. Range maps depict current known distribution (shaded) by county based on a review of more than 2,000 museum records (Appendix D), WDFW's Wildlife Survey Data Management (WSDM) database, and various reports and scientific papers from Washington. North American range maps of these species appear in Appendix A and size measurements are presented in Table 5.

An additional species, either the eastern red bat (*Lasiurus borealis*) or western red bat (*L. blossevillii*), may also occur in the state, but remains unconfirmed to date (J. E. Bassett, pers. comm.). Based on evidence from western Canada, the highly migratory eastern red bat is probably the more likely of the two species to visit Washington (Bassett 2011, Nagorsen and Paterson 2012). Eastern red bats range across much of eastern North America, rarely reaching the Rocky Mountains (Adams 2003, Cryan 2003). However, recent records suggest the species is expanding its range westward, including into northeastern British Columbia (AESRD 2012, Nagorsen and Paterson 2012). Western red bats occur from California and the Southwest U.S. into South America and are partially migratory (Cryan 2003, Pierson et al. 2006).

Table 5. Size measurements of bat species occurring in Washington.

Species	Weight (g)	Total length (mm)	Forearm length (mm)	Wingspan length (mm)	Hind foot length (mm)	Ear length (mm)	Tragus length (mm)	Source[a]
Big brown bat	8.3-24.9	87-156	39-54	205-393	8-15	10-21	5-11	1,2,3,4,5,6,7,8
California myotis	2.5-9.0	60-97	26-40	209-251	5-12	8-17	4-8	1,3,5,7,9,10
Canyon bat	2.0-6.5	60-86	26-33	190-230	4-7	9-13	-	1,7,8
Fringed myotis	4.7-10.4	78-96	32-46	250-300	8-11	13-21	8-11	2,3,5,7,11,12
Hoary bat	19.3-37.9	99-145	41-58	338-415	9-15	11-20	9-10	1,5,6,7
Keen's myotis	3.8-8.0	63-94	34-40	209-262	5-10	13-20	6-12	5,9,13,16
Little brown myotis	4.0-11.0	60-108	31-41	224-274	6-13	7-17	4-10	1,3,5,7,9,14
Long-legged myotis	3.1-11.0	83-112	32-49	215-272	5-11	8-20	5-7	1,3,5,7,9
Pallid bat	12.0-28.0	98-135	47-61	310-370	9-17	25-36	12-17	5,7
Silver-haired bat	5.8-16.7	80-117	35-47	200-354	6-12	9-19	4-9	1,3,5,6,7,15
Spotted bat	15.2-21.4	107-125	48-54	336-355	9-10	34-46	13-14	5,7
Townsend's big-eared bat	6.0-19.0	80-118	34-56	232-340	7-12	26-40	10-15	1,5,7
Western long-eared myotis	4.1-9.0	74-103	32-42	243-294	7-11	15-24	8-12	3,5,7
Western small-footed myotis	2.8-7.0	72-93	23-36	205-245	6-8	8-18	4-9	2,3,5,7,10
Yuma myotis	3.8-9.0	60-99	26-38	205-260	6-13	8-16	5-10	1,3,5,7,14

[a] Sources: 1, Adams (2003); 2, Fleckenstein (2000); 3, Holroyd et al. (1994); 4, Kurta and Baker (1990); 5, Nagorsen and Brigham (1993); 6, van Zyll de Jong (1985); 7, Verts and Carraway (1998); 8, Wilson and Ruff (1999); 9, Boland et al. (2009b); 10, Constantine (1998); 11, Collard et al. (1990); 12, Keinath (2004); 13, Burles and Nagorsen (2003); 14, Rodhouse et al. (2008); 15, Kunz (1982b); Burles et al. (2009).

Big Brown Bat (*Eptesicus fuscus*)

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Description. This species is one of the largest bats in Washington (Table 5) and features a heavy body, large head, and broad nose (Kurta and Baker 1990, Nagorsen and Brigham 1993). The pelage varies from pale to dark brown, is darker above and lighter below, and has an oily texture. Individual hairs on the back are relatively long (>10 mm) and extend one-quarter of the way down the upper surface of the tail membrane. Wing membranes and ears are black. Ears are relatively rounded and short, and barely reach the nose when pressed forward. The tragus is also short and blunt. The foot is large and about half the length of the tibia, and the calcar has a prominent keel.

Taxonomy. Twelve subspecies are recognized (Simmons 2005), with only *E. f. bernardinus* confirmed in Washington. A second subspecies, *E. f. pallidus*, may extend into extreme eastern Washington (Hall 1981).

Distribution. Big brown bats range from southern and central Canada to northern South America and the Caribbean (Kurta and Baker 1990; Appendix A). This species is present throughout Washington (WDFW WSDM database).

Population status. This species is common in many parts of its range, but information on population size and trend is generally lacking. Whitaker and Gummer (2000) suggested that abundance in northern populations has perhaps expanded over time with the increased availability of heated buildings for hibernacula. In Washington, big brown bats have been found at nearly every location where surveys have been conducted (Johnson and Cassidy 1997). Detections were common or moderately common during acoustic or capture surveys at various sites in the eastern and western Cascades (Thomas 1988, Erickson 1993, Taylor 1999, Christophersen and Kuntz 2000, Baker and Lacki 2004), Moses Coulee (Fleckenstein 2000, Rosier and Rosenberg 2006), Hanford (Gitzen et al. 2002), Turnbull National Wildlife Refuge in Spokane County (Rancourt et al. 2007), and the general areas around Olympia in Thurston County and Joint Base Lewis-McChord in Pierce County (Wunder et al. 1992, Falxa 2005, 2008a; G. Falxa, pers. comm.). In contrast, detections were infrequent or not made at other locations in the western Cascades (West et al. 1984, Thomas 1988, Petterson 2001), the Selkirk Mountains (Campbell 1993), at the Yakima Training Center (Christy et al. 1995), Hanford (Lindsey et al. 2012), Badger Gulch in Klickitat County (Fleckenstein 2001a), in the San Juan Islands (Dalquest 1940), and on the Olympic Peninsula (Erickson et al. 1998, Jenkins et al. 1999, West et al. 2004).

Habitat. The big brown bat is a habitat generalist that occupies a variety of forest types, rangeland, and urban areas (Whitaker et al. 1977, 1981a, Nagorsen and Brigham 1993, Johnson and Cassidy 1997, Adams 2003). In Washington and Oregon, the species appears to be more common in forest than shrub-steppe and alpine areas (Whitaker et al. 1977, 1981a, Johnson and Cassidy 1997). Occurrence in the West extends from sea level to 3,800 m elevation (Nagorsen and Brigham 1993, Adams 2003). In mountainous areas, males inhabit higher elevations than females (Kurta and Baker 1990, Baker and Lacki 2004).

Roosts and roosting behavior. Summer day roosts of this species, including maternity colonies, occur in a variety of settings, including buildings (e.g., inside attics and walls), trees, snags, caves, mines, crevices in cliffs, and bridges (van Zyll de Jong 1985, Hendricks et al. 2005, WBWG 2005, NatureServe 2009). Reproductive females are colonial and occupy sites offering suitable temperature gradients. Maternity roosts are often in older buildings having appropriate entry points (Williams and Brittingham 1997, Neubaum et al. 2007) or in large live or dead trees in intermediate stages of decay (Brigham 1991, Betts 1996, Vonhof 1996, Kalcounis and Brigham 1998, Willis et al. 2006a, Rancourt et al. 2007, Vonhof and Gwilliam 2007, Arnett and Hayes 2009). Occupation of trees and snags depends on the presence of cavities, hollow trunks, crevices, loose exfoliating bark, and dead or broken tops; cavity volume; openness from surrounding vegetation; and older age of the forest stand. Ponderosa pine, aspen, and Douglas-fir are among the main tree species used for roosting (Brigham 1991, Betts 1996, Kalcounis and Brigham 1998, Rabe et al. 1998a, Rancourt et al. 2007, Vonhof and Gwilliam 2007, Arnett and Hayes 2009).

Maternity roosts in the West usually contain anywhere from about a dozen to several hundred individuals (WBWG 2005), but in other regions, females sometimes roost in smaller groups or alone (Lausen and Barclay 2002). Maternity colonies in trees are reportedly larger than those in buildings in British Columbia (Nagorsen and Brigham 1993), but it's unclear whether this pattern applies elsewhere in the West. Buildings offer greater safety from predators and warm microclimates, resulting in earlier births, faster juvenile growth, and increased energy savings, and therefore are probably preferred as roosts over some types of natural sites (Lausen and Barclay 2006). Most adult females return to the same maternity roost or roost area in successive years.

Pregnant and nursing females also demonstrate strong daily fidelity to roosts in permanent structures such as buildings, whereas those roosting in trees and erodible cliffs commonly switch roosts every few days or less (Brigham 1991, Betts 1996, Kalcounis and Brigham 1998, Lausen and Barclay 2002, Willis and Brigham 2004, Rancourt et al. 2007, Arnett and Hayes 2009). Forest- and cliff-dwelling females form fission-fusion societies composed of a number of groups spread among multiple cavities at any one time (Lausen and Barclay 2002, Willis and Brigham 2004). As a whole, the bats are too numerous to live in a single cavity, but individuals remain loyal to an area of forest and over time roost with most colony mates in other trees. Non-reproductive females may or may not roost within maternity colonies (Hamilton and Barclay 1994, Lausen and Barclay 2006). Maternity colonies begin to break up in August (Barbour and Davis 1969). Both reproductive and non-reproductive females regularly use torpor while day roosting during summer (Hamilton and Barclay 1994, Lausen and Barclay 2003).

Adult males use buildings, trees, and rock crevices as summer day roosts. At Moses Coulee, males roosted only in basalt cliffs (Rosier and Rosenberg 2006). Males usually roost singly or in small groups, but sometimes join maternity colonies (Kurta and Baker 1990, Hamilton and Barclay 1994, Adams 2003). Some males (e.g., those inhabiting rock crevices) frequently switch roosts (Brigham 1991). Males use torpor more often and enter it more deeply than reproductive females (Hamilton and Barclay 1994).

Bridges are regularly used for night roosting in Oregon, California, and probably Washington (Pierson et al. 1996, Adam and Hayes 2000; M. MacDonald, pers. comm.). Bridge roosts are mostly occupied by solitary males or mother-young pairs, but aggregations of more than 75 animals have been noted (Pierson et al. 1996). Basalt cliffs are also used (Rosier and Rosenberg 2006).

Hibernacula include buildings, caves, mines, and rock crevices (Kurta and Baker 1990, Neubaum et al. 2006), but the extent that other natural sites (e.g., hollow trees) are used is poorly known. Buildings are considered the most important hibernacula in western Canada and western Oregon (Nagorsen and Brigham 1993, Maser 1998). Relatively little is known about hibernation sites in Washington, but buildings are known to be used (Perkins et al. 1990). Hibernacula generally have air temperatures of 0-18°C (32-64°F) (Barbour and Davis 1969, Brack and Twente 1985, Whitaker and Gummer 1992, Neubaum et al. 2006). Some winter sites also function as maternity roosts in summer (Whitaker and Gummer 1992, 2000).

Swarming behavior occurs at mines and caves before hibernation (Nagorsen and Brigham 1993). Hibernation lasts from November to April in interior British Columbia (Nagorsen and Brigham 1993). Hibernacula rarely hold more than a few hundred individuals (NatureServe 2009), with those present usually roosting alone or in small clusters of fewer than 20 animals (van Zyll de Jong 1985, Kurta and Baker 1990, Whitaker and Gummer 1992). Both sexes hibernate together (Whitaker and Gummer 2000). Individuals may lose 25% of their pre-hibernation body weight over winter (Nagorsen and Brigham 1993), thus failure to accumulate sufficient fat reserves can be a major mortality factor, particularly for juveniles. Movement among hibernacula is common within a winter (Boyles et al. 2006).

Reproduction. Adult males have descended testes beginning in mid-July (Baker and Lacki 2004). Mating likely occurs in the fall and occasionally during winter arousals from hibernation (Kurta and Baker 1990). Sperm remain in the uterus over winter, with ovulation and fertilization occurring in spring after hibernation ends (Wimsatt 1944). Pregnancy lasts about 60 days (Kurta and Baker 1990). Births occur from May to August (Barbour and Davis 1969, Adams 2003, Baker and Lacki 2004), but dates can vary within and among roosts probably due to annual differences in weather (Nagorsen and Brigham 1993). Most births in British Columbia and western Oregon occur in June or early July (Nagorsen and Brigham 1993, Holroyd et al. 1994, Maser 1998), but pregnancies have been recorded as late as 12 August in Washington (Baker and Lacki 2004). Litter size is usually one young in western North America (Barbour and Davis 1969, O'Shea et al. 2010). Lactation lasts 32-40 days (Kunz 1974). Juveniles begin to fly at 18-35 days (Kurta and Baker 1990). In Washington, Baker and Lacki (2004) began seeing flying young by 12 August. Males attain sexual maturity in their first fall, but only 50-75% of females do so (Christian 1956, Schowalter and Gunson 1979, O'Shea et al. 2010). Survival rates are lower in juveniles than in adults (O'Shea et al. 2010, 2011).

Food habits and foraging. The large powerful jaw musculature and heavy teeth of big brown bats allow them to feed on hard-bodied insects as well as other prey (Freeman 1981). Beetles typically form the bulk of the diet (Brigham and Saunders 1990, Kurta and Baker 1990, Whitaker 1995, Hamilton and Barclay 1998, Moosman et al. 2012). Several studies from western and eastern Oregon and Idaho support the preference for beetles, with 34-53% of the diet comprised of these insects (Whitaker et al. 1977, 1981a, Lacki et al. 2007b, Ober and Hayes 2008a). Moths, termites, true bugs, leafhoppers, flies, and flying ants are other main foods. Other regional studies have found preferences for caddisflies (Brigham 1990, Verts et al. 1999), bees, and ants (Henny et al. 1982).

Big brown bats usually emerge from day roosts between sunset and darkness (Whitaker et al. 1977, Kurta and Baker 1990) and may initially forage in large circles high above the ground, but soon descend to feed within 15 m (50 ft) of the ground (Whitaker et al. 1977, Kurta and Baker 1990, Brigham 1990). Flight is strong, direct, and moderately fast (van Zyll de Jong 1985). Several foraging flights are made per night and are interspersed with visits to night roosts. Foraging individuals have been documented traveling up to 10 km from their days roosts (Kurta and Baker 1990, Brigham 1991, Rosier and Rosenberg 2006), with males using larger foraging areas (average = 5 km^2) than females (average = 2.7 km^2) (Wilkinson and Barclay 1997). In the Pacific Northwest, big brown bats forage above the forest canopy; along forest and rural roads, forest edges, and cliffs; over clearings and water courses; and in urban areas. In forest, individuals forage among and over the tops of trees rather than under the canopy (van Zyll de Jong 1985).

Seasonal movements. Most big brown bats travel less than 90 km from summer roosts to hibernacula (Mills et al. 1975, Neubaum et al. 2006). Winter specimen records from the Pacific Northwest (Perkins et al. 1990, Nagorsen et al. 1993) suggest the possibility that many individuals remain close to their summer range.

Threats. Major large-scale threats are not known, but localized populations can be affected by one or more concerns (Agosta 2002, WBWG 2005, NatureServe 2009). Logging probably causes the loss of roost trees. Roost disturbance and destruction can be harmful, particularly exclusion and eradication in buildings, closures of mine, and cave and mine visitation by people. Increased urbanization, grazing, and loss of riparian habitat can reduce foraging habitat. Big brown bats are vulnerable to pesticides, which can cause mortality, alter behavior, and be transferred to nursing young. Mortality from white-nose syndrome is another threat.

Conservation measures. Protection of maternity roosts and sizeable hibernacula is a priority for conservation. For tree-dwelling populations, retention and recruitment of large snags, decadent trees, and hollow trees is important (Hayes 2003, Willis and Brigham 2004, Vonhof and Gwilliam 2007, Arnett and Hayes 2009). On intensively managed forests, management agreements and incentives for protecting large-diameter roost trees are desirable (Hayes 2003). Maintaining remnant patches of structurally diverse forest with abundant large snags is another protective strategy (Waldien et al. 2000). Providing roost structures within 2-3 km of open water or riparian areas is probably beneficial by providing ready access to drinking and foraging sites (Hayes 2003). Maintaining potential roosts across a variety of topographical positions is also desirable so that bats have a range of suitable roosting sites to select from. Where eviction from buildings is necessary, appropriate actions should be taken to minimize negative impacts to the bats. Precautions to reduce disturbance should be taken when mine and cave surveys are conducted during the breeding season and winter hibernation. Seasonal inventories of bat use should be conducted at mines and caves considered for closure, with bat gates installed where occupancy is documented.

California Myotis (*Myotis californicus*)

Description. California myotis are one of the smallest bats in Washington (Table 5). Fur coloration of the two subspecies found in Washington ranges from rusty to blackish brown and lacks a glossy sheen, with *M. c. caurinus* having darker fur than *M. c. californicus* (van Zyll de Jong 1985, Nagorsen and Brigham 1993, Simpson 1993). Ears and flight membranes are black. The ears are relatively short, but nevertheless extend beyond the nose when pressed forward. The tragus is long and narrow. The hind foot is relatively small and less than half the tibia length, and the calcar has a distinct keel.

Differences between California myotis and western small-footed myotis are subtle and variable, making identification of the two species difficult when based only on physical characteristics. California myotis tend to have darker fur that is less contrasting with the dark ears and flight membranes, a smaller bare area on the snout, and a more abrupt forehead than western small-footed myotis (Nagorsen and Brigham 1993, Simpson 1993). Rodriguez and Ammerman (2004) reported genetic overlap between the two species. California myotis have an echolocation call with a characteristic frequency of 50 kHz call, whereas western small-footed myotis calls have a characteristic frequency of 40 kHz (O'Farrell et al. 1999b, Gannon et al. 2001). The combination of morphometric and full-spectrum call analyses generally allows accurate field identification.

Taxonomy. Four subspecies are recognized (Simmons 2005), with two present in Washington. *Myotis c. caurinus* occurs in western Washington and Chelan County (Hall 1981), while *M. c. californicus* is found in the remainder of eastern Washington (Simpson 1993).

Distribution. California myotis range southward from southeastern Alaska and southern British Columbia to much of the western U.S., Mexico, and Guatemala (Simpson 1993, Parker et al. 1997; Appendix A).

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This species is present in all counties in Washington (WDFW WSDM database). Some records from eastern Washington may be erroneous because of past confusion with western small-footed myotis.

Population status. Little information is available on population size and trend, although the species is considered common to abundant in some locations and regions, such as western Oregon (Whitaker et al. 1977) and Utah (Oliver 2000). In Washington, detections of California myotis were common or moderately common during acoustic or capture surveys at various sites in the western and eastern Cascades (West et al. 1984, Thomas 1988, Christophersen and Kuntz 2003, Baker and Lacki 2004), the Selkirk Mountains (Campbell 1993), at Badger Gulch in Klickitat County (Fleckenstein

2001a), at Joint Base Lewis-McChord (Wunder et al. 1992, Falxa 2008a), at Woodard Bay in Thurston County (Falxa 2007b), at Long Island in Pacific County (Christy 1993), on the Olympic Peninsula (West et al. 2004), and in the San Juan Islands (Dalquest 1940). The species was uncommon or rare at other locations in the eastern Cascades (Frazier 1997, Taylor 1999), on the Olympic Peninsula (Erickson et al. 1998, Jenkins et al. 1999), at Mt. Rainier (Petterson 2001), at Moses Coulee (Rosier and Rosenberg 2006), and at Hanford (Gitzen et al. 2002, Lindsey et al. 2012). Abundance at Joint Base Lewis-McChord may have declined from 1992 to 2008 (Wunder et al. 1992, Falxa 2008a).

Habitat. California myotis inhabit deserts, canyons, shrub-steppe, arid grasslands, and dry interior forests, as well as moister environments such as humid coastal and montane forests comprised of deciduous or coniferous trees, riparian forests, and mountain meadows (Nagorsen and Brigham 1993, Verts and Carraway 1998, Adams 2003). Urban and semi-urban locations are also used (Adams 2003, Falxa 2007a). In arid regions, presence is commonly dependent on the availability of water sources (Johnson and Cassidy 1997, WBWG 2005). Elevations from sea level to 2,750 m are occupied (Nagorsen and Brigham 1993, Oliver 2000).

Roosts and roosting behavior. Roost sites include crevices beneath tree bark and rocks; in tree cavities, caves, mines, buildings, and bridges; on shrubs; and on the ground (Nagorsen and Brigham 1993, Wilson and Ruff 1999). Maternity colonies occur in many of these same types of sites. In tree-dwelling populations, reproductive females form relatively small colonies averaging about 10–20 individuals (range = 4–52 bats) (Brigham et al. 1997, Barclay and Brigham 2001, Vonhof and Gwilliam 2007). Females in these populations prefer tall large-diameter roost trees in relatively open patches of forest, with ponderosa pine and Douglas-fir selected preferentially at some locations (Table 3; Brigham et al. 1997, Vonhof and Gwilliam 2007). Females most frequently roost under loose bark in trees or snags in intermediate stages of decay (Brigham et al. 1997, Barclay and Brigham 2001, Vonhof and Gwilliam 2007). Roost trees probably remain suitable for periods of only a few years (Barclay and Brigham 2001). Reproductive females switch roost trees frequently (daily or once every few days) and show low fidelity to individual trees (Brigham et al. 1997). As a result, the number of bats emerging from any individual roost tree often varies considerably from day to day. Distances moved between roosts average about 400 m (range = 6–1,000 m).

Males and probably non-reproductive females roost singly or in small groups separate from reproductive females during summer and also change roosts often (Nagorsen and Brigham 1993, Barclay and Brigham 2001). Males occasionally use stumps as day roosts (Waldien et al. 2003).

This species appears flexible in its choice of night roosts and may use any natural or human-made shelter (Nagorsen and Brigham 1993). Mines, caves, buildings, tree hollows, rock crevices, bridges, trees, and shrubs are among the structures occupied at night (Barbour and Davis 1969, Hirshfeld et al. 1977, Adam and Hayes 2000).

California myotis hibernate alone or in small groups in buildings, caves, and mines (van Zyll de Jong 1985, Perkins et al. 1990, Wilson and Ruff 1999). In Washington, Oregon, and British Columbia, this species commonly hibernates in buildings (Perkins et al. 1990, Nagorsen and Brigham 1993) and has been found in lava tubes (Senger et al. 1974). Winter surveys of more than 650 caves and 70 buildings in these states during the 1980s found single individuals at just two caves in Oregon (Perkins et al. 1990). Both sexes roost together in fall and winter (van Zyll de Jong 1985). In western and eastern Washington and elsewhere, this species emerges from hibernation to become active on both mild and below freezing evenings (Nagorsen and Brigham 1993, Wilson and Ruff 1999, Falxa 2007a; N. Williams, pers. comm.).

Reproduction. Descended testes are evident in males by mid-July (Baker and Lacki 2004). Mating occurs in the late fall in most of the range, including the Pacific Northwest (Simpson 1993). Sperm are stored overwinter and fertilization occurs in spring. One young is born annually and births occur from about May to early July in Oregon, Washington, British Columbia, and Alaska (Wunder et al. 1992, Nagorsen and Brigham 1993, Maser 1998, Baker and Lacki 2004, Boland et al. 2009b). Young are able to fly at about one month of age (Wilson and Ruff 1999).

Food habits and foraging. A variety of prey is consumed. In most studies from the Pacific Northwest, moths and flies dominate the diet, with beetles, caddisflies, neuropterans, termites, and bees/ants also sometimes eaten in significant amounts (Whitaker et al. 1977, 1981a, Henny et al. 1982, Wunder et al. 1992, Kellner and Harestad 2005, Lacki et al. 2007b, Ober and Hayes 2008a). However, caddisflies and to a lesser extent beetles were the primary foods in one study from British Columbia (Woodsworth 1981). Spiders are also sometimes consumed (Whitaker et al. 1977, Kellner and Harestad 2005).

Foraging activity usually begins before dark (Brigham et al. 1997, Verts and Carraway 1998), although in western Oregon, Whitaker et al. (1977) detected almost no activity until after nightfall. Foraging is often greatest within a few hours of darkness, with additional peaks in activity sometimes noted during the rest of the night (Wunder et al. 1992, Verts and Carraway 1998). Foraging occurs over water, near the ground, within the forest canopy, along forest margins, and high above open ground (Fenton et al. 1980, Woodsworth 1981, Wilson and Ruff 1999). California myotis have rounded wing tips, low wing loading, and low aspect ratios, which give them slow maneuverable flight (Ober and Hayes 2008a). Their high frequency echolocation suggests that most insects are detected at close range (Ober and Hayes 2008a). Distances between capture sites and maternity roosts averaged 1,529 m (range = 500–3,140 m) in British Columbia (Brigham et al. 1997). Foraging is known to extend through winter in parts of western Washington (Falxa 2007a).

Seasonal movements. No information is available. However, presence of numerous individuals in western Washington throughout the year (Falxa 2007a; G. Falxa, pers. comm.; G. Green, pers. comm.), sometimes in the same roost in multiple seasons, suggests that seasonal movements are limited or do not exist in some regions. The species has also been recorded year-round in Spokane County (N. Williams, pers. comm.).

Threats. California myotis are probably negatively affected by some logging practices, particularly the removal of large-diameter trees and snags (WBWG 2005). High levels of pesticide residues were detected in this species for at least three years after aerial spraying of DDT to control larvae of the Douglas-fir tussock moth (Henny et al. 1982), although use of this chemical has since been discontinued. Roost sites may be lost through closure (i.e., blockage) of abandoned mines and from disturbance at caves by recreational cavers.

Conservation measures. Retention and recruitment of large trees and snags during timber harvest is likely crucial to the conservation of California myotis in forested landscapes. On intensively managed forests, management agreements and incentives for protecting large-diameter roost trees and snags are desirable (Hayes 2003). Maintaining remnant patches of structurally diverse forest with abundant large snags is another protective strategy (Waldien et al. 2000). Where eviction from buildings is necessary, non-lethal exclusion measures should be taken to minimize negative impacts on the bats. Precautions to reduce disturbance should be taken when mine and cave surveys are conducted during the breeding season and winter hibernation. Seasonal inventories of bat use should be conducted at mines and caves considered for closure, with bat gates installed where occupancy is documented. Before pesticide spraying projects, surveys to identify roosting and foraging habitat should be conducted to avoid spraying of important habitats.

Canyon Bat (*Parastrellus hesperus*)

Description. The canyon bat (formerly known as the western pipistrelle) is one of the smallest bats in Washington (Table 5) and North America (WBWG 2005). The face, ears, and flight membranes are blackish and contrast with the paler fur, which varies from pale yellowish or orange-yellow to gray-brown. The short (usually half the length of the ear) blunt, club-shaped tragus distinguishes this species from California myotis and western small-footed myotis. The hind foot is less than half the length of the tibia and the calcar is keeled.

Taxonomy. Two subspecies are recognized (Simmons 2005), with *P. h. hesperus* occurring in Washington. The species was until recently placed in the genus *Pipistrellus* (Hoofer et al. 2006).

Distribution. Canyon bats are mainly distributed from the southwestern U.S. to central Mexico, but a narrow finger of the species' range extends into eastern Oregon and eastern Washington, which is the northern extent of the species' range (Hall 1981; Appendix A). The species has been reported from 10 eastern Washington counties, with most records coming from along the Columbia and Snake rivers and large coulees (WDFW WSDM database).

Population status. Population size and trends are unknown throughout the species' range, including Washington. It is considered common to abundant in much of its distribution (Wilson and Ruff 1999), but has been recorded at relatively few locations in Washington. Echolocation surveys at the Hanford Site revealed it to be relatively uncommon overall, although it was detected during 14% of all surveys and was common in the cliffs and gullies at White Bluffs along the Columbia River (Gitzen et al. 2002). Similar surveys at Hanford by Lindsey et al. (2012) found it to be rare. It is uncommon at Moses Coulee (Rosier and Rosenberg 2006), but fairly widespread in eastern Grant and northwestern Adams counties (Wisniewski et al. 2010).

Habitat. Canyon bats occur most commonly in lowland arid habitats, including desert, dry grasslands, shrub-steppe, and associated riparian zones (Verts and Carraway 1998, Kuenzi et al. 1999, Wilson and Ruff 1999, WBWG 2005, Rodhouse et al. 2011). Canyon environments with cliffs are especially preferred. Mixed conifer forest up to higher elevations is also inhabited in parts of the species' range, although this has not been documented in Washington. Elevations from sea level to 2,825 m are inhabited (Wilson and Ruff 1999). In Washington, the species has been detected most often in deep river canyons and coulees with shrub-steppe, especially at rocky locations (Johnson and Cassidy 1997, Gitzen et al. 2002, Rosier and Rosenberg 2006, Wisniewski et al. 2010). At Hanford, it has also been recorded

infrequently at sites with buildings, bunchgrass, dunes, ponds, rivers, and trees (Gitzen et al. 2002). In Moses Coulee, it occurs in shrub-steppe, riparian zones, and near cliffs, including some sites distant from water sources (Fleckenstein 2000, Rosier and Rosenberg 2006, Rosier 2008).

Roosts and roosting behavior. Little is known about the summer and winter roosting ecology of canyon bats in the Pacific Northwest. Canyon bats prefer day roosting in small crevices of cliffs, rock outcrops, caves, mines, and buildings, but rodent burrows and sites beneath rocks are possibly occupied as well (Wilson and Ruff 1999, WBWG 2005). Females with young roost solitarily or form small maternity colonies of less than 20 individuals (WBWG 2005). Maternity roosts occur separately from the day roosts of males and non-reproductive females.

Little information exists on night roosts, but use of mines has been reported (WBWG 2005). Johnson and Cassidy (1997) suggested that perches on sagebrush are important as roosts at night.

Canyon bats are known to hibernate in mines (Kuenzi et al. 1999). Three occupied mines in Nevada had average winter temperatures of 7.3ºC (45.1°F; range = 0-14ºC, 32-57.2°F) and humidities of 37% (range = 21-52%), and held only one or two canyon bats each (Kuenzi et al. 1999).

Reproduction. Mating likely happens in the fall, with ovulation and fertilization occurring in spring. Females are pregnant for about 40 days. Births take place from late May through early July, with two young born per litter (Verts and Carraway 1998, Kuenzi et al. 1999, WBWG 2005). Young are likely capable of flight within a month. Both males and females probably breed during their first autumn.

Food habits and foraging. The diet includes small swarming insects such as moths, leafhoppers, flying ants, mosquitoes, and fruit flies (Wilson and Ruff 1999, WBWG 2005). In eastern Oregon, the most common prey were flies, moths, hymenopterans, beetles, true bugs, and leafhoppers (Whitaker et al. 1981a). Canyon bats are slow and weak fliers. Foraging often begins before sunset and may continue until well after dawn. Early evening activity usually decreases 1-2 hours after sunset. Foraging occurs in a variety of habitats, including canyons, along cliffs, in riparian zones, and over lava beds (Whitaker et al. 1981a, Rodhouse et al. 2011). During hibernation, individuals may regularly arouse to forage on warm winter days, with males appearing to be more active in winter than females (Verts and Carraway 1998, WBWG 2005).

Seasonal movements. Canyon bats are considered non-migratory (Wilson and Ruff 1999). Verts and Carraway (1998) noted the lack of winter records for Washington and Oregon, and questioned whether the species migrates, hibernates, or hibernates only intermittently in these states.

Threats. Human development through mining, road and building construction, and creation of water impoundments can destroy roost sites and kill roosting canyon bats (WBWG 2005). The species has presumably also experienced a reduction in foraging habitat caused by the loss and fragmentation of shrub-steppe and grasslands near cliff faces with day roosts.

Conservation measures. Based on the little available information from other states, cliffs, rock outcrops, and mines may be important roost sites for canyon bats and should be surveyed for seasonal presence of this species. Where roosting habitat occurs, it should be identified and not disturbed. Steps should be taken to reduce the conversion of shrub-steppe and grassland near cliff faces to preserve accessible foraging habitat.

Fringed Myotis (*Myotis thysanodes*)

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Description. Fringed myotis are small bats, but one of the larger species of *Myotis* in Washington (Table 5). Pelage color ranges from yellowish brown to darker olive, with little discernible difference between the back and underparts except in Canada, where the back is pale brown and the undersides are paler (O'Farrell and Studier 1980, van Zyll de Jong 1985, Nagorsen and Brigham 1993). Ears and flight membranes are blackish. The outer edge of the tail membrane is lined with small stiff hairs that are visible to the naked eye, giving this species its common name. Ears are long and extend beyond the nose when pushed forward. The tragus is long and slender. The foot is large, about half the length of the tibia, and the calcar is not keeled.

Fringed myotis are one of three physically similar long-eared *Myotis* species in Washington. Problems can exist in distinguishing this species from western long-eared myotis and Keen's myotis (Rasheed et al. 1995). However, fringed myotis are usually separable from other species by the conspicuous fringe of hairs along the rear edge of their tail membrane and by their relatively longer forearms and larger ears.

Taxonomy. Four subspecies are recognized (Simmons 2005), with two subspecies present in Washington. *Myotis t. thysanodes* occurs in eastern and perhaps western Washington. *Myotis t. vespertinus* has been described from southwestern Washington, western Oregon, and northwestern California (Manning and Jones 1988), but is not considered a valid subspecies by some authorities.

Distribution. This species ranges across much of western North America from south-central British Columbia to southern Mexico (Keinath 2004, Nagorsen 2004b; Appendix A). In Washington, fringed myotis occur primarily east of the Cascade crest (WDFW WSDM database). Only a few confirmed records exist for western Washington, these being from Whatcom County (Perkins 1988), Jefferson County (Scheffer 1995, Nagorsen 2004b), Thurston County (WDFW WSDM database), and Skamania County (West et al. 1984). Records of uncertain validity or location exist for Skamania and Clark counties (Johnson and Cassidy 1997), the southwestern Cascades (Thomas 1988), Clallam and Jefferson counties (West et al. 2004), and Kitsap, Jefferson, and Snohomish counties (Ormsbee and Hohmann 2010, Ormsbee 2011). Despite listing the subspecies *M. t. vespertinus* as present in southwestern Washington, Manning and Jones (1993) provided no documentation of records from there.

Population status. Little is known about population size and trends throughout the range of fringed myotis, including Washington. The species is gen-

erally considered uncommon to rare across much of its distribution, but can be locally common (Baker and Lacki 2004, Keinath 2004). In eastern Washington, fringed myotis were relatively common and comprised 13% of total bat captures in ponderosa pine forest along the east slope of the Cascades in Yakima and Kittitas counties (Baker and Lacki 2004), but were uncommon or absent at other southeastern Cascades sites (Frazier 1997, Taylor 1999). It is one of the most common bats at Moses Coulee (Fleckenstein 2000, Rosier and Rosenberg 2006), but was not detected at Hanford (Gitzen et al. 2002, Lindsey et al. 2012), the Yakima Training Center (Christy et al. 1995), eastern Grant or northwestern Adams counties (Wisniewski et al. 2010), or the Selkirk Mountains (Campbell 1993). The few records from western Washington (West et al. 1984, Perkins 1988, Thomas 1988, Nagorsen 2004b, WDFW WSDM database) suggest that it is rare throughout this region.

Habitat. Fringed myotis inhabit a variety of plant communities including desert scrub, dry grasslands, shrub-steppe, drier forest, moist coastal coniferous forest, and riparian forest, but drier woodlands (e.g., oak, pinyon-juniper, and ponderosa pine) are often preferred (O'Farrell and Studier 1980, Nagorsen 2004b, Keinath 2004). Access to water sources appears to be important. This species occurs from sea level to 2,850 m, but is most common at middle elevations from 1,200 to 2,100 m (WBWG 2005). In ponderosa pine forest in eastern Washington, it was more common in a lower elevation watershed (760-1,260 m) than a somewhat higher watershed (1,000-1,400 m) (Baker and Lacki 2004). Other state records come from sites with a mix of riparian vegetation, shrub-steppe, and cliffs (Williams 1968, Fleckenstein 2000, Rosier and Rosenberg 2006); shrub-steppe, ponderosa pine, and cliffs (Sarell and McGuinness 1993); Douglas-fir-western hemlock forest (West et al. 1984, Thomas 1988); and westside forest (Perkins 1988). Males are more common than females at higher elevations in eastern Washington (Baker and Lacki 2004).

Roosts and roosting behavior. Day roosts, including maternity colonies, occur in trees, snags, rock crevices, caves, mines, and buildings (O'Farrell and Studier 1973, 1980, Weller and Zabel 2001, Keinath 2004, Nagorsen 2004b, Lacki and Baker 2007). In regions of dry climate, fringed myotis commonly prefer rock crevices as roosts (Rosier and Rosenberg 2006, Lacki and Baker 2007). For example, in ponderosa pine forest along the eastern slope of the Cascades in Washington and Oregon, Lacki and Baker (2007) reported that most reproductive and non-reproductive females roosted in rocky substrates (i.e., outcrops, talus slopes, large boulders, and boulder fields) in predominantly nonforested areas, with far less use of snags, stumps, and downed logs. In other parts of its range, live trees and snags are used exclusively, especially those having larger diameters and heights and in the early to moderate stages of decay with exfoliating bark present (Table 3; Chung-MacCoubrey 1996, Rabe et al. 1998a, Weller and Zabel 2001, Lacki and Baker 2007). Although Lacki and Baker's (2007) study suggests that tree roosts are less important than those in rocks in parts of eastern Washington, they noted that the three largest roosts, holding 14-118 bats, occurred in large ponderosa pine snags.

Maternity colonies form from about mid-April to September (O'Farrell and Studier 1980, Rasheed et al. 1995). Those in buildings can rarely exceed 1,000 animals (WBWG 2005). In contrast, nursery colonies in trees or rock crevices are much smaller (Nagorsen 2004b). Day roosts with one to seven females (reproductive status not stated) have been reported for Washington (Lacki and Baker 2007). Females sometimes roost in tight clusters (O'Farrell and Studier 1973). Females in trees or rock crevices frequently switch day roosts, using a site for less than two days on average (range = 1-16 days) before moving (Cryan et al. 2001, Weller and Zabel 2001, Lacki and Baker 2007), whereas fidelity to roosts in caves and buildings is much higher (Keinath 2004). Cryan et al. (2001) reported that nursing females changed roosts together while carrying young.

Much less is known about the day roosts of males, but Rosier and Rosenberg (2006) found them roosting exclusively in basalt cliffs at Moses Coulee. Males are believed to roost alone or in small groups separate from females during much of the non-hibernation season (O'Farrell and Studier 1980, WBWG 2005). This species is known to use torpor while day roosting (O'Farrell and Studier 1980).

Caves, mines, rock crevices, buildings, and bridges are used as night roosts (O'Farrell and Studier 1980, Nagorsen and Brigham 1993, Adam and Hayes 2000). Individuals have been reported night roosting under bridges in Whatcom County (Perkins 1988) and in caves in Skamania County (Perkins 1985).

Hibernacula occur in caves, mines and buildings (Perkins et al. 1990, WBWG 2005). Animals have been found hibernating solitarily in Oregon (Perkins et al. 1990). An individual collected beneath a 1.5-m diameter rock in Okanogan County on 30 October (Johnson 1961) was perhaps at a hibernation site.

Reproduction. Adult males begin sperm production by late July to early August in preparation for breeding (Baker and Lacki 2004, Lacki and Baker 2007). Mating occurs in the fall after maternity colonies dissolve (O'Farrell and Studier 1973, 1980). Ovulation, fertilization, and implantation are delayed until spring. Pregnancy lasts 50-60 days and is followed by the birth of a single young usually between late June and early July (O'Farrell and Studier 1980, Rasheed et al. 1995, Baker and Lacki 2004, Lacki and Baker 2007). Lactation extends to about early August (Baker and Lacki 2004, Lacki and Baker 2007). Young are placed in clusters separate from adults and become capable of limited flight at 17 days of age and full flight at 21 days of age (O'Farrell and Studier 1973). Young beginning flying by late July or early August (Baker and Lacki 2004, Lacki and Baker 2007). Females may breed in their first autumn, but males apparently wait until their second year.

Food habits and foraging. Fringed myotis feed on beetles, moths, flies, leafhoppers, lacewings, crickets, spiders, harvestmen, and other invertebrates (Keinath 2004, WBWG 2005). Presence of flightless insects in the diet indicates that some prey are gleaned from foliage (Nagorsen and Brigham 1993). Analyses of stomach contents indicate that the main prey include moths, arachnids, leaf and plant hoppers, and beetles in western Oregon (Whitaker et al. 1977, Ober and Hayes 2008a) and moths and leafhoppers in eastern Oregon (Whitaker et al. 1981). The slow and highly maneuverable flight of this species is well suited to both aerial capture and gleaning of prey from foliage (van Zyll de Jong 1985). This, together with the type of echolocation call, suggests that fringed myotis are adapted for foraging within forests and along forest edges (WBWG 2005). Foraging peaks one to two hours after sunset (Keinath 2004). Foraging sites averaged 1.6 km from day roosts in ponderosa pine forests in Washington and Oregon (Lacki and Baker 2007). Rosier and Rosenberg (2006) recorded one individual traveling 6.6 km to a foraging site.

Seasonal movements. This species appears to migrate in Arizona and New Mexico, but little other information is available on distances traveled, timing, destinations, and whether all populations do so (O'Farrell and Studier 1980, Keinath 2004).

Threats. This species is considered sensitive to human disturbance (O'Farrell and Studier 1973), thus roosts are vulnerable to activities such as recreational caving, cave vandalism, and mine exploration (Keinath 2004, Nagorsen 2004b, WBWG 2005). Loss of roosting habitat is another threat and can be caused by closure (i.e., blockage) or renewed activity at abandoned mines, loss of large decadent trees, timber harvest, and replacement of buildings and bridges with structures that lack roosting opportunities for bats. Loss or modification of foraging habitat can result from timber harvest, livestock grazing, and residential and agricultural expansion. Pesticide spraying is an additional concern.

Conservation measures. In eastern Washington, managers should work to maintain a diversity of roost structures, including large-diameter ponderosa pine snags and crevices in rocks. Occupation of snags is greater in forests with larger-diameter trees and snags (Lacki and Baker 2007), thus the structural characteristics of the surrounding forest influence roost use and should be part of forest unit management prescriptions. Managers should also maintain the integrity of basalt rock outcrops and talus slopes to protect potential roosts in rock crevices. Proximity of day roosts to foraging and drinking sites should be considered. In dry environments, maintaining day roosts within 2 km of water sources (e.g., ephemeral ponds and pools along creeks) will likely benefit reproductive females (Lacki and Baker 2007). Riparian areas are probably important sites for foraging and drinking in low elevation westside forests and should remain protected (Ober and Hayes 2008a). Bat surveys should be conducted in western Washington to determine abundance, distribution, and subspecific affiliation of the population there.

Hoary Bat (*Lasiurus cinereus*)

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Description. The hoary bat is the largest bat in Washington (Table 5). The fur is a mixture of yellowish-brown, dark brown, and white, giving it a distinctive frosty or "hoary" appearance (Nagorsen and Brigham 1993, WBWG 2005). Individual hairs on the back have four distinct color bands, with blackish-brown at the base followed by yellowish-brown, blackish-brown, and silvery-white at the tips. Yellow or white fur occurs on the shoulders and wrists. Yellow fur also encircles the ears and is present on the throat and underside of the wing membranes. Wing membranes are blackish-brown with paler brown strips along the forearm and metacarpals. Wings are long and narrow. The upper surface of the tail membrane is densely furred. Ears are short and rounded with a dark brown or black margin, and the tragus is short and broad. The calcar has a narrow keel.

Taxonomy. Three subspecies are recognized (Simmons 2005), with *L. c. cinereus* present in North America, including Washington.

Distribution. Hoary bats have the broadest geographic distribution of any bat in the New World, including much of North America and South America, as well as Hawaii (Shump and Shump 1982a; Appendix A). This species has been documented in most of Washington's counties (WDFW WSDM database), but is probably present in all.

The sexes are relatively segregated within the species' summer distribution, with males occurring primarily in the mountainous regions of western North America and females more numerous in eastern regions (Shump and Shump 1982a, Cryan 2003). This pattern may simply reflect that females tend to migrate farther distances than males from major wintering areas in California and Mexico. Among the few individuals captured during surveys in Washington, nearly all have thus far been males (West et al. 1984, Thomas 1988, Campbell 1993, Fleckenstein 2000, 2001a, Baker and Lacki 2004; H Ferguson, pers. comm.; BLM, unpubl. data). Examination of bats killed at wind farms in Washington indicate that some females pass through the state during fall migration (e.g., Kronner et al. 2008).

Population status. Population sizes and trends in North America are unknown (NatureServe 2009). Shump and Shump (1982a) considered this species common in the Pacific Northwest, but most survey data from Washington instead suggest that it is relatively rare at most locations except during migration, when it is more common (Johnson and Erickson 2011). Hoary bats were infrequently or rarely detected during acoustic surveys at Mt. Rainier National Park (Petterson 2001), other sites in the

western Cascades (Thomas 1988, Erickson 1993), North Cascades National Park (Christophersen and Kuntz 2003), Hanford (Gitzen et al. 2002), and the Yakima Training Center (Christy et al. 1995). Capture surveys have yielded similar results in the eastern and western Cascades (West et al. 1984, Thomas 1988, Frazier 1997, Taylor 1999, Baker and Lacki 2004), the Selkirk Mountains (Campbell 1993), at Moses Coulee (Fleckenstein 2000, Rosier and Rosenberg 2006), at Badger Gulch in Klickitat County (Fleckenstein 2001a), and on the Olympic Peninsula (West et al. 2004). In contrast to these surveys, it was frequently detected at Joint Base Lewis-McChord (Falxa 2008a) and at Hanford (Lindsey et al. 2012). Because of this species' tendency to forage above the forest canopy, capture surveys are not effective in assessing levels of abundance.

Habitat. In Washington and elsewhere, hoary bats are mainly associated with a variety of forest types, but also occur in open cover types (e.g., grasslands, deserts, clearcuts, meadows), particularly when foraging and migrating (Whitaker et al. 1981a, Hart et al. 1993, Nagorsen and Brigham 1993, Johnson and Cassidy 1997, Kalcounis et al. 1999, Adams 2003). Urban areas are also used (Nuetzmann 2001; G. Falxa, pers. comm.). Late successional forests are often occupied, perhaps because the presence of larger trees provides higher quality roosting habitat (Perkins and Cross 1988, Jung et al. 1999). Jung et al. (1999) further hypothesized that hoary bats were attracted to old-growth forests with relatively open canopies because such habitat may offer improved foraging opportunities. Elevational range varies from sea level to at least 1,620 m in the Pacific Northwest (Nagorsen and Brigham 1993, Petterson 2001), but reaches 3,100 m elsewhere (Storz and Williams 1996). In California, Vaughan and Krutzsch (1954) suggested that females may be more common in lowlands and coastal valleys, and males more common in foothills and mountainous areas.

Roosts and roosting behavior. Hoary bats roost alone or with dependent young primarily in the foliage of coniferous and deciduous trees at heights ranging from 3-16 m above the ground (Shump and Shump 1982a, WBWG 2005, Willis and Brigham 2005, Klug et al. 2012). Roost trees are commonly near the edges of clearings (Constantine 1966), and may or may not be taller than the adjacent canopy (Jung et al. 1999, Willis and Brigham 2005). Reproductive females appear to select locations on the south sides of tree canopies that provide protection from wind and greater sun exposure, which likely enhances warming (Willis and Brigham 2005, Klug et al. 2012). Easy flight access and concealment from predators are other desirable roost characteristics (Nagorsen and Brigham 1993, Klug et al. 2012). Rarely, roosting can occur in tree cavities, caves, buildings, and squirrel nests; beneath rock ledges and bridges; and other locations (Nagorsen and Brigham 1993, Hendricks et al. 2005, WBWG 2005). Detailed information on summer roost selection by this species appears to be lacking for the Pacific Northwest.

During summer, family groups comprised of a female and her young may use the same roost for a two weeks or more (Nagorsen and Brigham 1993, Willis and Brigham 2005), or may change roosts much frequently (Veilleux et al. 2009). Adult females and their nursing young commonly enter torpor while roosting (Hickey and Fenton 1996, Koehler and Barclay 2000, Klug and Barclay 2013). Periods of multi-day torpor during pregnancy have also been observed (Willis et al. 2006b).

Relatively little is known about the night and migration roosts of this species. Hibernating individuals have been found on tree trunks and in tree cavities, squirrel nests, and clumps of Spanish-moss (NatureServe 2009). Other details of hibernation are poorly known.

Reproduction. Mating likely occurs in fall or early winter before, during, or after migration, with ovulation and fertilization delayed until spring (Shump and Shump 1982a, Van Zyll de Jong 1985, Cryan et al. 2012). Gestation lasts about 90 days (NatureServe 2009). Females produce one to four pups in a single litter per year, with an average litter size of two (Shump and Shump 1982a, Willis and Brigham 2005). Breeding has not been confirmed in the Pacific Northwest (Nagorsen and Brigham 1993, Johnson and Cassidy 1997, Verts and Carraway 1998), but if it occurs, births probably take place in June followed by nursing through July (Nagorsen and Brigham 1993). Females may carry their young in flight until they are 6-7 days old (Shump and Shump 1982a). Young are capable of sustained flight by one month of age, but remain dependent on the female for several additional weeks (Nagorsen and Brigham 1993, Koehler and Barclay 2000). Some or most juvenile males and females become sexually mature in their first autumn (Cryan et al. 2012).

Food habits and foraging. This species is commonly considered a moth specialist (Shump and Shump 1982a), but Barclay (1985) reported it to be simply an opportunistic feeder with a preference for large prey. The only dietary data for the Pacific Northwest come from Oregon, where several studies suggest a preference for moths, with leaf hoppers, true bugs, mosquitoes, and other insects consumed in lesser amounts (Whitaker 1977, 1981a, Ober and Hayes 2008a). In other regions, hoary bats also feed on beetles, grasshoppers, dragonflies, wasps, termites, midges, and other flies (Shump and Shump 1982a, Barclay 1985, Rolseth et al. 1994, Valdez and Cryan 2009, Reimer et al. 2010).

Emergence from day roosts usually occurs later in the evening after other bat species become active (Shump and Shump 1982a). Feeding lasts all night, but often peaks during the middle of the night (Shump and Shump 1982a, Barclay 1985). Hoary bats are fast straight fliers with less maneuverability than most other bats, and have low frequency echolocation calls that are adapted for long range detection of prey (Barclay 1985, 1986). Thus, foraging occurs mainly in open areas, such as above the forest canopy, over clearings and other open areas, along roads with trees, over lakes and streams, and at street lights (Whitaker et al. 1981a, Barclay 1985, Nagorsen and Brigham 1993, Hart et al. 1993, Kalcounis et al. 1999). Individuals may forage 1.6 km or more from their day roosts (NatureServe 2009). This species sometimes establishes feeding territories that are defended against other bats through chasing, vocalizing, and occasional physical contact (Barclay 1985). Reproductive females gradually increase the amount of time spent foraging until the young fledge (Barclay 1989).

Seasonal movements. Hoary bats are considered migratory, but most details of migration are poorly known. California and Mexico are significant wintering areas, but some hoary bats overwinter in the eastern U.S. as well (Cryan 2003). A few winter records also exist for the northwestern U.S. and British Columbia (Cryan 2003), including two January records from Washington (a specimen from Mukilteo, Perkins et al. 1990; an acoustic record from Thurston County, G. Falxa, pers. comm.). It is unknown whether these represent unusual occurrences or if the species winters in greater numbers in the region than currently realized. Spring migration probably occurs mainly from April to June (Koehler and Barclay 2000, Cryan 2003, Valdez and Cryan 2009), with females migrating earlier than males (van Zyll de Jong 1985, Valdez and Cryan 2009). Most females that winter in California may travel east, whereas most males from there may move north to localities that include the Pacific Northwest (Cryan 2003). The earlier migration by females may reflect their longer flights to breeding season locations. Valdez and Cryan (2009) reported hoary bats traveling at low elevations along water courses during spring migration. Most fall migration probably occurs between early August and October (Dalquest 1943, Nagorsen and Brigham 1993, Koehler and Barclay 2000, Cryan 2003). Based on mortalities at wind energy farms, these dates also apply to fall migration through Washington (e.g., Kronner et al. 2008; numerous other unpublished reports). Hoary bats from the Pacific Northwest probably migrate to California or Mexico (Nagorsen and Brigham 1993, Cryan 2003). Migration routes in both seasons are poorly understood (Cryan 2003), although sizeable numbers of males and females are known to move through eastern Washington and north-central Oregon in autumn (Johnson and Erickson 2011). Hoary bats sometimes migrate in groups that can number in the hundreds (Shump and Shump 1982a, NatureServe 2009).

Threats. Mortality at wind energy facilities is likely the greatest threat to the species, with large numbers killed during migration in Washington and much of North America (Arnett et al. 2008, Johnson and Erickson 2011). Logging of larger trees is another concern to this species because it eliminates or reduces roosting habitat (WBWG 2005). Widespread application of pesticides on forest lands is a potential source of mortality to roosting bats and their insect prey. In suburban settings, where jays and crows thrive in association with humans, these birds may kill some sleeping or hibernating hoary bats (WBWG 2005).

Conservation measures. Pre-construction surveys of proposed wind energy facilities should be used to establish the timing and location of potential conflicts so that mitigation measures can be used to reduce mortality to this species. At existing wind farms, surveys are needed to document mortalities and measures are needed to further reduce mortalities. Evidence from Perkins and Cross (1988) and from other species of *Lasiurus* in eastern forests (Shump and Shump 1982b, Menzel et al. 1998, Hutchinson and Lacki 2000) suggest that retention of older forests with large trees may benefit hoary bats in the West. Documentation of the temporal and spatial distribution of this species throughout Washington, including important migratory pathways, will help inform conservation measures and the appropriate time to apply them.

Keen's Myotis (*Myotis keenii*)

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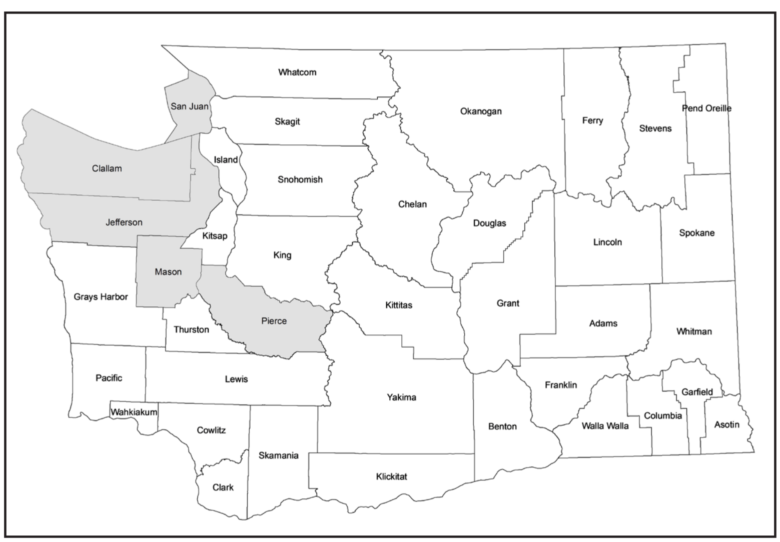
Description. Keen's myotis is a small bat with a long tail, short forearm, and short hind foot (Table 5). The fur on the back is dark brown with an indistinct dark spot at the shoulder; the underside is paler (Nagorsen and Brigham 1993). The ear extends slightly beyond the tip of the nose when laid forward. Ears and wing membranes are dark brown, not black. The tragus is long, narrow, and pointed. Tiny scattered hairs extend along the border of the tail membrane. An indistinct keel is present on the calcar.

Keen's myotis is one of three physically similar long-eared *Myotis* species in Washington. Strong similarities between Keen's myotis and the western long-eared myotis, particularly *M. evotis pacificus*, make simple field identification impossible where these species overlap in southwestern British Columbia and western Washington (Burles and Nagorsen 2003). Van Zyll de Jong and Nagorsen (1994) determined a variety of skull and body measurements that can be used to correctly distinguish specimens of the two species nearly 100% of the time (e.g., see Parker and Cook [1996] for southeast Alaska). However, a few individuals are morphologically intermediate, including some from western Washington, and cannot be reliably identified using these features. Mitochondrial DNA testing of tissue samples is desirable for identification (T. Dewey, unpubl. data, in Burles and Nagorsen 2003; Boland et al. 2009b).

Taxonomy. No subspecies are recognized (Simmons 2005). Keen's myotis was formerly combined with the northern myotis, but was recognized as distinct by van Zyll de Jong (1979). Recent genetic work suggests that Keen's myotis is most closely related to and perhaps conspecific with western long-eared myotis (T. Dewey, unpubl. data, in Burles and Nagorsen 2003).

Distribution. Keen's myotis has one of the smallest distributions of any North American bat, occurring in coastal areas from southeast Alaska to the Olympic Peninsula, Puget Sound, and Mt. Rainier in Washington (Burles and Nagorsen 2003, Boland et al. 2009b, WDFW WSDM database; Appendix A). In Washington, it has been recorded in San Juan, Clallam, Jefferson, Mason, and Pierce counties (van Zyll de Jong and Nagorsen 1994; E. Myers, pers. comm.; WDFW WSDM database) and may occur in the Skagit Valley (L. Friis, pers. comm.). Possible specimen records (held at the Burke Museum, University of Washington) from Kitsap and Island counties need confirmation. Previous records from Pacific and Clark counties probably represent western long-eared myotis (van Zyll de



Jong and Nagorsen 1994). Older literature and museum records from eastern Washington also represent western long-eared myotis (van Zyll de Jong and Nagorsen 1994).

Population status. Population size and trends are unknown throughout the species' range, including Washington (NatureServe 2009). Keen's myotis is generally considered rare, but problems with field identification have complicated efforts to assess population size or status. Low densities also have been reported in British Columbia (Firman et al. 1993, Burles and Nagorsen 2003) and southeast Alaska (Boland et al. 2009b). Low densities probably also occur in Washington, based on the few known confirmed records (WDFW WSDM database). More recent surveys in northwestern Washington have either not detected the species (Wunder et al. 1992, Erickson et al. 1998, Fleckenstein 1998, Jenkins et al. 1999, Christophersen and Kuntz 2003, Freed and McAllister 2008, Ormsbee and Hohmann 2010, Ormsbee 2011) or captured one to three individuals that were only later confirmed through genetic testing (Petterson 2001, Falxa 2008a).

Habitat. During the active season, the species is largely restricted to moist coastal forests of lower elevations dominated by western hemlock, Sitka spruce, and other conifers, although a few records come from urban sites (Firman et al. 1993, Burles and Nagorsen 2003, Boland et al. 2009a). Mid-elevation caves are used for hibernation. A record of an adult male caught in a subalpine meadow at 1,637 m on 19 September 2000 at Mt. Rainier National Park (E. Myers, pers. comm.) suggests that habitat use may be broader than currently recognized.

Roosts and roosting behavior. Keen's myotis roost in caves, rock crevices, large trees, snags, and buildings (Burles and Nagorsen 2003, Boland et al. 2009b, Burles et al. 2009). Burles and Nagorsen (2003) described two maternity sites, one of which held a colony of at least 70 females (Firman et al. 1993) and occurred in a small hydrothermally heated cave and associated boulders and rock crevices. This roost had temperatures ranging up to 34ºC (93ºF) and was shared with little brown myotis (Burles et al. 2009). The second site was inside a cave, rock crevice, or adjacent tree snag. Several reproductive females have been found roosting in trees in old-growth forest (Burles and Nagorsen 2003) and a maternity roost with 19 females in a tree was reported by Boland (2007). Reproductive females occupy nursery roosts from April or May until about late August or September (Burles and Nagorsen 2003, Burles et al. 2009). Non-reproductive females and males appear to roost separately from maternity colonies early in the summer, but may join the maternity colonies later in the season (Burles and Nagorsen 2003, Burles et al. 2009).

In some locations, day roosts commonly occur in structurally complex forests with abundant decadent living trees and snags. In southeast Alaska, radio-tagged adult females (reproductive status and group size not given) roosted exclusively in trees from May to September, with western redcedar the preferred species (Boland 2007, Boland et al. 2009a). Roosts occurred mainly in live or recently dead trees with large diameters (mean dbh 106.5 cm) and structural defects (i.e., a broken top, a crack or cavity in the trunk) (Table 3). Roost trees were found in areas with greater abundance of potential roost trees (i.e., >20 cm dbh, and either live trees with defects or snags in the early stages of decay) and greater basal area of canopy trees. Female presence was greater in areas with more old-growth and fewer clearcuts.

Males, which typically roost solitarily, mainly used trees and stumps, and occasionally rock crevices and quarries, for day roosts (Boland 2007, Boland et al. 2009a). Preferred tree roosts were cedar and hemlock snags in intermediate and late stages of decay with cracks, cavities, broken tops, and sloughing bark (Table 3). Males generally roosted in smaller, shorter trees (mean dbh 65.6 cm) with less bark than those used by females. Roost trees used by males were in areas with greater abundance of potential roost trees (i.e., >20 cm dbh and in the early to late stages of decay). Roost use by males and females was greater near riparian forest and roads.

Most tree-roosting Keen's myotis switch roosts daily and reuse previously occupied sites (Boland

2007, Boland et al. 2009a). Distances between consecutive tree roosts average about 100-150 m for both sexes. Individuals use torpor to overcome seasonal temperature extremes and food shortages (Burles and Nagorsen 2003).

Male Keen's myotis have been observed night roosting under bridges (Boland 2007). The few known hibernacula occur in mid-elevation caves at 550-945 m with inner temperatures of 2.4-4.0ºC (36-39ºF), high (100%) humidity, and depths of >100 m (see citations in Burles and Nagorsen 2003). Caves at lower elevations may be too warm to allow hibernation. Hibernation on Vancouver Island reportedly lasts from mid-October to late May (M. Davis, pers. comm.). Males begin swarming at the entrances of hibernacula in late July. This activity increases through August and peaks by early September with the arrival of females and juveniles (M. Davis, pers. comm.).

Reproduction. Little information is available on reproduction in Keen's myotis. As in other species of myotis, mating probably occurs in the fall at hibernacula and extends into winter, with females likely storing sperm and delaying ovulation until the following spring (Firman et al. 1993). The majority of adult females give birth each year to a single pup (Firman et al. 1993, Burles 2001). Pregnancy lasts from about late May until early to late July, births occur from early to late July, nursing extends until late August or early September, and young are able to fly by early August to mid-September (Burles et al. 2009). Burles et al. (2009) reported that pregnancies were not prolonged and births were not delayed during a summer with cooler wetter weather.

Food habits and foraging. In mature conifer forests of coastal British Columbia, moths and spiders were the most common foods of Keen's myotis (Burles et al. 2008). In southeast Alaska, trichopterans, spiders, and flies were consumed (Parker and Cook 1996). Both studies involved small sample sizes, but indicate that prey are caught in flight and perhaps gleaned from bark, needles, and leaves. The relatively short broad wings and long ears of Keen's myotis are consistent with features advantageous for foraging in structurally complex forests and rainy conditions (Burles and Nagorsen 2003). Bats depart their day roosts about 30 minutes after sunset and regularly forage within 3 m of the ground (Burles 2001). Riparian and estuarine habitats near mature conifer forests are important foraging sites on Vancouver Island (Burles and Nagorsen 2003). Boland (2007) captured bats at riparian feeding sites located an average of 350 m (max = 1,125 m) from roosts for females and 631 m (max = 2,282 m) for males. Foraging also occurs in old-growth forest. Evidence to date suggests that clearcuts and dense secondary forest are used much less than mature forest (see citations in Burles and Nagorsen 2003).

Seasonal movements. On Vancouver Island, Keen's myotis moves to mid-elevation caves for swarming and hibernation in the late summer after spending much of the summer at low elevations (M. Davis, pers. comm.). It is unknown whether similar movements occur in Washington, but individuals have been captured as late as September 23 at low elevations at Joint Base Lewis-McChord (WDFW WSDM database).

Threats. Threats or potential threats include loss of habitat caused by clearcutting of old-growth coastal forests and human development; disturbance of hibernacula and maternity sites through human visitation and logging road construction; and pesticide use in forests (Burles and Nagorsen 2003, NatureServe 2009). Keen's myotis also appears to be vulnerable to cat predation (Burles and Nagorsen 2003).

Conservation measures. Additional information on taxonomic status, geographic range, and abundance is a priority conservation measure for the species. Large decadent trees and snags are important roost structures for both sexes (Boland et al. 2009a) and should be maintained in a range of decay classes and elevations. Maintaining and recruiting these tree structures in close proximity to riparian areas will likely benefit reproductive females. When discovered, maternity colonies and hibernacula should be protected from human disturbance. Because moths are an important food, pesticide spraying and other management activities that adversely affect this food source should be avoided.

Little Brown Myotis (*Myotis lucifugus*)

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Description. Little brown myotis are small bats, but medium-sized among the species of *Myotis* in Washington (Table 5). Dorsal coloration is variable, with individuals in Washington ranging from yellow or olive in the subspecies *M. l. carissima* to blackish in *Myotis l. alascensis* (van Zyll de Jong 1985, Nagorsen and Brigham 1993). Underparts are noticeably paler. The fur is usually longer and glossier than in other similar *Myotis* species. Ears and flight membranes are dark brown. Ears reach the tip of the nostril when pressed forward. The tragus is about half as long as the ear and blunt. The hind foot is relatively large, exceeding half the length of the tibia, and the calcar is not keeled.

Little brown myotis and Yuma myotis are closely similar in appearance, which can make identification difficult. Little brown myotis usually feature glossier dorsal fur, a gradually sloping forehead, and slightly longer forearms than Yuma myotis, but these characters are variable and therefore unreliable for separating the two species (Weller et al. 2007, Rodhouse et al. 2008). Weller at al. (2007) obtained about 90% reliability in identifying the two using a combination of forearm length and echolocation call characteristics, but recommended use of genetic testing to obtain complete certainty of identification.

Taxonomy. Five subspecies are recognized (Simmons 2005), with two present in Washington (Fenton and Barclay 1980). *Myotis l. alascensis* occurs west of the Cascade crest and in southeastern Washington; *M. l. carissima* is present elsewhere in eastern Washington.

Distribution. The range of the little brown myotis extends across most of North America from the forested portions of Alaska and northern Canada southward to California, Colorado, and the southeastern U.S. (Fenton and Barclay 1980; Appendix A). The species occurs throughout Washington (WDFW WSDM database). Some records may be erroneous because of past confusion with Yuma myotis.

Population status. Despite a severe recent population collapse in the northeastern U.S. due to white-nose syndrome (Frick et al. 2010b), this species remains one of the most common and widespread bats elsewhere in North America, including in the Pacific Northwest (Nagorsen and Brigham 1993, Holroyd et al. 1994, Verts and Carraway 1998). In Washington, it typically ranks as one of the most common species along both flanks of the Cascades (West et al. 1984, Thomas 1988, Frazier 1997, Petterson 2001, Christophersen and Kuntz 2003), in northeastern Washington (Campbell 1993, Sarell and McGuinness 1993), at various locations in the Columbia Basin

(Fleckenstein 2000, Rosier and Rosenberg 2006, Lindsey et al. 2012; BLM, unpubl. data), on the Olympic Peninsula (West et al. 2004), and at some lowland sites elsewhere in western Washington (Dalquest 1940, Falxa 2005, 2008a). Studies from the Cascades, the Olympics, and the Columbia Basin that have lumped little brown myotis and Yuma myotis because of identification problems suggest that little brown myotis may be common or fairly common at additional locations (Christy et al. 1995, Taylor 1997, Erickson et al. 1998, Jenkins et al. 1999, Gitzen et al. 2002). Several surveys have reported it to be relatively rare in eastern Washington (Fleckenstein 2001a, Baker and Lacki 2004). Rodhouse et al. (2012), drawing on Bat Grid data, estimated the probability of occurrence of the species in 100-km^2 grid cells across Oregon and Washington to average about 90%, but was as low as 38% in the drier unforested portions of the region.

Habitat. This species is a habitat generalist that uses a broad range of ecosystems. In Washington and Oregon, it occurs most commonly in both conifer and hardwood forests, but also occupies open forests, forest margins, shrub-steppe, clumps of trees in open habitats, sites with cliffs, and urban areas (Whitaker et al. 1977, 1981a, Johnson and Cassidy 1997, Verts and Carraway 1998, Lindsey et al. 2012, Rodhouse et al. 2012). Within these habitats, riparian areas and sites with open water are usually preferred. Elevations up to tree line are inhabited, with males being more common than females at higher elevations.

Roosts and roosting behavior. Day roosting occurs in a variety of sites, including buildings and other structures, tree cavities and beneath bark, rock crevices, caves, and mines (Fenton and Barclay 1980, Nagorsen and Brigham 1993, WBWG 2005). Reproductive females usually live separately from males and non-reproductive females, forming maternity roosts at sites with warm (30-55°C) (86-131°F), stable temperatures that facilitate rapid development of the young. Nursery colonies contain anywhere from a dozen individuals to more than 1,000 bats (van Zyll de Jong 1985, Nagorsen and Brigham 1993). The largest known maternity roost of little brown myotis in Washington contains about 1,000 adults and roosts together with about 2,000 adult Yuma myotis under an abandoned railroad trestle near Olympia (Falxa 2007b, 2008b). Tree-roosting reproductive females commonly use older patches of forest and select for taller, large-diameter trees (Table 3; Kalcounis and Hecker 1996, Crampton and Barclay 1998). Roost trees are often in the early stages of decay and have deep cavities. Tree-roosting colonies are transient, with individuals moving frequently between roosts (Crampton and Barclay 1996). Reproductive females frequently use torpor while day roosting (Dzal and Brigham 2013).

Day roosts of adult males and non-reproductive females include buildings; crevices and cavities in live trees, snags, stumps, and beneath stones; and caves (Fenton and Barclay 1980, Kalcounis and Hecker 1996). Males and non-reproductive females commonly enter torpor when day roosting (Fenton and Barclay 1980). Males and non-reproductive females are more nomadic than reproductive females and usually live singly or in small groups (Barclay 1991). Tree roosting males often prefer large live trees and snags harboring fungal heart rot (Kalcounis and Hecker 1996).

Buildings and bridges serve as night roosts for adults and juveniles of both sexes (Perlmeter 1996, Adam and Hayes 2000). Females often gather in clusters in night roosts. Greater use occurs on cooler nights, when bats are probably attracted to the warmer temperatures within roosts. Reproductive condition of females also influences use. Pregnant females are known to occupy night roosts, allowing them to reduce energy expenditures while also maintaining high body temperatures to ensure rapid embryo development (Barclay 1982). However, females with non-volant pups return to maternity roosts to nurse their young (Henry et al. 2002; G. Falxa, pers. comm.) and therefore may forego most night roosting.

Hibernacula are poorly known in the West, but include caves, abandoned mines, and lava tubes (Senger et al. 1974, Nagorsen and Brigham 1993, WBWG 2005). Hibernation generally occurs from September or October until March or April (Nagorsen and Brigham 1993, Maser 1998).

Although winter roosts often contain thousands of individuals in other parts of North America, little brown myotis have thus far only been found hibernating singly or in small clusters in the Pacific Northwest (Perkins et al. 1990, Nagorsen and Brigham 1993). Hibernation has been confirmed in Washington (Senger et al. 1974), but the extent to which resident breeding bats winter in the state and their locations are unknown.

Both sexes appear to hibernate together. Within hibernacula, microsites are preferred where humidity is high (70-95%) and temperatures remain above freezing (1-5°C, 33.8-41°F) (Nagorsen and Brigham 1993). Hibernating individuals lose about 25% of their weight during winter, thus acquisition of sufficient fat reserves before hibernation is essential for overwinter survival (Kunz et al. 1998).

Reproduction. Mating mostly occurs in late summer and early autumn during swarming before hibernation and may continue into winter (Thomas et al. 1979, Fenton and Barclay 1980, Nagorsen and Brigham 1993). Males sometimes copulate with hibernating females (Wai-Ping and Fenton 1988). Ovulation and pregnancy are delayed until after hibernation ends in spring, with gestation lasting 50-60 days (Fenton and Barclay 1980). Females give birth to a single pup per year; twins are rare. Births probably occur earlier at lower elevations than at higher elevations (Nagorsen and Brigham 1993). Births occur in June in western Washington (G. Falxa, pers. comm.), from early June to mid-July in the dry interior of British Columbia (Fenton et al. 1980, Herd and Fenton 1983, Grindal et al. 1992, Holroyd et al. 1994), and from late July to August in the western Cascades of Oregon (Perlmeter 1996). Young can fly by three weeks of age (Fenton and Barclay 1980). Births may be substantially delayed or reduced in years with cooler wetter weather (Grindal et al. 1992, Burles et al. 2009). Some females breed in their first autumn, but most delay doing so until their second year (Herd and Fenton 1983). Males do not breed until their second autumn. Survival rates are lower in juveniles (23-46%) than in adults (63-90%; Frick et al. 2010a).

Food habits and foraging. Emerging aquatic insects (especially midges) are major prey, but moths, beetles, non-aquatic flies, a variety of other insects, and spiders are also taken (Fenton and Barclay 1980, Barclay 1991, Whitaker and Lawhead 1992, Adams 1997, 2003, Moosman et al. 2012). Flies, moths, and beetles are primary prey in eastern Oregon (Whitaker et al. 1981a), whereas flies, caddisflies, and moths are important in western Oregon (Whitaker et al. 1977, Ober and Hayes 2008a). Several studies have examined diet in British Columbia, with principal prey listed as follows: midges in spring and caddisflies and mayflies in summer in the Okanagan Valley (Herd and Fenton 1983); flies, moths, neuropterans, and hymenopterans on northern Vancouver Island (Kellner and Harestad 2005); and moths and flies in the Queen Charlotte Islands (Burles et al. 2008).

Little brown myotis possess low wing loading, low aspect ratios, rounded wing tips, and high frequency echolocation, which give the species maneuverable flight and allow it to specialize on small insects (Ober and Hayes 2008a). Foraging is often concentrated over or near water, but also occurs along forest edges, in forests, over lawns and streets, and in other cover types (Herd and Fenton 1983, van Zyll de Jong 1985, Barclay 1991). Feeding is most active during the 2-3 hours after dusk when insect activity often peaks (Herd and Fenton 1983, Lunde and Harestad 1986). Additional foraging bouts follow during the night intermixed with visits to night roosts. Foraging commonly occurs within 5 m of the ground, with both circular and zigzagging flight patterns used (Whitaker et al. 1977, Fenton and Barclay 1980, Adams 1997). Most prey is captured in the air and consumed in flight (Nagorsen and Brigham 1993). Nightly foraging movements usually range 1-14 km from day roosts (Henry et al. 2002, WBWG 2005; G. Falxa, pers. comm.). Nursing females may return several times to the maternity roost during the night (Crampton and Barclay 1998; G. Falxa, pers. comm.).

Seasonal movements. In eastern North America, individuals may travel up to 1,000 km between summer roosts and hibernacula (Fenton and Barclay 1980, Wilson and Ruff 1999, Norquay et al. 2013). Little information exists on seasonal movements in Washington or elsewhere in the West (WBWG 2005).

Threats. Threats include deforestation and associated loss of snags, use of pesticides, destruction of caves, closure (i.e., blockage) of mines, and localized use of cyanide in mining (Fenton and Barclay 1980, Parker et al. 1996, WBWG 2005, NatureServe 2009). This species often occupies human structures and is vulnerable to pest control operations (WBWG 2005). It is also susceptible to disturbance of breeding colonies and hibernation sites. Little brown myotis are severely affected by white-nose syndrome in the eastern U.S. (Veilleux 2008).

Conservation measures. Protection of roosts is a priority for conservation. Where appropriate, steps should be taken to preserve or replace human-made structures used as roosts and to reduce disturbance. Where eviction from buildings is necessary, actions (e.g., use of suitable exclusion methods, installation of nearby bat houses) should be taken to attempt to reduce negative impacts to bats. In forests, retention and recruitment of large snags (e.g., McComb and Lindenmeyer 1999), decadent trees, and hollow trees is important. On intensively managed forests, management agreements and incentives for protecting large-diameter roost trees are desirable (Hayes 2003). Maintaining remnant patches of structurally diverse forest with abundant large snags is another protective strategy (Waldien et al. 2000). Providing snags and roost trees within 2-3 km of open water or riparian areas is probably beneficial by providing ready access to drinking and foraging sites (Hayes 2003). Maintaining potential roosts across a range of topographical positions is also desirable. During roost surveys, precautions should be taken to reduce disturbance.

Long-legged Myotis (*Myotis volans*)


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Description. Long-legged myotis are small bats, but one of the larger species of *Myotis* in Washington (Table 5). Fur color on the back ranges from reddish brown to blackish in the subspecies *M. v. longicrus* and is reddish buff in *M. v. interior* (Warner and Czaplewski 1984, Nagorsen and Brigham 1993, Verts and Carraway 1998). Fur on the underparts is relatively dark and extends to the undersides of the wing membranes, where it reaches the elbows and knees and is longer and denser than in other *Myotis*. Ears and flight membranes are blackish brown. Ears have rounded tips and are relatively short, barely reaching the nose when pushed forward. The tragus is long and slender. The foot is relatively small, about half the length of the tibia, and the calcar has a distinct keel.

Taxonomy. Four subspecies are recognized (Simmons 2005), with two present in Washington (Warner and Czaplewski 1984). *Myotis v. longicrus* ranges across most of the state and is replaced by *M. v. interior* in southeastern Washington.

Distribution. Long-legged myotis are distributed from southeastern Alaska, Northwest Territories, and western North Dakota southward to central Mexico (Warner and Czaplewski 1984; Appendix A). This species has been recorded in nearly all counties in Washington (WDFW WSDM database).

Population status. This bat is common to abundant in much of the West (Barbour and Davis 1969, Oliver 2000, Adams 2003), but firm data on population sizes and trends are generally lacking (NatureServe 2009). In Washington, capture surveys have found it to be the most common or second most common species at sites in the southeastern Cascades (Frazier 1997, Taylor 1999, Baker and Lacki 2004). However, similar surveys elsewhere have reported it as uncommon in the southwestern Cascades (West et al. 1984, Thomas 1988), Mt. Rainier National Park (Petterson 2001), North Cascades National Park (Christophersen and Kuntz 2003), the Olympic Peninsula (Erickson et al. 1998, Jenkins et al. 1999, West et al. 2004), Joint Base Lewis-McChord (Wunder et al. 1992, Falxa 2008a), and Badger Gulch in Klickitat County (Fleckenstein 2001a), or as rare or absent in the Selkirk Mountains (Campbell 1993), Moses Coulee (Fleckenstein 2000, Rosier and Rosenberg 2006), Hanford (Gitzen et al. 2002, Lindsey et al. 2012), the Yakima Training Center (Christy et al. 1995), and San Juan Islands (Dalquest 1940). The species may be common in the Blue Mountains, based on the findings of Henny et al. (1982) for the Oregon side of the Blues.

Habitat. Long-legged myotis occur mainly in moist and dry coniferous forests, but also inhabit riparian forests and dry rangeland (Warner and Czaplewski 1984, Nagorsen and Brigham 1993, Johnson and Cassidy 1997, Oliver 2000, Adams 2003). Thomas (1988) reported a strong preference for old-growth forest over fire-regenerated mature and young forests, but other studies have found broader use of different forest age classes if sufficient roosts are present (Ormsbee and McComb 1998, Humes et al. 1999, Taylor 1999, Johnson et al. 2007, Arnett and Hayes 2009). Elevational distribution ranges from sea level to 3,500 m (Nagorsen and Brigham 1993, Adams 2003). Males occur more commonly at higher elevations than reproductive females at some locations (e.g., Cryan et al. 2000), including a site in Washington's southeastern Cascades (Baker and Lacki 2004). Surveys in shrub-steppe in the Columbia Basin have found the species to be scarce or absent (Christy et al. 1995, Fleckenstein 2000, Gitzen et al. 2002, Lindsey et al. 2012), but it is perhaps more likely to be present along the region's water courses (Johnson and Cassidy 1997).

Roosts and roosting behavior. Roost sites include snags and live trees with loose bark, long vertical cracks, or hollows; cracks and crevices in rocks, stream banks, and the ground; buildings; bridges; caves; and mines (Barbour and Davis 1969, Warner and Czaplewski 1984, Nagorsen and Brigham 1993, Chung-MacCoubrey 1996, Ormsbee and McComb 1998, Rabe et al. 1998a, Baker and Lacki 2006). In the Pacific Northwest, maternity sites have been mainly found in snags, but live trees, rock crevices, mines, and buildings are also used (Nagorsen and Brigham 1993, Ormsbee and McComb 1998, Baker and Lacki 2006, Johnson et al. 2007, Arnett and Hayes 2009, Lacki et al. 2010; BLM, unpubl. data).

A number of traits characterize the snags and trees used by reproductive females. Roost snags and trees are typically taller and larger in diameter (Table 3) than other snags and trees in the surrounding canopy, are farther from neighboring tall trees, occur in areas of lower canopy closure, and are in the early to intermediate stages of decay when more loose bark remains for roosting under (Vonhof and Barclay 1996, Frazier 1997, Ormsbee and McComb 1998, Rabe et al. 1998a, Taylor 1999, Baker and Lacki 2006, Arnett 2007, Johnson et al. 2007, Arnett and Hayes 2009, Lacki et al. 2010). These features presumably provide bats with greater numbers of potential roost spaces as well as increased warmth from sun exposure, which hastens the growth of young (Arnett and Hayes 2009). In dry forests, ponderosa pine and firs are the main species used for roosting (Chung-MacCoubrey 1996, Rabe et al. 1998a, Cryan et al. 2001, Baker and Lacki 2006), whereas Douglas-fir is the primary species occupied in moister forests (Ormsbee and McComb 1998, Arnett and Hayes 2009).

In western Oregon, Ormsbee and McComb (1998) and Arnett and Hayes (2009) located maternity roosts in all age classes of forest, although stands 41-80 years old on federal lands were most used and younger stands were least occupied. Roosts were generally located in upland habitats and closer to streams. In eastern Washington and eastern Oregon, pregnant females roost about evenly between upslope and riparian locations, whereas nursing and post-nursing females spend much more time roosting upslope (Baker and Lacki 2006). However, in Idaho's Bitterroot Mountains, females prefer mid-slope roosts throughout the reproductive season (Lacki et al. 2010).

Most maternity colonies contain fewer than 50 bats, but larger roosts of up to several hundred bats are regularly present (Nagorsen and Brigham 1993, Ormsbee 1996, Baker and Lacki 2006). Reproductive females usually switch day roosts about once every two to three days on average (Ormsbee 1996, Baker and Lacki 2006, Arnett and Hayes 2009), although Vonhof and Barclay (1996) reported an average of 11 days between changes. Duration of roost use may be influenced by reproductive stage of the female, the characteristics and lifespan of the roost, and weather (Vonhof and Barclay 1996, Baker and Lacki 2006). Large colonies appear to move en masse when switching roosts (Baker and Lacki 2006). Females have been reported moving averages of 28 m, 413 m, and 1.4 km between successive roosts (Ormsbee 1996, Vonhof and Barclay 1996, Baker and Lacki 2006).

Males and non-reproductive females roost primarily in large snags and to a lesser extent in live or partially dead trees (Nagorsen and Brigham

1993, Herder and Jackson 1999, Frazier 1997, Taylor 1999). Frazier (1997). In the eastern Cascades of Washington, Taylor (1999) found selection for tall, large-diameter snags and trees, and a preference for grand fir, which often features loose bark. Taylor (1999) reported that males selected roosts in the oldest available forest stands; late-successional forest was used on national forest lands, and moderately mature forest stands, middle to late successional pine/oak stands, and aggregate retention patches were preferred on a nearby commercial forest. Canopy cover and height, stand diameter, basal area, and tree density were all significantly greater for roosts on national forest lands compared to roosts in commercial forest. Males also selected snags in earlier stages of decay and with more exfoliating bark on national forest (classes 1-3) than on private forest (classes 1-5). Use of large snags by males has also been recorded in western Washington (Wunder et al. 1992). Males and non-reproductive females make frequent roost changes (once every 1-10 days) during summer (Vonhof and Barclay 1996, Frazier 1997, Taylor 1999).

Bridges, abandoned buildings, caves, mines, and trees in riparian habitats are used for night roosting (Barbour and Davis 1969, Perlmeter 1996, Ormsbee and McComb 1998, Adam and Hayes 2000; G. Falxa, pers. comm.). At bridges occupied at night in Oregon (Perlmeter 1996) and Washington (G. Falxa, pers. comm.), females outnumber males and roost in clusters or alone, whereas males are solitary. Counts at night roosts are highest in August when most females are pregnant or nursing, and roost temperatures are at their maximum (Perlmeter 1996). Larger bridges with warmer than ambient temperatures attract the largest numbers of long-legged myotis (Perlmeter 1996). Ormsbee (1996) reported an average distance of 2.5 km (range = 0.7-6.5 km) between night roosts and day roosts.

Caves and mines are used as winter hibernacula (Warner and Czaplewski 1984, Nagorsen and Brigham 1993, Adams 2003). Hibernacula usually contain more males than females (Senger et al. 1974, Adams 2003). Long-legged myotis have been found hibernating alone or in aggregations of 2-64 individuals in lava tubes in Skamania County and in caves in Klickitat County, Washington, and in Oregon (Senger et al. 1974, Perkins et al. 1990). Winter surveys of more than 650 caves and 70 buildings in these states during the 1980s found this species at nine caves (Perkins et al. 1990). Hibernation in Washington extends from about early November to late March (Senger et al. 1974). Senger et al. (1974) reported a tendency by individuals to reuse the same hibernacula between years. Perkins et al. (1990) noted that long-legged myotis sometimes hibernate in clusters.

Reproduction. Sperm production in males occurs in July and August (Warner and Czaplewski 1984, Baker and Lacki 2004) and mating takes place in late August or September before hibernation (Nagorsen and Brigham 1993). Females store sperm overwinter, with ovulation and pregnancy occurring in the spring (Warner and Czaplewski 1984). Females produce one young per year. Timing of births is variable and probably influenced by elevation and latitude (Barbour and Davis 1969). In the Pacific Northwest, births occur between late June and mid-August (Nagorsen and Brigham 1993, Holroyd et al. 1994, Perlmeter 1996, Baker and Lacki 2004). Some males and probably some females breed in their first autumn (Schowalter 1980, Warner and Czaplewski 1984).

Food habits and foraging. Moths are the dominant prey, with termites, flies, beetles, lacewings, wasps, leafhoppers, true bugs, spiders, and other invertebrates also eaten (Warner and Czaplewski 1984, Warner 1985). In eastern and western Oregon and north-central Idaho, moths comprise 42-78% of the diet (Whitaker et al. 1977, 1981a, Henny et al. 1982, Johnson et al. 2007, Lacki et al. 2007b, Ober and Hayes 2008a). Beetles are also important in Idaho.

Long-legged myotis emerge from their day roosts early in the evening (Whitaker et al. 1981a). Foraging activity occurs throughout the night, but is greatest during the first 3-4 hours (Adams 2003). Prey are caught aerially (van Zyll de Jong 1985) along forest edges and cliff faces, inside forests, over the forest canopy, and over water (Whitaker et al. 1977, 1981a, Warner and Czaplewski 1984, Thomas 1988, Nagorsen and Brigham 1993).

This species is characterized by rapid direct flight (WBWG 2005). Home ranges of males and reproductive females in Idaho averaged 647 ha and 376 ha, respectively, although this difference was not significant due to the variability in home range sizes (Johnson et al. 2007).

Seasonal movements. No information is available on seasonal movements.

Threats. Loss of large-diameter trees and snags during timber harvest can negatively affect this species (WBWG 2005). High pesticide residues were found in long-legged myotis for at least three years after aerial spraying of DDT to control larvae of the Douglas-fir tussock moth (Henny et al. 1982), although use of this chemical has since been discontinued. Hibernacula may be lost by closure of abandoned mines without adequate surveys and from disturbance by recreational cavers. Roosts in buildings are vulnerable to pest control operations.

Conservation measures. Forest management practices that result in the long-term availability of large snags (generally > 50-80 cm in diameter) with loose bark, distributed across all landscape positions are probably most beneficial to this species (Ormsbee and McComb 1998, Baker and Lacki 2006, Johnson et al. 2007, Arnett and Hayes 2009, Lacki et al. 2012). There is good evidence that long-legged myotis use trees and snags remaining after timber harvest (Taylor 1999, Johnson et al. 2007). Retention of patches of snags (e.g., at densities of more than 40 snags per ha; Baker and Lacki 2006) is also desirable because these bats require multiple roosts within localized areas. Creation of buffer zones around snags used by large colonies is recommended. Thinning of young ponderosa pine forests will speed the establishment of large trees and reduce the risk of stand-replacing fires (Rabe et al. 1998a, Baker and Lacki 2006). Implementation of more natural fire regimes can help create large snags. Minimization of human disturbance may be sufficient for management of rock habitats used as day roosts (Baker and Lacki 2006).

Where eviction from buildings is necessary, appropriate steps should be taken to minimize negative impacts on the bats. Precautions to reduce disturbance should be taken when mine and cave surveys are conducted during the hibernation period. Winter inventories of bat use should be conducted at mines and caves considered for closure (i.e., blockage), with bat gates installed where hibernation is documented. Before pesticide spraying projects, surveys to identify roosting and foraging habitat of this species should be conducted to avoid spraying of important areas.

Pallid Bat (*Antrozous pallidus*)

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Description. The pallid bat is the second largest bat in Washington (Table 5). Its pelage is pale yellow with a tinge of brown on the back and creamy white on the underparts (Hermanson and O'Shea 1983, van Zyll de Jong 1985, Nagorsen and Brigham 1993). Individual hairs are short, pale at the base, and darker brown or gray at the tips. Wing membranes are pale brown. Ears are large, pale, and not connected at the base. The tragus is long and narrow with a finely serrated outer edge. The snout has prominent glandular swellings on both sides and scroll-shaped nostrils. Eyes are relatively large in comparison to other bats in Washington. Pallid bats are the only bat species in the state with two pairs of lower incisors. The foot is large, about half of the tibia length, and the calcar is not keeled. In Washington, pallid bats can only be confused with Townsend's big-eared bat, which is smaller and darker, has its ears joined at the base, and two prominent bumps on the nose. Pallid bats near their roosts commonly give a distinctive multi-syllable call that is audible to people (Arnold and Wilkinson 2011).

Taxonomy. Seven subspecies are recognized (Simmons 2005), with only *A. p. pallidus* present in Washington.

Distribution. Pallid bats occur across much of western North America from the Okanagan Valley of south-central British Columbia to central Mexico (Hermanson and O'Shea 1983, WBWG 2005; Appendix A). The species is present in at least 12 counties in eastern Washington (WDFW WSDM database).

Population status. The species is fairly common in many locations, especially in the central and southern parts of its range (WBWG 2005, NatureServe 2009). Status and population trends are unknown for Washington, but the species is generally considered rare to uncommon in the state. Pallid bat calls comprised a small portion of total bat vocalizations heard during acoustic surveys at Hanford (5.1%, Gitzen et al. 2002; 0.8%, Lindsey et al. 2012) and the Yakima Training Center (0.4%, Christy et al. 1995), respectively, but such surveys are probably not well-suited for the species because it relies less on echolocation while foraging than most other bat species. Detections of small numbers of individuals have also been reported at Moses Coulee (Fleckenstein 2000) and sites in Okanogan, Grant, Klickitat, and Spokane counties (Sarell and McGuinness 1993, Fleckenstein 2001a; E. Rowan and N. Williams, pers. comm.). In contrast to these findings, pallid bats were one of the most common species captured at Moses Coulee by Rosier and Rosenberg (2006).

Habitat. Pallid bats primarily inhabit drier

environments, such as deserts, canyon lands, shrub-steppe, and dry coniferous forest, but also occur in mixed conifer forests, riparian forest, and oak woodland (WBWG 2005, Baker et al. 2008). Within these habitats, the bats are commonly associated with rock outcrops, cliffs, and water sources (Orr 1954, van Zyll de Jong 1985, Holroyd et al. 1994). Some use of vineyards also occurs (Rambaldini and Brigham 2011). Elevations up to 2,440 m are occupied (Hermanson and O'Shea 1983). In Washington, the species has been detected at lower elevations in buildings, shrub-steppe, sparsely vegetated dunes, riparian areas, bunchgrass, basalt cliffs and mounds, and planted hardwood trees (Dalquest 1948, Christy et al. 1995, Fleckenstein 2000, 2001a, Gitzen et al. 2002, Rosier and Rosenberg 2006). Ponderosa pine forests near cliff faces are also used in British Columbia (Nagorsen and Brigham 1993).

Roosts and roosting behavior. Pallid bats roost both solitarily and gregariously in groups ranging from several to more than 200 individuals (Orr 1954, Hermanson and O'Shea 1983, van Zyll de Jong 1985, Nagorsen and Brigham 1993, Lewis 1996, WBWG 2005, Baker et al. 2008, West et al. 2011). Rock crevices, holes in rock overhangs, and large snags and decadent trees are often preferred as day roosts, but caves, mines, bridges, and other open human-made structures are also used (Orr 1954, Hermanson and O'Shea 1983, van Zyll de Jong 1985, Lewis 1996, Rabe et al. 1998a, Baker et al. 2008, Rambaldini and Brigham 2008). At the Hanford Site, Washington, maternity colonies have been found occupying the inside of a former reactor building (>100 females present) and associated bat houses (Fitzner and Gray 1991, West et al. 2011). Roosts may be shared with other bat species, especially species of myotis (Vaughan and O'Shea 1976). When approaching or departing their roosts, pallid bats commonly give a loud contact call to communicate with roostmates (Arnold and Wilkinson 2011).

Maternity colonies form in late March and early April and disperse between August and October (van Zyll de Jong 1985). Nursing females are more likely to be communal than pregnant females (Lewis 1996). Day roost selection by reproductive females is influenced by the thermal qualities of sites and stage of reproduction (Lewis 1996, Rabe et al. 1998a). Nursery roosts in rock crevices often have southern or southeastern exposures that offer early warming by the morning sun and protection from the more intense afternoon sun (Lewis 1996). During cooler seasons, vertical crevices with temperatures widely fluctuating between cool morning and warm evening extremes are commonly selected (Hermanson and O'Shea 1983).

Roost trees and snags occupied by adult females are typically large in size with a high percentage of remaining bark, receive considerable solar exposure, and are generally located on south-facing slopes in patches of mature trees (Baker et al. 2008). In the southern part of the species' range, reproductive females prefer day roosts located higher on slopes and closer to water (Rabe et al. 1998a). Females regularly switch day roosts every 1-13 days (Lewis 1996, Rabe et al. 1998a, Rambaldini and Brigham 2008). Distances traveled between roosts are usually <200 m (Lewis 1996).

Males sometimes roost separately from females, but they also regularly join maternity colonies (Hermanson and O'Shea 1983, Nagorsen and Brigham 1993). Groups of more than 100 males have been reported (Rambaldini and Brigham 2008). Males apparently enter torpor only in their day roosts (Rambaldini and Brigham 2008).

Pallid bats enter night roosts to consume prey, enter torpor, and probably socialize (Hermanson and O'Shea 1983, van Zyll de Jong 1985, Nagorsen and Brigham 1993, Lewis 1994, 1996, Pierson et al. 1996). Caves, mines, cliff overhangs, rock crevices, tree cavities, bridges, porches, and garages are all used as night roosts. The species makes frequent use of bridges as night roosts in eastern Washington (J. Fleckenstein, pers. comm.). Live ponderosa pines are used in British Columbia, but may function only as convenient feeding perches (Chapman et al. 1994). In central Oregon, night roosts were dark and enclosed spaces protected from the elements, and spacious enough to allow free flight (Lewis 1994). Night roosts are usually located within 3 km of foraging areas and 0.5-1.5 km of day roosts (Hermanson and O'Shea 1983, Lewis 1994).

Activity at night roosts can begin soon after evening emergence and peaks 1-4 hours after sunset. More time is spent at night roosts during cooler weather in spring and fall than in summer (van Zyll de Jong 1985). Under cooler conditions, pallid bats at night roosts may form clusters and enter torpor for up to 5 hours (Hermanson and O'Shea 1983). Some studies have documented greater use of night roosts by adult females and volant young (Lewis 1994, Pierson et al. 1996), while others have noted predominantly males in groups of up to 100 individuals (Hermanson and O'Shea 1983).

Winter roosting habits have not been described in much of the species' range, including Washington (Fleckenstein 2000) and British Columbia (Nagorsen and Brigham 1993). Use of buildings, rock crevices, mines, and caves as hibernacula has been noted in Nevada and the Great Plains (Hall 1946, Twente 1955). Pallid bats typically hibernate alone or in groups of a few individuals; large aggregations appear to be rare.

Reproduction. Male gonads begin to enlarge in late August and decrease in size from mid-October to April. Breeding occurs from October to December, and possibly into February (Hermanson and O'Shea 1983). Sperm is stored in the female's uterus over winter, with ovulation and fertilization occurring the following spring (Hermanson and O'Shea 1983, van Zyll de Jong 1985). Timing of births is dependent on local climate, possibly because increased use of torpor in cooler years may slow fetal development (Hermanson and O'Shea 1983, Lewis 1993). Thus, gestation length is variable, ranging from 53 to 71 days (average = 63 days) (Hermanson and O'Shea 1983, van Zyll de Jong 1985, Nagorsen and Brigham 1993). In central Oregon, cooler spring temperatures have been correlated with large numbers of non-reproductive females, delayed birth dates, reduced synchrony of births, and lower body mass of adult females (Lewis 1993).

Young are born from late April to July, with birth dates in the northern part of the species' range occurring later in this period (Hermanson and O'Shea 1983, van Zyll de Jong 1985, Nagorsen and Brigham 1993, WBWG 2005). Yearling females usually give birth to one young, whereas older females usually have twins annually. Young are capable of flight at 4-7 weeks of age and are weaned at 6-8 weeks, but remain with their mothers to forage into July and August (Hermanson and O'Shea 1983, van Zyll de Jong 1985). Females become sexually mature in their first year, but age of sexual maturity in males is unknown (Nagorsen and Brigham 1993).

Food habits and foraging. Targeted prey are usually medium-sized to large ground-dwelling or slow-flying arthropods, such as crickets, grasshoppers, moths, beetles, and scorpions, but small lizards and small mammals are also rarely caught (Whitaker et al. 1977, Johnston and Fenton 2001, WBWG 2005, Rambaldini 2006, Rambaldini and Brigham 2011). Crickets represented 60% of the diet followed by moths (20%) in eastern Oregon (Whitaker et al. 1981a). In the Okanagan Valley of British Columbia, scarab beetles are mainly eaten (primarily ten-lined June beetles and May beetles), with Jerusalem crickets, moths, and lacewings being minor prey items (Nagorsen and Brigham 1993, Rambaldini and Brigham 2011). Combined diet samples from Hanford and Winthrop, Washington, were comprised mainly of Jerusalem crickets (36%), beetles (18%), and short-horned grasshoppers (13%) (Rambaldini 2006). Pallid bats also consume flower nectar in some locations (Frick et al. 2009).

Emergence from day roosts is often relatively late and may not occur until an hour after sunset. Prey are often caught on the ground, although some are also taken in flight or gleaned from vegetation (Hermanson and O'Shea 1983). While foraging, pallid bats usually fly slowly with rhythmic dips and rises within a few meters of the ground (Whitaker et al. 1977, Bell 1982, van Zyll de Jong 1985). Terrestrial prey is detected by their rustling sounds rather than by echolocation (Bell 1982, van Zyll de Jong 1985, Fuzessery et al. 1993). The bats then typically drop to the ground, landing on feet and wrists, beside or on top of the prey. Captured prey are carried off and either eaten in flight or taken to night roosts. Foraging occurs primarily in uncluttered, sparsely vegetated habitats. In British Columbia, most foraging occurs in large (>0.5 km in length) areas of exposed sandy soil with sparse shrubs and grasses (Nagorsen and Brigham 1993, Chapman et al. 1994). Rambaldini and Brigham (2011) noted a preference for foraging in shrub-steppe rather than vineyards, but noted the presence of suitable prey in vineyards.

Seasonal movements. Pallid bats are believed to hibernate in the general vicinity of their summer range (Orr 1954, Barbour and Davis 1969).

Threats. The species' gregarious roosting habits and relative sensitivity to disturbance means that disturbances have the potential to displace larger numbers of bats (Chapman et al. 1994, WBWG 2005). Maternity colonies and hibernating bats are especially susceptible to disturbance. Roosts and hibernacula can be damaged or destroyed by vandalism, mine closures (i.e., blockages) and reclamation, rock climbing, timber harvest and other forestry practices, demolition or modification of occupied buildings, and intentional eradication or exclusion from buildings. An additional threat is the loss or extensive modification of primary foraging habitat due to agricultural expansion (including orchards and vineyards), cheatgrass invasion, fire, urban development, excessive livestock grazing, and pesticide use (Willis and Bast 2000). The species has undoubtedly lost considerable habitat in Washington because of agricultural expansion.

Conservation measures. Ferguson and Azerrad (2004) reviewed conservation actions for pallid bats in Washington. Caves and mines within the species' range should be surveyed. Known hibernacula and maternity roosts should be protected from human activity. Conversion of shrub-steppe, especially near roosting habitat, should be avoided and restoration of potential habitat is recommended. Where overgrazing is considered problematic to this species' habitat, land managers should reduce livestock numbers, use deferred rotation or rest-rotation grazing systems, and space water developments to disperse livestock. Use of pesticides within the species' range should be minimized, particularly near maternity colonies and hibernacula. Bridges can be important as night roosts, thus new bridges should incorporate design features that provide opportunities for roosting and older bridges should be retrofitted following these designs. Proposed wind power projects should identify potential impacts to this species, especially if located near maternity sites or hibernacula.

Silver-haired Bat
(*Lasionycteris noctivagans*)

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Description. The silver-haired bat is a medium-sized bat (Table 5) with black or dark brown hairs tipped in silver (Kunz 1982b, Van Zyll de Jong 1985, Nagorsen and Brigham 1993). The wings and tail membrane are black. Ears are short and round with a short, blunt-tipped tragus. The dorsal surface of the tail membrane is partially furred and the calcar lacks a keel.

Taxonomy. No subspecies are recognized (Simmons 2005).

Distribution. Silver-haired bats range broadly across North America from southeastern Alaska across the southern half of Canada south through most of the contiguous U.S. and into northeastern Mexico (Kunz 1982b; Appendix A). The species is present throughout Washington (WDFW WSDM database).

Silver-haired bats are migratory across much of their range, with males and females appearing to occupy separate summer ranges over broad regions (Wilson and Ruff 1999, Cryan 2003). Males are usually predominant in western North America, whereas females occur mainly in midwestern and eastern regions, although there are deviations to this pattern, including in the Pacific Northwest. Male:female ratios have not been widely documented in Washington. Campbell (1993) reported an even sex ratio among individuals (n = 30) captured from May to September in Stevens and Pend Oreille counties, whereas Baker and Lacki (2004) caught only males (n = 81) from May to August in Kittitas and Yakima counties. Females comprise 37% of the museum specimens (n = 118) collected year-round from across the state, including 30% during winter (n = 27), 47% in spring-summer (n = 38), and 34% in fall (n = 53). These data appear to refute Perkins and Cross' (1991) suggestion that the two sexes are geographically separated in Washington, but increasingly occur together as fall migration progresses in late August and September.

Population status. Population size and trends are unknown throughout the species' range (WBWG 2005), but it usually occurs at low densities (NatureServe 2009). Surveys in Washington indicate that silver-haired bats are common in drier forests along the east slope of the Cascade Mountains in Kittitas and Yakima counties (Baker and Lacki 2004) and in the Selkirk Mountains (Campbell 1993). The species was regularly detected during acoustic and/or capture surveys in the northern Cascades (Christophersen and Kuntz 2003), southern Cascades (Thomas 1988, Erickson 1993), at Mount Rainier National Park (Petterson

2001), at Joint Base Lewis-McChord (Falxa 2008a), at Woodard Bay in Thurston County (Falxa 2007b), in the San Juan Islands (Dalquest 1940), in Spokane County (H. Ferguson, pers. comm.), and at several sites in Lincoln County (BLM, unpubl. data). In riparian areas of the Columbia Basin in eastern Washington, these bats were recorded uncommonly at Hanford (Gitzen et al. 2002) and the Yakima Training Center (Christy et al. 1995), and were uncommon or rare at Moses Coulee, where some detected individuals may have been migrants (Fleckenstein 2000, Rosier and Rosenberg 2006). However, a second survey at Hanford found it to be widespread and the second-most commonly recorded species (Lindsey et al. 2012). West et al. (1984, 2004) captured only single individuals during surveys in the southwestern Cascades and on the Olympic Peninsula, respectively.

Habitat. Silver-haired bats typically reside in forests and riparian zones (Kunz 1982b, Nagorsen and Brigham 1993, Johnson and Cassidy 1997, Verts and Carraway 1998). Older, more structurally diverse forests generally appear preferable to younger, intensively managed forests due to differences in roost availability and canopy structure suitable for foraging (Perkins and Cross 1988, Thomas 1988, Betts 1998a, Jung et al. 1999). In Washington, this species occurs in forests and suburban/developed areas, and has been described as largely absent from shrub-steppe except during migration (Perkins and Cross 1988, Johnson and Cassidy 1997). However, Gitzen et al. (2002) and Lindsey et al. (2012) documented the calls of silver-haired bats at Hanford throughout summer, and Fleckenstein (2000) captured a few individuals at Moses Coulee in summer. This suggests the species is a summer resident in some areas of shrub-steppe; clumps of trees found in riparian areas or on farmsteds in this habitat may be sufficient to support resident populations. Elevations from sea level to at least 1,830 m are used (Nagorsen and Brigham 1993, Petterson 2001, Christophersen and Kuntz 2003).

Roosts and roosting behavior. Silver-haired bats roost most commonly in snags and live trees, including ponderosa pine, Douglas-fir, lodgepole pine, western white pine, western larch, western redcedar, grand fir, aspen, and black cottonwoods (*Populus balsamifera* ssp. *trichocarpa*; Nagorsen and Brigham 1993, Betts 1996, 1998a, Campbell et al. 1996, Mattson et al. 1996, Vonhof 1996, Crampton and Barclay 1998, Vonhof and Gwilliam 2007). Buildings (especially exteriors), bat houses, and wood piles are also regularly occupied in Washington (G. Falxa, pers. comm.). Maternity colonies usually contain 5-25 females and have rarely reached 70 individuals (Rainey and Pierson 1994, Mattson et al. 1996, Vonhof and Barclay 1996, Betts 1998a, Vonhof and Gwilliam 2007). Maternity groups roost mainly in cavities in large snags in various stages of decay, especially those protruding above the surrounding canopy, being farther from other tall trees, and having less vegetative matter immediately above and below the roost site (Table 3; Betts 1996, 1998a, Campbell et al. 1996, Mattson et al. 1996, Vonhof and Barclay 1996, Vonhof and Gwilliam 2007). These attributes may promote absorption of solar radiation and retention of heat that provide thermoregulatory benefits to reproductive females. Reproductive females change their roosts regularly (e.g., once a day to once every 18 days or longer; Betts 1996, 1998b, Vonhof and Barclay 1996).

Males and non-reproductive females roost solitarily away from nurseries (Humphrey 1975, Mattson et al. 1996). Their day roosts occur in large trees in intermediate stages of decay under loose bark, in cracks or crevices, and in cavities (Mattson et al. 1996). Solitary individuals may switch roosts daily or less frequently (Campbell et al. 1996, Mattson et al. 1996).

Information about night roosts is lacking, but the species rarely if ever occurs at sites (e.g., bridges, buildings) commonly used by other bat species (Perlmeter 1996, Pierson et al. 1996, Adam and Hayes 2000). During migration, silver-haired bats roost mainly in trees (Barclay et al. 1988, McGuire et al. 2012). Most migrating individuals roost alone, although single bats may occur in different parts of the same tree. Other roost structures used during migration include buildings, lumber piles, fence posts, utility poles, and mines (Barbour and Davis 1969, Nagorsen and Brigham 1993, McGuire et al. 2012; BLM, unpubl. data). Migrating bats may remain torpid for several days during cool temperatures (Barclay et al. 1988).

Silver-haired bats occupy a variety of winter roost sites, including trees, buildings, abandoned mines, and more rarely in rock crevices and caves (Kunz 1982b, Maser 1998). In western Washington, buildings, trees, and bat houses are occupied at this time of year (G. Falxa, pers. comm.). Caves do not appear to be widely used as hibernacula in the state (Perkins et al. 1990). In British Columbia and Washington, winter roost trees include large western redcedar, large Douglas-fir trees and snags, and decadent big-leaf maples, with crevices and sites beneath loose bark being occupied (Cowan 1933, Nagorsen and Brigham 1993; G. Falxa, pers. comm.). Hibernation roosts require stable microclimates (Humphrey 1975). Ambient temperatures of –0.5 to –2ºC (28.4–31.1°F) have been reported in old mines used as hibernacula (Nagorsen and Brigham 1993). During winter, silver-haired bats hibernate and/or use daily torpor depending on the severity of weather conditions. Hibernation and winter daily torpor may be interspersed with bouts of foraging, especially in western Washington (Falxa 2007a). Silver-haired bats winter alone or in small groups that can contain both sexes (Humphrey 1975, Kunz 1982b).

Reproduction. Males have enlarged testes from July to September in the Pacific Northwest (Maser 1998, Baker and Lacki 2004). Mating likely occurs during autumn migration and winter (Kunz 1982b, Nagorsen and Brigham 1993, Cryan et al. 2012). Sperm is probably stored in the uterus during winter followed by ovulation and fertilization in late April and early May (Kunz 1982b). Pregnancy lasts 50-60 days, with births occurring in late June or early July (van Zyll de Jong 1985, Nagorsen and Brigham 1993). Females give birth to one or two young, with two being most common (Barbour and Davis 1969, Kunz 1982b, Parsons et al. 1986, Nagorsen and Brigham 1993). Lactation lasts about 36 days (Kunz 1982b). Young are able to fly by three weeks of age (Nagorsen and Brigham 1993). In Washington, volant young have been detected beginning in early August (Campbell 1993, Baker and Lacki 2004). Most juvenile males and females reach sexual maturity in their first autumn (Kunz 1982b, Cryan et al. 2012).

Food habits and foraging. In the Pacific Northwest, this species forages mainly on moths, flies, beetles, leafhoppers, true bugs, neuropterans, and caddisflies (Whitaker et al. 1977, 1981b, Nagorsen and Brigham 1993, Kellner and Harestad 2005, Lacki et al. 2007b, Ober and Hayes 2008a). Moths and flies are important prey in some coastal wet forests (Whitaker et al. 1977), with evidence of moderate dietary specialization on moths in inland dry forests (Whitaker et al. 1981b, Lacki et al. 2007b).

Foraging typically occurs in and over forests and riparian zones; over openings, streams, and ponds; and along forest margins (Whitaker et al. 1977, 1981a, Kunz 1982b, Thomas 1988, Thomas and West 1991, Johnson and Cassidy 1997). In western Washington, peaks in nocturnal activity occur for several hours after sunset and again before sunrise (G. Falxa, pers. comm.). Foraging may be reduced on summer nights with cool air temperatures (<8°C, <46°F) (Nagorsen and Brigham 1993), but is known to extend through winter in Washington (Falxa 2007a). Adults generally forage singly, although pairs and groups of 3-4 bats are also observed (Barbour and Davis 1969). During migration, silver-haired bats feed along intact riparian areas in arid rangelands (Whitaker et al. 1981b). Because of their short broad wings, low- to mid-frequency echolocation calls, and slow agile flight, they are able to detect and capture small insects at close range (Barclay 1985, 1986, Nagorsen and Brigham 1993).

Seasonal movements. Most northern populations migrate to the more southern parts of the species' range to overwinter (Izor 1979, Wilson and Ruff 1999, Cryan 2003). However, Washington's population is comprised of both year-round residents and migratory individuals. Museum records and detections of foraging and roosting animals suggest that large numbers of silver-haired bats occur year-round in western Washington (Johnson 1953, Falxa 2007a; G. Falxa, pers. comm.; G. Green, pers. comm.), whereas smaller numbers are present in eastern Washington (E. Rowan, pers. comm.; N. Williams, pers. comm.). It appears that significant numbers of individuals also migrate through the state, as indicated by mortality records from wind energy facilities and other data (Perkins and Cross

1991, Johnson and Erickson 2011). Data from wind farms show that spring migration in Washington occurs from about late April to late May and that fall migration lasts from about mid-August to late October (e.g., Kronner et al. 2008; numerous other unpublished reports). This species appears to migrate singly or, less often, in small groups (Barbour and Davis 1969, Barclay et al. 1988). In eastern North America, fall-migrating silver-haired bats move in waves, make brief stopovers of one or two days before continuing onward, and generally forage on non-travel nights (McGuire et al. 2012). Individuals fly about 250-300 km per night while migrating (McGuire et al. 2012).

Threats. During migration, silver-haired bats are one of the species most commonly killed at wind farms, including in Washington (Arnett et al. 2008, Johnson and Erickson 2011). Given the species' use of snags for roosting, particularly large snags for maternity sites, forestry practices that greatly reduce existing snags and curtail development of large snags may adversely affect local populations. Loss of temporary roosts along migration routes is a potential threat, as is loss of foraging habitat in riparian areas and reduction of prey due to application of pesticides (WBWG 2005).

Conservation measures. Pre-construction surveys of proposed wind energy facilities should be made to establish the timing and location of potential conflicts so that mitigation measures can be used to reduce mortality to this species. At existing wind farms, surveys are needed to document mortalities and measures are needed to reduce mortalities. Forestry practices should maintain an abundance of large snags to provide a diversity of potential roost sites so that the different seasonal thermoregulatory needs of males and females are met (Betts 1998a, Vonhof and Gwilliam 2007). To be suitable as maternal roosts, snags should be large in diameter (>60 cm dbh depending on site and species), tall, in the early stages of decay with retention of most of the stem, and positioned in a way that increases their conspicuousness and exposure to solar radiation, such as protruding above the canopy and being isolated from other tall trees (Betts 1996, 1998a, Campbell et al. 1996). In inland dry forests, Campbell et al. (1996) recommended that snags be situated in canopy gaps or open areas >100 m upslope from riparian areas. Providing small groups of suitable snags may increase use of a site by silver-haired bats because of the availability of alternate roosts in close proximity (Campbell et al. 1996). Documentation of the temporal and spatial distribution of this species throughout Washington, including important migratory pathways, will help inform conservation measures and the appropriate time to apply them.

Spotted Bat (*Euderma maculatum*)

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Description. The spotted bat is one of the larger bat species in Washington (Table 5) and is easily recognizable by its black dorsal fur with two large white spots on the shoulders and one on the rump (van Zyll de Jong 1985, Nagorsen and Brigham 1993). Smaller white patches occur at the base of the ears, and the belly is whitish with black underfur. Individual hairs are short, pale at the base, and darker brown or grey at the tips. Wing membranes are pinkish-red to grey-brown in color. A bare patch, circular in shape and non-glandular, occurs on the throat and may be hidden beneath the fur. The long pinkish ears are joined at their bases across the forehead and have transverse ribs extending to their rear edge. A fringe of fine hairs extends along the top border on the back of the ears. The tragus is long and broad, and the calcar is not keeled. Spotted bats produce a low-pitched (6-16 kHz) echolocation call that is audible to people and distinctive from other bats in Washington.

Taxonomy. No subspecies are currently recognized (Simmons 2005).

Distribution. Spotted bats occur in much of western North America from south-central British Columbia and southern Montana south to central Mexico (Luce and Keinath 2007; Appendix A). The core area of the species' distribution appears to be the southwestern U.S. (van Zyll de Jong 1985). Spotted bats have been recorded in seven counties in eastern Washington (Sarell and McGuinness 1993, Fleckenstein 2000, 2001a, Gitzen et al. 2001; WDFW WSDM database; BLM, unpubl. data). Highly anomalous records from Woodway, Snohomish County, in 1997 and Seattle in November 2008 probably represent accidentally transported individuals.

Population status. Population size and trends are largely unknown throughout the species' range, including Washington (Luce and Keinath 2007). Spotted bats have long been thought of as one of the least common bats in North America, but Luce and Keinath (2007) recently suggested that this bat naturally occurs in highly localized populations and is absent from large intervening areas. The species is more common and widespread in Oregon than once believed (Rodhouse et al. 2005), but in British Columbia, its numbers may total fewer than 1,000 animals (Nagorsen 2004a). In general, populations do not appear to be limited by the availability of foraging habitat (Navo et al. 1992, Storz 1995, Priday and Luce 1999). Typical survey methods using mist nets and acoustic devices poorly detect the species (Rodhouse et al. 2005).

Spotted bats weren't documented in Washington until 1991, when one animal was observed foraging over a marsh complex at Dry Falls in Sun Lakes State Park, Grant County (Sarell et al. 1991). Subsequent evidence suggests that the species is probably highly localized in association with suitable roosting cliffs and water sources (Sarell and McGuinness 1993, Gitzen et al. 2002). Significant numbers have been reported at Moses Coulee (Fleckenstein 2000) and two sites in Okanogan County (Sarell and McGuinness 1993). The species has also been found at other locations in Okanogan, Douglas, and Grant counties where surveyors did not assess population size (Sarell and McGuinness 1993, Fleckenstein 2001a, Gitzen et al. 2001, Rosier and Rosenberg 2006) and it may occur in cliffs along the Columbia River south to Crab Creek Wildlife Management Area (S. West, pers. comm.). Surveys in shrub-steppe at the Yakima Training Center and the Hanford Site did not find this species (Christy et al. 1995, Gitzen et al. 2002, Lindsey et al. 2012). Calls have been detected at two locations in the channeled scablands in Lincoln County (southwest of Davenport and south of Sprague) and near Metaline Falls in Pend Oreille County, but abundance levels at these locations are also unknown (BLM, unpubl. data).

Habitat. Spotted bats occupy habitats ranging from desert and shrub-steppe to montane coniferous forest and meadows (Pierson and Rainey 1998, Nagorsen 2004a, Rodhouse et al. 2005, WBWG 2005, Luce and Keinath 2007). The species is more closely associated with high sheer cliffs, which are required as day roosts, than specific vegetation types (Pierson and Rainey 1994, Priday and Luce 1999). In Washington and adjoining areas, spotted bats have been found using a variety of habitats, including ponderosa pine forest, Douglas-fir forest, forest openings, shrub-steppe, hayfields, cliffs, talus slopes, marshes, open water, riparian forests, and golf courses (Blood 1993, Johnson and Cassidy 1997, Nagorsen 2004a). Elevations from below sea level to 3,230 m are used across the species' range (Luce and Keinath 2007), but in Washington, occupied sites vary from 300 to 850 m in elevation (Sarell and McGuinness 1993, Gitzen et al. 2001).

Roosts and roosting behavior. Spotted bats roost extensively in the crevices of steep cliffs (Wai-Ping and Fenton 1989, Priday and Luce 1999, Nagorsen 2004a, WBWG 2005, Luce and Keinath 2007), but have been noted to use caves and buildings as well (Sherwin and Gannon 2005). Availability of day-roosting habitat in cliffs is often believed to limit the species' distribution and population size (Pierson and Rainey 1994). In Washington, high (>30 m) vertical cliffs of granitic gneiss or columnar basalt are used as day roosts (Sarell and McGuinness 1993). Warm aspects are favored at sites with light colored granitic rock, whereas cool aspects are used on dark basalt cliffs.

Spotted bats probably roost solitarily, with the exception of mother-young pairs (Sarell and McGuinness 1993). However, loose aggregations may form in areas with abundant roost crevices, such as at Moses Coulee and McGlaughlin Canyon in eastern Washington (Sarell and McGuinness 1993). In British Columbia, females demonstrate strong fidelity to the same day roosts from May to July, but are less predictable in their use of day roosts in August (Wai-Ping and Fenton 1989).

Little is known about the summer day roosts of males and non-reproductive females and whether they occur separately from those of reproductive females. In British Columbia, a radio-tagged male returned to the same cliff over a four-day period (Leonard and Fenton 1983).

Night roosts are used in some locations, but not at others (Wai-Ping and Fenton 1989, Rabe et al. 1998b). Use probably depends on availability of nearby day-roosting sites and differences in foraging behavior. Night roosts have been located in caves and aspen groves (Rabe et al. 1998b, Priday and Luce 1999).

Hibernacula and wintering behavior are poorly known in much of this species' range (Luce and Keinath 2007). Spotted bats are active in low-elevation canyons in Oregon from as early as February to as late as October, suggesting hibernation occurs during the remaining months (Rodhouse et al. 2005; T. Rodhouse, pers. comm.). In Arizona, the species is active year-round, although activity during winter is generally on warmer nights with favorable weather conditions (WBWG 2005).

Reproduction. Reproductive habits are not well known. Like most other temperate vespertilionids, spotted bats likely mate in the late summer or fall (WBWG 2005). Reproductive data from the northern part of the species' range suggest that young – one per year – are born from mid-June to early July (Watkins 1977, Nagorsen and Brigham 1993). Females are believed to give birth while roosting alone rather than becoming communal. Age of sexual maturity is unknown, but probably occurs by the first autumn in both sexes (Nagorsen and Brigham 1993).

Food habits and foraging. The diet consists primarily of medium-sized moths, especially noctuid moths (Watkins 1977, Wai-Ping and Fenton 1989, WBWG 2005). Spotted bats use low frequency echolocation calls to find prey (Leonard and Fenton 1984, Fullard and Dawson 1997). Emergence from day roosts often occurs during the first hour after sunset (Wai-Ping and Fenton 1989, Rodhouse et al. 2005, Luce and Keinath 2007). Spotted bats may use the same commuting paths night after night (Woodsworth et al. 1981, Wai-Ping and Fenton 1989). Commuting distances between day roosts and feeding areas can range from 1 to 39 km depending on the proximity of suitable areas (Rabe et al. 1998b). Wai-Ping and Fenton (1989) reported commuting distances of 6-10 km in British Columbia.

Spotted bats appear to use a "trapline" foraging strategy, whereby individuals forage at several sites during an evening and consistently return to these same sites on consecutive nights (Woodsworth et al. 1981, van Zyll de Jong 1985, Wai-Ping and Fenton 1989, Rabe et al. 1998b). Foraging usually occurs within 50 m of the ground (Rodhouse et al. 2005, WBWG 2005). Although bat species with large ears are typically associated with a gleaning foraging strategy, evidence of gleaning by spotted bats has not yet been found (Wai-Ping and Fenton 1989, Nagorsen and Brigham 1993, Storz 1995). Spotted bats have been observed hunting alone and individuals using adjoining foraging grounds appear to avoid each other, which may reduce intraspecific competition (Leonard and Fenton 1983). In California, spotted bats maintain individual feeding territories (Pierson and Rainey 1994) and may use echolocation calls to space themselves while foraging (Leonard and Fenton 1983). However, Wai-Ping and Fenton (1989) documented overlapping foraging areas in British Columbia, suggesting that exclusive feeding territories are not maintained at some locations. Wai-Ping and Fenton (1989) reported that female spotted bats forage continuously throughout the night, whereas Rabe et al. (1998b) noted that foraging can be punctuated by visits to night roosts. Use of night roosts may occur where bats are forced to travel long distances from their day roosts (Rabe et al. 1998b).

In Washington, spotted bats have been detected foraging and/or traveling over rock cliffs, talus slopes, sagebrush-bunchgrass, open ponderosa pine-bunchgrass, riverine habitat, open water, deciduous copses, and a golf course (Sarell and McGuinness 1993, Gitzen et al. 2001). Other foraging habitats noted in British Columbia and Oregon include ponderosa pine forests, old fields surrounded by ponderosa pine forest, Douglas-fir uplands usually in close proximity to wetlands or rivers, juniper forest, irrigated fields, marshes adjacent to lakes, and abandoned pastures within 10 km of cliffs (Woodsworth et al. 1981, Leonard and Fenton 1983, Wai-Ping and Fenton 1989, Blood 1993, Nagorsen and Brigham 1993, Holroyd et al. 1994, Rodhouse et al. 2005).

Seasonal movements. It is unknown whether spotted bats hibernate locally or migrate, although there is evidence of the species moving to lower elevations to overwinter (WBWG 2005, Luce and Keinath 2007). Spotted bats disappear from their summer range in British Columbia by late October (Nagorsen and Brigham 1993), suggesting that migration, hibernation, or both occur by that time.

Threats. Spotted bats seem to be sensitive to human activity, thus there is concern that land development below day roosts and at drinking sites, and recreational rock climbing on occupied cliffs may cause abandonment of roosts (Blood 1993, Nagorsen 2004a, WBWG 2005, Luce and Keinath

2007). There appears to be little information on the impacts of destruction or degradation of foraging habitat on the species (Luce and Keinath 2007), but Nagorsen (2004a) considered this a minor concern for this bat because of its adaptable foraging behavior. Extensive reservoir creation along the Columbia and possibly Snake Rivers in Washington during the mid-20th century likely destroyed riparian foraging habitat used by spotted bats. Large-scale, non-target pesticide spraying could adversely affect spotted bat populations through secondary poisoning of bats and reduction of their prey base. Wind turbines have the potential to cause direct mortality of spotted bats and could pose a threat to small local populations.

Conservation measures. Surveys of potential roosting and foraging habitat are needed to gain a better understanding of the distribution and potential threats to this species. At sites where presence is documented, habitat and water sources should be identified and mapped. Winter roost sites are unknown and should be located. Given the rarity of this bat in Washington, scientific collection could pose a threat to local populations and should be restricted by WDFW. Outreach to recreational climbing organizations about the effects of climbing on bat populations may be necessary in some locales to prevent disturbance. Pesticide applications proposed for areas used by spotted bats should identify foraging and roosting areas and water resources at project sites and avoid spraying in these areas (see references in Luce and Keinath [2007] for guidance on buffers around bat resources). Bat mortalities at wind energy facilities in Washington should be monitored for this species.

Townsend's Big-eared Bat
(*Corynorhinus townsendii*)

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Description. Townsend's big-eared bat (formerly known as the lump-nosed bat or western big-eared bat) is a medium-sized bat for Washington (Table 5), with very large ears connected at the base and two prominent lumps on either side of the nostrils (Nagorsen and Brigham 1993, Gruver and Keinath 2006). The fur on the back is light brown in eastern Washington and darker brown in western Washington. The calcar is not keeled. In Washington, this species can only be confused with the pallid bat, which is larger and paler, does not have its ears joined at the base, and lacks the prominent bumps on its nose.

Taxonomy. Five subspecies are recognized, with only *C. t. townsendii* present in Washington (Piaggio and Perkins 2005, Simmons 2005). This species was previously placed in the genus *Plecotus*.

Distribution. Townsend's big-eared bat occurs from southern British Columbia southward through most of the western U.S. to central Mexico (Kunz and Martin 1982, NatureServe 2009; Appendix A). Isolated populations also exist in the Ozarks and Appalachians. Documented records exist for most counties in Washington, but are lacking for the southern Columbia Basin and the Blue Mountains (WDFW WSDM database). Within its range, distribution is often linked to the presence of suitable maternity roosts and hibernacula located near foraging habitat (Gruver and Keinath 2006).

Population status. This species generally occurs at low densities across its range (Gruver and Keinath 2006). Long-term population trends are difficult to assess for many western populations because of the scarcity of adequate count data and the species' dynamic roosting behavior and use of multiple roosts under some conditions (Ellison et al. 2003, Sherwin et al. 2003, Gruver and Keinath 2006). However, significant declines in abundance have been reported for California (Pierson and Rainey 1996) and Oregon (Perkins and Levesque 1987), and many other areas have likely experienced some level of decline due to chronic disturbance of roosts and widespread mine closure programs (Pierson et al. 1999). In Washington, long-term count data are available for only a small number of roosts. Comparisons of bat numbers during the 1970s-1980s against those in the 1990s-2000s can be made for six hibernacula, with four of these showing increases and two being stable during this period (WDFW WSDM database). However, two of the sites featuring increases experienced major declines (from >200 bats to ≤30 bats) from the mid-1960s to early 1970s, probably

due to researcher activity (Senger and Crawford 1984). One of these has subsequently recovered, but the other remains at less than half its former size. Count data for the 1970s-1980s versus the 1990s-2000s are available for only two maternity colonies in the state, with one showing an increase and one a decrease (WDFW WSDM database). A third site that held a major maternity roost into the 1930s was abandoned by the 1960s and remains unoccupied by breeding bats (St. Hilaire 2013).

Townsend's big-eared bats are difficult to capture in mist nets (Oliver 2000) and have quiet echolocation calls (WBWG 2005), making standard capture and acoustic surveys poorly suited for measuring presence and activity levels. This may partially account for the rarity or absence of the species during surveys at a number of locations in Washington, including the Olympic Peninsula (Erickson et al. 1998, Jenkins et al. 1999), both slopes of the Cascades (West et al. 1984, Thomas 1988, Erickson 1993, Frazier 1997, Petterson 2001, Christophersen and Kuntz 2003, Baker and Lacki 2004), the Columbia Basin (Christy et al. 1995, Gitzen et al. 2002, Lindsey et al. 2012), the Selkirk Mountains (Campbell 1993), and the San Juan Islands (Dalquest 1940). Several other surveys reporting them in somewhat higher numbers have been near known or suspected colonies (southern Cascades, Taylor 1999; Moses Coulee, Fleckenstein 2000, Rosier and Rosenberg 2006; Badger Gulch in Klickitat County, Fleckenstein 2001a; Olympic Peninsula, West et al. 2004; Joint Base Lewis-McChord, Falxa 2008a).

Habitat. Townsend's big-eared bats occupy a broad range of dry and moist environments, including coniferous and hardwood forests, riparian communities, desert, grasslands, shrub-steppe, and active agricultural areas (Nagorsen and Brigham 1993, Pierson et al. 1999, WBWG 2005, Gruver and Keinath 2006). In Washington, this species is found in lowland conifer-hardwood forest, montane conifer forest, ponderosa pine forest and woodland, shrub-steppe, riparian habitats, and open fields (Johnson and Cassidy 1997, Woodruff and Ferguson 2005, Falxa 2008a, 2009). Falxa (2008a) speculated that most maternity colonies in western Washington occur near late successional conifer forests. In eastern Washington, maternity colonies are often located near a lake or river (H. Ferguson, pers. comm.). This species occupies elevations from sea level to 3,200 m (Nagorsen and Brigham 1993, Pierson et al. 1999), but occurs mainly at low- to mid-elevations in Washington (Johnson and Cassidy 1997).

Roosts and roosting behavior. Most day roosts are in caves, mines, abandoned buildings, and attics, but bridges, rock crevices, and very large trees with basal hollows are also used (Nagorsen and Brigham 1993, Pierson et al. 1999, Sherwin et al. 2000, 2003, Mazurek 2004, WBWG 2005, Reid et al. 2010). In Washington, lava tube caves, mines, old buildings, bridges, and concrete bunkers are commonly occupied (Senger and Crawford 1984, Fursman and Aluzas 2005, Woodruff and Ferguson 2005). Large old-growth trees with basal hollows may have formerly been an important roost type in the state. Temperatures within potential roosting structures are particularly important in the selection of sites, as well as roost dimensions, sizes of openings, light quantity, and extent of airflow (Pierson et al. 1999, Gruver and Keinath 2006). Fidelity to roosts is high in this species, with individuals often returning to the same site or group of sites year after year (Pierson et al. 1999, Sherwin et al. 2003). Use of multiple roosts within seasons throughout the year is probably common in many areas and may be related to colony size, roost type and availability, or other factors (Sherwin et al. 2003). These bats often aggregate in highly visible clusters on open surfaces within several meters of the ground when roosting at sites with cooler temperatures (Pierson et al. 1999, Betts 2010a). Colonies are highly sensitive to human disturbance (Nagorsen and Brigham 1993, Pierson et al. 1999), but solitary individuals can be tolerant of moderate human activity when roosting in buildings (G. Falxa, pers. comm.).

Maternity roosts with adult females and their young occur in many of the types of sites listed above (Pierson et al. 1999, Woodruff and Ferguson 2005). Of the 29 maternity sites reported in Washington since 1980, 16 were in buildings, five in caves, five in mines, two in concrete vaults, and one under a collapsed railroad structure (WDFW

WSDM database). Although maternity roosts are susceptible to disturbance, one site in Washington is located in an active barn over a pen usually occupied by horses (Fleckenstein 2001a).

Temperatures in California maternity colonies typically range from 19-30°C (66-86°F; Pierson et al. 1991), but Betts (2010a) noted an attic roost in Oregon averaging up to 35°C (95°F) and Reid et al. (2010) reported cave roosts varying from 7-25°C (45-77°F) in British Columbia. Observations in Washington also indicate that these bats tolerate a wide range of temperatures at maternity colonies, especially those in buildings with structural features (e.g., A-frame roofs) that enhance daily temperature gradients (Woodruff 2000, Mathis 2005). Cooler locations (either within a roost or at different sites) are preferred early in pregnancy, which allows females to enter torpor and save energy, but warmer sites are chosen later in pregnancy and while nursing (Pierson and Rainey 1996). Maternity roosts must also be fairly spacious (Pierson et al. 1991, 1999). Availability of roosts with proper internal conditions for reproductive females is often limited. For example, in northern Utah, maternity colonies existed in only 1.8% of the 715 mines and caves surveyed for this species (Sherwin et al. 2000). Maternity colonies may occupy more than one roost per season (Sherwin et al. 2000). At least three such colonies in Washington are known to use two or three roosts per maternity season (Woodruff 2000, Mathis 2005, Falxa 2009).

In Washington, maternity colonies have been reported to form in April, begin to break up by mid-August or early September, and are vacant by September or early October (Woodruff 2000, Mathis 2005; D. Young, pers. comm.). These roosts in Washington and elsewhere in the West usually range in size from about 10 to 250 bats, although large colonies can reach 450 bats (Pearson et al. 1952, Humphrey and Kunz 1976, Perkins 1991, 1992, Pierson and Rainey 1996; WDFW WSDM database). Of 29 recent maternity roost records for Washington, six held fewer than 50 bats, 11 held 50-100 bats, six held 101-200 bats, one held about 250 bats, and five held undetermined numbers (WDFW WSDM database). Colony attendance can be dynamic, causing daily variation in bat numbers (Mathis 2005). Maternity colonies appear to represent multi-generational groups of related females (Pierson 1988). Day-roosting adults spend most of their time resting and grooming (Mathis 2005, Betts 2010b).

During summer, males and non-reproductive females usually roost alone or in small groups of several individuals separate from nurseries (Pierson et al. 1999), although they occasionally join nurseries, especially in spring (Gruver and Keinath 2006). Cool caves, mines, buildings, bridges, and other kinds of sites are inhabited (Senger et al. 1972, Pierson et al. 1999, Sherwin et al. 2000, Fursman and Aluzas 2005), which facilitate the use of torpor (Gruver and Keinath 2006). Hibernacula are sometimes used as bachelor roosts during summer (Sherwin et al. 2000).

Both sexes are known to use multiple interim roosts in caves, mines, and buildings during spring after emerging from hibernacula and again in fall before hibernation (Dobkin et al. 1995, Pierson et al. 1999, Gruver and Keinath 2006; G. Falxa, pers. comm.). Movement among these roosts appears to be frequent. Some fall swarming sites are also used as hibernacula (Ingersoll et al. 2010).

Townsend's big-eared bats use night roosts as resting places during foraging and for social interaction. Night roosting occurs in caves, mines, buildings, culverts, and bridges (Dalquest 1947, Perkins 1990a, Perlmeter 1996, Pierson et al. 1999, Adam and Hayes 2000, Fursman and Aluzas 2005). Dropped insect parts, such as moth wings, can be used to identify night roosts.

Hibernacula occur mainly in caves, mines, lava tubes, and occasionally in buildings (Pierson et al. 1999, Gruver and Keinath 2006, Hayes et al. 2011). Of the 61 hibernacula reported in Washington since 1980, 46 were in caves, 11 in mines, two in concrete vaults, and two in buildings (WDFW WSDM database). Western hibernacula commonly hold single bats or small aggregations of a few to several dozen individuals of both sexes, but rarely may exceed 1,000 bats (Pierson et al. 1999, Gruver and Keinath 2006). Recent hibernacula records for Washington indicate that about half (32 of 61) of the sites held 1-3 bats, 13 held 4-10 bats, seven held 11-50 bats, four held 51-100 bats, four held 101-300 bats, and one held undetermined numbers (WDFW WSDM database). Bats begin arriving at hibernacula in October or early November. Abundance peaks in January and mid-February, then declines into April (Adler 1977, Pierson et al. 1999). Hibernating individuals roost singly or in small groups of multiple individuals, and hang in open areas with both ears often curled in the shape of ram horns (Hughes 1968, Adler 1977, Adams 2003). Areas near entrances are commonly used. Bats frequently arouse and shift locations within a hibernaculum or move to a different roost to seek suitable temperatures or to avoid disturbance (Pearson et al. 1952, Adler 1977).

Hibernacula feature moderate airflow and stable temperatures typically ranging from -3 to 13°C (27-55°F), with those below 10°C (50°F) preferred (Adler 1977, Genter 1986, Pierson 1988, Nagorsen and Brigham 1993, Perkins et al. 1994, Doering 1996, Szewczak et al. 1998, Kuenzi et al. 1999, Pierson et al. 1999, Ingersoll et al. 2010, Hayes et al. 2011). Hibernacula are often warmer in coastal locations than at interior sites (Hughes 1968, Pierson 1988, Nagorsen and Brigham 1993). In Washington, winter hibernacula temperatures vary from about -1 to 4°C (30-39°F) in the Cascades, but are about 3°C (5.4°F) higher at coastal Chuckanut Mountain in Whatcom and Skagit counties (Hughes 1968, Adler 1977, Perkins 1985).

Reproduction. Sperm production and mating peak in late summer or early fall, although some breeding occurs during arousals from hibernation (Pearson et al. 1952, Gruver and Keinath 2006). Females store sperm through winter and delay ovulation and fertilization until spring. Length of pregnancy is quite variable, lasting 56 to 100 days depending on the frequency of torpor by females. Timing of births can therefore show considerable variation within and among colonies and years. For example, initial birth dates ranged between June 20 and July 26 and between early July and July 28 at two nursery colonies near one another in Okanogan County, Washington, over a three-year span (Woodruff 2000). Newborns have been seen at Washington colonies from June to late July (Scheffer 1930, Dalquest 1948, Mathis 2005, Woodruff and Ferguson 2005). One pup is born annually. Young can fly by 3 weeks of age and stop nursing by 6 weeks of age (Pearson et al. 1952). Females mate in their first autumn, but males do not reach sexual maturity until their second fall.

Food habits and foraging. More than 90% of the diet is usually comprised of moths (Pierson et al. 1999, WBWG 2005, Gruver and Keinath 2006). Smaller amounts of other prey such as beetles, flies, and lacewings are also eaten. Small dietary samples from Oregon support the preference for moths in the Pacific Northwest (Whitaker et al. 1977, 1981a; Ober and Hayes 2008a). Tissue moths (*Triphosa haesitata*), a hibernating moth that develops fat pads in fall, and other moths (e.g., *Scoliopteryx libatrix*) occur in some of the caves used by Townsend's big-eared bats in fall and winter in Washington and may be an important autumn food source for these bats prior to hibernation (Senger and Crawford 1984).

Foraging activity extends from after sunset to before sunrise (Dobkin et al. 1995, Maser 1998, Fellers and Pierson 2002, Mathis 2005). Travel distances of 1-18 km between day roosts and foraging sites are probably typical in the West (Dobkin et al. 1995, Bradley 1996, Fellers and Pierson 2002, Falxa 2009; H. Ferguson, pers. comm.), although longer nightly foraging movements have been noted (e.g., more than 150 km; R. Sherwin, pers. comm., in Piaggio et al. 2009). Individuals are often loyal to foraging sites and travel routes over successive nights (Dobkin et al. 1995, Fellers and Pierson 2002, Falxa 2009). Townsend's big-eared bats are characterized by slow and highly maneuverable flight, and feed mainly on flying insects caught near and among foliage (Kunz and Martin 1982, Fellers and Pierson 2002, Gruver and Keinath 2006). Gleaning has been observed, but the extent of this technique is unknown (Pierson et al. 1999). In the West, this species forages in closed-canopy forests, canopy gaps, forest edges, riparian corridors, and shrub-steppe (Dobkin et al. 1995, WBWG 2005, Gruver and Keinath 2006). On managed commercial forests in western Washington, Erickson and West (1996) detected minor use of clearcuts (2-3 years old) and pre-commercially thinned stands 12-20 years old, but no use of 30-40-year-old unthinned stands or 50-70-year-old thinned stands. Bats tracked by Falxa (2008a, 2009) fed extensively near large conifers with complex branch systems along the edges of 60-80-year-old forests.

Seasonal movements. This species has been recorded moving distances of 3-64 km between summer and winter roosts (Kunz and Martin 1982, Gruver and Keinath 2006). However, recent genetic analyses suggest that some males disperse even greater distances (Piaggio et al. 2009). Seasonal elevational movements have been reported in some areas (Cryan et al. 2000). After emerging from hibernacula in spring, females in eastern Oregon do not move directly to maternity roosts, but instead use a series of interim roosts located up to 24 km from the hibernacula before arriving at maternity roosts (Dobkin et al. 1995). Males possibly remain closer to their winter roosts (Dobkin et al. 1995).

Threats. Human disturbance of roosts (e.g., by recreational cavers and vandals) and closure or reuse of abandoned mines are considered the two major threats to Townsend's big-eared bats (Senger and Crawford 1984, Pierson et al. 1999, WBWG 2005, Gruver and Keinath 2006). This species is generally highly sensitive to disturbance and roosts that experience repeated human visitation frequently show severe population declines or abandonment. Loss of roosts in buildings from gradual structural decay, destruction, reuse by people, or deliberate exclusion practices is also a problem. Non-target pesticide spraying to control outbreaks of moth pests (e.g., spruce budworm, tussock moths, and gypsy moths) and other insects on forest and agricultural lands near roosts may affect overall moth abundance, thereby reducing food resources for this species. Degradation or loss of foraging and roosting habitat from timber harvest practices, land conversion, and livestock grazing is another threat. Wing injuries and disturbance from banding efforts in the 1960s and 1970s very likely led to large population declines at several caves in Washington (Senger and Crawford 1984, Ellison 2008, 2010).

Conservation measures. Actions to reduce human disturbance and destruction of roosts are considered the most important conservation measures for Townsend's big-eared bats (Pierson et al. 1999, WBWG 2005, Woodruff and Ferguson 2005, Gruver and Keinath 2006). Management of human access to roosts is strongly recommended, with appropriate activities including sign posting, seasonal road and trail closures, permanent gating, and enforcement of restrictions. This species appears to tolerate most types of gating (WBWG 2005). Roosts should be closed to human visitation during important periods of occupation (i.e., from 15 September to 15 May for hibernacula and 1 April to 15 September for maternity sites; Woodruff and Ferguson 2005). Surveys of old buildings are important and those with roosts should be repaired or maintained to preserve the structure and be protected through conservation easements, agreements, or acquisitions. Expanded survey coverage of mines and caves should be performed before any mine closure or logging is conducted in suspected occupied habitat (Altenbach et al. 2000, Sherwin et al. 2003). Timber harvest and associated road building within 400 m of roosts should be restricted during specific seasons to avoid disturbance (i.e., from 15 September to 15 May for hibernacula and from 1 April to 15 September for maternity sites). Alteration or removal of the forest canopy should be avoided above and within 150 m of occupied caves and mines to prevent changes in temperature, humidity, and airflow in these sites as well as loss of foraging habitat. No burning of vegetation should be conducted within 2.4 km of roosts and spraying of insecticides on forests and farmlands should be avoided within 3.2 km of roosts (Pierson et al. 1999).

Western Long-eared Myotis
(*Myotis evotis*)

Description. Western long-eared myotis are small bats (Table 5) and one of the mid-sized species of *Myotis* in Washington (van Zyll de Jong 1985, Nagorsen and Brigham 1993). In the two subspecies present in Washington, the fur on the upperparts is yellowish brown in *M. e. evotis* and darker brown to nearly black in *M. e. pacificus*. Distinct but poorly defined blackish-brown patches may be evident on the shoulders. Pelage color on the undersides is relatively light. Small hairs along the edge of the tail membrane form an inconspicuous fringe that is less distinct than in fringed myotis. Ears and flight membranes are blackish and contrast with the paler fur. Ears are relatively long, extending 5 mm or more beyond the nose when pressed forward. The tragus is long and slender with a small lobe at its base. The foot is relatively small, less than half the length of the tibia, and the calcar lacks a distinct keel.

The western long-eared myotis is one of three physically similar long-eared *Myotis* species in Washington. Strong similarities between western long-eared myotis, especially *M. e. pacificus*, and Keen's myotis make simple field identification impossible where these species overlap in southwestern British Columbia and western Washington (Burles and Nagorsen 2003). Van Zyll de Jong and Nagorsen (1994) determined through multivariate analysis that a variety of skull and body measurements can be used to correctly distinguish the two species nearly 100% of the time. However, a few individuals are morphologically intermediate, including some from western Washington, and cannot be reliably identified using these features. Mitochondrial DNA testing of tissue samples has been used to correctly identify captured individuals (T. Dewey, unpubl. data, in Burles and Nagorsen 2003).

Taxonomy. Six subspecies are recognized (Simmons 2005), with two

occurring in Washington (Manning 1993). *Myotis e. pacificus* is present in the western part of the state and *M. e. evotis* exists in the eastern part. Genetic work suggests that this species is closely related to and perhaps conspecific with Keen's myotis (T. Dewey, unpubl. data, in Burles and Nagorsen 2003).

Distribution. Western long-eared myotis occur in western North America from central British Columbia and southern Saskatchewan to central New Mexico and the Baja peninsula (Manning and Jones 1989; Appendix A). Records occur for most of Washington's counties, but are missing from the south-central Columbia Basin (WDFW WSDM

database). Some records from western Washington may be erroneous because of confusion with Keen's myotis.

Population status. Population size and trends are unknown throughout the species' range, including Washington (NatureServe 2009). In Washington, it is considered the most common bat in lodgepole pine forests and in some other eastside conifer forests (Johnson and Cassidy 1997, Baker and Lacki 2004), and it may be common in the Blue Mountains based on the findings of Henny et al. (1982) at adjacent areas in Oregon. The species is somewhat common to common in low and mid-elevation forests in the northern Cascades (Christophersen and Kuntz 2003) and at Joint Base Lewis-McChord (Wunder et al. 1992, Falxa 2005, 2008a), but was found more infrequently or not detected in other forested locations (Mt. Baker-Snoqualmie National Forest, Perkins 1988; the Olympic Peninsula, Perkins 1988, Erickson et al. 1998, Jenkins et al. 1999, West et al. 2004; the southwestern Cascades, Thomas 1988; Long Island, Pacific County, Christy 1993). Western long-eared myotis were uncommon at Moses Coulee (Rosier and Rosenberg 2006), but were rare or absent during other shrub-steppe surveys in the Columbia Basin (Christy et al. 1995, Fleckenstein 2000, Gitzen et al. 2002, Lindsey et al. 2012). It is regularly captured at multiple sites in Spokane County (H. Ferguson, pers. comm.). This species appears to be adept at avoiding mist nets and has quiet echolocation, which may result in standard capture and acoustic surveys underestimating its abundance (Falxa 2008a).

Habitat. Western long-eared myotis are most commonly associated with conifer forests ranging from drier ponderosa pine to humid coastal and montane forests (Manning and Jones 1989, Johnson and Cassidy 1997, Wilson and Ruff 1999). Non-forested habitats are also used, including shrub-steppe, chaparral, and agricultural lands, if suitable roosting sites, water sources, and riparian habitats are available (e.g., Rosier 2008). Presence of broken rock outcroppings and snags appears to be more important in determining habitat suitability than vegetation type (Wilson and Ruff 1999). The species occurs from sea level to 3,100 m, and is consistently found at higher elevations in Canada (Nagorsen and Brigham 1993). Many of the habitats noted here are occupied in Washington, including subalpine forests up to 1,640 m in elevation (Petterson 2001, Christophersen and Kuntz 2003). Elevation appears to limit the distribution of reproductive females in Washington. Baker and Lacki (2004) found proportionately fewer adult females at higher (1,000-1,400 m) elevations compared to lower (760-1,260 m) elevations along the east slope of the Cascades in Kittitas and Yakima counties.

Roosts and roosting behavior. Day roosts are located beneath loose bark on trees, snags, stumps, and downed logs, as well as in buildings, crevices in ground-level rocks and cliffs, tree cavities, caves, and mines (Manning and Jones 1989, Vonhof and Barclay 1996, 1997, Ormsbee and McComb 1998, Rabe et al. 1998a, Waldien et al. 2000, 2003, Chruszcz and Barclay 2002, Rancourt et al. 2005, Solick and Barclay 2007, Arnett and Hayes 2009, Nixon et al. 2009). Maternity colonies typically contain 4-30 females, whereas males and non-reproductive females live singly or in small groups, occasionally occupying the same site as a maternity colony (Manning and Jones 1989, Nagorsen and Brigham 1993, Rancourt et al. 2005). Conifer snags used as maternity roosts are usually large in diameter and height, and in intermediate stages of decay with exfoliating bark present (Table 3; Ormsbee and McComb 1998, Rabe et al. 1998a, Waldien et al. 2000, Arnett and Hayes 2009). Such roosts often occur in canopy gaps or near forest margins, and are located mainly in upslope areas near water. Stumps in clearcuts are also important as day roosts for reproductive and non-reproductive females and males in areas, but are usually occupied only 5-10 years before over-topping vegetation prevents access (Vonhof and Barclay 1997, Waldien et al. 2000). Stumps and downed logs may be mostly used when snags are unavailable (Arnett and Hayes 2009). At Turnbull National Wildlife Refuge in eastern Washington, maternity colonies occur almost entirely in crevices in small rock formations (Rancourt et al. 2005). Maternity colonies have also been noted in an attic in Clallam County (Perkins 1988) and in mines in Ferry and Stevens counties (BLM, unpubl. data). Females and males switch day roosts once every

1-4 days (Vonhof and Barclay 1996, 1997, Waldien et al. 2000, Chruszcz and Barclay 2002, Rancourt et al. 2005, Solick and Barclay 2007, Arnett and Hayes 2009, Nixon et al. 2009). Ground roosts are usually clumped within a relatively small area (Solick and Barclay 2007, Nixon et al. 2009).

Reproductive females show considerable flexibility in their use of torpor based on location and reproductive stage. Females in mountainous areas enter torpor less frequently than those in lowland regions (Solick and Barclay 2007). Pregnant animals use deep torpor more often than lactating ones in some locations (Chruszcz and Barclay 2002, Solick and Barclay 2007).

Caves, mines, bridges, and outbuildings are used as night roosts (Manning and Jones 1989, Nagorsen and Brigham 1993, Adam and Hayes 2000; H. Ferguson, pers. comm.). In the Columbia River Gorge, caves serve as night roosts, but not as day roosts (Maser 1998).

Caves, mines, and possibly buildings serve as hibernacula (Marcot 1984, Nagorsen and Brigham 1993). In northwestern California, hibernacula occur in low- to mid-elevation (800-1200 m) caves with a southerly orientation near permanent streams (Marcot 1984). In Washington, single individuals have been found hibernating in a lava tube in Skamania County (Senger et al. 1974) and a cave in Klickitat County (Perkins et al. 1990). Whether this species hibernates in trees is unknown. Hibernation begins from about late September to late October (Nagorsen and Brigham 1993, Maser 1998).

Reproduction. Sperm production in males begins in July or early August in preparation for breeding (Manning and Jones 1989). In eastern Washington, males with descended testes were noted by 12 July (Baker and Lacki 2004). Mating occurs in fall or early winter, presumably after females and young join males at swarming sites outside hibernacula, with ovulation and fertilization delayed until spring (Wilson and Ruff 1999). In eastern Washington, pregnancies have been noted from June until late July (Baker and Lacki 2004). Births have been reported in mid-July in western Washington (Maser et al. 1981) and from late June to early July in south-central British Columbia (Holroyd et al. 1994). Females give birth to one young per year. Lactation occurs from late June or early July to early August in eastern Washington and British Columbia (Holroyd et al. 1994, Baker and Lacki 2004). Young begin to fly about a month after birth (Caire et al. 1979), with flying young first observed on 2 August in eastern Washington (Baker and Lacki 2004).

Food habits and foraging. Moths are important food items for western long-eared myotis, but beetles, flies, spiders, true bugs, and other insects are also eaten (Barclay 1991, Wilson and Ruff 1999, Lacki et al. 2007b). Diet has been well studied in Oregon and is similar on both sides of the state (Whitaker et al. 1977, 1981a, Henny et al. 1982, Ober and Hayes 2008a), as well as in north-central Idaho, with moths dominating the diet in all three regions (Lacki et al. 2007b). Moths, caddisflies, and termites were the main foods in a small sample from Joint Base Lewis-McChord, Washington (Wunder et al. 1992). This species displays flexible feeding behavior, catching prey either by aerial hawking or gleaning from vegetation or the ground while hovering (Manning and Jones 1989). These bats are considered slow fliers with good maneuverability (van Zyll de Jong 1985).

Western long-eared myotis emerge from day roosts near dusk to forage and return about 2 hr before sunrise (Nagorsen and Brigham 1993, Waldien and Hayes 2001). Bats forage for about half of the night, averaging four activity periods that are interspersed with short periods of inactivity. Foraging occurs in a variety of forest types, along forest edges, and over open meadows, but riparian areas and other habitats near water appear to be especially preferred (Manning and Jones 1989, Barclay 1991, Waldien and Hayes 2001, Rosier 2008). On the west slope of the Cascades in Oregon, activity areas of adult females averaged 38 ha and were centered an average of 518 m from day roosts (Waldien and Hayes 2001).

Seasonal movements. This bat probably migrates short distances between summer roosts and winter hibernacula (Manning and Jones 1989). Nothing is known about seasonal movements in Washington.

Threats. Activities causing the destruction of roosts in large trees, cliffs, caves, and abandoned mines are considered the major threat to this species (Wilson and Ruff 1999, WBWG 2005, NatureServe 2009). Because of the extensive loss of large snags and decadent trees in low elevation forests resulting from timber harvest, winter roost sites may be a limiting resource for this species. Loss or degradation of riparian zones likely has negative impacts, especially in drier regions. Disturbance of maternity roosts and hibernacula represents another threat. Pesticide applications in occupied regions may also be harmful. White-nose syndrome may pose a substantial risk for this species because of its similar roosting behavior and sometimes close association with little brown myotis, which has been severely affected by the disease in eastern North America.

Conservation measures. Maintaining and recruiting large numbers of large-diameter (>60 cm dbh), tall conifer snags in the early to middle stages of decay should provide suitable day-roosting structures for this species when located near water, foraging habitat, and night roosts. At the stand-scale, large snags are more likely to be used if they occur in clusters of other snags and if they are easily accessible to bats or have greater sun exposure (Waldien et al. 2000, Arnett and Hayes 2009). Maintaining high densities of suitable snags at a variety of elevations will help meet seasonal thermoregulatory requirements. In westside forests, snags in upland sites are preferred to those in riparian areas (Arnett and Hayes 2009). Thinning dense forests may increase bat activity and accelerate development of large trees and, depending on management, snags for use as roosts. Green tree retention of large trees, such as Douglas-fir in westside forests and ponderosa pine, grand fir, and Douglas-fir in eastside forests, can provide future snags as day roosts. Conservation of riparian zones is likely important to maintaining populations in drier locations.

Caves and mines may provide hibernacula; if entry by people is a conservation or safety issue, these structures should be signed and/or gated based on established gating procedures. Silvicultural prescriptions should be evaluated and modified, if necessary, to ensure that suitable conditions are maintained for the main prey (i.e., moths, beetles, and flies) of this species. This includes evaluation of pesticide spraying programs to control forest insect pests, which may adversely affect non-target moths.

Western Small-footed Myotis
(*Myotis ciliolabrum*)

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Description. Western small-footed myotis are one of the smallest bats in Washington (Table 5). Pelage ranges from pale tan to orange-yellow on the back and is paler (often buff or nearly white) on the undersides (Holloway and Barclay 2001). The black face, ears, and flight membranes contrast strikingly with the paler overall color of the fur. Ears are relatively long, reaching or extending beyond the snout by about 1 mm when pressed forward. The tragus is narrow and long, about half the length of the ear. The calcar is keeled and the foot is small, about half the length of the tibia.

Western small-footed myotis and California myotis are similar in appearance, but the former has paler fur that contrasts more sharply with the black wings, face, and ears, and has a longer bare area on the nose (Holloway and Barclay 2001). The characteristic frequency of the echolocation call occurs in the 40 kHz range, whereas the California myotis call occurs in the 50 kHz frequency range (O'Farrell et al. 1999b, Gannon et al. 2001). The combination of body measurements and full-spectrum call analysis generally allows accurate field identification.

Taxonomy. Two subspecies are recognized (Holloway and Barclay 2001), with *M. c. melanorhinus* occurring in Washington. However, some recent authors (e.g., Simmons 2005) treat this taxon as a full species known as the dark-nosed small-footed myotis (*M. melanorhinus*). *Myotis ciliolabrum* was formerly included in both *M. leibii* and *M. subulatus*. Rodriguez and Ammerman (2004) reported genetic overlap between western small-footed myotis and California myotis.

Distribution. This bat occurs in western North America from south-central British Columbia and the short-grass prairies of southern Alberta and Saskatchewan south to central Mexico (Holloway and Barclay 2001; Appendix A). Western small-footed myotis are widely distributed in eastern Washington, being present in at least 19 of 20 counties, but are absent from western Washington (WDFW WSDM database). West et al. (1984) reported two captures from southwestern Skamania County, but this county record requires reconfirmation. Some records may be erroneous because of past confusion with California myotis.

Population status. Population size and trends are unknown throughout the species' range, including Washington (WBWG 2005). Dalquest (1948) considered it the most common bat in the "desert" portions of eastern Washington, and it is known from many locations in the Columbia Basin (Fleckenstein 2000). Surveys indicate that it is common at Moses Coulee (Fleckenstein 2000, Rosier and

Rosenberg 2006), probably common at the Yakima Training Center (Christy et al. 1995), widespread in eastern Grant and northwestern Adams counties (Wisniewski et al. 2010), and uncommon or localized on the Hanford Site (Gitzen et al. 2002, Lindsey et al. 2012). It was also fairly common in the Selkirk Mountains (Campbell 1993) and uncommon in the eastern Cascades in Kittitas and Yakima counties (Baker and Lacki 2004). By contrast, Sarell and McGuinness (1993) detected only one individual during echolocation and netting surveys in six counties of north-central Washington.

Habitat. Western small-footed myotis reside in deserts, shrublands, grasslands, riparian areas, and coniferous forest, usually occurring near cliffs, rock outcrops, and talus (Nagorsen and Brigham 1993, Garcia et al. 1995, Holloway and Barclay 2001). Elevations from 300 to 3,300 m are used. In Washington, dry open habitats appear to be most frequently occupied (Dalquest 1948, Johnson and Cassidy 1997), especially those with rock outcrops and cliffs (Williams 1968, Fleckenstein 2000, Gitzen et al. 2002, Rosier and Rosenberg 2006). Most captures at Hanford and probably at the Yakima Training Center were in riparian trees or along creeks, with others taken in gullies, a planted tree, and a building (Christy et al. 1995, Gitzen et al. 2002). The species also inhabits mixed conifer forest (Campbell 1993) and ponderosa pine forest up to about 1,400 m (Baker and Lacki 2004).

Roosts and roosting behavior. Maternity roosts and other day roosts of both sexes occur in small sheltered crevices in rock faces and cliffs, among boulders in talus, beneath the bark of trees, in buildings, caves, and mines, and under bridges (Holloway and Barclay 2001, WBWG 2005). Average temperatures in roosts range from 27-29ºC (81-84ºF) (Tuttle and Heany 1974). Individuals roost alone or in small groups (WBWG 2005). Summer day roosts of males and non-reproductive females are separate from nurseries (Humphrey 1975). No maternity sites have yet been found in Washington. Christy et al. (1995) reported a roost probably containing this species where the bats roosted among crevices in the ceiling timbers of an abandoned railroad tunnel. This site held at least 12 adult males, one female, and one juvenile in late August.

Night roosting occurs in caves, mine entrances, buildings, and bridges (Dalquest 1948, Nagorsen and Brigham 1993). Some day roosts serve as night roosts. Night roosts are sometimes shared with other species, such as big brown bats and Townsend's big-eared bats (Holloway and Barclay 2001).

In Oregon, British Columbia, and elsewhere, hibernacula occur in tight crevices of caves, abandoned mines, and rarely in buildings, with ambient temperatures typically ranging from –3º to 9ºC (27-48ºF) and relative humidities from 24% to 66% (Perkins et al. 1990, Nagorsen et al. 1993, Choate and Anderson 1997, Szewczak et al. 1998, Kuenzi et al. 1999). Nothing is known about the locations or characteristics of wintering sites in Washington. This species usually hibernates in small numbers per site, either singly or in clusters of two or three individuals (Perkins et al. 1990, Nagorsen et al. 1993, Szewczak et al. 1998, Kuenzi et al. 1999). Hibernation extends until at least early April in British Columbia (Nagorsen et al. 1993).

Reproduction. Mating happens in the fall prior to hibernation, with sperm stored by females until spring when ovulation and fertilization occur (WBWG 2005). In Washington and British Columbia, pregnancies range from May until mid-July, with births occurring from mid-June to late July depending on annual conditions (Fenton et al. 1980, Grindal et al. 1992, Nagorsen and Brigham 1993, Baker and Lacki 2004). Unfavorable weather during gestation can delay births if females need to enter torpor (Grindal et al. 1992). Litter size is almost always one (Holloway and Barclay 2001). Juveniles are capable of flight about a month after birth.

Food habits and foraging. Western small-footed myotis feed on a variety of small flying insects, with moths, caddisflies, true bugs, and flies being the most common prey reported in eastern Oregon and British Columbia (Whitaker et al. 1981a, Woodsworth 1981). Foraging begins shortly after sunset and peaks at 10-11 p.m. and again at 1-2 a.m. (Woodsworth 1981). This species displays slow erratic flight as it forages, usually at heights from 1 m above the ground to treetop level (Fenton et al.

1980). It is highly maneuverable and is therefore able to forage in complex habitats.

Seasonal movements. Individuals are believed to hibernate in the vicinity of their summer range (Garcia et al. 1995).

Threats. Threats include human disturbance of hibernacula and maternity colonies and the closure of abandoned mines (Garcia et al. 1995, WBWG 2005, NatureServe 2009). Loss or degradation of shrub-steppe for agriculture, grazing, and other uses has reduced the amount of foraging habitat and likely altered prey availability. Pesticide use is a possible threat, either through direct poisoning or by decreasing the prey base.

Conservation measures. Although information is sparse, it appears that cliffs, rock outcrops, talus slopes, caves, and mines are important roost sites; efforts should be made to protect roosts in these types of sites whenever possible. Conversion of shrub-steppe and grassland and degradation of riparian habitats near cliff faces should be avoided because of the potential to reduce foraging habitat. Before pesticide spraying projects, surveys to identify bat roosting and foraging areas should be conducted to avoid spraying of important habitats.

Yuma Myotis (*Myotis yumanensis*)

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Description. Yuma myotis are small bats (Table 5) and one of the smaller species of *Myotis* in Washington. Of the two subspecies occurring in the state, *M. y. saturatus* has dark brown to chestnut fur and dark ears and wings, whereas *M. y. sociabilis* has pale yellowish or grayish-brown fur with pale ears and wings (van Zyll de Jong 1985, Nagorsen and Brigham 1993). The underparts are paler than the back in both subspecies. The ears are relatively short and reach the nostrils when pressed forward; the tragus is about half the length of the ear and blunt in shape. The calcar is not keeled.

Yuma myotis and little brown myotis are similar in appearance and size, which can make identification difficult. Yuma myotis usually have duller dorsal fur, a sharply sloping forehead, and slightly shorter forearms than little brown myotis, but these characters are variable and therefore unreliable for separating the two species (Weller et al. 2007, Rodhouse et al. 2008). Weller at al. (2007) obtained about 90% reliability in identifying the two species using a combination of forearm length and echolocation call characteristics, but recommended use of genetic testing to obtain complete certainty of identification.

Taxonomy. Six subspecies are recognized (Simmons 2005), with *M. y. saturatus* occurring in western Washington to about the crest of the Cascades and *M. y. sociabilis* present in eastern Washington, including the eastern Cascades (Dalquest 1948, Hall 1981, van Zyll de Jong 1985).

Distribution. This bat ranges from southeast Alaska and western Montana south to western Texas and central Mexico (Hall 1981, Wilson and Ruff 1999; Appendix A). Yuma myotis are widely distributed in Washington, with records existing for nearly all counties (WDFW WSDM database). Some records may be erroneous because of past confusion with little brown myotis.

Population status. This species is widespread within its geographic range and can be locally abundant, but population sizes and trends are unknown, including in Washington (NatureServe 2009). Population status in Washington is somewhat difficult to infer from capture results because of potential confusion with little brown myotis. Overall, Yuma myotis are considered common in the state (Dalquest 1948, Fleckenstein 2000) and it ranks as one of the more common species at some sites in the Cascades (Erickson 1993, Frazier 1997, Christophersen and Kuntz 2003), northeastern Washington (Campbell 1993, Sarell and McGuinness 1993), at Moses Coulee (Rosier and Rosenberg 2006), on the Olympic

Peninsula (West et al. 2004), and the lowlands of western Washington (Dalquest 1940, Johnson and Johnson 1952, Scheffer 1995, Falxa 2008a). Additional studies from the Cascades and Columbia Basin that have lumped Yuma myotis and little brown myotis because of identification problems suggest that Yuma myotis may be common or fairly common elsewhere (Christy et al. 1995, Taylor 1997, Erickson et al. 1998, Jenkins et al. 1999, Petterson 2001, Gitzen et al. 2002). In contrast, several surveys have found this species to be relatively uncommon or rare in eastern Washington (Fleckenstein 2000, 2001a, Baker and Lacki 2004, Lindsey et al. 2012) and western Washington (West et al. 1984, Thomas 1988). Within its range in British Columbia, it is the most common bat netted over water (Nagorsen and Brigham 1993).

Habitat. Yuma myotis reside in moist and dry forests, riparian zones, grasslands, shrub-steppe, and deserts, and are closely associated with rivers, streams, ponds, and lakes (Barbour and Davis 1969, Whitaker et al. 1977, Nagorsen and Brigham 1993, Wilson and Ruff 1999, Adams 2003, Falxa 2007b, 2008b, Lucas 2011). This species is generally found at lower elevations (Johnson and Cassidy 1997). Records extend up to 730 m elevation in British Columbia (Nagorsen and Brigham 1993), but reach as high as 3,050 m in other parts of the West (Adams 2003).

Roosts and roosting behavior. Buildings, bridges, cliff crevices, caves, mines, and trees are used as summer day roosts, especially when located near water (WBWG 2005). Maternity colonies occupy buildings, caves, mines, and the undersides of train trestles and piers (Adams 2003; WDFW WSDM database). In the Pacific Northwest, large maternity colonies in buildings and other human-made structures appear to contain more individuals (1,500-4,100 adults; Nagorsen and Brigham 1993, Holroyd et al. 1994, Falxa 2008b, West et al. 2011) than those in caves and mines (500-750 adults; Betts 1997). Roosts with as many as 10,000 individuals have been reported in the Southwest (Cockrum et al. 1996). Nursery roosts are commonly shared with other species, especially little brown myotis (Wilson and Ruff 1999). The largest known colonies of Yuma myotis in Washington are located at Hanford (4,100 adults; West et al. 2011); in Whitman County (2,300 adults; WDFW WSDM database); near Olympia (about 2,000 adults; Falxa 2008b); and in Lincoln County (1,500 adults; WDFW WSDM database). Dates of occupancy at two of these colonies extend from early April to late October at Hanford (Lucas 2011) and from late April to late August near Olympia (Falxa 2007b). A nursery colony with 1,100 adult female Yuma myotis in three adjoining bat houses in San Juan County is also noteworthy (WDFW WSDM database).

Ambient air temperatures in nurseries can reach up to 40ºC (104ºF) in buildings (Nagorsen and Brigham 1993, Lucas 2011), but only 14-20ºC (57-68ºF) in mines (Betts 1997). By roosting in clusters in domed areas of mines, bats can raise the temperature of these sites substantially above ambient (e.g., up to 37ºC [99ºF], Betts 1997), thereby reducing thermoregulatory costs. Betts (1997) reported that high relative humidity (>90%) during the nursing period appeared to be more important than ambient temperature in the selection of maternity sites in eastern Oregon. High humidity reduces evaporative water loss in bats roosting in high ambient temperatures.

Pregnant and nursing females are also known to roost solitarily in large living conifer and hardwood trees at sites with substantial forest cover near water (Evelyn et al. 2004). Females roosting in trees switch sites about every 5 days on average.

During summer, males roost singly or in small groups during the day in buildings, caves, rock crevices, trees, and stumps away from nurseries (Nagorsen and Brigham 1993, Wilson and Ruff 1999, Waldien et al. 2003). Tree roosting individuals prefer large living conifer and hardwood trees in areas with high forest cover near water (Evelyn et al. 2004). Small numbers of adult males have also been captured emerging from sites with maternity colonies from late August to mid-September (Lucas 2011).

Night roosts have been found on porches, in buildings, and under bridges (Nagorsen and Brigham 1993, Pierson et al. 1996, Maser 1998, Adam and Hayes 2000, Falxa 2008a). Concrete bridges are favored over other bridge types (Adam and Hayes 2000). Adult females show strong fidelity to the same night roost in subsequent years (Pierson et al. 1996).

Winter roost selection is poorly known in the Pacific Northwest (Nagorsen et al. 1993). Hibernating Yuma myotis have been found in caves in coastal Washington (Nagorsen and Brigham 1993), in lava tubes in Skamania County (Senger et al. 1974), and a former underground water storage structure at Hanford (Lucas 2011). Hibernation occurs from late October or early November until March in eastern Washington (Lucas 2011) and western Oregon (Maser 1998).

***Reproduction*.** Sperm production increases during July and August (Herd and Fenton 1983) and mating occurs in autumn prior to hibernation (Adams 2003). Ovulation and fertilization are delayed until spring (Adams 2003), and females give birth to a single young. Births occur primarily in the first two weeks of June to at least late June in western and eastern Washington (Dalquest 1948, Falxa 2007b; J. Lucas, pers. comm.), from early June to mid-July in British Columbia depending on annual conditions (Fenton et al. 1980, Herd and Fenton 1983, Grindal et al. 1992, Milligan and Brigham 1993, Nagorsen and Brigham 1993, Holroyd et al. 1994), and from late June to mid-July in eastern Oregon (Betts 1997). Births may be substantially delayed or reduced in years with cooler wetter weather (Grindal et al. 1992). Milligan and Brigham (1993) reported that juveniles were able to fly and had stopped nursing by early August. Females are capable of breeding during their first autumn, but the age of sexual maturity in males is unknown (Nagorsen and Brigham 1993). Survival in juveniles is lower than in adults (Frick et al. 2007).

***Food habits and foraging*.** A variety of arthropods are eaten, with aquatic insects (i.e., caddisflies, mayflies, and midges), moths, beetles, neuropterans, leafhoppers, termites, and spiders being the most common prey reported in Oregon and British Columbia (Whitaker et al. 1977, 1981a, Herd and Fenton 1983, Brigham et al. 1992, Kellner and Harestad 2005, Ober and Hayes 2008a). Foraging begins shortly after sunset (Whitaker et al. 1977) and occurs mostly low over water and in adjacent shoreline vegetation (Whitaker et al. 1977, Fenton et al. 1980, Herd and Fenton 1983, Brigham et al. 1992). Along rivers and streams, Yuma myotis fly in relatively straight patterns up and down the watercourse, whereas circular flight patterns are used over ponds and lakes (Whitaker et al. 1977). The species is known to commute up to 13 km one way between day roosts and feeding sites in lowland western Washington (Falxa 2008b).

Seasonal movements. No information is available on this topic.

Threats. This species is vulnerable to disturbance of maternity roosts and hibernacula, destructive pest control activities in buildings, closure of abandoned mines, and some management practices affecting riparian zones and forests (WBWG 2005). Yuma myotis are especially likely to abandon roosts when disturbed by people (Verts and Carraway 1998).

***Conservation measures*.** Protection of nursery colonies and hibernacula from human disturbance is a priority. Where eviction from buildings is necessary, appropriate actions should be taken to minimize negative impacts on the bats. Buildings, caves, and mines should be surveyed to determine seasonal occupancy by this species, with appropriate precautions taken to minimize disturbance by surveyors. Because of the dependence of this species on aquatic habitats and associated insects for food, it is important to avoid human activities that destroy or degrade riparian habitats and water quality. Protection of large trees along stream corridors should be continued as a means for providing potential roost sites.

CHAPTER 3: CONSERVATION STRATEGIES AND TASKS

Conservation of bats has typically focused on those species that form conspicuous aggregations at relatively few sites such as caves, mines, and buildings, including Townsend's big-eared bat, big brown bat, and little brown myotis. This is due to the disproportionate affect a single disturbance can have on a population. For example, in Washington, agencies and non-governmental organizations have taken actions to protect Townsend's big-eared bat maternity sites and hibernacula from human disturbance through gating of caves, mines, and military bunkers. However, many of Washington's bat species tend to roost singly or in small groups in places difficult for humans to observe or access, such as crevices in trees, rocks, and buildings. These species may be affected by chronic-level impacts, but these effects are more difficult to observe, quantify, and alleviate. Increasing attention and action is needed to address known or potential threats to bats from loss or degradation of habitat, expanded wind energy production, introduction of contaminants and disease, and anticipated environmental changes brought on by climate change. This plan identifies conservation actions for both concentrated and diffuse threats.

Obtaining basic information on distribution, abundance, and ecological requirements is one of the primary needs for bat conservation in the state. This information will contribute to an improved understanding of the conservation needs for the 15 species of bats in Washington. In the meantime, this plan identifies conservation objectives, strategies, and tasks that should be undertaken and implemented to benefit bats in the state.

Addressing threats and maintaining healthy populations of bats will require cooperation and partnerships among government agencies, private resource management entities, non-governmental organizations, tribes, and the public. Partners can also work together to secure funding to implement priority bat conservation strategies and tasks identified in the plan.

CONSERVATION OBJECTIVES

1) Collect baseline inventory data and monitor bat populations to assess trends.
2) Safeguard bats from sources of mortality and disturbance.
3) Manage habitat to maintain and enhance bat species diversity and abundance.
4) Conduct research to determine requirements for bat populations.
5) Conduct conservation planning to benefit bats.
6) Establish partnerships with agencies, landowners, and other groups to achieve bat conservation.
7) Develop and implement public outreach and education programs for bats.

CONSERVATION STRATEGIES AND TASKS

1. Develop 1-5-year action plans to identify specific conservation measures and survey priorities for bat species in Washington.

A variety of partners and collaborators from agencies, private non-governmental entities, and universities will be involved in conservation work and surveys for bats in Washington. Partners should work together to develop action plans prioritizing species and areas for these efforts, as needed. The plans would also identify potential funding sources and determine the lead agency and partners to facilitate implementation.

2. Inventory and monitor bat populations in Washington.

Baseline information on population sizes and distribution is needed for all bat species in Washington to determine population changes over time, assess conservation status, appraise threats, and track responses to conservation actions. At present, quantitative data on abundance and trends of different bat species in the state are limited and sporadic.

2.1. Inventory and monitor bat populations.

2.1.1. <u>Determine species baseline data and conduct long-term monitoring</u>.

Conduct inventories to determine species presence and abundance for a site at a single point in time to better document species distributions and to gather baseline data on populations. Repeated follow-up visits can then be conducted to monitor population status and trends at locations over time. Inventories and monitoring are particularly important to obtain baseline data on Townsend's big-eared bat, Keen's myotis, fringed myotis, spotted bats, pallid bats, canyon bats, and western small-footed myotis, as well as other species susceptible to white-nose syndrome. Surveys to determine important migration routes for hoary bats and silver-haired bats should also be conducted because those species are vulnerable to mortality at wind energy sites.

Surveys need to minimize disturbance to bats, especially at maternity roosts and hibernacula (Task 3.1), should adhere to appropriate safety precautions, and should follow decontamination guidelines for avoiding the spread of white-nose syndrome (Task 3.5.3). Monitoring for detection of white-nose syndrome is discussed in Task 3.5.2. Surveys to monitor the number of bats killed should be conducted routinely at all wind power facilities and publicly reported.

2.1.2. <u>Use available techniques to inventory and monitor bat populations</u>.

Roost counts, netting, acoustic surveys, mark-recapture techniques, and other methods are currently available for surveying bats at roosts, in foraging habitats, and along movement corridors (O'Shea and Bogan 2003, Weller 2007, Hayes et al. 2009, Kunz et al. 2009). The appropriate methods that should be used to sample and detect bat species will vary depending on the species and the survey objectives. When scientifically designed and widely implemented, the use of standardized monitoring designs can be important for gaining a robust and geographically-extensive scope of inference (Rodhouse et al. 2011) and for dealing with difficult issues like imperfect detection (Rodhouse et al. 2012). Improved methods for population inventories and monitoring should be applied in the field as they are developed.

2.2. Maintain a statewide database of bat survey efforts and detections.

The WDFW Wildlife Survey Data Management (WSDM) database holds extensive data on bat detections in Washington, with records obtained from state and federal agencies, conservation organizations, researchers, consultants, museums, tribes, and private landowners. Data collected by WDFW biologists will be input into the WSDM database. Sharing of survey data among partner groups and submission to the database should be encouraged to provide the most up-to-date information on bat distribution and abundance in Washington. Under WDFW's sensitive data policy (Policy 5210), information from the WSDM database is available to other government agencies, tribes, landowners, and certain other entities.

2.3. Implement a web-based reporting form for the public to submit observations of bat roosts and significant bat mortality events.

An online reporting form of this type, maintained by WDFW or another entity, would provide an easy method for the public to submit observations of roosts, significant mortality events, or other bat activity. Noteworthy submissions would be investigated.

3. Protect bats in Washington from sources of mortality and roost disturbance.

There are a number of human activities that have the potential to adversely impact bat populations that can be mitigated or reduced through management actions. Implementation of these actions can contribute to the long-term conservation of bat species in Washington.

3.1. Minimize human disturbance at bat roosts.

Human disturbance of roosting bats, both accidental and deliberate, can be a primary cause in the declines of some bat populations. Access restrictions have proven successful in reducing disturbance and increasing bat numbers at aggregation sites (e.g., Olson et al. 2011). Measures that can prevent or reduce disturbance at maternity sites, hibernacula, and other seasonally occupied roost sites are: (1) gating or fencing of caves, mines, and other sites, (2) establishing restrictions on site access through seasonal or year-round closures, (3) closing or eliminating access roads and trails leading to roosts, (4) posting signs to discourage visitation of sites, (5) working with private landowners to limit visitation of sites, (6) working with caving organizations to publicize and respect cave closures, (7) ensuring compatible timber management around sites, and (8) refining bat survey protocols and limiting survey visits to ensure minimal disturbance of bats.

3.2. Protect bats roosting in mines identified for closure or renewed mining.

Some mines in Washington have been permanently sealed in recent decades because of concerns over public safety. Whenever possible, alternative solutions for resolving safety issues should be sought before closing mines occupied by bats. Gating of mine entrances is usually the preferred means and allows continued use by bats. A number of Washington mines used by bats have been gated successfully. In situations where mines used by bats are scheduled for resumed mining, this should be initiated during an appropriate season when bats are absent or after bats have been properly excluded from the site. Bat-related management recommendations for mines identified for closure or renewed mining appear in Tuttle and Taylor (1998) and Sherwin et al. (2009).

3.2.1. <u>Conduct bat surveys at mines identified for closure or renewed mining</u>.

It is important that mines identified for closure or renewed mining be adequately surveyed in advance for bats. This requires multiple surveys during different seasons to determine whether sites serve as hibernacula, maternity roosts, or transient roosts. The Washington Department of Natural Resources has assisted the U.S. Forest Service and Bureau of Land Management in prioritizing mines with human safety hazards on or near their lands for bat surveys prior to closure. Private mine owners should be encouraged to report mines suspected to have bats so that surveys can be conducted and to identify mines not known to support bats. Details on conducting bat surveys at mines appear in Tuttle and Taylor (1998) and Sherwin et al. (2009).

3.2.2. <u>Update the state's database and GIS coverage of mine locations</u>.

The locations of many old mines in the state are poorly known. To help rectify this problem, the Geology and Earth Resources Division of the Washington Department of Natural Resources has produced a database and GIS coverage of mines for use in surveys to assess human hazards and bat habitat. The database and GIS coverage should be updated as new information becomes available.

3.3. Where bats must be removed from buildings, strive to use non-lethal methods.

Although bats are classified as Protected Wildlife (WAC 232-12-011), there is an exception for bats found in or immediately adjacent to dwellings or other occupied buildings. Various non-lethal techniques exist for excluding bats from buildings (Greenhall 1982, Link 2004). WDFW's Living with Wildlife webpage (http://wdfw.wa.gov/living/bats.html) gives more information on excluding bats from buildings, including do-it-yourself information. Use of these measures should be widely encouraged to avoid the needless killing of bats roosting in buildings. Non-lethal measures for bat-proofing buildings are also preferable because they offer a permanent solution to the situation, are humane, are safer for people and pets occupying the building, and avoid odor problems caused by dead bats. Exclusions should always be performed outside of the maternity season. Names of WDFW-certified wildlife control operators are available through (http://wdfw.wa.gov/living/nuisance/damage_control.html).

3.4. Implement measures to minimize bat mortality at wind power facilities.

Continued growth of wind energy production over the next several decades is a serious concern for bat conservation because of the large numbers of bats killed at some facilities (Kunz et al. 2007). Fatalities at wind facilities in Washington have mostly involved migrating hoary bats and silver-haired bats during the late summer and early fall. While eliminating wind energy as a source of bat mortality is impossible, actions can be taken to significantly reduce mortalities.

3.4.1. Avoid siting wind energy facilities in areas known to receive high use by bats.

Siting decisions should be based on pre-construction surveys conducted over two or more years (from March to November) to determine whether proposed facilities occur in areas of high bat activity. Survey method recommendations appear in Weller and Baldwin (2012).

3.4.2. Manipulate the operation of wind turbines during periods of high bat activity.

At operational wind projects where bats become abundant, curtailing wind turbine operation during periods of low wind speeds has the potential to reduce bat fatalities without greatly affecting the amount of electricity produced (Baerwald et al. 2009, Arnett et al. 2011). Low-wind idling can be accomplished either by increasing the rotor cut-in speed to higher levels, or by changing the pitch angle (i.e., feathering) of rotor blades and lowering the generator speed required for electricity production. Turbine operations might also be reduced during predictable periods of moderate to high bat activity, such as during migration, certain moon phases, passage of weather fronts, or various other weather conditions (Weller and Baldwin 2012). Improved operational mitigation strategies should be implemented as they are developed through research (Task 5.3.1).

3.4.3. Regularly update WDFW's wind power guidelines with the latest recommendations for protecting bats at wind energy sites.

Efforts to minimize conflicts between bats and wind energy development have focused on risk avoidance and impact mitigation. Minimizing impacts to migrating bats at wind facilities at local and landscape scales will require 1) the highest scientific standards in research methods and survey design, 2) standardization of methods and metrics used in studies, 3) research that provides better predictive capabilities for assessing bat fatalities to inform pre-siting decisions and developing methods to reduce bat fatalities at operational wind facilities (Task 5.3.1), and 4) open access of pre- and post-construction survey data (Anderson et al. 1999, Kunz et al. 2007b, Piorkowski et al. 2012). WDFW and the wind industry should strive to incorporate these recommendations into the guidelines, which do not currently require pre-construction surveys and data sharing.

Risk avoidance involves conducting surveys prior to construction to avoid sites with high levels of use by bats. At local and landscape scales these data could allow developers and regulators to assess relative risk and to avoid areas of highest risk to bats. Develop methods and models that provide a greater understanding of the relationships between spatial and temporal movement patterns of bats and environmental and topographical features that could increase predictive capabilities for forecasting risk to bats and inform pre-construction siting.

Impact mitigation has focused on developing methods to reduce bat fatalities at operational wind facilities. Mitigation measures include deterrent devices or changes in facility operations (curtailment measures). Post-construction surveys are necessary to assess bat fatalities at operational wind facilities and these data are required by WDFW's current (2009) wind power guidelines. New information on mitigation measures should be incorporated into the guidelines as it is developed.

Open access to pre- and post-construction data are important for increasing knowledge of bat movements and risk around wind energy facilities, assessing cumulative impacts, and improving industry siting and operating practices. WDFW should include pre- and post-construction data for bats at wind facilities in the state in the WSDM database.

Sampling protocols and methodologies used to quantify bat fatalities need to be rigorous and scientifically valid and the methods and metrics used need to be standardized to allow for meaningful comparisons among project sites and for assessing cumulative impacts. WDFW should require the use of standard methods/survey design (e.g., Before-After-Control-Impact design) and definitions of exposure risk.

3.5. Implement measures to detect white-nose syndrome in Washington's bats and reduce its spread by people.

3.5.1. <u>Obtain improved baseline data on bat roosts and roosting behavior to inform surveillance for white-nose syndrome in Washington</u>.

Although white-nose syndrome has not yet reached the West, planning efforts have begun to work toward early detection of the disease upon its arrival in the region. Surveillance in eastern North America has mainly occurred at hibernacula in caves and mines in late winter and involved searches for diseased bats and acoustic surveys for detecting increased bat activity outside hibernacula. These methods currently have limited applicability in Washington because of the few known colonial winter roosts. Obtaining greater knowledge of roosts and roosting habits, especially during winter (Task 5.2.1), is crucial for expanding surveillance of the disease in the state.

3.5.2. <u>Prioritize sites and determine appropriate sampling methods for conducting surveillance for white-nose syndrome in Washington, and implement surveillance monitoring where needed</u>.

Incorporate updated surveillance strategies for detecting white-nose syndrome as they become available. Prioritization of survey locations should also be conducted. Although most surveillance efforts will likely occur during winter, surveillance during other seasons (e.g., during spring or summer captures of bats to look for wing tissue damage; Francl et al. 2011) may also have some applicability. Reichard's Wing Damage Index (http://www.fws.gov/northeast/PDF/Reichard_Scarring%20index%20bat%20wings.pdf) is recommended for assessing this type of damage. All surveillance work must follow established decontamination protocols. An online reporting form for the public to report bat observations (Task 2.3), including large mortality events, could be helpful in detecting the presence of the disease in the state.

3.5.3. Reduce the potential for people to transmit the fungus causing white-nose syndrome between sites.

Evidence suggests that people can transport the fungus (or its spores) causing white-nose syndrome on clothes, shoes, and caving gear. Bat researchers should follow established decontamination protocols for clothing and equipment used in caves, mines, buildings, and other roost structures or during capture activities away from roosts to prevent the spread of the disease to Washington (the website http://whitenosesyndrome.org/ provides the most recent decontamination protocols). WDFW currently requires bat researchers working under scientific collecting permits in the state to not utilize clothing and gear used in bat work outside of Washington, Oregon, Idaho, and British Columbia. Established decontamination protocols are also effective against chytrid, a fungal infection that kills large numbers of amphibians that can be spread by bat researchers working in wetlands and other wet environments.

If white-nose syndrome spreads to Washington in the future, it may be appropriate to close some caves to people to reduce the risk of spreading the fungus. Outreach should also be directed at caving groups and other user groups to encourage their members to follow decontamination protocols. Updated decontamination protocols should always be used as they become available and disseminated to all user groups.

3.6. Minimize chemical contamination of bats and their habitats.

Concerns over the harmful effects of pesticides and other contaminants on North American bats date back to the 1950s (Clark and Shore 2001). Bats obtain contaminants from many sources related to their diets, drinking water, and roosting locations. Agriculture, forestry, mining runoff, use of preservatives in buildings, and non-point sources of water pollution are some of the main origins of exposure.

3.6.1. Minimize inputs of contaminants into the environment.

Conventional pollution control practices have greatly improved in the U.S. during recent decades, yet much remains to be done in reducing the environmental inputs of a wide diversity of chemical compounds that, individually or in combination, are potentially harmful to bats. Mitigation activities should be conducted at the local, state, and national levels. A host of activities should be continued or expanded, including reviewing the safety of older chemicals, evaluating potential new chemicals and uses, enforcing pesticide and other pollution requirements, and conducting pesticide user education programs.

3.6.2. Identify and remediate sites in need of cleanup.

Actions should be taken to identify and clean up contaminated locations used by bats, such as rivers, streams, lakes, stock ponds, mining sites, and roost sites. Exclusion of bats from smaller sites and installation of alternative roosts (e.g., bat houses) may be appropriate in some cases.

4. Identify, maintain, protect, and enhance roosting, foraging, and drinking resources for bats in Washington.

Roosts and associated foraging and drinking habitat are critical resources for bats, making habitat preservation and management a top priority for bat conservation. Activities under each of the listed tasks are necessary on both public and private lands, and can be achieved by working with agencies, partner groups, and private landowners. Habitat conservation activities should incorporate the results of research on habitat requirements (Task 5.2) as they become available. Efforts to protect and improve roosting, foraging, and drinking habitat for bats may be assisted through long-term cooperative agreements, easements, land exchanges, and acquisitions from willing landowners.

4.1. Maintain, protect, and enhance roosting habitat for bats.

Washington's 15 bat species use a variety of natural and human-made roosts as maternity sites, hibernacula, and other seasonally occupied roosts, many of which are used on a long-term basis. Loss or degradation of roosting habitat has the potential to cause significant loss of bat populations; therefore, it is important that actions be taken to preserve roosting resources for all species. Some of the activities listed in this section overlap with other tasks described in this plan (Tasks 3, 8).

4.1.1. Maintain, protect, and enhance roosts in caves and mines.

Occupied caves and mines should be protected from adverse modifications to maintain suitable roosting conditions for bats. Preparation of cave management plans by land managers may be useful in the management of some sites. Sites should be periodically monitored to watch for potentially damaging changes. Where problems exist, properly designed gates, signs, and fences can be used to discourage human entry and prevent damage to cave structures, vandalism, and littering. Seasonal closures of roads and trails leading to caves may also reduce access.

The surface area within 400 m (0.25 mi) of cave and mine roosts should be managed to prevent or eliminate harmful activities that can alter the suitability of subsurface environments for bats. Activities outside of sites, such as logging, prescribed burning, and bulldozing, can result in changes in natural drainage patterns and air flow, which can in turn alter temperature and humidity regimes within sites. Creation of soil erosion and other debris can potentially block site entrances, which can also alter air flow patterns. Broader buffer zones around occupied sites should be considered under some circumstances (Keinath 2004).

Rehabilitation of sites that have been adversely modified in the past should be considered if it may improve roosting conditions for bats (e.g., reopening closed entrances).

4.1.2. Maintain, protect, and enhance roosts in snags and trees.

Wildlife managers should work with private and public forestry managers and landowners to maintain and recruit suitable snags and decadent trees as roosting habitat for bats (Lacki et al. 2012). This includes retaining green trees of various sizes and appropriate densities and distributions (in both upland and riparian sites) to serve as future roosts and to accommodate the roost switching behavior of bats. Snags can also be created through girdling, topping, use of herbicides, or prescribed burning. Forest thinning may help expedite the recruitment of large trees and snags. Maintaining small clusters of potential roost trees in a variety of topographic locations may also be desirable.

Retention of dead and dying trees and trees with basal hollows in timber harvest areas should be encouraged, wherever possible. Snag management recommendations should be provided to forest and land managers. The adequacy of existing State Forest Practice Rules should be assessed in providing adequate roosting habitat for tree-roosting bats on state and private forest lands. In particular, fire prevention practices and post-disturbance (i.e., fire, windstorm, insect) salvage logging activities should be reviewed for state and private lands. These practices should be incorporated into WDFW's forest management plans for its wildlife areas. Deployment of artificial roosts may also help supplement the short-term availability of roost sites in trees and snags in some situations (Mering and Chambers 2012).

4.1.3. Maintain, protect, and enhance roosts in buildings and bridges.

Human-made structures such as barns, bridges, homes, commercial buildings, and churches, which may be in current use, vacant, or abandoned, can provide important roosting habitat for a number of Washington's bat species. This habitat can be lost or degraded through structure renovation, dilapidation, or demolition, or deliberate exclusion of bats. Managers should promote the preservation of roost sites in buildings and bridges by providing outreach and information on the construction of artificial replacement roosts such as bat houses and roost boards to structure owners, wildlife control contractors, and agency personnel (e.g., transportation staff and county and local planners). Repair of dilapidated structures with roosts has been successful in preserving sites for bats. In some cases, it may be appropriate to protect or preserve structures with roosts through management plans, owner agreements, or conservation easements. Where eviction of bats from buildings is necessary, only appropriate non-lethal exclusion methods should be used (Task 3.3).

Where feasible, wildlife managers and transportation officials should work to maintain and protect known bat colonies located on bridges and to create new opportunities for bat roosting habitat on bridges. Creation of new habitat can be done easily and inexpensively by retrofitting existing bridges with suitable roosting sites or by designing such sites into new bridges (Keeley and Tuttle 1999, Arnett and Hayes 2000). The California Department of Transportation regularly adds bat roost features during seismic retrofits and in some new bridges at little or no extra cost.

4.1.4. Maintain and protect roosts in cliff faces, talus, and other rock formations.

Although these sites have probably not experienced extensive loss or degradation in Washington, they nevertheless can be destroyed by mining, reservoir floodings, road construction, or other forms of development. Where roosting bats are known to occur in cliff crevices or other rocky habitats, these formations should be identified, preserved, and protected wherever possible.

4.2. Maintain, protect, and enhance foraging habitat for bats.

In general, management of foraging habitats for bats should strive to maintain or restore natural vegetation conditions, connectivity, and water quality, and mitigate loss or degradation of habitat caused by forestry, agriculture, urbanization, mining, and other types of land-use change. However, because of variation among species and lack of adequate knowledge, it is difficult to establish specific management recommendations that meet the needs of all species within a habitat (Guldin et al. 2007, Wigley et al. 2007). Future research will help clarify species requirements and appropriate management measures pertaining to foraging habitat (Tasks 5.2.2 and 5.2.3).

Preservation and restoration of shrub-steppe and grasslands, especially near roost sites and water sources, should be a focus of conservation efforts for bats in eastern Washington. Good management of these habitats depends on stopping further losses from conversion, preventing overgrazing by livestock, reducing the risk of wildfires, controlling invasive plants, restoring native vegetation, and preventing drift of insecticides and herbicides used on adjacent croplands and road rights-of-way.

In all habitats, retention and enhancement of riparian zones, overall maintenance of water quality, and limiting insecticide use are desirable for retaining insect populations attractive to bats. In urban areas, maintenance of parks and other open space will benefit bats.

4.3. Maintain, protect, and enhance drinking sites for bats.

Land managers should strive to maintain or enhance streams, rivers, wetlands, and artificial drinking sites (e.g., livestock watering troughs, tanks, stock ponds, guzzlers) to benefit bats, particularly near significant roosts. Artificial water sources may be created at locations where natural water sources disappear during dry conditions. It is important that artificial sites be fitted with functional escape devices to prevent bats and other wildlife from drowning. Maintaining consistent water availability in artificial sites after livestock have departed should also be ensured. Some drinking sites may need to be modified to improve access for bats. A handbook describing methods to overcome these problems is available for landowners and range managers (Taylor and Tuttle 2012). In all cases, water quality should be maintained so that bats are not exposed to harmful chemicals.

5. Conduct research necessary to conserve bat populations in Washington.

Insufficient information exists on the biology, threats, and management of all bat species in the Pacific Northwest. Additional research is needed to help inform the conservation actions described in other parts of this plan. Many of the studies conducted on western bats since the 1990s have focused on the requirements of reproductive females during summer. Future research should be expanded to investigate the ecological needs of males, non-reproductive females, and juveniles, as well as adult females outside of the pup-rearing period (Weller et al. 2009). Uncommon or declining species, such as Townsend's big-eared bat and Keen's myotis, are priorities for research. In some cases, development of new technology may be necessary for accomplishing research tasks. Research can be conducted by a variety of entities, including universities, agencies, and others.

5.1. Improve survey techniques for bat populations.

Continued development of methods for inventorying and monitoring trends in bat populations remains a high priority conservation need (O'Shea and Bogan 2003, O'Shea et al. 2003). Many shortcomings exist with current survey methods due to the nocturnal activity of bats, their nightly and seasonal mobility, and their often cryptic roosting behavior. Bat populations in Washington require multiple approaches to surveying because of the diverse behavior of different species. Use of indices to estimate and track bat populations is generally an inferior technique and should be replaced by statistically robust methods that will allow for detection of population changes (O'Shea and Bogan 2003).

Survey methods that detect changes in species distribution (e.g., occupancy analysis; Weller 2008) hold much promise for monitoring populations across large spatial scales. New technology (e.g., acoustic monitoring, genetic sampling, infrared imagery, cell phone technology) may also benefit inventory and monitoring efforts. For example, inventory efforts could be expanded through the development of a smartphone app for collecting bat records from the public. Improved species identification methods (acoustic and/or genetic) may help with difficult species such as Keen's myotis.

5.2. Investigate the life history, habitat needs, and limiting factors of bat species.

Greater information on roosting and foraging behavior, habitat requirements, migratory patterns, reproduction, population dynamics, and diet is needed for all bat species in Washington. Studies on these topics should be done in different habitats and regions of the state during all seasons to determine the variation in requirements that exist within species. Some of the key research needs are listed below.

5.2.1. <u>Determine winter habitat use and behavior of bats</u>.

Little information is available on the hibernation sites and wintering behavior of most bat species in Washington. Information is needed on the extent that bats shift geographically to overwinter, the structures most commonly occupied, the numbers of bats typically present per site, and the normal winter activity levels of bat species in different parts of the state. Resulting data can be used to determine sites and populations vulnerable to white-nose syndrome (Task 3.5), to implement resource protection, and to assess human activities that may adversely impact wintering bats.

5.2.2. Determine the roosting and foraging ecology of forest-dwelling bats.

Further research on roosting and foraging ecology will yield valuable data for establishing suitable habitat management practices for forest bats, particularly in western Washington, where studies are underrepresented. Species needing additional study include Keen's myotis, long-legged myotis, western long-eared myotis, fringed myotis, California myotis, silver-haired bats, hoary bats, and big brown bats. Research needs include (1) determining important local, stand, and landscape factors affecting roost selection and foraging activity by forest bats, (2) determining the roosting and foraging ecology of bats in burned forests, (3) identifying the effects of forest thinning and other silvicultural methods on the roosting and foraging ecology of bats, (4) identifying the effects of forest pesticide applications on the foraging ecology of bats, and (5) determining the behavior and habitat use of entire colonies of tree-roosting bat species in forest landscapes.

5.2.3. Determine the roosting and foraging ecology of bats in semi-arid ecosystems.

More information is needed on the habitat requirements of bats occurring in shrub-steppe and dry grasslands of eastern Washington, especially for pallid bats, spotted bats, canyon bats, and western small-footed myotis. Studies of this type will provide useful data for conducting habitat management for bats in these habitats. Research needs include (1) determining important local, patch, and landscape factors affecting bat roost selection and foraging activity, and (2) determining the roosting and foraging ecology of bats in burned shrub-steppe and grassland.

5.2.4. Determine the effects of vegetation management on the insect prey populations of bats.

Studies are needed to better document the influence of vegetation structure, composition, and amount on insect biomass, abundance, and species richness in different habitats.

5.2.5. Determine the behavior, movements, and habitat use of bats during spring and fall.

Relatively little information is available on the activities, movements, and habitat use of bats during the transitional periods of spring and fall in the Pacific Northwest. Many species may undertake seasonal migration within the region as they travel between wintering and summering locations, but few data exist on the extent and destination of such movements. Similarly, little is known about the timing and location of autumn swarming and mating behavior in bat species. Although some of this activity may take place at the entrances of caves and mines, additional data should be collected to determine the importance of other habitats among different species.

5.2.6. Determine the genetic structure of bat populations.

Research on genetic structure within and among bat colonies is needed to assess dispersal, connectivity among populations, and presence of metapopulations.

5.3. Investigate important threats to bat populations.

5.3.1. Identify methods to reduce bat fatalities at wind power facilities.

Efforts to reduce bat fatalities at wind power facilities will require analysis of available information and studies to understand important factors influencing bat vulnerability at these sites. They include (1) an analysis of data from pre- and post-construction monitoring of bat activity and fatalities at wind power sites to determine regional patterns in species occurrence and vulnerability, (2) determining migration patterns for hoary bats, silver-haired bats, and other species, (3) assessing factors affecting bat activity at wind facilities, (4) enhancing existing methods of altering turbine operations to reduce bat mortality, and (5) determining whether bats are attracted to turbines and, if so, developing methods to reduce attraction.

5.3.2. Evaluate the impacts of environmental contaminants on bat populations.

There is a continuing need to investigate the harmful effects of a variety of long-used and recently-derived environmental contaminants on bat populations. Key needs include (1) assessing contaminant levels in bat populations, (2) evaluating the effects of elevated concentrations of contaminants on survival, physiology, and reproduction, (3) assessing population-level impacts of contaminants, and (4) determining sources of contaminant exposure for bats.

5.3.3. Evaluate the impacts of climate change on bat populations.

Bats could be important bioindicators of climate change (Jones et al. 2009, Newson et al. 2009). Some specific areas of investigation for assessing effects of climate change include investigating (1) thermoregulatory behaviors of bats and winter activity in relation to temperature and humidity at hibernacula (Jones et al. 2009), (2) local and global range shifts (Humphries et al. 2002, Jones et al. 2009), (3) timing of reproductive events (Jones et al. 2009), and (4) changes in maternity colony locations or behavior in relation to water availability (Adams 2010).

6. Review, revise, and prepare conservation planning documents and legal classifications for bats in Washington.

6.1. Periodically update the Washington State Bat Conservation Plan.

The plan should be revised, when needed, to incorporate new scientific information and management strategies as they become available, and to reflect changing conservation priorities.

6.2. Integrate the Washington State Bat Conservation Plan into other plans and initiatives.

Bat conservation issues and needs overlap significantly with those of other wildlife, especially birds. Conservation initiatives by WDFW and many other state, local, and federal partners (e.g., Washington's Wildlife Action Plan [WDFW 2005], Partners in Flight, and the Arid Lands Initiative) and management plans for other species and protected lands (including various habitat conservation plans and WDFW's habitat conservation plan for its wildlife areas) can be excellent vehicles to advance bat conservation. Integration into these initiatives for multiple landscapes in the state can result in improved conservation benefit for bat populations in Washington and efficient use of resources by all partners in bat conservation.

6.3. Evaluate the designation of additional bat species as Species of Greatest Conservation Need.

Washington's Wildlife Action Plan (WDFW 2005) will be updated by WDFW in 2015. During the update, additional bat species should be considered for designation as Species of Greatest Conservation Need. They include:

- Spotted bats and pallid bats, both of which are associated with declining shrub-steppe habitats.
- Silver-haired bats and hoary bats, two migratory species that face increasing mortality rates as rapid expansion of wind energy facilities continues in the state and elsewhere along suspected migration routes in North America.
- Long-legged myotis, fringed myotis, western long-eared myotis, and silver-haired bats, all of which occur primarily in forests and make extensive use of large snags and decadent trees for roosting, particularly reproductive females. Past management practices in private and public forests at lower and mid-elevations have nearly eliminated the availability of large snags for these species.

6.4. Evaluate whether additional bat species should be added as state candidate species.

The state candidate species list is updated annually. A species is added as a state candidate when preliminary evidence suggests that it may meet the definition for possible listing as a state endangered, threatened, or sensitive (WDFW Policy 5301, Appendix C). Keen's myotis and Townsend's big-eared bat are currently classified as state candidates, but other species such as the spotted bat and pallid bat may merit this status or qualify in the future.

6.5. Evaluate the classification of additional bat species as state endangered, threatened, or sensitive species.

Status reviews should be written for Keen's myotis and Townsend's big-eared bat when sufficient information on status is available to determine if they should be recommended for listing as state endangered, threatened, or sensitive species.

7. Partner with agencies, landowners, and other groups to achieve bat conservation in Washington.

Cooperation and coordination among different groups is vital in all aspects of bat conservation, including surveys, management activities, research, surveillance for white-nose syndrome, data exchange, and outreach. Cooperators include WDFW, U.S. Forest Service, U.S. Fish and Wildlife Service, National Park Service, Bureau of Land Management, Washington Department of Natural Resources, Bats Northwest and other conservation organizations, universities, landowners, caving groups, timber companies, consultants, tribes, Washington State Department of Health, county governments, and others. Of particular importance, collaboration among groups can assist with securing funding for bat conservation activities from government and non-government sources.

8. Develop and implement public outreach and education programs for bats in Washington.

The success of conservation efforts for Washington's bats depends in part on greater public understanding and acceptance of bats, their biological needs, and their importance to the environment. Outreach and education efforts should strive to increase the public's overall knowledge of bats. Information should reflect the diversity of the state's 15 species of bats and that each has unique characteristics and conservation requirements. Materials on public health and nuisance issues are also important to develop. Partnerships among different entities are vital to expanding awareness of bats. Bilingual programs for bats should also be included. Walsh and Morton (2009) provided useful methods and considerations for developing effective outreach and education programs for bats.

8.1. Develop and provide information about bats and bat conservation to the general public.

Information materials should be prepared and distributed on bat status, biology, threats, ecological role, and place as a part of Washington's natural heritage. Increased use of agency and non-government organization websites and social media are important tools for expanding the availability of information.

8.2. Develop and provide information about bats, bat conservation, and bat management to specialized audiences.

Information on specific topics should be prepared and provided to important audiences including teachers, property owners, wildlife managers, foresters, caving groups, miners, geologists, animal control and public health officials, bat rehabilitators, and others.

8.2.1. <u>Train biologists and interested volunteers in identification, survey methods, data collection, and reporting to assist in survey and outreach efforts.</u>

Training of this type is needed to expand efforts to inventory and monitor bat populations in Washington and could contribute to citizen science efforts to assist in data collection. A second desirable outcome of this training would be to increase the number of biologists and volunteers available to conduct public outreach and information on bats.

8.2.2. <u>Provide teachers with educational materials on bats for use in classrooms</u>.

Inclusion of bat information into classroom curricula and other environmental education programs is a key priority. Educational materials on bats are available from Bat Conservation International, Bats Northwest, and other entities.

8.2.3. Conduct outreach to caving groups and cave visitors on measures to prevent disturbance of bat colonies roosting in caves.

When properly informed about the needs of bats, caving groups and their dedicated members often become strong advocates for cave closures and bat conservation. Outreach and information about the vulnerability of cave-roosting bats should also be extended to the general public who visit caves.

8.2.4. Conduct outreach to caving groups, biologists, and others on prevention measures associated with white-nose syndrome.

Information on decontamination protocols, recognition of symptoms of white-nose syndrome in bats, and how to report suspected cases of the disease should be provided to biologists and user groups that regularly visit caves and mines, as well as landowners with caves or abandoned mines on their property.

8.2.5. Provide building owners with information on bat-friendly methods to exclude bats from homes and other buildings rather than using lethal control.

Outreach materials describing non-lethal techniques for excluding bats from buildings and the names of WDFW-certified wildlife control operators are available to home and building owners through the webpages of WDFW and several bat conservation organizations (Task 3.3). This information should be made available through other potential outlets, such as county conservation district staff.

8.2.6. Provide landowners and land managers with habitat management information for bats.

Private forest owners and managers should be informed about methods for protecting and enhancing roosting and foraging habitat for bats on their lands during forest management and timber harvest. Landowners with abandoned mines on their property should be encouraged to have bat surveys made at the sites before deciding to close or reopen the mines. Landowners and land managers should also be informed about the importance of maintaining water sources that are both available and safe for bats.

8.2.7. Work with public health authorities to disseminate factual information about rabies in bats.

LITERATURE CITED

Adam, M. D. and J. P. Hayes. 2000. Use of bridges as night roosts by bats in the Oregon Coast Range. Journal of Mammalogy 81:402-407.

Adams, R. A. 1997. Onset of volancy and foraging patterns of juvenile little brown bats, *Myotis lucifugus*. Journal of Mammalogy 78:239-246.

Adams, R. A. 2003. Bats of the Rocky Mountain West: natural history, ecology, and conservation. University Press of Colorado, Boulder, Colorado.

Adams, R. A. 2010. Bat reproduction declines when conditions mimic climate change projections for western North America. Ecology 91:2437-2445.

Adams, R. A. and M. A. Hayes. 2008. Water availability and successful lactation by bats as related to climate change in arid regions of western North America. Journal of Animal Ecology 77:1115-1121.

Adler, R. 1977. Bat hibernation: a winter with the western big-eared. Thesis, Reed College, Portland, Oregon.

AESRD (Alberta Environment and Sustainable Resource Development). 2012. Eastern red bat (*Lasiurus borealis*). Alberta Environment and Sustainable Resource Development, Edmonton, Alberta. <http://www.srd.alberta.ca/FishWildlife/WildSpecies/Mammals/Bats/EasternRedBat.aspx>

Agosta, S. J. 2002. Habitat use, diet and roost selection by the big brown bat (*Eptesicus fuscus*) in North America: a case for conserving an abundant species. Mammal Review 32:172-198.

Altenbach, J. S., R. Sherwin, and P. Brown. 2000. Pre-mine closure bat survey and inventory techniques. *In* K. C. Vories and D. Throgmorton, editors. Proceedings of bat conservation and mining: a technical interactive forum. U.S. Department of the Interior, Office of Surface Mining, Alton, Illinois, and Coal Research Center, Southern Illinois University, Carbondale, Illinois.

Altringham, J. D. 1996. Bats: biology and behavior. Oxford University Press, New York, New York.

Anderson, R., M. Morrison, K. Sinclair, and D. Strickland. 1999. Studying wind energy/bird interactions: a guidance document. National Wind Coordinating Committee, Washington, D.C.

Arita, H. C. and M. B. Fenton. 1997. Flight and echolocation in the ecology and evolution of bats. Trends in Ecology and Evolution 12:53-58.

Arnett, E. B. 2005. Relationships between bats and wind turbines in Pennsylvania and West Virginia: an assessment of fatality search protocols, patterns of fatality, and behavioral interactions with wind turbines. Final report submitted to Bats and Wind Energy Cooperative, Bat Conservation International, Austin, Texas.

Arnett, E. B. 2007. Presence, relative abundance, and resource selection of bats in managed forest landscapes in western Oregon. Dissertation, Oregon State University, Corvallis, Oregon.

Arnett, E. B. and J. P. Hayes. 2000. Bat use of roosting boxes installed under flat-bottom bridges in western Oregon. Wildlife Society Bulletin 28:890-894.

Arnett, E. B. and J. P. Hayes. 2009. Use of conifer snags as roosts by female bats in western Oregon. Journal of Wildlife Management 73:214-225.

Arnett, E. B., W. K. Brown, W. P. Erickson, J. K. Fieldler, B. L. Hamilton, T. H. Henry, A. Jain, G. D. Johnson, J. Kerns, R. R. Koford, C. P. Nicholson, T. J. O'Connell, M. D. Piorkowski, and R. D. Tankersley, Jr. 2008. Patterns of bat fatalities at wind energy facilities in North America. Journal of Wildlife Management 72:61-75.

Arnett, E. B., M. P. Huso, M. Schirmacher, and J. P. Hayes. 2011. Altering turbine speed reduces bat mortality at wind-energy facilities. Frontiers in Ecology and the Environment 9: 209–214.

Arnold, B. D. and G. S. Wilkinson. 2011. Individual specific contact calls of pallid bats (*Antrozous pallidus*) attract conspecifics at roosting sites. Behavioral Ecology and Sociobiology 65:1581-1593.

Aubry, K. B., J. P. Hayes, B. L. Biswell, and B. G. Marcot. 2003. The ecological role of tree-dwelling mammals in western coniferous forests. Pages 405-443 *in* C. J. Zabel and R. G. Anthony, editors. Mammal community dynamics: management and conservation in the coniferous forests of western North America. Cambridge University Press, New York, New York.

Audet, D. and M. B. Fenton. 1988. Heterothermy and the use of torpor by the bat *Eptesicus fuscus* (Chiroptera: Vespertilionidae): a field study. Physiological Zoology 61:197-204.

Avila-Flores, R. and M. B. Fenton. 2005. Use of spatial features by foraging insectivorous bats in a large urban landscape. Journal of Mammalogy 86:1193-1204.

AWEA (American Wind Energy Association). 2012. Wind energy facts: Washington. American Wind Energy Association, Washington, D.C. <http://www.awea.org/>

Baerwald, E. F. and R. M. R. Barclay. 2009. Geographic variation in activity and fatality of migratory bats at wind energy facilities. Journal of Mammalogy 90:1341-1349.

Baerwald, E. F. and R. M. R. Barclay. 2011. Patterns of activity and fatality of migratory bats at a wind energy facility in Alberta, Canada. Journal of Wildlife Management 75:1103–1114.

Baerwald, E. F., G. H. D'Amours, B. J. Klug, and R. M. R. Barclay. 2008. Barotrauma is a significant cause of bat fatalities at wind turbines. Current Biology 18:695-696.

Baerwald, E. F., J. Edworthy, M. Holder, and R. M. R. Barclay. 2009. A large-scale mitigation experiment to reduce bat fatalities at wind energy facilities. Journal of Wildlife Management 73:1077-1081.

Baker, M. D. and M. J. Lacki. 2004. Forest bat communities in the east Cascade Range, Washington. Northwest Science 78:234-241.

Baker, M. D. and M. J. Lacki. 2006. Day-roosting habitat of female long-legged myotis in ponderosa pine forests. Journal of Wildlife Management 70:207-215.

Baker, M. D., M. J. Lacki, G. A. Falxa, P. L. Droppelman, R. A. Slack, and S. Slankard. 2008. Habitat use of pallid bats in coniferous forests of northern California. Northwest

Science 82:269-275.
Barbour, R. W. and W. H. Davis. 1969. Bats of America. University Press of Kentucky, Lexington, Kentucky.
Barclay, R. M. R. 1982. Night roosting behavior of the little brown bat, Myotis *lucifugus*. Journal of Mammalogy 63:464-474.
Barclay, R. M. R. 1985. Long- versus short-range foraging strategies of hoary (*Lasiurus cinereus*) and silver haired (*Lasionycteris noctivagans*) bats and the consequences for prey selection. Canadian Journal of Zoology 63:2507-2515.
Barclay, R. M. R. 1986. The echolocation calls of hoary (*Lasiurus cinereus*) and silver-haired (*Lasionycteris noctivagans*) bats as adaptations for long- versus short-range foraging strategies and the consequences for prey selection. Canadian Journal of Zoology 64:2700-2705.
Barclay, R. M. R. 1989. The effect of reproductive condition on the foraging behavior of female hoary bats, *Lasiurus cinereus*. Behavioral Ecology and Sociobiology 24:31-37.
Barclay, R. M. R. 1991. Population structure of temperate zone insectivorous bats in relation to foraging behaviour and energy demand. Journal of Applied Ecology 60:165-178.
Barclay, R. M. R. 1999. Bats are not birds - a cautionary note on using echolocation calls to identify bats: a comment. Journal of Mammalogy 80:290-296.
Barclay, R. M. R. and R. M. Brigham. 2001. Year-to-year re-use of tree roosts by California bats (*Myotis californicus*) in southern British Columbia. American Midland Naturalist 146:80-85.
Barclay, R. M. R. and A. Kurta. 2007. Ecology and behavior of bats roosting in tree cavities and under bark. Pages 17-50 *in* M. J. Lacki, J. P. Hayes, and A. Kurta, editors. Bats in forests: conservation and management. Johns Hopkins University Press, Baltimore, Maryland.
Barclay, R. M. R., E. F. Baerwald, and J. C. Gruver. 2007. Variation in bat and bird fatalities at wind energy facilities: assessing the effects of rotor size and tower height. Canadian Journal of Zoology 85:381-387.
Barclay, R. M. R., P. A. Faure, and D. R. Farr. 1988. Roosting behavior and roost selection by migrating silver-haired bats (*Lasionycteris noctivagans*). Journal of Mammalogy 69:821-825.
Bassett, J. E. 2011. Update on the status of the western red bat in Washington state: death of an urban legend? Washington Bat Working Group Newsletter 2011(summer):2-4.
Bats Northwest. 2011. Bat houses. Bats Northwest, Lynnwood, Washington. <http://www.batsnorthwest.org/bat_houses.html#faqs>
Beak Consultants. 1993. Habitat conservation plan for the northern spotted owl (*Strix occidentalis caurina*) on timberlands owned by the Murray Pacific Corporation, Lewis County, Washington. Beak Consultants, Kirkland, Washington.
Bell, G. P. 1982. Behavioral and ecological aspects of gleaning by a desert insectivorous bat, *Antrozous pallidus* (Chiroptera: Vespertilionidae). Behavioral Ecology and Sociobiology 10:217-223.
Bell, G. P. 1985. The sensory basis of prey location by the California leaf-nosed bat *Macrotus californicus* (Chiroptera: Phyllostomidae). Behavioral Ecology and Sociobiology 16:343-347.
Bell, G. P., G. A. Bartholomew, and K. A. Nagy. 1986. The roles of energetics, water economy, foraging behavior, and geothermal refugia in the distribution of the bat, *Macrotus californicus*. Journal of Comparative Physiology, B. Biochemical, Systemic, and Environmental Physiology 156:441–450.
Belsky, A. J. and D M. Blumenthal. 1997. Effects of livestock grazing on stand dynamics and soils in upland forests of the Interior West. Conservation Biology 11:315-327.
Belsky, A. J., A. Matzke, and S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. Journal of Soil and Water Conservation 54:419-431.
Betts, B. J. 1996. Roosting behaviour of silver-haired bats (*Lasionycteris noctivagans*) and big-brown bats (*Eptesicus fuscus*) in northeast Oregon. Pages 55-61 *in* R. M. R. Barclay and R. M. Brigham, editors. Bats and forests symposium. Working Paper 23/1996, Research Branch, British Columbia Ministry of Forests, Victoria, British Columbia.
Betts, B. J. 1997. Microclimate in Hell's Canyon mines used by maternity colonies of *Myotis yumanensis*. Journal of Mammalogy 78:1240-1250.
Betts, B. J. 1998a. Roosts used by maternity colonies of silver-haired bats in northeastern Oregon. Journal of Mammalogy 79:643-650.
Betts, B. J. 1998b. Variation in roost fidelity among reproductive female silver-haired bats in northeastern Oregon. Northwestern Naturalist 79:59-63.
Betts, B. J. 2009. The effect of a fuels-reduction silvicultural treatment on bat activity in northeastern Oregon. Northwestern Naturalist 90:107-116.
Betts, B. J. 2010a. Thermoregulatory mechanisms used in a maternity colony of Townsend's big-eared bats in northeastern Oregon. Northwestern Naturalist 91:288-298.
Betts, B. J. 2010b. Activity budgets of Townsend's big-eared bats at a maternity colony in northeastern Oregon. Northwestern Naturalist 91:13-22.
Blehert, D. S., A. C. Hicks, M. Behr, C. U. Meteyer, B. M. Berlowski-Zier, E. L. Buckles, J. T. H. Coleman, S. R. Darling, A. Gargas, R. Niver, J. C. Okoniewski, R. J. Rudd, and W. B. Stone. 2009. Bat white-nose syndrome: an emerging fungal pathogen? Science 323:227.
Blehert, D. S., J. M. Lorch, A. E. Ballmann, P. M. Cryan, and C. U. Meteyer. 2011. Bat white-nose syndrome in North America. Microbe 6:267-273.
Blood, D. A. 1993. Spotted bat. Ministry of Environment, Lands and Parks, Victoria, British Columbia.
Bock, C. E., V. A. Saab, T. D. Rich, and D. S. Dobkin. 1993. Effects of livestock grazing on neotropical migratory landbirds in western North America. Pages 296-309 *in* D. M. Finch and P. W. Stangel, editors. Status and management of neotropical migratory birds. General Technical Report RM-229, Rocky Mountain Forest and Range Experiment Station, U.S. Forest Service, Fort Collins, Colorado.

Boland, J. L. 2007. Distribution of bats in southeast Alaska and selection of day-roosts in trees by Keen's myotis on Prince of Wales Island, southeast Alaska. Thesis, Oregon State University, Corvallis, Oregon.

Boland, J. L., J. P. Hayes, W. P. Smith, and M. M. Huso. 2009a. Selection of day-roosts by Keen's myotis (*Myotis keenii*) at multiple spatial scales. Journal of Mammalogy 90:222-234.

Boland, J. L., W. P. Smith, and J. P. Hayes. 2009b. Survey of bats in southeast Alaska with emphasis on Keen's myotis (*Myotis keenii*). Northwest Science 83:169-179.

Bolsinger, C. L., N. McKay, D. R. Gedney, and C. Alerich. 1997. Washington's public and private forests. Resource Bulletin PNW-RB-218, Pacific Northwest Research Station, USDA Forest Service, Portland, Oregon.

Booth, E. S. 1947. Systematic review of the land mammals of Washington. Dissertation, State College of Washington, Pullman, Washington.

Boyles, J. G. and D. P. Aubrey. 2006. Managing forest with prescribed fire: implications for a cavity-dwelling bat species. Forest and Ecology and Management 222:108-115.

Boyles, J. G., P. M. Cryan, G. F. McCracken, and T. H. Kunz. 2011. Economic importance of bats in agriculture. Science 332:41-42.

Boyles, J. G., M. B. Dunbar, and J. O. Whitaker, Jr. 2006. Activity following arousal in winter in North American vespertilionid bats. Mammal Review 36:267-280.

Brack, V., Jr. and J. W. Twente. 1985. The duration of the period of hibernation of three species of vespertilionid bats. I. Field studies. Canadian Journal of Zoology 63:2952-2954.

Bradley, B. A. 2010. Assessing ecosystem threats from global and regional change: hierarchical modeling of risk to sagebrush ecosystems from climate change, land use, and invasive species in Nevada, USA. Ecography 33:198-208.

Bradley, P. V. 1996. Foraging activity of adult female pale big-eared bats (*Corynorhinus townsendii pallescens*) in east-central Nevada. Bat Research New 37:21.

Bradshaw, P. A. 1996. The physical nature of vertical forest habitat and its importance in shaping bat species assemblages. Pages 199-212 *in* R. M. R. Barclay and R. M. Brigham, editors. Bats and forests symposium. Working Paper 23/1996, Research Branch, British Columbia Ministry of Forests, Victoria, British Columbia.

Brass, D. A. 1994. Rabies in bats: natural history and public health implications. Livia Press, Ridgefield, Connecticut.

Brigham, R. M. 1990. Prey selection by big brown bats (*Eptesicus fuscus*) and common nighthawks (*Chordeiles minor*). American Midland Naturalist 124:73-80.

Brigham, R. M. 1991. Flexibility in foraging and roosting behaviour by the big brown bat (*Eptesicus fuscus*). Canadian Journal of Zoology 69:117-121.

Brigham, R. M. and M. B. Saunders. 1990. The diet of big brown bats (*Eptesicus fuscus*) in relation to insect availability in southern Alberta, Canada. Northwest Science 64:7-10.

Brigham, R. M., H. D. J. N. Aldridge, and R. L. Mackey. 1992. Variation in habitat use and prey selection by Yuma bats, *Myotis yumanensis*. Journal of Mammalogy 73:640-645.

Brigham, R. M., M. J. Vonhof, R. M. R. Barclay, and J. C. Gwilliam. 1997. Roosting behavior and roost-site preferences of forest-dwelling California bats (*Myotis californicus*). Journal of Mammalogy 78:1231-1239.

Buchalski, M. R., J. B. Fontaine, P. A. Heady III, J. P. Hayes, and W. F. Frick. 2013. Bat response to differing fire severity in mixed-conifer forest California, USA. PLoS ONE 8(3): e57884. doi:10.1371/journal.pone.0057884

Burford, L. S., M. J. Lacki, and C. V. Covell, Jr. 1999. Occurrence of moths among habitats in a mixed mesophytic forest: implications for management of forest bats. Forest Science 45:323-332.

Burles, D. W. 2001. Influence of weather on life history characteristics of two bats, *Myotis lucifugus* and *Myotis keenii* at Gandll K'in Gwaayaay, Haida Gwaii. Thesis, University of Victoria, Victoria, British Columbia.

Burles, D. W. and D. W. Nagorsen. 2003. COSEWIC assessment and update status report on Keen's long-eared bat *Myotis keenii* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario.

Burles, D. W., R. M. Brigham, R. A. Ring, and T. E. Reimchen. 2008. Diet of two insectivorous bats, *Myotis lucifugus* and *Myotis keenii*, in relation to arthropod abundance in a temperate Pacific Northwest rainforest environment. Canadian Journal of Zoology 86:1367-1375.

Burles, D. W., R. M. Brigham, R. A. Ring, and T. E. Reimchen. 2009. Influence of weather on two insectivorous bats in a temperate Pacific Northwest rainforest. Canadian Journal of Zoology 87:132-138.

Caire, W., R. K. LaVal, M. L. LaVal, and R. Clawson. 1979. Notes on the ecology of *Myotis keenii* (Chiroptera, Vespertilionidae) in eastern Missouri. American Midland Naturalist 102:404-407.

Campbell, L. A. 1993. Bat diversity and habitat use in managed forests of northeastern Washington. Thesis, Washington State University, Pullman, Washington.

Campbell, L. A., J. G. Hallett, and M. A. O'Connell. 1996. Conservation of bats in managed forest: use of roosts by *Lasionycteris noctivagans*. Journal of Mammalogy 77:976-984.

Campbell, S., K. W. Addell, and A. Gray. 2010. Washington's forest resources, 2002-2006: five-year forest inventory and analysis report. General Technical Report PNW-GTR-800, Pacific Northwest Research Station, USDA Forest Service, Portland, Oregon.

Carey, H. V., M. T. Andrews, and S. L. Martin. 2003. Mammalian hibernation: cellular and molecular responses to depressed metabolism and low temperature. Physiological Reviews 83:1153-1181.

Chapman, K., K. McGuinness, and R. M. Brigham. 1994. Status of the pallid bat in British Columbia. Wildlife Working Report WR-61, British Columbia Ministry of the Environment, Lands and Parks, Victoria, British Columbia.

Choate, J. R. and J. M. Anderson. 1997. Bats of Jewel Cave National Monument South Dakota. Prairie Naturalist 29:39-47.

Christian, J. J. 1956. The natural history of a summer aggregation of the big brown bat, *Eptesicus fuscus fuscus*.

American Midland Naturalist 55:66-95.

Christophersen, R. G. and R. C. Kuntz II. 2003. A survey of bat species composition, distribution, and relative abundance, North Cascades National Park Service Complex, Washington. National Park Service Technical Report NPS/NOCA/NRTR-2003/01.

Christy, R. 1993. Radiotracking *Myotis* bats on Long Island, Washington. Thesis, University of Washington, Seattle, Washington.

Christy, R. E., S. Paulus, and J. Duncan. 1995. Ecology of bats on the Yakima Training Center. ENSR Consulting and Engineering Document No. 9000-028-240.

Chruszcz, B. J. and R. M. R. Barclay. 2002. Thermoregulatory ecology of a solitary bat, *Myotis evotis*, roosting in rock crevices. Functional Ecology 16:18-26.

Chung-MacCoubrey, A. L. 1996. Bat species composition and roost use in pinyon-juniper woodlands of New Mexico. Pages 118-123 *in* R. M. R. Barclay and R. M. Brigham, editors. Bats and forests symposium. Working Paper 23/1996, Research Branch, British Columbia Ministry of Forests, Victoria, British Columbia.

CIG (Climate Impacts Group). 2009. The Washington climate change impacts assessment. Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, Washington.

City of Seattle. 2000. Cedar River Watershed habitat conservation plan for the issuance of a permit to allow incidental take of threatened and endangered species. City of Seattle, Seattle, Washington.

Clark, D. R., Jr. and R. L. Hothem. 1991. Mammal mortality at Arizona, California, and Nevada gold mines using cyanide extraction. California Fish and Game 77:61-69.

Clark, D. R., Jr. and R. F. Shore. 2001. Chiroptera. Pages 159-214 *in* R. F. Shore and B. A. Rattner, editors. Ecotoxicology in wild mammals. John Wiley & Sons, New York, New York.

Cockrum, E. L., B. Musgrove, and Y. Petryszyn. 1996. Bats of Mohave County, Arizona: populations and movements. The Museum, Texas Tech University Occasional Papers 157.

Coleman, J. L. and R. M. R. Barclay. 2011. Influence of urbanization on demography of little brown bats (*Myotis lucifugus*) in the prairies of North America. PLoS ONE 6(5):e20483. doi:10.1371/journal.pone.0020483

Coleman, J. L. and R. M. R. Barclay. 2012. Urbanization and the abundance and diversity of prairie bats. Urban Ecosystems 15:87-102.

Collard, T. S., S. D. Grindal, R. M. Brigham, and R. M. R. Barclay. 1990. Identification of the status and critical habitats of the spotted bat (*Euderma maculatum*), pallid bat (*Antrozous pallidus*), and fringed bats (*Myotis thysanodes*) in the south Okanogan Valley, British Columbia. Unpublished report submitted to the World Wildlife Fund, British Columbia Ministry of the Environment, and the British Columbia Habitat Conservation Fund.

Constantine, D. G. 1966. Ecological observations on lasiurine bats in Iowa. Journal of Mammalogy 47:34-41.

Constantine, D. G. 1993. Chiroptera: bat medicine, management, and conservation. Pages 310-321 *in* M. E. Fowler, editor. Zoo & wild animal medicine: current therapy 3. W. B. Saunders, Philadelphia, Pennsylvania.

Constantine, D. G. 1998. An overlooked external character to differentiate *Myotis californicus* and *Myotis ciliolabrum* (Vespertilionidae). Journal of Mammalogy 79:624-630.

Constantine, D. G. 2009. Bat rabies and other lyssavirus infections. U.S. Geological Survey Circular 1329, U.S. Geological Survey, Reston, Virginia.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2012. Emergency assessment concludes that three bat species are endangered in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario. <http://www.cosewic.gc.ca/eng/sct7/Bat_Emergency_Assessment_Press_Release_e.cfm>

Cowan, I. McT. 1933. Some notes on the hibernation of *Lasionycteris noctivagans*. Canadian Field-Naturalist 47:74-75.

Crampton, L. H. and R. M. R. Barclay. 1996. Habitat selection by bats in fragmented and unfragmented aspen mixedwood stands of different ages. Pages 238-259 *in* R. M. R. Barclay and R. M. Brigham, editors. Bats and forests symposium. Working Paper 23/1996, Research Branch, British Columbia Ministry of Forests, Victoria, British Columbia.

Crampton, L. H. and R. M. R. Barclay. 1998. Selection of roosting and foraging habitat by bats in different-aged aspen mixedwood stands. Conservation Biology 12:1347-1358.

Cryan, P. M. 2003. Seasonal distribution of migratory tree bats (*Lasiurus* and *Lasionycteris*) in North America. Journal of Mammalogy 84:579-593.

Cryan, P. M. and R. M. R. Barclay. 2009. Causes of bat fatalities at wind turbines: hypotheses and predictions. Journal of Mammalogy 90:1330-1340.

Cryan, P. M. and J. P. Veilleux. 2007. Migration and use of autumn, winter, and spring roosts by tree bats. Pages 153-175 *in* M. J. Lacki, J. P. Hayes, and A. Kurta, editors. Bats in forests: conservation and management. Johns Hopkins University Press, Baltimore, Maryland.

Cryan, P. M., M. A. Bogan, and J. S. Altenbach. 2000. Effect of elevation on distribution of female bats in the Black Hills, South Dakota. Journal of Mammalogy 81:719-725.

Cryan, P. M., M. A. Bogan, and G. Y. Yanega. 2001. Roosting habits of four bat species in the Black Hills of South Dakota. Acta Chiropterologica 3:43-52.

Cryan, P. M., J. W. Jameson, E. F. Baerwald, C. K. R. Willis, R. M. R. Barclay, E. A. Snider, and E. G. Crichton. 2012. Evidence of late-summer mating readiness and early sexual maturation in migratory tree-roosting bats found dead at wind turbines. PLoS ONE 7(10):e47586. doi:10.1371/journal.pone.0047586

Cryan, P. M., C. U. Meteyer, J. G. Boyles, and D. S. Blehert. 2010. Wing pathology of white-nose syndrome in bats suggests life-threatening disruption of physiology. BMC Biology 8:135.

Dalquest, W. W. 1938. Bats in the state of Washington. Journal of Mammalogy 19:211-213.

Dalquest, W. W. 1940. Bats in the San Juan Islands, Washington. Murrelet 21:4-5.

Dalquest, W. W. 1943. Seasonal distribution of the hoary bat along the Pacific coast. Murrelet 24:21-24.

Dalquest, W. W. 1947. Notes on the natural history of the *Corynorhinus rafinesquii* in California. Journal of Mammalogy 28:17-30.

Dalquest, W. W. 1948. Mammals of Washington. University of Kansas Publications, Museum of Natural History 2:1-444.

De Serres, G., F. Dallaire, M. Cote, and D. Skowronski. 2008. Bat rabies in the United States and Canada from 1950 through 2007: human cases with and without bat contact. Clinical Infectious Diseases 46:1329-1337.

Dobler, F. C., J. Eby, C. Perry, S. Richardson, and M. Vander Haegen. 1996. Status of Washington's shrub-steppe ecosystem: extent, ownership, and wildlife/vegetation relationships. Washington Department of Fish and Wildlife, Olympia, Washington.

Dobkin, D. S., R. D. Gettinger, and M. G. Gerdes. 1995. Springtime movements, roost use, and foraging activity of Townsend's big-eared bat (*Plecotus townsendii*) in central Oregon. Great Basin Naturalist 55:315-321.

Doering, R. W. 1996. Thermal implications of roost site selection in hibernating *Plecotus townsendii*. Thesis, Idaho State University, Pocatello, Idaho.

Duchamp, J. E., D. W. Sparks, and J. O. Whitaker Jr. 2004. Foraging-habitat selection by bats at an urban-rural interface: comparison between a successful and a less successful species. Canadian Journal of Zoology 82:1157-1164.

Dzal, Y. A. and R. M. Brigham. 2013. The tradeoff between torpor use and reproduction in little brown bats (*Myotis lucifugus*). Journal of Comparative Physiology B 183:279-288.

Ellison, L. E. 2008. Summary and analysis of the U.S. Government Bat Banding Program. Open-File Report 2008-1363, U.S. Geological Survey, Fort Collins, Colorado.

Ellison, L. E. 2010. A retrospective survival analysis of Townsend's big-eared bat (*Corynorhinus townsendii*) from Washington State. Northwestern Naturalist 91:172-182.

Ellison, L. E., T. J. O'Shea, M. A. Bogan, A. L. Everette, and D. M. Schneider. 2003. Existing data on colonies of bats in the United States: summary and analysis of the U.S. Geological Survey's bat population database. Pages 127-237 *in* T. J. O'Shea and M. A. Bogan, editors. Monitoring trends in bat populations in the United States and territories: problems and prospects. U.S. Geological Survey, Biological Resources Discipline, Information and Technology Report USGS/BRD/ITR –2003-0003.

Erickson, J. L. 1993. Bat activity in managed forests of the southwestern Cascade Range. Thesis, University of Washington, Seattle, Washington.

Erickson, J. L. and M. J. Adams. 2003. A comparison of bat activity at low and high elevations in the Black Hills of western Washington. Northwest Science 77:126-131.

Erickson, J. L. and S. D. West. 1996. Managed forests in the western Cascades: the effects of seral stage on bat habitat use patterns. Pages 215-227 *in* R. M. R. Barclay and R. M. Brigham, editors. Bats and forests symposium. Working Paper 23/1996, Research Branch, British Columbia Ministry of Forests, Victoria, British Columbia.

Erickson, J. L. and S. D. West. 2003. Associations of bats with local structure and landscape features of forested stands in western Oregon and Washington. Biological Conservation 109:95-102.

Erickson, J. L., K. Jenkins, and J. Yeager. 1998. Relative activity and composition of bat communities in Olympic National Park: preliminary inventory. Unpublished annual progress report, Olympic National Park, Port Angeles, Washington.

Erman, N. A. 1996. Status of aquatic invertebrates. *In* Sierra Nevada ecosystem project: final report to Congress, Volume II. Centers for Waters and Wildlife Resources, University of California, Davis, Davis, California.

Evelyn, M. J., D. A. Stiles, and R. A. Young. 2004. Conservation of bats in suburban landscapes: roost selection by *Myotis yumanensis* in a residential area in California. Biological Conservation 115:463-473.

Everette, A. L., T. J. O'Shea, L. E. Ellison, L. A. Stone, and J. L. McCance. 2001. Bat use of a high-plains urban wildlife refuge. Wildlife Society Bulletin 29:967-973.

Ewing, W. G., E. H. Studier, and M. J. O'Farrell. 1970. Autumn fat deposition and gross body composition in three species of *Myotis*. Comparative Biochemistry and Physiology 36:119-129.

Falxa, G. 2005. A species inventory of the bats at McChord Air Force Base, Pierce County, Washington. Cascadia Research Collective, Olympia, Washington.

Falxa, G. 2006. 2006 addendum to: a species inventory of the bats at McChord Air Force Base, Pierce County, Washington. Cascadia Research Collective, Olympia, Washington.

Falxa, G. 2007a. Winter foraging of silver-haired and California myotis bats in western Washington. Northwestern Naturalist 88:98-100.

Falxa, G. 2007b. Little brown and Yuma bat maternity colony of the Woodard Bay Natural Resource Conservation Area. Cascadia Research Collective, Olympia, Washington. <http://cascadiaresearch.org/bats/>

Falxa, G. 2008a. Fort Lewis 2008 bat survey: final report. Cascadia Research Collective, Olympia, Washington.

Falxa, G. 2008b. An overview of an extraordinary colony of *Myotis* bats. Bat Research News 49:120-121.

Falxa, G. 2009. Fort Lewis 2009 Townsend's big-eared bat study. Cascadia Research Collective, Olympia, Washington.

Faure, P. M. and R. M. R. Barclay. 1992. The sensory basis of prey detection by the long-eared bat, *Myotis evotis*, and the consequences for prey selection. Animal Behaviour 44:31-39.

Fellers, G. M. and E. D. Pierson. 2002. Habitat use and foraging behavior of Townsend's big-eared bat (*Corynorhinus townsendii*) in coastal California. Journal of Mammalogy 83:167-177.

Fenton, M. B. 1982. Echolocation, insect hearing, and feeding ecology of insectivorous bats. Pages 261-285 *in* T. H. Kunz, editor. Ecology of bats. Plenum Press, New York, New York.

Fenton, M. B. 1990. The foraging behavior and ecology of animal-eating bats. Canadian Journal of Zoology 68:411-

422.

Fenton, M. B. 1997. Science and the conservation of bats. Journal of Mammalogy 78:1-14.

Fenton, M. B. and R. M. R. Barclay. 1980. Myotis lucifugus. Mammalian Species 142:1-8.

Fenton, M. B., C. G. van Zyll de Jong, G. P. Bell, D. B. Campbell, and M. Laplante. 1980. Distribution, parturition dates, and feeding of bats in south-central British Columbia. Canadian Field-Naturalist 94:416–420.

Ferguson, H. and J. M. Azerrad. 2004. Pallid bat, *Antrozous pallidus*. *In* J. M. Azerrad, editor. Management recommendations for Washington's priority species. Volume V: mammals. Washington Department of Fish and Wildlife, Olympia, Washington. <http://wdfw.wa.gov/publications/00027/>

Finch, D. M., J. L. Ganey, W. Yong, R. T. Kimball, and R. Sallabanks. 1997. Effects and interactions of fire, logging, and grazing. Pages 103-136 *in* W. M. Block and D. M. Finch, technical editors. Songbird ecology in southwestern ponderosa pine forests: a literature review. General Technical Report RM-292, Rocky Mountain Forest and Range Experiment Station, U.S. Forest Service, Fort Collins, Colorado.

Findley, J. S. 1993. Bats: a community perspective. Cambridge University Press, New York, New York.

Firman, M., M. Getty, and R. M. R. Barclay. 1993. Status of Keen's long-eared myotis in British Columbia. Wildlife Working Report WR-59, British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia.

Fitzner, R. E. and R. H. Gray. 1991. The status, distribution and ecology of wildlife on the U.S. DOE Hanford Site: a historical overview of research activities. Environmental Monitoring and Assessment 18:173-202.

Fleckenstein, J. 1998. Survey of abandoned mines on the Olympic Peninsula for Townsend's big-eared bat (*Corynorhinus townsendii*). Washington Department of Natural Resources, Olympia, Washington.

Fleckenstein, J. 2000. Survey of bats in Moses Coulee, Douglas County, Washington. Natural Heritage Program, Washington Department of Natural Resources, Olympia, Washington.

Fleckenstein, J. 2001a. Bats of Badger Gulch and Barker Mountain Natural Area Preserves. Natural Heritage Program, Washington Department of Natural Resources, Olympia, Washington.

Fleckenstein, J. 2001b. Use of abandoned mines by bats. Natural Heritage Program, Washington Department of Natural Resources, Olympia, Washington.

Fleckenstein, J. 2002. Use of abandoned mines by bats: final report. Natural Heritage Program, Washington Department of Natural Resources, Olympia, Washington.

Fleming, T. H. and P. Eby. 2003. Ecology of bat migration. Pages 156-208 *in* T. H. Kunz and M. B. Fenton, editors. Bat ecology. University of Chicago Press, Chicago, Illinois.

Flory, A. R., S. Kumar, T. J. Stohlgren, and P. M. Cryan. 2012. Environmental conditions associated with bat white-nose syndrome in the north-eastern United States. Journal of Applied Ecology 49:680-689.

Francl, K. E., D. W. Sparks, V. J. Brack, and J. Timpone. 2011. White-nose syndrome and wing damage index scores among summer bats in the northeastern United States. Journal of Wildlife Diseases 47:41-48.

Frazier, M. W. 1997. Roost site characteristics of the long-legged myotis (*Myotis volans*) in the Teanaway River Valley of Washington. Thesis, University of Washington, Seattle, Washington.

Freed, S. and K. McAllister. 2008. Occurrence and distribution of mammals on the McChord Air Force Base, Washington. Environmental Practice 10:116-124.

Freeman, P. W. 1981. Correspondence of food habits and morphology in insectivorous bats. Journal of Mammalogy 62:166–173.

Frick, W. F., P. A. Heady III, and J. P. Hayes. 2009. Facultative nectar-feeding behavior in a gleaning insectivorous bat (*Antrozous pallidus*). Journal of Mammalogy 90:1157-1164.

Frick, W. F., J. F. Pollock, A. C. Hicks, K. E. Langwig, D. S. Reynolds, G. G. Turner, C. M. Butchkoski, and T. H. Kunz. 2010b. An emerging disease causes regional population collapse of a common North American bat species. Science 329:679-682.

Frick, W. F., W. E. Rainey, and E. D. Pierson. 2007. Potential effects of environmental contamination on Yuma myotis demography and population growth. Ecological Applications 17:1213-1222.

Frick, W. F., D. S. Reynolds, and T. H. Kunz. 2010a. Influence of climate and reproductive timing on demography of little brown bats (*Myotis lucifugus*). Journal of Animal Ecology 79:128-136.

Fullard, J. H. and J. W. Dawson. 1997. The echolocation calls of the spotted bat *Euderma maculatum* are relatively inaudible to moths. Journal of Experimental Biology 200:129-137.

Fursman, V. and K. Aluzas. 2005. Interagency special status/sensitive species program (ISSSSP) report – FY2005 Olympic NF bat surveys. Olympic National Forest, Olympia, Washington.

Fuzessery, Z. M., P. Buttenhoff, B. Andrews, and J. M. Kennedy. 1993. Passive sound localization of prey by the pallid bat (*Antrozous p. pallidus*). Journal of Comparative Physiology A 171:767-777.

Gaisler, J., J. Zukal, Z. Rehak, and M. Homolka. 1998. Habitat preference and flight activity of bats in a city. Journal of Zoology, London 244:439-445.

Gannon, W. L., R. E. Sherwin, T. N. deCarvalho, and M. J. O'Farrell. 2001. Pinnae and echolocation call differences between *Myotis californicus* and *M. ciliolabrum* (Chiroptera: Vespertilionidae). Acta Chiropterologica 3:77-91.

Gano, K. A., J. G. Lucas, and C. T. Lindsey. 2009. Identification and protection of a bat colony in the 183-F clearwell: mitigation of bat habitat on the Hanford Site. WCH-312, Washington Closure Hanford, Richland, Washington.

Garcia, P. F. J., S. A. Rasheed, and S. L. Holroyd. 1995. Status of the western small-footed myotis in British Colombia. Wildlife Working Report Number WR-74, British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia.

Gargas, A., M. T. Trest, M. Christensen, T. J. Volk, and D. S. Blehert. 2009. *Geomyces destructans* sp. nov. associated with bat white-nose syndrome. Mycotaxon 108:147-154.

Gehrt, S. D. and J. E. Chelsvig. 2003. Bat activity in an urban landscape: patterns at the landscape and microhabitat scale. Ecological Applications 13:939-950.

Gehrt, S. D. and J. E. Chelsvig. 2004. Species-specific patterns of bat activity in an urban landscape. Ecological Applications 14:625-635.

Geiser, F. 2004. Metabolic rate and body temperature reduction during hibernation and daily torpor. Annual Review of Physiology 66:239-274.

Geiser, F. 2010. Aestivation in mammals and birds. Pages 95-111 *in* C. A. Navas and J. E. Carvalho, editors. Aestivation: molecular and physiological aspects. Springer-Verlag, Berlin, Germany.

Geiser, F. 2011. Hibernation: endotherms. *In* Encyclopedia of life sciences, John Wiley & Sons, Chichester, United Kingdom. DOI: 10.1002/9780470015902.a0003215.pub2

Gellman, S. T. and W. J. Zielinski. 1996. Use by bats of old-growth redwood hollows on the north coast of California. Journal of Mammalogy 77:255-265.

Genter, D. L. 1986. Wintering bats of the upper Snake River plain: occurrence in lava-tube caves. Great Basin Naturalist 46:241-244.

Gerrell, R. and K. Lundberg. 1993. Decline of a bat, *Pipistrellus pipistrellus*, population in an industrialized area of southern Sweden. Biological Conservation 65:153-157.

Gitzen, R. A., J. L. Erickson, and S. D. West. 2002. Bat activity and species occurrence on the Hanford Site in eastern Washington. Northwestern Naturalist 83:35-46.

Gitzen, R. A., S. D. West, and J. A. Baumgardt. 2001. A record of the spotted bat (*Euderma maculatum*) from Crescent Bar, Washington. Northwestern Naturalist 82:28-30.

Green, G. A., J. Piasecke, and S. Negri. 2009. Boundary hydroelectric project (FERC no. 2144), study no. 20, bat surveys and habitat inventory: final report. Seattle City Light, Seattle, Washington.

Greenhall, A. M. 1982. House bat management. Resource Publication 143, U.S. Fish and Wildlife Service, Washington, D.C.

Grindal, S. D. and R. M. R. Brigham. 1998. Short-term effects of small-scale habitat disturbance on activity by insectivorous bats. Journal of Wildlife Management 62:996-1003.

Grindal, S. D. and R. M. R. Brigham. 1999. Impacts of forest harvesting on habitat use by foraging insectivorous bats at different spatial scales. Ecoscience 6:25-34.

Grindal, S. D., T. S. Collard, R. M. Brigham, and R. M. R. Barclay. 1992. The influence of precipitation on reproduction by *Myotis* bats in British Columbia. American Midland Naturalist 128:339-344.

Grindal, S. D., J. L. Morissette, and R. M. R. Brigham. 1999. Concentration of bat activity in riparian habitats over an elevational gradient. Canadian Journal of Zoology 77:972-977.

Grinevitch, L., S. L. Holroyd, and R. M. R. Barclay. 1995. Sex differences in the use of daily torpor and foraging time by big brown bats (*Eptesicus fuscus*) during the reproductive season. Journal of Zoology, London 235:301-309.

Grodsky, S. M., M. J. Behr, A. Gendler, D. Drake, B. D. Dieterle, R. J. Rudd, and N. L. Walrath. 2011. Investigating the causes of death for wind turbine-associated bat fatalities. Journal of Mammalogy 92:917–925.

Grodsky, S. M., C. S. Jennelle, D. Drake, and T. Virzi. 2012. Bat mortality at a wind-energy facility in southeastern Wisconsin. Wildlife Society Bulletin 36:773-783.

Grue, C. E., P. L. Gilbert, and M. E. Seeley. 1997. Neurophysiological and behavioral changes in non-target wildlife exposed to organophosphate and carbamate pesticides: thermoregulation, food consumption, and reproduction. American Zoologist 37:369-388.

Gruver, J. C. and D. A. Keinath. 2006. Townsend's big-eared bat (*Corynorhinus townsendii*): a technical conservation assessment. Rocky Mountain Region. USDA Forest Service, Golden, Colorado.

Guldin, J. M., W. H. Emmingham, S. A. Cater, and D. A. Saugey. 2007. Silvicultural practices and management of habitat for bats. Pages 177-205 *in* M. J. Lacki, J. P. Hayes, and A. Kurta, editors. Bats in forests: conservation and management. Johns Hopkins University Press, Baltimore, Maryland.

Hagen, E. M. and J. L. Sabo. 2011. A landscape perspective on bat foraging ecology along rivers: does channel confinement and insect availability influence the response of bats aquatic resources in riverine landscapes? Oecologia 166:751-760.

Hall, E. R. 1946. Mammals of Nevada. University of California Press, Berkeley, California.

Hall, E. R. 1981. The mammals of North America. Volume I, 2nd edition. John Wiley & Sons, New York, New York.

Halliday, W. R. 1963. Caves of Washington. Information Circular No. 40, Division of Mines and Geology, Washington Department of Natural Resources, Olympia, Washington.

Hamilton, I. M. and R. M. R. Barclay. 1994. Patterns of daily torpor and day-roost selection by male and female big brown bats (*Eptesicus fuscus*). Canadian Journal of Zoology 72:744-749.

Hamilton, I. M. and R. M. R. Barclay. 1998. Diets of juvenile, yearling, and adult big brown bats (*Eptesicus fuscus*) in southeastern Alberta. Journal of Mammalogy 79:764-771.

Hammond, P. C. and J. C. Miller. 1998. Comparison of the biodiversity of Lepidoptera within three forested ecosystems. Annals of the Entomological Society of America 91:323-328.

Harestad, A. S. and D. G. Keisker. 1989. Nest tree use by primary cavity-nesting birds in south-central British Columbia. Canadian Journal of Zoology 67:1067-1073.

Hart, J. A., G. L. Kirkland, Jr., and S. C. Grossman. 1993. Relative abundance and habitat use by tree bats, *Lasiurus* spp., in south-central Pennsylvania. Canadian Field-Naturalist 107:208-212.

Hayes, J. P. 2003. Habitat ecology and conservation of bats in western coniferous forests. Pages 81-119 *in* C. J. Zabel and R. G. Anthony, editors. Mammal community dynamics in coniferous forests of western North America:

management and conservation. Cambridge University Press, New York, New York.
Hayes, J. P. and J. C. Gruver. 2000. Vertical stratification of bat activity in an old-growth forest in western Washington. Northwest Science 74:102-108.
Hayes, J. P. and S. C. Loeb. 2007. The influences of forest management on bats in North America. Pages 207-235 *in* M. J. Lacki, J. P. Hayes, and A. Kurta, editors. Bats in forests: conservation and management. Johns Hopkins University Press, Baltimore, Maryland.
Hayes, J. P., H. K. Ober, and R. E. Sherwin. 2009. Survey and monitoring of bats. Pages 112-129 *in* T. H. Kunz and S. Parsons, editors. Ecological and behavioral methods for the study of bats. Johns Hopkins University Press, Baltimore, Maryland.
Hayes, M. A., R. A. Schorr, and K. W. Navo. 2011. Hibernacula selection by Townsend's big-eared bat in southwestern Colorado. Journal of Wildlife Management 75:137-143.
Hendricks, P. 2012. Winter records of bats in Montana. Northwestern Naturalist 93:154-162.
Hendricks, P., J. Johnson, S. Lenard, and C. Currier. 2005. Use of a bridge for day roosting by the hoary bat, *Lasiurus cinereus*. Canadian Field-Naturalist 119:132-133.
Henny, C. J., C. Maser, J. O. Whitaker, Jr., and T. E. Kaiser. 1982. Organochlorine residues in bats after a forest spraying with DDT. Northwest Science 56:329-337.
Henry, M., D. W. Thomas, R. Vaudry, and M. Carrier. 2002. Foraging distances and home range of pregnant and lactating little brown bats (*Myotis lucifugus*). Journal of Mammalogy 83:767-774.
Herd, R. M. and M. B. Fenton. 1983. An electrophoretic, morphological, and ecological investigation of a putative hybrid zone between *Myotis lucifugus* and *Myotis yumanensis* (Chiroptera: Vespertilionidae). Canadian Journal of Zoology 61:2029-2050.
Herder, M. J. and J. G. Jackson. 1999. Characteristics of ponderosa pine snags selected as roosts by the long-legged myotis, *Myotis volans*. Bat Research News 40:173.
Hermanson, J. W. and T. J. O'Shea. 1983. Antrozous pallidus. Mammalian Species 213:1-8
Hickey, M. B. C. and M. B. Fenton. 1996. Behavioural and thermoregulatory responses of female hoary bats, *Lasiurus cinereus* (Chiroptera: Vespertilionidae), to variations in prey availability. Ecoscience 3:414-422.
Hill, J. E. and J. D. Smith. 1984. Bats: a natural history. University of Texas Press, Austin, Texas.
Hillen, J., A. Kieffer, and M. Veith. 2009. Foraging site fidelity shapes the spatial organisation of a population of female western barbastelle bats. Biological Conservation 142:817–823.
Hillen, J., A. Kieffer, and M. Veith. 2010. Interannual fidelity to roosting habitat and flight paths by female western barbastelle bats. Acta Chiropterologica 12:187-195.
Hirshfeld, J. R., Z. C. Nelson, and W. G. Bradley. 1977. Night roosting behavior in four species of desert bats. Southwestern Naturalist 22:427-433.
Hogberg, L. K., K. J. Patriquan, and R. M. R. Barclay. 2002. Use by bats of patches of residual trees in logged areas of the boreal forest. American Midland Naturalist 148:282-288.
Holloway, G. L. and R. M. R. Barclay. 2000. Importance of prairie riparian zones to bats in southeastern Alberta. Ecoscience 7:115-122.
Holloway, G. L. and R. M. R. Barclay. 2001. Myotis ciliolabrum. Mammalian Species 670:1-5.
Holroyd, S. L., R. M. R. Barclay, L. M. Merk, and R. M. Brigham. 1994. A survey of the bat fauna of the dry interior of British Columbia. Wildlife Working Report No. WR-63, British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia.
Horn, J. W., E. B. Arnett, and T. H. Kunz. 2008. Behavioral responses of bats to operating wind turbines. Journal of Wildlife Management 72:123-132.
Hoofer, S. R., R. A. Van Den Bussche, and I. Horáček. 2006. Generic status of the American pipistrelles (Vespertilionidae) with description of a new genus. Journal of Mammalogy 87:981-992.
Hughes, S. E. 1968. Temperature of the bat, P*lecotus townsendii*, during arousal. Journal of Mammalogy 49:140-142.
Humes, M. L., J. P. Hayes, and M. W. Collopy. 1999. Bat activity in thinned, unthinned, and old-growth forests in western Oregon. Journal of Wildlife Management 63:553-561.
Humphrey, S. R. 1975. Nursery roosts and community diversity of nearctic bats. J. of Mammalogy 56:321-346.
Humphrey, S. R. and T. H. Kunz. 1976. Ecology of a Pleistocene relict, the western big-eared bat (*Plecotus townsendii*), in the southern Great Plains. Journal of Mammalogy 57:470-494.
Humphries, M. M., D. W. Thomas, and J. R. Speakman. 2002. Climate-mediated energetic constraints on the distribution of hibernating mammals. Nature 418:313-316.
Hutchinson, J. T. and M. J. Lacki. 2000. Selection of day roosts by red bats in mixed mesophytic forests. Journal of Wildlife Management 64:87-94.
Hutson, A. M., S. P. Mickleburgh, and P. A. Racey, compilers. 2001. Microchiropteran bats: global status survey and conservation action plan. IUCN/SSC Chiroptera Specialist Group, IUCN, Gland, Switzerland.
Ingersoll, T. E., K. W. Navo, and P. de Valpine. 2010. Microclimate preferences during swarming and hibernation in the Townsend's big-eared bat, *Corynorhinus townsendii*. Journal of Mammalogy 91:1242-1250.
Ingles, L. G. 1965. Mammals of the Pacific states: California, Oregon, and Washington. Stanford University Press, Stanford, California.
Izor, R. J. 1979. Winter range of the silver-haired bat. Journal of Mammalogy 60:641-643.
Jacobson, J. E. and M. C. Snyder. 2000. Shrubsteppe mapping of eastern Washington using Landsat Satellite Thematic Mapper data. Washington Department of Fish and Wildlife, Olympia, Washington.
Jenkins, K., J. Erickson, and J. Yeager. 1999. Relative activity and composition of bat communities in old-growth Douglas-fir forests, Olympic National Park. Unpublished annual progress report, Olympic National Park, Port Angeles, Washington.
Johnson, G. D. and W. P. Erickson. 2011. Avian, bat and habitat cumulative impacts associated with wind energy

development in the Columbia Plateau ecoregion of eastern Washington and Oregon. Western EcoSystems Technology, Inc., Cheyenne, Wyoming.

Johnson, J. B., J. E. Gates, and W. M. Ford. 2008. Distribution and activity of bats at local and landscape scales within a rural–urban gradient. Urban Ecosystems 11:227-242.

Johnson, J. S., M. J. Lacki, and M. D. Baker. 2007. Foraging ecology of long-legged myotis (*Myotis volans*) in north-central Idaho. Journal of Mammalogy 88:1261-1270.

Johnson, M. L. 1953. Fall and winter record of silver-haired bat for Washington state. Murrelet 34:32.

Johnson, M. L. 1961. Another Washington record of the fringed myotis. Murrelet 42:44.

Johnson, M. L. and S. Johnson. 1952. Check list of mammals of the Olympic Peninsula. Murrelet 33:32-37.

Johnson, R. E. and K. M. Cassidy. 1997. Terrestrial mammals of Washington state: location data and predicted distributions. Pages 67-97 *in* K. M. Cassidy, C. E. Grue, M. R. Smith, and K. M. Dvornich, editors. Washington State Gap Analysis – Final Report. Volume 3. Washington Cooperative Fish and Wildlife Research Unit, University of Washington, Seattle, Washington.

Johnston, D. S. and M. B. Fenton. 2001. Individual and population-level variability in diets of pallid bats (*Antrozous pallidus*). Journal of Mammalogy 82:362-373.

Jonasson, K. A. and C. K. R. Willis. 2012. Hibernation energetics of free-ranging little brown bats. Journal of Experimental Biology 215:2141-2149.

Jones, G., D. S. Jacobs, T. H. Kunz, M. R. Willig, and P. A. Racey. 2009. Carpe noctem: the importance of bats as bioindicators. Endangered Species Research 8:93-115.

Jung, T. S., I. D. Thompson, R. D. Titman, and A. P. Applejohn. 1999. Habitat selection by forest bats in relation to mixed-wood stand types and structure in central Ontario. Journal of Wildlife Management 63:1306-1319.

Kalcounis, M. C. and R.M. Brigham. 1998. Secondary use of aspen cavities by tree-roosting big brown bats. Journal of Wildlife Management 62:603-611.

Kalcounis, M. C. and K. R. Hecker. 1996. Intraspecific variation in roost-site selection by little brown bats (*Myotis lucifugus*). Pages 81-90 *in* R. M. R. Barclay and R. M. Brigham, editors. Bats and forests symposium. Working Paper 23/1996, Research Branch, British Columbia Ministry of Forests, Victoria, British Columbia.

Kalcounis, M. C., K. A. Hobson, R. M. Brigham, and K. R. Hecker. 1999. Bat activity in the boreal forest: importance of stand type and vertical strata. Journal of Mammalogy 80:673-682.

Kalcounis-Rüppell, M. C., J. M. Psyllakis, and R. M. Brigham. 2005. Tree roost selection by bats: an empirical synthesis using meta-analysis. Wildlife Society Bulletin 33:1123-1132.

Kannan, K., S. H. Yun, R. J. Rudd, and M. Behr. 2010. High concentrations of persistent organic pollutants including PCBs, DDT, PBDEs and PFOs in little brown bats with white-nose syndrome in New York, USA. Chemosphere 80:613-618.

Keeley, B. W. and M. D. Tuttle. 1999. Bats in American bridges. Resource Publication No. 4, Bat Conservational International, Austin, Texas.

Keinath, D. A. 2004. Fringed myotis (*Myotis thysanodes*): a technical conservation assessment. Rocky Mountain Region, USDA Forest Service, Golden, Colorado.

Kellner, A. M. E. and A. S. Harestad. 2005. Diets of bats in coastal rainforests on Vancouver Island, British Columbia. Northwestern Naturalist 86:45-48.

Kerns, J., W. P. Erickson, and E. B. Arnett. 2005. Bat and bird fatality at wind energy facilities in Pennsylvania and West Virginia. Pages 24-95 *in* E. B. Arnett, editor. Relationships between bats and wind turbines in Pennsylvania and West Virginia: an assessment of bat fatality search protocols, patterns of fatality, and behavioral interactions with wind turbines. Final report submitted to the Bats and Wind Energy Cooperative, Austin, Texas.

Kiser, M. and S. Kiser. 2004. A decade of bat house discovery. The Bat House Researcher 12(1):1-12. <http://www.batcon.org/index.php/get-involved/install-a-bat-house/subcategory/46.html>

Klug, B. J. and R. M. R. Barclay. 2013. Thermoregulation during reproduction in the solitary, foliage roosting hoary bat (*Lasiurus cinereus*). Journal of Mammalogy 94:477–487.

Klug, B. J., D. A. Goldsmith, and R. M. R. Barclay. 2012. Roost selection by the solitary, foliage-roosting hoary bat (*Lasiurus cinereus*) during lactation. Canadian Journal of Zoology 90:329-336.

Klug, B. J., A. S. Turmelle, J. A. Ellison, E. F. Baerwald, and R. M. R. Barclay. 2011. Rabies prevalence in migratory tree-bats in Alberta and the influence of roosting ecology and sampling method on reported prevalence of rabies in bats. Journal of Wildlife Diseases 47:64-77.

Koehler, C. E. and R. M. R. Barclay. 2000. Post-natal growth and breeding biology of the hoary bat (*Lasiurus cinereus*). Journal of Mammalogy 81:234-244.

Kronner, K., B. Gritski, and S. Downes. 2008. Big Horn Wind Power Project wildlife fatality monitoring study, 2006-2007. Northwest Wildlife Consultants, Goldendale, Washington.

Kruess, A. and T. Tscharntke. 2002. Contrasting responses of plant and insect diversity to variation in grazing intensity. Biological Conservation 106:293-302.

Kuenzi, A. J., G. T. Downard, and M. L. Morrison. 1999. Bat distribution and hibernacula use in west central Nevada. Great Basin Naturalist 59:213-220.

Kunz, T. H. 1974. Reproduction, growth, and mortality of the vespertilionid bat, *Eptesicus fuscus*, in Kansas. Journal of Mammalogy 55:1-13.

Kunz, T. H. 1982a. Roosting ecology of bats. Pages 1-55 *in* T. H. Kunz, editor. Ecology of bats. Plenum Press, New York, New York.

Kunz, T. H. 1982b. Lasionycteris noctivagans. Mammalian Species 172:1-5.

Kunz, T. H. and L. F. Lumsden. 2003. Ecology of cavity and foliage roosting bats. Pages 3-89 *in* T. H. Kunz and M. B. Fenton, editors. Bat ecology. University of Chicago Press, Chicago, Illinois.

Kunz, T. H. and R. A. Martin. 1982. Plecotus townsendii. Mammalian Species 175:1-6.

Kunz, T. H. and J. D. Reichard. 2010. Status review of the little brown myotis (*Myotis lucifugus*) and determination that immediate listing under the Endangered Species Act is scientifically and legally warranted. Center for Ecology and Conservation Biology, Boston University, Boston, Massachusetts.

Kunz, T. H. and D. S. Reynolds. 2004. Bat colonies in buildings. Pages 91-102 *in* T. J. O'Shea and M. A. Bogan, editors. Monitoring trends in bat populations in the United States and territories: problems and prospects. U.S. Geological Survey, Biological Resources Discipline, Information and Technology Report USGS/BRD/ITR –2003-0003.

Kunz, T. H., E. B. Arnett, W. P. Erickson, A. R. Hoar, G. D. Johnson, R. P. Larkin, M. D. Strickland, R. W. Thresher, and M. D. Tuttle. 2007. Ecological impacts of wind energy development on bats: questions, research needs, and hypotheses. Frontiers in Ecology and the Environment 5:315-324.

Kunz, T. H., M. Betke, N. I. Hristov, and M. J. Vonhof. 2009. Methods for assessing colony size, population size, and relative abundance of bats. Pages 133-157 *in* T. H. Kunz and S. Parsons, editors. Ecological and behavioral methods for the study of bats. Johns Hopkins University Press, Baltimore, Maryland.

Kunz, T. H., E. Braun de Torrez, D. Bauer, T. Lobova, and T. H. Fleming. 2011. Ecosystem services provided by bats. Annals of the New York Academy of Sciences 1223:1-38.

Kunz, T. H., J. O. Whitaker, Jr., and M. D. Wadanoli. 1995. Dietary energetics of the insectivorous Mexican free-tailed bat (*Tadarida brasiliensis*) during pregnancy and lactation. Oecologia 101:407-415.

Kunz, T. H., J. A. Wrazen, and C. D. Burnett. 1998. Changes in body mass and fat reserves in pre-hibernating little brown bats (*Myotis lucifugus*). Ecoscience 5:8-17.

Kurta, A. and R. H. Baker. 1990. Eptesicus fuscus. Mammalian Species 356:1-10.

Kurta A. and T. H. Kunz. 1987. Size of bats at birth and maternal investment during pregnancy. Symposia of the Zoological Society of London 57:79-106.

Kurta, A. and J. A. Teramino. 1992. Bat community structure in an urban park. Ecography 15:257-261.

Kurta, A., G. P. Bell, K. A. Nagy, and T. H. Kunz. 1989. Energetics of pregnancy and lactation in free-ranging little brown bats (*Myotis lucifugus*). Physiological Zoology 62:804-818.

Kurta A., T. H. Kunz, and K. A. Nagy. 1990. Energetics and water flux of free-ranging big brown bats (*Eptesicus fuscus*) during pregnancy and lactation. Journal of Mammalogy 71:59-65.

Lacki, M. J. and M. D. Baker. 2007. Day roosts of female fringed myotis (*Myotis thysanodes*) in xeric forests of the Pacific Northwest. Journal of Mammalogy 88:967-973.

Lacki, M. J., S. K. Amelon, and M. D. Baker. 2007a. Foraging ecology of bats in forests. Pages 83-127 *in* M. J. Lacki, J. P. Hayes, and A. Kurta, editors. Bats in forests: conservation and management. Johns Hopkins University Press, Baltimore, Maryland.

Lacki, M. J., M. D. Baker, and J. S. Johnson. 2010. Geographic variation in roost-site selection of long-legged myotis in the Pacific Northwest. Journal of Wildlife Management 74:1218-1228.

Lacki, M. J., M. D. Baker, and J. S. Johnson. 2012. Temporal dynamics of roost snags of long-legged myotis in the Pacific Northwest, USA. Journal of Wildlife Management 76:1310-1316.

Lacki, M. J., D. R. Cox, L. E. Dodd, and M. B. Dickinson. 2009. Response of northern bats (*Myotis septentrionalis*) to prescribed fires in eastern Kentucky forests. Journal of Mammalogy 90:1165-1175.

Lacki, M. J., J. S. Johnson, L. E. Dodd, and M. D. Baker. 2007b. Prey consumption of insectivorous bats in coniferous forests of north-central Idaho. Northwest Science 81:199-205.

Langwig, K. E., W. F. Frick, J. T. Bried, A. C. Hicks, T. H. Kunz, and A. M. Kilpatrick. 2012. Sociality, density-dependence and microclimates determine the persistence of populations suffering from a novel fungal disease, white-nose syndrome. Ecology Letters 15:1050-1057.

Lausen, C. L. and R. M. R. Barclay. 2002. Roosting behaviour and roost selection of female big brown bats (*Eptesicus fuscus*) roosting in rock crevices in southeastern Alberta. Canadian Journal of Zoology 80:1069-1076.

Lausen, C. L. and R. M. R. Barclay. 2003. Thermoregulation and roost selection by reproductive female big brown bats (*Eptesicus fuscus*) roosting in rock crevices. Journal of Zoology, London 260:235-244.

Lausen, C. L. and R. M. R. Barclay. 2006. Benefits of living in a building: big brown bats (*Eptesicus fuscus*) in rocks versus buildings. Journal of Mammalogy 88:362-370.

Leonard, M. L. and M. B. Fenton. 1983. Habitat use by spotted bats (*Euderma maculatum*, Chiroptera: Vespertilionidae): roosting and foraging behaviour. Canadian Journal of Zoology 61:1487-1491.

Leonard, M. L. and M. B. Fenton. 1984. Echolocation calls of *Euderma maculatum* (Vespertilionidae): use in orientation and communication. Journal of Mammalogy 65:122-126.

Lewis, S. E. 1993. Effect of climatic variation on reproduction by pallid bats (*Antrozous pallidu*s). Canadian Journal of Zoology 71:1429-1433.

Lewis, S. E. 1994. Night roosting ecology of pallid bats (*Antrozous pallidus*) in Oregon. American Midland Naturalist 132:219-226.

Lewis, S. E. 1995. Roost fidelity of bats: a review. Journal of Mammalogy 76:481-496.

Lewis, S. E. 1996. Low roost-site fidelity in pallid bats: associated factors and effect on group stability. Behavioral Ecology and Sociobiology 39:335-344.

Lindsey, C., J. Nugent, R. Luhrs, and G. Malin. 2012. Summer bat monitoring report for calendar year 2012. HNF-53759, Mission Support Alliance, Richland, Washington.

Link, R. 2004. Living with wildlife in the Pacific Northwest. University of Washington Press, Seattle, Washington.

Littell, J. S., E. E. Oneil, D. McKenzie, J. A. Hicke, J. A. Lutz, R. A. Norheim, and M. M. Elsner. 2009. Forest ecosystems, disturbances, and climatic change in Washington state, USA. Pages 255-284 *in* M. M. Elsner, J. Littell, and L. W. Binder, editors. The Washington climate change impacts assessment: evaluating Washington's future in a changing climate. Climate Impacts Group, University of Washington, Seattle, Washington.

Loeb, S. C., C. J. Post, and S. T. Hall. 2009. Relationship between urbanization and bat community structure in national parks of the southeastern U.S. Urban Ecosystems 12:197-214.

Lorch, J. M., C. U. Meteyer, M. J. Behr, J. G. Boyles, P. M. Cryan, A. C. Hicks, A. E. Ballmann, J. T. H. Coleman, D. N. Redell, D. M. Reeder, and D. S. Blehert. 2011. Experimental infection of bats with *Geomyces destructans* causes white-nose syndrome. Nature 480:376-378. doi.10.1038/nature 10590

Lorch, J. M., L. K. Muller, R. E. Russell, M. O'Connor, D. L. Lindner, and D. S. Blehert. 2013. Distribution and environmental persistence of the causative agent of white-nose syndrome, *Geomyces destructans*, in bat hibernacula of the eastern United States. Applied and Environmental Microbiology 79:1293-1301.

Lucas, J. G. 2011. Use of underground facilities by bats at the Hanford Site in shrub-steppe habitats in Washington. Thesis, Washington State University, Pullman, Washington.

Luce, R. J. and D. Keinath. 2007. Spotted bat (*Euderma maculatum*): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region, Golden, Colorado.

Lunde, R. E. and A. S. Harestad. 1986. Activity of little brown bats in coastal forests. Northwest Science 60:206-209.

Lundquist, R. W. and J. M. Mariani. 1991. Nesting habitat and abundance of snag-dependent birds in the southern Washington Cascades Range. Pages 221-238 *in* L. F. Ruggiero, K. B. Aubry, A. B. Carey, and M. H. Huff, technical coordinators. Wildlife and vegetation of unmanaged Douglas-fir forests. General Technical Report PNW-GTR-285, Pacific Northwest Research Station, U.S. Forest Service, Portland, Oregon.

Malison, R. L. and C. V. Baxter. 2010. The fire pulse: wildfire stimulates flux of aquatic prey to terrestrial habitats driving increases in riparian consumers. Canadian Journal of Fisheries and Aquatic Sciences 67:570-579.

Mann, S. L., R. J. Steidl, and V. M. Dalton. 2002. Effects of cave tours on breeding *Myotis velifer*. Journal of Wildlife Management 66:618-624.

Manning, R. W. 1993. Systematics and evolutionary relationships of the long-eared bat, *Myotis evotis* (Chiroptera: Vespertilionidae). Special Publications, Museum of Texas Tech University 37:1-58.

Manning, R. W. and J. K. Jones, Jr. 1988. A new subspecies of fringed Myotis, *Myotis thysanodes*, from the northwestern coast of the United States. Occasional Papers of the Museum, Texas Tech University 123:1-6.

Manning, R. W. and J. K. Jones, Jr. 1989. Myotis evotis. Mammalian Species 329:1-5.

Marcot, B. G. 1984. Winter use of some northwestern California caves by western big-eared and long-eared myotis. Murrelet 65:46.

Maser, C. 1998. Mammals of the Pacific Northwest: from the coast to the high Cascades. Oregon State University Press, Corvallis, Oregon.

Maser, C., B. R. Mate, J. F. Franklin, and C. T. Dryness. 1981. Natural history of the Oregon coast mammals. General Technical Report GTR-PNW-133, Pacific Northwest Research Station, U.S. Forest Service, Portland, Oregon.

Mathis, T. J. 2005. Behaviors of a maternity colony of Townsend's big-eared bats. Thesis, Eastern Washington University, Cheney, Washington.

Mattson, T. A., S. W. Buskirk, and N. L. Stanton. 1996. Roost sites of the silver-haired bat (*Lasionycteris noctivagans*) in the Black Hills, South Dakota. Great Basin Naturalist 56:247-253.

Mazurek, M. J. 2004. A maternity roost of Townsend's big-eared bats (*Corynorhinus townsendii*) in coast redwood basal hollows in northwestern California. Northwestern Naturalist 85:60-62.

McFaul, E. J., G. T. Mason, Jr., W. B. Ferguson, and B. R. Lipin. 2000. U.S. Geological Survey mineral databases – MRDS and MAS/MILS. Digital Data Series DDS-52, U.S. Geological Survey, Reston Virginia.

McGuire, L. P., C. G. Guglielmo, S. A. Mackenzie, and P. D. Taylor. 2012. Migratory stopover in the long-distance migrant silver-haired bat, *Lasionycteris noctivagans*. Journal of Animal Ecology 81:377-385.

Menzel, M. A., T. C. Carter, B. R. Chapman, and J. Laerm. 1998. Quantitative comparison of tree roosts used by red bats (*Lasiurus borealis*) and Seminole bats (*L. seminolus*). Canadian Journal of Zoology 76:630-634.

Mering, E. D. and C. L. Chambers. 2012. Artificial roosts for tree-roosting bats in northern Arizona. Wildlife Society Bulletin 36:765-772.

Messenger, S. L., J. S. Smith, L. A. Orciari, P. A. Yager, and C. E. Rupprecht. 2003. Emerging pattern of rabies deaths and increased viral infectivity. Emerging Infectious Diseases 9:151-154.

Messenger, S. L., J. S. Smith, and C. E. Rupprecht. 2002. Emerging epidemiology of bat-associated cryptic cases of rabies in humans in the United States. Clinical Infectious Diseases 35:738-746.

Meteyer, C. U., D. Barber, and J. N. Mandl. 2012. Pathology in euthermic bats with white nose syndrome suggests a natural manifestation of immune reconstitution inflammatory syndrome. Virulence 3(7):1-6.

Meteyer, C. U., E. L. Buckles, D. S. Blehert, A. C. Hicks, D. E. Green, V. Shearn-Bochsler, N. J. Thomas, A. Gargas, and M. J. Behr. 2009. Histopathologic criteria to confirm white-nose syndrome in bats. Journal of Veterinary Diagnostic Investigation 21:411-414.

Miller, J. C. 1990. Field assessment of the effects of a microbial pest control agent on nontarget Lepidoptera. American Entomologist 36:135-139.

Miller, J. C. 2000. Monitoring the effects of *Bacillus thuringiensis kurstaki* on nontarget Lepidoptera in woodlands and forests of western Oregon. Pages 277-286 *in* P. A. Follett and J. J. Duan, editors. Nontarget effects of biological control. Kluwer Academic Publishers, Boston, Massachusetts.

Milligan, B. N. and R. M. Brigham. 1993. Sex ratio variation in the Yuma bat (*Myotis yumanensis*). Canadian Journal of Zoology 71:937-940.

Mills, R. S., G. W. Barrett, and M. P. Farrell. 1975. Populations dynamics of the big brown bat (*Eptesicus fuscus*) in southwestern Ohio. Journal of Mammalogy 56:591-604.

Moosman, P. R., Jr., H. H. Thomas, and J. P. Veilleux. 2012.

Diet of the widespread insectivorous bats *Eptesicus fuscus* and *Myotis lucifugus* relative to climate and richness of bat communities. Journal of Mammalogy 93:491-496.

Mote, P. W. 2003. Trends in temperature and precipitation in the Pacific Northwest during the twentieth century. Northwest Science 77:271-282.

Mote, P. W. and E. P. Salathé, Jr. 2009. Future climate in the Pacific Northwest. Pages 21-43 *in* M. M. Elsner, J. Littell, and L. W. Binder, editors. The Washington climate change impacts assessment. University of Washington, Seattle, Washington.

Muir, P. S., R. L. Mattingly, J. C. Tappeiner II, J. D. Bailey, W. E. Elliot, J. C. Hagar, J. C. Miller, E. B. Peterson, and E. E. Starkey. 2002. Managing for biodiversity in young Douglas-fir forests of western Oregon. Biological Science Report USGS/BRD/BSR-2002-0006, Biological Resources Division, U.S. Geological Survey, Corvallis, Oregon.

Nagorsen, D. 2004a. COSEWIC assessment and update status report on the spotted bat *Euderma maculatum* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario.

Nagorsen, D. 2004b. COSEWIC assessment and update status report on the fringed bat *Myotis thysanodes* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario.

Nagorsen, D. W. and R. M. Brigham. 1993. Bats of British Columbia. UBC Press, Vancouver, British Columbia.

Nagorsen, D. W. and B. Paterson. 2012. An update on the status of red bats, *Lasiurus blossevillii* and *Lasiurus borealis*, in British Columbia. Northwestern Naturalist 93:235-237.

Nagorsen, D. W., A. A. Bryant, D. Kerridge, G. Roberts, and M. J. Sarell. 1993. Winter bat records for British Columbia. Northwestern Naturalist 74:61-66.

NASS (National Agricultural Statistical Service). 2009. 2007 census of agriculture: Washington, state and county data. Volume 1, Geographic Area Series, Part 47. National Agricultural Statistics Service, U.S. Department of Agriculture, Washington, D.C.

NatureServe. 2009. NatureServe explorer: an online encyclopedia of life [web application]. Version 7.0. NatureServe, Arlington, Virginia. <http://www.natureserve.org/explorer>.

Navo, K. W., J. A. Gore, and G. T. Skiba. 1992. Observations on the spotted bat, *Euderma maculatum*, in northwestern Colorado. Journal of Mammalogy 73:547-551.

Neubaum, D. J., T. J. O'Shea, and K. R. Wilson. 2006. Autumn migration and selection of rock crevices as hibernacula by big brown bats in Colorado. Journal of Mammalogy 87:470-479.

Neubaum, D. J., K. R. Wilson, and T. J. O'Shea. 2007. Urban maternity-roost selection by big brown bats in Colorado. Journal of Wildlife Management 71:728-736.

Neuweiler, G. 1989. Foraging ecology and audition in echolocating bats. Trends in Ecology and Evolution 4:160-166.

Newson, S. E., S. Mendes, H. Q. P. Crick, N. K. Dulvy, J. D. R. Houghton, G. C. Hays, A. M. Hutson, C. D. MacLeod, G. J. Pierce, and R. A. Robinson. 2009. Indicators of the impact of climate change on migratory species. Endangered Species Research 7:101-113.

Niwa, C. G., R. E. Sandquist, R. Crawford, T. J. Frest, T. Griswold, P. Hammond, E. Ingham, S. James, E. J. Johannes, J. James, W. P. Kemp, J. LaBonte, J. D. Lattin, J. McIver, J. McMillin, A. Moldenke, J. John, D. Ross, T. Schowalter, V. Tepedino, and M. R. Michael. 2001. Invertebrates of the Columbia River Basin assessment area. General Technical Report PNW-GTR-512, Pacific Northwest Research Station, U.S. Forest Service, Portland, Oregon.

Nixon, A. E., J. C. Gruver, and R. M. Barclay. 2009. Spatial and temporal patterns of roost use by western long-eared bats (*Myotis evotis*). American Midland Naturalist 162:139-147.

Norberg, U. M. 1990. Vertebrate flight. Springer-Verlag, Berlin, Germany.

Norberg, U. M. and J. M. V. Rayner. 1987. Ecological morphology and flight in bats (Mammalia; Chiroptera): wing adaptations, flight performance, foraging strategy and echolocation. Philosophical Trans. of the Royal Society of London B, Biological Series 316:335-427.

Norquay, K. J. O., F. Martinez-Nuñez, J. E. Dubois, K. M. Monson, and C. K. R. Willis. 2013. Long-distance movements of little brown bats (Myotis lucifugus). Journal of Mammalogy 94:506–515.

NREL (National Renewable Energy Laboratory). 2007. 50 m wind power resource: Washington. National Renewable Energy Laboratory, Golden, Colorado. <http://www.nrel.gov/gis/images/eere_wind/eere_wind_washington-01.jpg>

Nuetzmann, M. C. 2001. Effects of urbanization on bat activity and foraging. Thesis, Eastern Washington University, Cheney, Washington.

NWC (Northwest Wildlife Consultants). 2010. Ecological baseline studies and impact assessment for the Lund Hill Wind Project, Klickitat County, Washington. Prepared for Iberdrola Renewables by Northwest Wildlife Consultants, Pendleton, Oregon.

Ober, H. K. and J. P. Hayes. 2008a. Prey selection by bats in forests of western Oregon. Journal of Mammalogy 89:1191-1200.

Ober, H. K. and J. P. Hayes. 2008b. Influence of vegetation on bat use of riparian areas at multiple spatial scales. Journal of Wildlife Management 72:396-404.

Ober, H. K. and J. P. Hayes. 2008c. Influence of forest riparian vegetation on abundance and biomass of nocturnal flying insects. Forest Ecology and Management 256:1124-1132.

Ober, H. K. and J. P. Hayes. 2010. Determinants of nocturnal Lepidopteran diversity and community structure in a conifer-dominated forest. Biodiversity and Conservation 19:761-774.

O'Donnell, C. F. J. 2009. Population dynamics and survivorship in bats. Pages 158-176 *in* T. H. Kunz and S. Parsons, editors. Ecological and behavioral methods for the study of bats. Johns Hopkins University Press, Baltimore, Maryland.

O'Farrell, M. J. and E. H. Studier. 1973. Reproduction, growth, and development in *Myotis thysanodes* and *M. lucifugus* (Chiroptera: Vespertilionidae). Ecology 54:18-30.

O'Farrell, M. J. and E. H. Studier. 1980. Myotis thysanodes. Mammalian Species 137:1-5.

O'Farrell, M. J., C. Corben, W. L. Gannon, and B. W. Miller. 1999a. Confronting the dogma: a reply. Journal of Mammalogy 80:297-302.

O'Farrell, M. J., B. W. Miller, and W. L. Gannon. 1999b. Qualitative identification of free-flying bats using the anabat detector. Journal of Mammalogy 80:11-23.

OFM (Office of Financial Management). 2011. Forecast of the state population: November 2011 forecast. Office of Financial Management, Olympia, Washington. <http://www.ofm.wa.gov/pop/stfc/default.asp>

Okoniewski, J. C., J. Haines, A. C. Hicks, K. E. Langwig, R. I. Von Linden, and C. A. Dobony. 2010. Detection of the conidia of *Geomyces destructans* in Northeast hibernacula, at maternal colonies, and on gear – some findings based on microscopy and culture. Page 18 *in* Abstracts of Presented Papers and Posters for 2010 White-nose Syndrome Symposium, May 25-27, 2010, Pittsburgh, Pennsylvania. <http://whitenosesyndrome.org/white-nose-syndrome-symposiums>

Oliver, G. V. 2000. The bats of Utah: a literature review. Publication Number 00-14, Utah Division of Wildlife Resources, Salt Lake City, Utah.

Olson, C. R., D. P. Hobson, and M. J. Pybus. 2011. Changes in population size of bats at a hibernaculum in Alberta, Canada, in relation to cave disturbance and access restrictions. Northwestern Naturalist 92:224-230.

Oprea, M., P. Mendes, T. B. Vieira, and A. D. Ditchfield. 2009. Do wooded streets provide connectivity for bats in an urban landscape? Biodiversity and Conservation 18:2361-2371.

Ormsbee, P. C. 1996. Characteristics, use, and distribution of day roosts selected by female *Myotis volans* (long-legged myotis) in forested habitat of the central Oregon Cascades. Pages 124-131 *in* R. M. R. Barclay and R. M. Brigham, editors. Bats and forests symposium. Working Paper 23/1996, Research Branch, British Columbia Ministry of Forests, Victoria, British Columbia.

Ormsbee, P. C. 2008. The Bat Grid: a unique approach to reliable data. Bats 26:8-9.

Ormsbee, P. 2011. The Bat Grid inventory and monitoring project: a regional approach to inventorying and monitoring bat populations, 2009 report. Report 09-390, Legacy Resource Management Program, Department of Defense, Washington, D.C. <https://www.dodlegacy.org/Legacy/intro/ProductsList_NU.aspx>

Ormsbee, P. and M. Hohmann. 2010. The Bat Grid inventory and monitoring project: a regional approach to inventorying and monitoring bat populations, 2008 report. Report 08-390, Legacy Resource Management Program, Department of Defense, Washington, D.C. <https://www.dodlegacy.org/Legacy/intro/ProductsList_NU.aspx>

Ormsbee, P. C., and W. C. McComb. 1998. Selection of day roosts by female long-legged myotis in the central Oregon Cascade Range. Journal of Wildlife Management 62:596-603.

Ormsbee, P. C., J. D. Kiser, and S. I. Perlmeter. 2007. Importance of night roosts to the ecology of bats. Pages 129-145 *in* M. J. Lacki, J. P. Hayes, and A. Kurta, editors. Bats in forests: conservation and management. Johns Hopkins University Press, Baltimore, Maryland.

Orr, R. T. 1954. Natural history of the pallid bat, *Antrozous pallidus* (Le Conte). Proceedings of the California Academy of Science 18:165-246.

O'Shea, T. J. and M. A. Bogan, editors. 2003. Monitoring trends in bat populations of the United States and territories: problems and prospects. Information and Technology Report USGS/BRD/ITR-2003-0003, Biological Resources Discipline, U.S. Geological Survey, Fort Collins, Colorado.

O'Shea, T. J. and D. R. Clark, Jr. 2002. An overview of contaminants and bats, with special reference to insecticides and the Indiana bat. Pages 237-253 *in* A. Kurta and J. Kennedy, editors. The Indiana bat: biology and management of an endangered species. Bat Conservation International, Austin, Texas.

O'Shea, T. J. and J. J. Johnston. 2009. Environmental contaminants and bats. Pages 500-528 *in* T. H. Kunz and S. Parsons, editors. Ecological and behavioral methods for the study of bats. Johns Hopkins University Press, Baltimore, Maryland.

O'Shea, T. J., M. A. Bogan, and L. E. Ellison. 2003. Monitoring trends in bat populations of the United States and territories: status of the science and recommendations for the future. Wildlife Society Bulletin 31:16-29.

O'Shea, T. J., L. E. Ellison, D. J. Neubaum, M. A. Neubaum, C. A. Reynolds, and R. A. Bowen. 2010. Recruitment in a Colorado population of big brown bats: breeding probabilities, litter size, and first-year survival. Journal of Mammalogy 91:418-428.

O'Shea, T. J., L. E. Ellison, and T. R. Stanley. 2004. Survival estimation in bats: historical overview, critical appraisal, and suggestions for new approaches. Pages 297-336 *in* W. L. Thompson, editor. Sampling rare or elusive species: concepts, designs, and techniques for estimating population parameters. Island Press, Washington, D.C.

O'Shea, T. J., L. E. Ellison, and T. R. Stanley. 2011. Adult survival and population growth rate in Colorado big brown bats (*Eptesicus fuscus*). Journal of Mammalogy 92:433-443.

Park, K. J., C. T. Müller, S. Markman, O. Swinscow-Hall, D. Pascoe, and K. L. Buchanan. 2009. Detection of endocrine disrupting chemicals in aerial invertebrates at sewage treatment works. Chemosphere 77:1459-1464.

Parker, D. I. and J. A. Cook. 1996. Keen's long-eared bat, *Myotis keenii*, confirmed in southeast Alaska. Canadian Field-Naturalist 110:611-614.

Parker, D. I., J. A. Cook, and S. W. Lewis. 1996. Effects of timber harvest on bat activity in southeastern Alaska's temperate rainforests. Pages 277-292 *in* R. M. R. Barclay and R. M. Brigham, editors. Bats and forests symposium. Working Paper 23/1996, Research Branch, British Columbia Ministry of Forests, Victoria, British Columbia.

Parker, D. I., B. E. Lawhead, and J. A. Cook. 1997. Distributional limits of bats in Alaska. Arctic 50:256-265.

Parsons, H. J., D. A. Smith, and R. F. Whittam. 1986. Maternity colonies of silver-haired bats, *Lasionycteris noctivagans*, in Ontario and Saskatchewan. Journal of Mammalogy 67:598-600.

Pearson, O. P., M. R. Koford, and A. K. Pearson. 1952. Reproduction of the lump-nosed bat (*Corynorhinus rafinesquei*) in California. Journal of Mammalogy 33:273-320.

Perkins, J. M. 1985. Final report of the field inventory of *Plecotus townsendii* for Tara Zimmerman-Washington Department of Game, Neal Mettler-Mt. Adams Ranger District, and Alice Meyers-Wind River Ranger District. Unpublished report submitted to the U.S. Forest Service.

Perkins, J. M. 1988. Three year bat survey for Washington national forests: results of year two – Olympic and Mt. Baker-Snoqualmie National Forests. Unpublished report submitted to the U.S. Forest Service.

Perkins, J. M. 1990a. Three year bat survey for Washington national forests: results of year three – Wenatchee, Okanogan, and Colville National Forests. Unpublished report submitted to the U.S. Forest Service.

Perkins, J. M. 1990b. Results of population monitoring for the Category 2 species *Plecotus townsendii* in Oregon and Washington – 1989-90. Unpublished report.

Perkins, J. M. 1991. *Plecotus townsendii*: survey for the North Umqua Ranger District of the Umpqua National Forest. U.S. Forest Service, Roseburg, Oregon.

Perkins, J. M. 1992. *Plecotus townsendii*: survey for the Nez Perce National Forest. Idaho Fish and Game Conservation Data Center Report, Boise, Idaho.

Perkins, J. M. and S. P. Cross. 1988. Differential use of some coniferous forest habitats by hoary and silver-haired bats in Oregon. Murrelet 69:21-24.

Perkins, J. M. and S. P. Cross. 1991. Migratory patterns of *Lasionycteris noctivagans* in Oregon and Washington. Bat Research News 32:83.

Perkins, J. M. and C. Levesque. 1987. Distribution, status, and habitat affinities of Townsend's big-eared bat (P*lecotus townsendii*) in Oregon. Technical Report #86-5-01, Nongame Wildlife Program, Oregon Department of Fish and Wildlife, Salem, Oregon.

Perkins, J. M. and J. R. Peterson. 1996. Report on the bat survey of the Columbia River corridor for the Washington Department of Wildlife, summer, 1995. Unpublished report.

Perkins, J. M., J. M. Barss, and J. Peterson. 1990. Winter records of bats in Oregon and Washington. Northwestern Naturalist 71:59-62.

Perkins, J. M., J. R. Peterson, and A. J. Perkins. 1994. Roost selection in hibernating *Plecotus townsendii*. Bat Research News 35:110.

Perlmeter, S. I. 1996. Bats and bridges: patterns of night roost activity in the Willamette National Forest. Pages 132-150 *in* R. M. R. Barclay and R. M. Brigham, editors. Bats and forests symposium. Working Paper 23/1996, Research Branch, British Columbia Ministry of Forests, Victoria, British Columbia.

Perry, R. W. 2011. Fidelity of bats to forest sites revealed from mist-netting recaptures. Journal of Fish and Wildlife Management 2:112-116.

Petterson, J., Jr. 2001. Bat inventory and monitoring program development for Mount Rainier National Park, Washington. Unpublished report submitted to Bat Conservation International, Austin, Texas.

Piaggio, A. J. and S. L. Perkins. 2005. Molecular phylogeny of North American long-eared bats (Vespertilionidae: *Corynorhinus*); inter- and intraspecific relationships inferred from mitochondrial and nuclear DNA sequences. Molecular Phylogenetics and Evolution 37:762-775.

Piaggio, A. J., K. W. Navo, and C. W. Stihler. 2009. Intraspecific comparison of population structure, genetic diversity, and dispersal among three subspecies of Townsend's big-eared bats, *Corynorhinus townsendii townsendii*, *C. t. pallescens*, and the endangered *C. t. virginianus*. Conservation Genetics 10:143-159.

Pierson, E. D. 1988. The status of Townsend's big-eared bat (*Plecotus townsendii*) in California. Preliminary results: *P. t. townsendii* in coastal California, 1987-1988. California Department of Fish and Game, Sacramento, California.

Pierson, E. D. and W. E. Rainey. 1994. Distribution and habitat associations of *Eumpos perotis* and *Euderma maculatum* in California: implications for conservation. Bat Research News 35:110-111.

Pierson, E. D. and W. E. Rainey. 1996. The distribution, status, and management of Townsend's big-eared bat (*Corynorhinus townsendii*) in California. Bird and Mammal Conservation Program Report 96-7, California Department of Fish and Game, Sacramento, California.

Pierson, E. D. and W. E. Rainey. 1998. Distribution of the spotted bat, *Euderma maculatum*, in California. Journal of Mammalogy 79:1296-1305.

Pierson, E. D., W. E. Rainey, and C. Corben. 2006. Distribution and status of western red bats (*Lasiurus blossevillii*) in California. Species Conservation and Recovery Program Report 2006-04, California Department of Fish and Game, Sacramento, California.

Pierson, E. D., W. E. Rainey, and D. M. Koontz. 1991. Bats and mines: experimental mitigation for Townsend's big-eared bat at the McLaughlin mine in California. Pages 31-42 *in* R. D. Comer et al., editors. Proceedings V: issues and technology in the management of impacted wildlife. Thorne Ecological Institute, Snowmass, Colorado.

Pierson, E. D., W. E. Rainey, and R. Miller. 1996. Night roost sampling: a window on the forest bat community in northern California. Pages 151-163 *in* R. M. R. Barclay and R. M. Brigham, editors. Bats and forests symposium. Working Paper 23/1996, Research Branch, British Columbia Ministry of Forests, Victoria, British Columbia.

Pierson, E. D., M. C. Wackenhut, J. S. Altenbach, P. Bradley, P. Call, D. L. Genter, C. E. Harris, B. L. Keller, B. Lengus, L. Lewis, B. Luce, K. W. Navo, J. M. Perkins, S. Smith, and L. Welch. 1999. Species conservation assessment and strategy for Townsend's big-eared bat (*Corynorhinus townsendii townsendii* and *Corynorhinus townsendii pallascens*). Idaho Conservation Effort, Idaho Department of Fish and Game, Boise, Idaho.

Pikula, J., H. Bandouchova, L. Novotný, C. U. Meteyer, J. Zukal, N. R. Irwin, J. Zima, and N. Martínková. 2012. Histopathology confirms white-nose syndrome in bats in Europe. Journal of Wildlife Diseases 48:207-211.

Piorkowski, M. D., A. J. Farnsworth, M. Fry, R. W. Rohrbaugh, J. W. Fitzpatrick, and K. V. Rosenberg. 2012. Research priorities for wind energy and migratory wildlife. Journal of Wildlife Management 76:451-456.

Plum Creek Timber Company. 2000. Central Cascades habitat conservation plan. Plum Creek Timber Company, Seattle, Washington.

Podlutsky, A. J., A. M. Khritankov, N. D. Ovodov, and S. N. Austad. 2005. A new field record for bat longevity. Journal of Gerontology: Biological Sciences 60A:1366-1368.

Port Blakely Tree Farms. 1996. Habitat conservation plan for the Robert B. Eddy Tree Farm. Port Blakely Tree Farms, Seattle, Washington.

Prendergast, B. J., D. A. Freeman, I. Zucker, and R. J. Nelson. 2002. Periodic arousal from hibernation is necessary for initiation of immune responses in ground squirrels. American Journal of Physiology - Regulatory Integrative Comparative Physiology 282:R1054-R1062.

Priday, J. and B. Luce. 1999. New distributional records for spotted bat (*Euderma maculatum*) in Wyoming. Great Basin Naturalist 59:97-101.

Puechmaille, S. J., W. F. Frick, T. H. Kunz, P. A. Racey, C. C. Voigt, G. Wibbelt, and E. C. Teeling. 2011. White-nose syndrome: is this emerging disease a threat to European bats? Trends in Ecology and Evolution 26:570-576.

Quinn, M. A. 2004. Influence of habitat fragmentation and crop system on Columbia Basin shrubsteppe communities. Ecological Applications 14:1634-1655.

Rabe, M. J., T. E. Morrell, H. Green, J. C. DeVos, Jr., and C. R. Miller. 1998a. Characteristics of ponderosa pine snag roosts used by reproductive bats in northern Arizona. Journal of Wildlife Management 62:612-621.

Rabe, M. J., M. S. Siders, C. R. Miller, and T. K. Snow. 1998b. Long foraging distance for a spotted bat (*Euderma maculatum*) in northern Arizona. Southwestern Naturalist 43:266-286.

Racey, P. A. 1982. Ecology of bat reproduction. Pages 57-104 *in* T. H. Kunz, editor. Ecology of bats. Plenum Press, New York, New York.

Racey, P. A. and A. C. Entwistle. 2000. Life-history and reproductive strategies of bats. Pages 363-414 *in* E. G. Crichton and P. H. Krutzsch, editors. Reproductive biology of bats. Academic Press, San Diego, California.

Racey, P. A. and S. M. Swift. 1981. Variations in gestation length in a colony of pipistrelle bats (*Pipistrellus pipistrellus*) from year to year. Journal of Reproduction and Fertility 61:123-129.

Rainey, W. E. and E. D. Pierson. 1994. Maternity roosts and geographic scale of foraging activity of *Lasionycteris noctivagans* in northern California forests. Bat Research News 35:111.

Rambaldini, D. A. 2006. Behavioural ecology of pallid bats (Chiroptera: *Antrozous pallidus*) in British Columbia. Final report prepared for Osoyoos Indian Band, British Columbia Ministry of Environment, and Canadian Wildlife Service, Victoria, British Columbia.

Rambaldini, D. A. and R. M. Brigham. 2008. Torpor use by free-ranging pallid bats (*Antrozous pallidus*) at the northern extent of their range. Journal of Mammalogy 89:933-941.

Rambaldini, D. A. and R. M. Brigham. 2011. Pallid bat (*Antrozous pallidus*) foraging over native and vineyard habitats in British Columbia, Canada. Canadian Journal of Zoology 89:816-822.

Rancourt, S. J., M. I. Rule, and M. A. O'Connell. 2005. Maternity roost site selection of long-eared myotis, *Myotis evotis*. Journal of Mammalogy 86:77-84.

Rancourt, S. J., M. I. Rule, and M. A. O'Connell. 2007. Maternity roost site selection of big brown bats in ponderosa pine forests of the Channeled Scablands of northeastern Washington state, USA. Forest Ecology and Management 248:183-192.

Rasheed, S. A., P. F. J. Garcia, and S. L. Holroyd. 1995. Status of the fringed myotis in British Columbia. Wildlife Working Report Number WR-73, British Columbia Ministry of Environment, Lands and Parks, Victoria, British Columbia.

Reeder, D. M., C. L. Frank, G. G. Turner, C. U. Meteyer, A. Kurta, E. R. Britzke, M. E. Vodzak, S. R. Darling, C. W. Stihler, A. C. Hicks, R. Jacob, L. E. Grieneisen, S. A. Brownlee, L. K. Muller, and D. S. Blehert. 2012. Frequent arousal from hibernation linked to severity of infection and mortality in bats with white-nose syndrome. PLoS ONE 7(6):e38920. doi:10.1371/journal.pone.0038920

Reid, A., T. Hill, R. Clarke, J. Gwilliam, and J. Krebs. 2010. Roosting ecology of female Townsend's big-eared bats (*Corynorhinus townsendii*) in south-eastern British Columbia: implications for conservation management. Northwestern Naturalist 91:215-218.

Reimer, J. P., E. F. Baerwald, and R. M. R. Barclay. 2010. Diet of hoary (*Lasiurus cinereus*) and silver-haired (*Lasionycteris noctivagans*) bats while migrating through southwestern Alberta in late summer and autumn. American Midland Naturalist 164:160-167.

Rinne, J. N. 1988. Effects of livestock grazing exclosure on aquatic marcroinvertebrates in a montane stream, New Mexico. Great Basin Naturalist 48:146-153.

Robinson, R. A., H. Q. P. Crick, J. A. Learmonth, I. M. D. Maclean, C. D. Thomas, F. Bairlein, M. C. Forchhammer, C. M. Francis, J. A. Gill, B. J. Godley, J. Harwood, G. C. Hays, B. Huntley, A. M. Hutson, G. J. Pierce, M. M. Rehfisch, D. W. Sims, M. B. Santos, T. H. Sparks, D. A. Strous, and M. E. Visser. 2009. Travelling through a warming world: climate change and migratory species. Endangered Species Research 7:87-99.

Rodhouse, T. J., M. F. McCaffrey, and R. G. Wright. 2005. Distribution, foraging behavior, and capture results of the spotted bat (*Euderma maculatum*) in Oregon. Western North American Naturalist 65:215-222.

Rodhouse, T. J., P. C. Ormsbee, K. M. Irvine, L. A. Vierling, J. M. Szewcsak, and K. T. Vierling. 2012. Assessing the status and trend of bat populations across broad geographic regions with dynamic distribution models. Ecological Applications 22:1098-1113.

Rodhouse, T. J., S. A. Scott, P. C. Ormsbee, and J. M. Zinck. 2008. Field identification of *Myotis yumanensis* and *Myotis lucifugus*: a morphological evaluation. Western North American Naturalist 68:437-443.

Rodhouse, T. J., K. T. Vierling, and K. M. Irvine. 2011. A practical sampling design for acoustic surveys of bats. Journal of Wildlife Management 75:1094-1102.

Rodriguez, R. M. and L. K. Ammerman. 2004. Mitochondrial DNA divergence does not reflect morphological difference between *Myotis californicus* and M*yotis ciliolabrum*. Journal of Mammalogy 85:842-851.

Rogers, D. S., M. C. Belk, M. W. Gonzalez, and B. L. Coleman. 2006. Patterns of habitat use by bats along a riparian corridor in northern Utah. Southwestern Naturalist 51:52-58.

Rollins, K. E., D. K. Meyerholz, G. D. Johnson, A. P. Capparella, and S. S. Loew. 2012. A forensic investigation into the etiology of bat mortality at a wind farm: barotrauma or traumatic injury? Veterinary Pathology 49:362-371.

Rolseth, S. L., C. E. Koehler, and R. M. R. Barclay. 1994. Differences in the diets of juvenile and adult hoary bats, *Lasiurus cinereus*. Journal of Mammalogy 75:394-398.

Rosier, J. R. 2008. Activity of bats in relation to riparian habitat in an arid landscape. Thesis, Utah State University, Logan, Utah.

Rosier, J. and D. Rosenberg. 2006. Role of riparian areas on bat roosting and foraging in an arid landscape. Unpublished report, Utah State University, Logan, Utah.

Rupprecht, C. E., K. Stöhr, and C. Meredith. 2001. Rabies. Pages 313-329 *in* E. S. Williams and I. K. Barker, editors. Infectious diseases of wild mammals. Iowa State University Press, Ames, Iowa.

Sarell, M. J. and K. P. McGuinness. 1993. Rare bats of the shrub-steppe ecosystem of eastern Washington. Unpublished report for the Washington Department of Wildlife, Ophiuchus Consulting, Oliver, British Columbia.

Sarell, M. and D. Rambaldini. 2008. Recovery strategy for the pallid bat (*Antrozous pallidus*) in British Columbia. British Columbia Ministry of Environment, Victoria, British Columbia.

Sarell, M. J., A. Haney, and J. Craig. 1991. First observations of the spotted bat (*Euderma maculatum*) in Washington state. Unpublished report submitted to the Washington Department of Wildlife, Olympia, Washington.

Schamberger, M. L. 1970. Mammals of Mount Rainier National Park. Dissertation, Oregon State University, Corvallis, Oregon.

Scheffer, T. H. 1930. Bat matters. Murrelet 11(2):11-13.

Scheffer, V. B. 1995. Mammals of the Olympic National Park and vicinity. Northwest Fauna 2:5-133.

Schnitzler, H. and E. K. V. Kalko. 1998. How echolocating bats search and find food. Pages 183-196 *in* T. H. Kunz and P. A. Racey, editors. Bat biology and conservation. Smithsonian Institution Press, Washington, D.C.

Schnitzler, H. and E. K. V. Kalko. 2001. Echolocation by insect-eating bats. BioScience 51:557-569.

Schowalter, D. B. 1980. Swarming, reproduction, and early hibernation of *Myotis lucifugus* and *M. volans* in Alberta, Canada. Journal of Mammalogy 61:350-354.

Schowalter, D. B. and J. R. Gunson. 1979. Reproductive biology of the big brown bat (*Eptesicus fuscus*) in Alberta. Canadian Field-Naturalist 93:48-54.

Seidman, V. M. and C. J. Zabel. 2001. Bat activity along intermittent streams in northwestern California. Journal of Mammalogy 82:738-747.

Senger, C. and R. L. Crawford. 1984. Biological inventory, Mt. St. Helens Cave Basalt Flow Area. Unpublished report submitted to Gifford Pinchot National Forest, Vancouver, Washington.

Senger, C., R. Senger, D. Senger, and S. Senger. 1972. Notes on the bat *Plecotus townsendii* in western Washington. Murrelet 53:10-11.

Senger, C., R. Senger, D. Senger, and S. Senger. 1974. Winter records of myotid bats in western Washington. Murrelet 55:13-14.

Shepard, J. P., J. Creighton, and H. Duzan. 2004. Forestry herbicides in the United States: an overview. Wildlife Society Bulletin 32:1020-1027.

Sherwin, R. E. and W. L. Gannon. 2005. Documentation of an urban winter roost of the spotted bat (*Euderma maculatum*). Southwestern Naturalist 50:402-407.

Sherwin, R. E., J. S. Altenbach, and D. L. Waldien. 2009. Managing abandoned mines for bats. Bat Conservation International, Austin, Texas.

Sherwin, R. E., W. L. Gannon, and J. S. Altenbach. 2003. Managing complex systems simply: understanding inherent variation in the use of roosts by Townsend's big-eared bat. Wildlife Society Bulletin 31:62-72.

Sherwin, R. E., D. Stricklan, and D. S. Rogers. 2000. Roosting affinities of Townsend's big-eared bat (*Corynorhinus townsendii*) in northern Utah. Journal of Mammalogy 81:939-947.

Shump, K. A., Jr. and A. U. Shump. 1982a. Lasiurus cinereus. Mammalian Species 185:1-5.

Shump, K. A., Jr. and A. U. Shump. 1982b. Lasiurus borealis. Mammalian Species 183:1-6.

Simmons, N. B. 2005. Order Chiroptera. Pages 312-529 *in* D. E. Wilson and D. M. Reeder, editors. Mammal species of the world: a taxonomic and geographic reference. 3rd edition. Johns Hopkins University Press, Baltimore, Maryland.

Simpson, M. R. 1993. Myotis californicus. Mammalian Species 428:1-4.

Smith, W. B., P. D. Miles, C. H. Perry, and S. A. Pugh. 2009. Forest resources of the United States, 2007. General Technical Report WO-78, USDA Forest Service, Washington, D.C.

Solick, D. I. and R. M. R. Barclay. 2007. Geographic variation in the use of torpor and roosting behaviour of female western long-eared bats. Journal of Zoology, London 272:358-366.

St. Hilaire, J. 2013. Boulder Cave bat survey summary. Okanogan-Wenatchee National Forest, Wenatchee, Washington.

Storz, J. F. 1995. Local distribution and foraging behavior of the spotted bat (*Euderma maculatum*) in northwestern Colorado and adjacent Utah. Great Basin Naturalist 55:78-83.

Storz, J. F. and C. F. Williams. 1996. Summer population structure of subalpine bats in Colorado. Southwestern Naturalist 41:322-324.

Szewczak, J. M., S. M. Szewczak, M. L. Morrison, and L. S. Hall. 1998. Bats of the White and Inyo mountains of California-Nevada. Great Basin Naturalist 58:66-75.

Tait, C. K., J. L. Li, G. A. Lamberti, T. N. Pearsons, and H. W. Li. 1994. Relationships between riparian cover and community structure of high desert streams. Journal of the North American Benthological Society 13:45-56.

Taylor, D. A. R. and M. D. Tuttle. 2012. Water for wildlife:

a handbook for ranchers and range managers. Bat Conservation International, Austin, Texas.

Taylor, J. A. 1999. Roost-site and habitat selection of the long-legged myotis (*Myotis volans*) in a managed landscape of the eastern Cascade Range. Thesis, Michigan State University, East Lansing, Michigan.

Taylor, W. P. and W. T. Shaw. 1927. Mammals and birds of Mount Rainier National Park. National Park Service, Washington D.C.

Taylor, W. P. and W. T. Shaw. 1929. Provisional list of land mammals of the state of Washington. Occasional Papers of the Charles R. Conner Museum 2:1-32.

Thomas, D. W. 1988. The distribution of bats in different ages of Douglas-fir forests. Journal of Wildlife Management 52:619-626.

Thomas, D. W. 1995. Hibernating bats are sensitive to nontactile human disturbance. Journal of Mammalogy 76:940-946.

Thomas, D. W. and S. D. West. 1991. Forest age associations of bats in the southern Washington Cascade and Oregon Coast Ranges. Pages 295-303 *in* Wildlife and vegetation of unmanaged Douglas-fir forests. General Technical Report PNW-GTR-285, Pacific Northwest Research Station, U.S. Forest Service, Portland, Oregon.

Thomas, D. W., M. Dorais, and J.-M. Bergeron. 1990. Winter energy budgets and cost of arousals for hibernating little brown bats, *Myotis lucifugus*. Journal of Mammalogy 71:475-479.

Thomas, D. W., M. B. Fenton, and R. M. R. Barclay. 1979. Social behavior of *Myotis lucifugus*. I. Mating behavior. Behavioral Ecology and Sociobiology 6:129-136.

Threlfall, C. G., B. Law, and P. B. Banks. 2012. Sensitivity of insectivorous bats to urbanization: implications for suburban conservation planning. Biological Conservation 146:41-52.

Turbill, C. and F. Geiser. 2008. Hibernation by tree-roosting bats. Journal of Comparative Physiology B 178:597-605.

Turner, G. G., D. M. Reeder, and T. H. Coleman. 2011. A five-year assessment of mortality and geographic spread of white-nose syndrome in North American bats and a look to the future. Bat Research News 52(Summer):13-27.

Tuttle, M. D. 1976. Population ecology of the grey bat (*Myotis grisescens*): factors influencing growth and survival of newly volant young. Ecology 57:587-595.

Tuttle, M. D. 1979. Status, causes of decline, and management of endangered gray bats. Journal of Wildlife Management 43:1-17.

Tuttle, M. D. and L. R. Heaney. 1974. Maternity habits of *Myotis leibii* in South Dakota. Bulletin of the Southern California Academy of Science 73:80-83.

Tuttle, M. D. and D. Stevenson. 1982. Growth and survival of bats. Pages 105-150 *in* T. H. Kunz, editor. Ecology of bats. Plenum Press, New York, New York.

Tuttle, M. D. and D. A. R. Taylor. 1998. Bats and mines. Resource Publication Number 3, Bat Conservation International, Austin, Texas.

Twente, J. W., Jr. 1955. Some aspects of habitat selection and other behavior of cavern-dwelling bats. Ecology 36:706-732.

USFWS (U.S. Fish and Wildlife Service). 2011. Endangered and threatened wildlife and plants; 90 day finding on a petition to list the eastern small-footed bat and the northern long-eared bat as threatened or endangered. Federal Register 76(125):38095-38106.

Valdez, E. W. and P. M. Cryan. 2009. Food habits of the hoary bat (*Lasiurus cinereus*) during spring migration through New Mexico. Southwestern Naturalist 54:195–200.

van Zyll de Jong, C.G. 1979. Distribution and systematic relationships of long-eared *Myotis* in western Canada. Canadian Journal of Zoology 57:987–994.

van Zyll de Jong, C. G. 1985. Handbook of Canadian mammals. Volume 2. Bats. National Museum of Natural Sciences, Ottawa, Ontario.

van Zyll de Jong, C. G. and D. W. Nagorsen. 1994. A review of the distribution and taxonomy of *Myotis keenii* and *Myotis evotis* in British Columbia and the adjacent United States. Canadian Journal of Zoology 72:1069-1078.

Vander Haegen, W. M., F. C. Dobler, and D. J. Pierce. 2000. Shrubsteppe bird response to habitat and landscape variables in eastern Washington, USA. Conservation Biology 14:1145-1160.

Vander Haegen, W. M., S. M. McCorquodale, C. R. Peterson, G. A. Green, and E. Yensen. 2001. Wildlife of eastside shrubland and grassland habitats. Pages 292-316 *in* D. H. Johnson and T. A. O'Neil, managing editors. Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis, Oregon.

Vaughan, T. A. and P. H. Krutzsch. 1954. Seasonal distribution of the hoary bat in southern California. Journal of Mammalogy 35:431-432.

Vaughan, T. A. and T. J. O'Shea. 1976. Roosting ecology of the pallid bat, *Antrozous pallidus*. Journal of Mammalogy 57:19-42.

Veilleux, J. P. 2008. Current status of white-nose syndrome in the northeastern United States. Bat Research News 49:15-17.

Veilleux, J. P. and S. L. Veilleux. 2004. Intra-annual and interannual fidelity to summer roost areas by female eastern pipistrelles, *Pipistrellus subflavus*. American Midland Naturalist 152:196-200.

Veilleux, J. P., P. R. Moosman, Jr., D. S. Reynolds, K. E. LaGory, and L. J. Walston, Jr. 2009. Observations of summer roosting and foraging behavior of a hoary bat (*Lasiurus cinereus*) in southern New Hampshire. Northeastern Naturalist 16:148-152.

Verant, M. L., J. G. Boyles, W. Waldrep, Jr., G. Wibbelt, and D. S. Blehert. 2012. Temperature-dependent growth of *Geomyces destructans*, the fungus that causes bat white-nose syndrome. PLoS ONE 7(9):e46280. doi:10.1371/journal.pone.0046280

Verts, B. J. and L. N. Carraway. 1998. Land mammals of Oregon. University of California Press, Los Angeles, California.

Verts, B. J. L. N. Carraway, and J. O. Whitaker, Jr. 1999. Temporal variation in prey consumed by big brown bats (*Eptesicus fuscus*) in a maternity colony. Northwest Science 73:114-120.

Vonhof, M. J. 1996. Roost-site preferences of big-brown bats (*Eptesicus fuscus*) and silver-haired bats (*Lasionycteris noctivagans*) in the Pend d'Oreille Valley in southern

British Columbia. Pages 62-80 *in* R. M. R. Barclay and R. M. Brigham, editors. Bats and forests symposium. Working Paper 23/1996, Research Branch, British Columbia Ministry of Forests, Victoria, British Columbia.

Vonhof, M. J. and R. M. R. Barclay. 1996. Roost-site selection and roosting ecology of forest-dwelling bats in southern British Columbia. Canadian Journal of Zoology 74:1797-1805.

Vonhof, M. J. and R. M. R. Barclay. 1997. Use of tree stumps as roosts by the western long-eared bat. Journal of Wildlife Management 61:674-684.

Vonhof, M. J. and J. C. Gwilliam. 2007. Intra- and interspecific patterns of day roost selection by three species of forest-dwelling bats in southern British Columbia. Forest Ecology and Management 252:165-175.

Wagner, D. L., J. W. Peacock, J. L. Carter, and S. E. Talley. 1996. Field assessment of *Bacillus thuringiensis* on nontarget Lepidoptera. Environmental Entomology 25:1444-1454.

Wagner, R. G., M. Newton, E. C. Cole, J. H. Miller, and B. D. Shiver. 2004. The role of herbicides for enhancing forest productivity and conserving land for biodiversity in North America. Wildlife Society Bulletin 32:1028-1041.

Wai-Ping, V. and M. B. Fenton. 1988. Nonselective mating in little brown bats (*Myotis lucifugus*). Journal of Mammalogy 69:641-645.

Wai-Ping, V. and M. B. Fenton. 1989. Ecology of spotted bat (*Euderma maculatum*) roosting and foraging behavior. Journal of Mammalogy 70:617-622.

Waldien, D. L. and J. P. Hayes. 2001. Activity areas of female long-eared myotis in coniferous forests in western Oregon. Northwest Science 75:307-314.

Waldien, D. L., J. P. Hayes, and E. B. Arnett. 2000. Day-roosts of female long-eared myotis in western Oregon. Journal of Wildlife Management 64:785-796.

Waldien, D. L., J. P. Hayes, and B. E. Wright. 2003. Use of conifer stumps in clearcuts by bats and other vertebrates. Northwest Science 77:64-71.

Walsh, A. L. and P. A. Morton. 2009. Methods to promote bat conservation, outreach, and education through science- and research-based activities. Pages 868-885 *in* T. H. Kunz and S. Parsons, editors. Ecological and behavioral methods for the study of bats. Johns Hopkins University Press, Baltimore, Maryland.

Warner, R. M. 1985. Interspecific and temporal dietary variation in an Arizona bat community. Journal of Mammalogy 66:45-51.

Warner, R. M. and N. J. Czaplewski. 1984. Myotis volans. Mammalian Species 224:1-4.

Watkins, L. C. 1977. Euderma maculatum. Mammalian Species 77:1-4.

WBWG (Western Bat Working Group). 2005. Species accounts. Western Bat Working Group, Rapid City, South Dakota. <http://www.wbwg.org/speciesinfo/species_accounts/species_accounts.html>

WBWG (Western Bat Working Group). 2008. About the Western Bat Working Group. Western Bat Working Group, Rapid City, South Dakota. <http://wbwg.org/aboutus/aboutus.html>

WDFW (Washington Department of Fish and Wildlife). 1994. Priority habitat management recommendations: caves. Washington Department of Fish and Wildlife, Olympia, Washington.

WDFW (Washington Department of Fish and Wildlife). 2005. Washington's Comprehensive Wildlife Conservation Strategy. Washington Department of Fish and Wildlife, Olympia, Washington.

WDFW (Washington Department of Fish and Wildlife). 2009. Wind power guidelines. Washington Department of Fish and Wildlife, Olympia, Washington.

WDNR (Washington Department of Natural Resources). 1997. Final habitat conservation plan. Washington Department of Natural Resources, Olympia, Washington.

Webb, P. I., J. R. Speakman, and P. A. Racey. 1996. How hot is a hibernaculum? A review of the temperatures at which bats hibernate. Canadian Journal of Zoology 74:761-765.

Weller, T. J. 2007. Assessing population status of bats in forests: challenges and opportunities. Pages 263-291 *in* M. J. Lacki, J. P. Hayes, and A. Kurta, editors. Bats in forests: conservation and management. Johns Hopkins University Press, Baltimore, Maryland.

Weller, T. J. 2008. Using occupancy estimation to assess the effectiveness of a regional multiple-species conservation plan: bats in the Pacific Northwest. Biological Conservation 141:2279-2289.

Weller, T. J. and J. A. Baldwin. 2012. Using echolocation monitoring to model bat occupancy and inform mitigations at wind energy facilities. Journal of Wildlife Management 76:619-631.

Weller, T. J. and C. J. Zabel. 2001. Characteristics of fringed myotis day roosts in northern California. Journal of Wildlife Management 65:489-497.

Weller, T. J., P. M. Cryan, and T. J. O'Shea. 2009. Broadening the focus of bat conservation and research in the USA for the 21st century. Endangered Species Research 8:129-145.

Weller, T. J., S. A. Scott, T. J. Rodhouse, P. C. Ormsbee, and J. M. Zinck. 2007. Field identification of the cryptic vespertilionid bats, *Myotis lucifugus* and *M. yumanensis*. Acta Chiropterologica 9:133-147.

West, S. D., P. Adam, E. M. Bickford, and M. L. Noe. 2004. Bat inventory in Olympic National Park. College of Forest Resources, University of Washington, Seattle, Washington.

West, S. D., K. B. Aubry, and E. Dinerstein. 1984. Old-growth forest community pilot study: mammals. College of Forest Resources, University of Washington, Seattle, Washington.

West, W. J., J. G. Lucas, and K. A. Gano. 2011. 2011 river corridor closure contractor revegetation and mitigation monitoring report. WCH-512, Washington Closure Hanford, Richland, Washington.

Whaley, W. H., J. Anhold, and G. B. Schaalje. 1998. Canyon drift and dispersion of *Bacillus thuringiensis* and its effects on select nontarget Lepidoptera in Utah. Environmental Entomology 27:539-548.

Whitaker, J. O., Jr. 1995. Food of the big brown bat *Eptesicus fuscus* from maternity colonies in Indiana and Illinois. American Midland Naturalist 134:346-360.

Whitaker, J. O., Jr. and S. L. Gummer. 1992. Hibernation of the big brown bat, *Eptesicus fuscus*, in buildings. Journal of Mammalogy 73:312-316.

Whitaker, J. O., Jr. and S. L. Gummer. 2000. Population structure and dynamics of big brown bats (*Eptesicus fuscus*) hibernating in buildings in Indiana. American Midland Naturalist 143:389-396.

Whitaker, J. O., Jr. and B. Lawhead. 1991. Foods of *Myotis lucifugus* in a maternity colony in central Alaska. Journal of Mammalogy 73:646-648.

Whitaker, J. O., Jr., C. Maser, and S. P. Cross. 1981a. Food habits of eastern Oregon bats, based on stomach and scat analysis. Northwest Science 55:281-292.

Whitaker, J. O., Jr., C. Maser, and S. P. Cross. 1981b. Foods of Oregon silver-haired bats, *Lasionycteris noctivagans*. Northwest Science 55:75-77.

Whitaker, J. O., Jr., C. Maser, and L. E. Keller. 1977. Food habits of bats of western Oregon. Northwest Science 51:46-55.

Wibbelt, G., A. Kurth, D. Hellmann, M. Weishaar, A. Barlow, M. Veith, J. Prüger, T. Görföl, L. Grosche, F. Bontadina, U. Zöphel, H. Seidl, P. M. Cryan, and D. S. Blehert. 2010. White-nose syndrome fungus (*Geomyces destructans*) in bats, Europe. Emerging Infectious Diseases 16:1237-1242.

Wigley, T. B., D. A. Miller, and G. K. Yarrow. 2007. Planning for bats on forest industry lands in North America. Pages 293-318 *in* M. J. Lacki, J. P. Hayes, and A. Kurta, editors. Bats in forests: conservation and management. Johns Hopkins University Press, Baltimore, Maryland.

Wiles, G. J., H. L. Allen, and G. E. Hayes. 2011. Wolf conservation and management plan for Washington. Washington Department of Fish and Wildlife, Olympia, Washington.

Wilhere, G. F. 2003. Simulations of snag dynamics in an industrial Douglas-fir forest. Forest Ecology and Management 174:521-539.

Wilkinson, G. S. and J. M. South. 2002. Life history, ecology and longevity in bats. Aging Cell 1:124-131.

Wilkinson, L. C. and R. M. R. Barclay. 1997. Differences in the foraging behaviour of male and female big brown bats (*Eptesicus fuscus*) during the reproductive period. Ecoscience 4:279-285.

Williams, D. F. 1968. A new record of *Myotis thysanodes* from Washington. Murrelet 49:26-27.

Williams, L. M. and M. C. Brittingham. 1997. Selection of maternity roosts by big brown bats. Journal of Wildlife Management 61:359-368.

Willis, C. K. R. 2006. Daily heterothermy by temperate bats using natural roosts. Pages 38-55 *in* A. Zubaid, G. F. McCracken, and T. H. Kunz, editors. Function and evolutionary ecology of bats. Oxford University Press, New York, New York.

Willis, C. K. R. and M. L. Bast. 2000. COSEWIC assessment and update status report on the pallid bat *Antrozous pallidus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario.

Willis, C. K. R. and R. M. Brigham. 2004. Roost switching, roost sharing and social cohesion: forest-dwelling big brown bats, *Eptesicus fuscus*, conform to the fission-fusion model. Animal Behaviour 68:495-505.

Willis, C. K. R. and R. M. Brigham. 2005. Physiological and ecological aspects of roost selection by reproductive female hoary bats (*Lasiurus cinereus*). Journal of Mammalogy 86:85-94.

Willis, C. K. R., R. M. Brigham, and F. Geiser. 2006b. Deep, prolonged torpor by pregnant, free-ranging bats. Naturwissenschaften 93:80-83.

Willis, C. K. R., A. K. Menzies, J. G. Boyles, and M. S. Wojciechowski. 2011. Evaporative water loss is a plausible explanation for mortality of bats from white-nose syndrome. Integrative and Comparative Biology 10.1093.icb/icr076.

Willis, C. K. R., C. M. Voss, and R. M. Brigham. 2006a. Roost selection by forest-living female big brown bats (*Eptesicus fuscus*). Journal of Mammalogy 87:345-350.

Wilson, D. E. and S. Ruff. 1999. The Smithsonian book of North American mammals. Smithsonian Institution Press, Washington, D.C.

Wimsatt, W. A. 1944. Further studies on the survival of spermatozoa in the female reproductive tract of the bat. Anatomical Record 88:193-204.

Wisniewski, J., R. S. Finger, and B. Hoenes. 2010. Odessa subarea special study: wildlife survey final report. Washington Department of Fish and Wildlife, Ephrata, Washington.

Woodruff, K. 1999. Townsend's big-eared bat conservation project – interim report. Unpublished report, Methow Valley Ranger District, U.S. Forest Service, Winthrop, Washington.

Woodruff, K. 2000. Townsend's big-eared bat conservation project – interim report. Field season 2000. Unpublished report, Methow Valley Ranger District, U.S. Forest Service, Winthrop, Washington.

Woodruff, K. and H. Ferguson. 2005. Townsend's big-eared bat, *Corynorhinus townsendii*. *In* J. M. Azerrad, editor. Management recommendations for Washington's priority species. Volume V: mammals. Washington Department of Fish and Wildlife, Olympia, Washington. <http://wdfw.wa.gov/publications/00027/>

Woodsworth, G. C. 1981. Spatial partitioning by two species of sympatric bats, *Myotis californicus* and *Myotis leibii.* Thesis, Carleton University, Ottawa, Ontario.

Woodsworth, G. C., G. P. Bell, and M. B. Fenton. 1981. Observations of the echolocation, feeding behaviour, and habitat use of *Euderma maculatum* (Chiroptera: Vespertilionidae) in southcentral British Columbia. Canadian Journal of Zoology 59:1099-1102.

WSDH (Washington State Department of Health). 2007. Rabies. Washington State Department of Health, Olympia, Washington. <http://www.doh.wa.gov/YouandYourFamily/IllnessandDisease/Rabies.aspx>

Wunder, L. and A. B. Carey. 1996. Use of forest canopy by bats. Northwest Science 70:79-85.

Wunder, L., W. Kerschke, L. Olson, and A. B. Carey. 1992. Distribution, ecology and relative abundance of bats on Fort Lewis, Washington. Unpublished report, Pacific Northwest Research Station, USDA Forest Service, Olympia, Washington.

Zimmerman, R. 2009. Biologists struggle to solve bat deaths. Science 324:1134-1135.

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GLOSSARY OF TERMS

Acoustic survey – a method of surveying bats by recording, analyzing, and identifying their echolocation calls.

Ambient temperature – the temperature of the surrounding air.

Aspect ratio – in aerodynamics, the length of the wingspan squared divided by the surface area of the wing. Bats with lower aspect ratios and wing loading usually exhibit slower flight and greater maneuverability, whereas those with higher aspect ratios and wing loading usually have faster flight and less maneuverability.

Calcar – a cartilaginous structure attached to the ankle bone that extends into and helps support the wing membrane. Some species have a flap of skin on their calcar, which is referred to as a keel.

Clutter – obstacles in the environment that interfere with the use of echolocation, flying, and foraging by bats. These objects include branches, twigs, and foliage.

Conspecific – Of or belonging to the same species. Also, individuals of the same species.

Daily torpor – the use of torpor for short periods (i.e., hours), often on a daily basis, during the active season.

Dorsal – the upper side or back of an animal.

Echolocation – the use of vocalizations and their returning echoes to orient and navigate in the environment and to capture prey.

Flight membrane – a combination of the wing and tail membranes of a bat.

Glean – a foraging method in which prey are captured from a surface.

Guano – the droppings or excrement of bats.

Hibernaculum – a roost occupied by hibernating bats (plural is hibernacula).

Hibernation – the use of torpor for prolonged periods (i.e., multiple days or weeks) that are interrupted by brief periodic arousals. In bats, hibernation occurs during the colder months of the year.

Insectivorous – having a diet comprised of insects, although spiders and other arthropods are sometimes also eaten.

Interim roost – a day roost that is temporarily occupied in spring or fall as bats move between summer roosts and hibernacula.

Maternity (nursery) colony – an aggregation of females that are either pregnant or rearing their young. In bats, small numbers of males or nonreproductive females are sometimes present as well.

Maternity (nursery) roost – a roost site used by either pregnant females or females rearing their young.

Microchiropteran – bats belonging to the suborder Microchiroptera, which comprises the majority of bat species in the world. Microchiropterans are able to echolocate and most are predominantly insectivorous, although some species also feed on fruit, flowers, small vertebrates, or blood.

Pelage – the fur of a mammal.

Swarming – a behavior in which male and female bats interact with one another in and around the entrances of hibernacula or other roosts from late summer to fall. The behavior involves calling, chasing, and mating.

Tail membrane – the skin extending between the legs of a bat. In many species, the tail is enclosed within the tail membrane.

Thermoregulation – the ability to regulate body temperature either internally or externally.

Tibia – the inner and usually larger of the two bones between the knee and ankle.

Torpor – a physiological process in which some animals are able to greatly reduce their body temperature, metabolic rate, and other body functions, allowing them to become inactive during periods of harsh weather and/or food shortage. This allows the animal to conserve energy and water. There are two types of torpor: hibernation and daily torpor.

Tragus – a thin cartilaginous structure found at the base of a bat's ear.

Transient roost – a day roost that is temporarily occupied in spring or fall as bats move between summer roosts and hibernacula.

Volant – having the ability to fly.

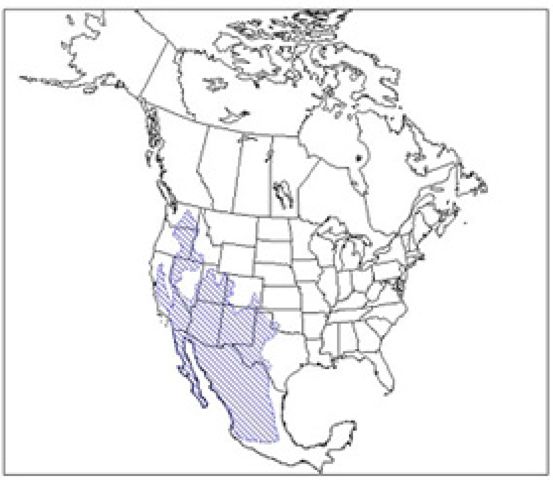
Wing loading – in aerodynamics, the weight of a flying animal or object divided by its total wing area. Bats with lower wing loading and aspect ratios usually exhibit slower flight and greater maneuverability, whereas those with higher wing loading and aspect ratios usually have faster flight and less maneuverability.

Wing membrane – the skin comprising a bat's wings.

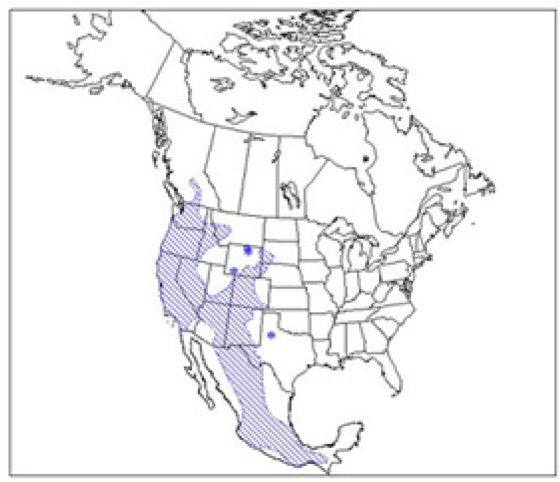
Appendix A. North American range maps for bat species that occur in Washington (source: Bat Conservation International, www.batcon.org).

Range of the big brown bat[a]

Range of the California myotis



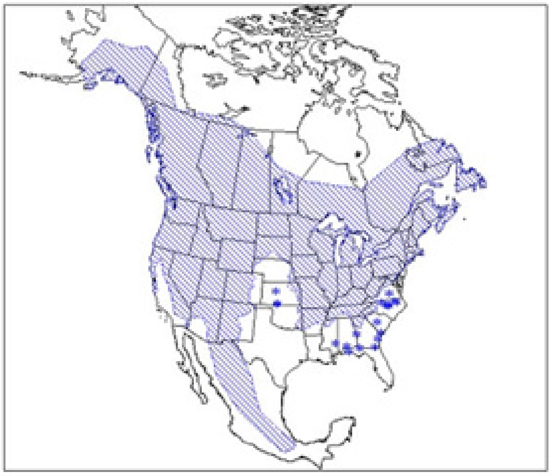
Range of the canyon bat



Range of the fringed myotis[a]

Range of the hoary bat[a]

Range of Keen's myotis

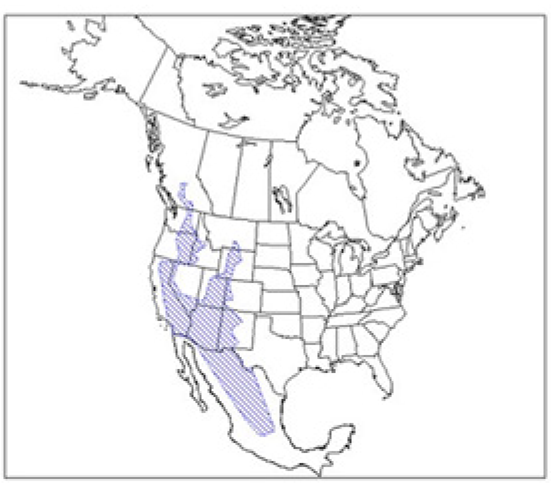


Range of the little brown myotis

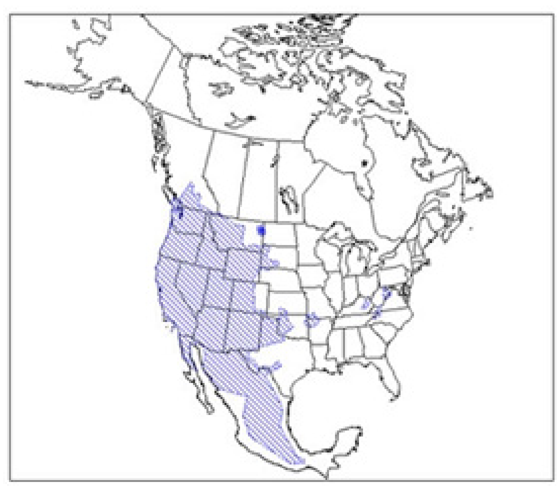
Range of the long-legged myotis[a]

Range of the pallid bat

Range of the silver-haired bat

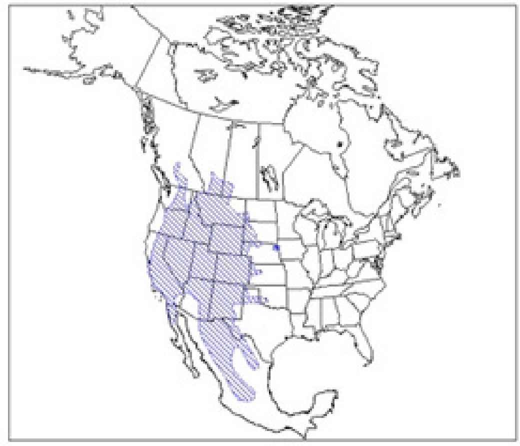


Range of the spotted bat



Range of Townsend's big-eared[a]

Range of the long-eared myotis

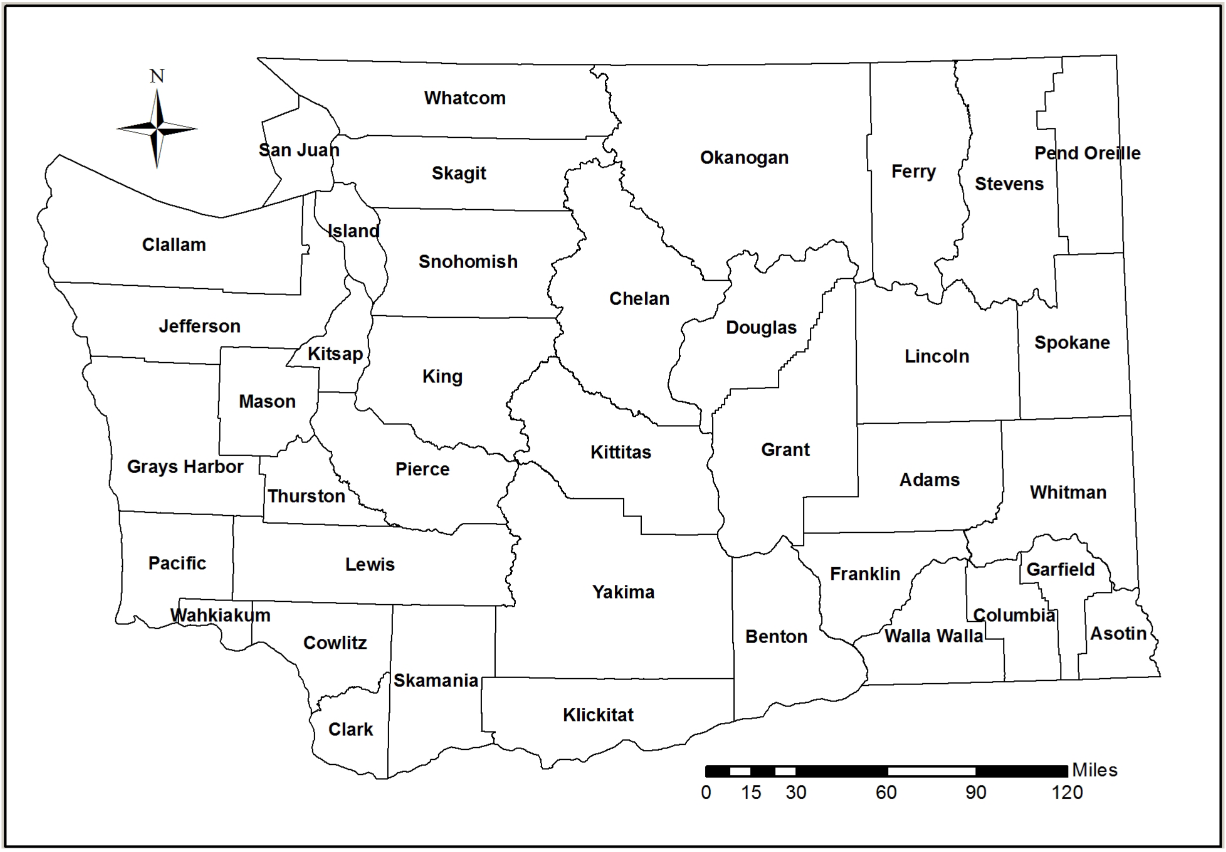


Range of the western small-footed myotis

Range of the Yuma myotis[a]

[a]Six species are known to have geographic ranges extending farther north than indicated in these maps, as follows: (1) big brown bats occur more widely in Alberta and Saskatchewan, (2) fringed myotis have a somewhat larger distribution in southern British Columbia, (3) hoary bats extend into southeast Alaska and the Yukon, (4) long-legged myotis reach southwestern Northwest Territories and northeastern British Columbia, (5) Townsend's big-eared bats are present in North Dakota, and (6) Yuma myotis extend into southeast Alaska (C. Lausen, pers. comm.).

Appendix B. Washington's 39 counties.



Appendix C. Washington Administrative Code 232-12-011, Revised Code of Washington 77.15.130, and WDFW Policy 5301.

WAC 232-12-011 Wildlife classified as protected shall not be hunted or fished.

Protected wildlife are designated into three subcategories: threatened, sensitive, and other.

(1) Threatened species are any wildlife species native to the state of Washington that are likely to become endangered within the foreseeable future throughout a significant portion of their range within the state without cooperative management or removal of threats. Protected wildlife designated as threatened include:

Common Name	Scientific Name
Mazama pocket gopher	*Thomomys mazama*
western gray squirrel	*Sciurus griseus*
Steller (northern) sea lion	*Eumetopias jubatus*
North American lynx	*Lynx canadensis*
ferruginous hawk	*Buteo regalis*
marbled murrelet	*Brachyramphus marmoratus*
green sea turtle	*Chelonia mydas*
loggerhead sea turtle	*Caretta caretta*
greater sage-grouse	*Centrocercus urophasianus*
sharp-tailed grouse	*Phasianus columbianus*

(2) Sensitive species are any wildlife species native to the state of Washington that are vulnerable or declining and are likely to become endangered or threatened in a significant portion of their range within the state without cooperative management or removal of threats. Protected wildlife designated as sensitive include:

Common Name	Scientific Name
gray whale	*Eschrichtius gibbosus*
common Loon	*Gavia immer*
peregrine falcon	*Falco peregrinus*
bald eagle	*Haliaeetus leucocephalus*
Larch Mountain salamander	*Plethodon larselli*
pygmy whitefish	*Prosopium coulteri*
margined sculpin	*Cottus marginatus*
Olympic mudminnow	*Novumbra hubbsi*

(3) Other protected wildlife include:

Common Name	Scientific Name
cony or pika	*Ochotona princeps*
least chipmunk	*Tamius minimus*
yellow-pine chipmunk	*Tamius amoenus*
Townsend’s chipmunk	*Tamius townsendii*
red-tailed chipmunk	*Tamius ruficaudus*
hoary marmot	*Marmota caligata*
Olympic marmot	*Marmota olympus*
Cascade golden-mantled ground squirrel	*Spermophilus saturatus*
golden-mantled ground squirrel	*Spermophilus lateralis*
Washington ground squirrel	*Spermophilus washingtoni*
red squirrel	*Tamiasciurus hudsonicus*
Douglas squirrel	*Tamiasciurus douglasii*
northern flying squirrel	*Glaucomys sabrinus*
Wolverine	*Gulo gulo*
painted turtle	*Chrysemys picta*
California mountain kingsnake	*Lampropeltis zonata*

All birds not classified as game birds, predatory birds or endangered species, or designated as threatened species or sensitive species; all bats, except when found in or immediately adjacent to a dwelling or other occupied building;

mammals of the order Cetacea, including whales, porpoises, and mammals of the order Pinnipedia not otherwise classified as endangered species, or designated as threatened species or sensitive species. This section shall not apply to hair seals and sea lions which are threatening to damage or are damaging commercial fishing gear being utilized in a lawful manner or when said mammals are damaging or threatening to damage commercial fish being lawfully taken with commercial gear.

[Statutory Authority: RCW 77.12.047, 77.12.020. 08-03-068 (Order 08-09), § 232-12-011, filed 1/14/08, effective 2/14/08; 06-04-066 (Order 06-09), § 232-12-011, filed 1/30/06, effective 3/2/06. Statutory Authority: RCW 77.12.047, 77.12.655, 77.12.020. 02-11-069 (Order 02-98), § 232-12-011, filed 5/10/02, effective 6/10/02. Statutory Authority: RCW 77.12.047. 02-08-048 (Order 02-53), § 232-12-011, filed 3/29/02, effective 5/1/02; 00-17-106 (Order 00-149), § 232-12-011, filed 8/16/00, effective 9/16/00. Statutory Authority: RCW 77.12.040, 77.12.010, 77.12.020, 77.12.770. 00-10-001 (Order 00-47), § 232-12-011, filed 4/19/00, effective 5/20/00. Statutory Authority: RCW 77.12.040, 77.12.010, 77.12.020, 77.12.770, 77.12.780. 00-04-017 (Order 00-05), § 232-12-011, filed 1/24/00, effective 2/24/00. Statutory Authority: RCW 77.12.020. 98-23-013 (Order 98-232), § 232-12-011, filed 11/6/98, effective 12/7/98. Statutory Authority: RCW 77.12.040. 98-10-021 (Order 98-71), § 232-12-011, filed 4/22/98, effective 5/23/98. Statutory Authority: RCW 77.12.040 and 75.08.080. 98-06-031, § 232-12-011, filed 2/26/98, effective 5/1/98. Statutory Authority: RCW 77.12.020. 97-18-019 (Order 97-167), § 232-12-011, filed 8/25/97, effective 9/25/97. Statutory Authority: RCW 77.12.040, 77.12.020, 77.12.030 and 77.32.220. 97-12-048, § 232-12-011, filed 6/2/97, effective 7/3/97. Statutory Authority: RCW 77.12.020. 93-21-027 (Order 615), § 232-12-011, filed 10/14/93, effective 11/14/93; 90-11-065 (Order 441), § 232-12-011, filed 5/15/90, effective 6/15/90. Statutory Authority: RCW 77.12.040. 89-11-061 (Order 392), § 232-12-011, filed 5/18/89; 82-19-026 (Order 192), § 232-12-011, filed 9/9/82; 81-22-002 (Order 174), § 232-12-011, filed 10/22/81; 81-12-029 (Order 165), § 232-12-011, filed 6/1/81.]

RCW 77.15.130 Protected fish or wildlife — Unlawful taking — Penalty — Criminal wildlife penalty assessment.

(1) A person is guilty of unlawful taking of protected fish or wildlife if:

(a) The person hunts, fishes, possesses, or maliciously kills protected fish or wildlife, or the person possesses or maliciously destroys the eggs or nests of protected fish or wildlife, and the taking has not been authorized by rule of the commission; or

(b) The person violates any rule of the commission regarding the taking, harming, harassment, possession, or transport of protected fish or wildlife.

(2) Unlawful taking of protected fish or wildlife is a misdemeanor.

(3) In addition to the penalties set forth in subsection (2) of this section, if a person is convicted of violating this section and the violation results in the death of protected wildlife listed in this subsection, the court shall require payment of the following amounts for each animal killed or possessed. This is a criminal wildlife penalty assessment that must be paid to the clerk of the court and distributed each month to the state treasurer for deposit in the fish and wildlife enforcement reward account created in RCW 77.15.425:

(a) Ferruginous hawk, two thousand dollars;
(b) Common loon, two thousand dollars;
(c) Bald eagle, two thousand dollars;
(d) Golden eagle, two thousand dollars; and
(e) Peregrine falcon, two thousand dollars.

(4) If two or more persons are convicted under subsection (1) of this section, and subsection (3) of this section is applicable, the criminal wildlife penalty assessment must be imposed against the persons jointly and separately.

(5)(a) The criminal wildlife penalty assessment under subsection (3) of this section must be imposed regardless of and in addition to any sentence, fines, or costs otherwise provided for violating any provision of this section. The criminal wildlife penalty assessment must be included by the court in any pronouncement of sentence and may not be suspended, waived, modified, or deferred in any respect.

(b) This subsection may not be construed to abridge or alter alternative rights of action or remedies in equity or under common law or statutory law, criminal or civil.

(6) A defaulted criminal wildlife penalty assessment authorized under subsection (3) of this section may be collected by any means authorized by law for the enforcement of orders of the court or collection of a fine or costs, including but not limited to vacation of a deferral of sentencing or vacation of a suspension of sentence.

(7) The department shall revoke the hunting license and suspend the hunting privileges of a person assessed a criminal wildlife penalty assessment under this section until the penalty assessment is paid through the registry of the court in which the penalty assessment was assessed.

(8) The criminal wildlife penalty assessments provided in subsection (3) of this section must be doubled in the following instances:

(a) When a person commits a violation that requires payment of a criminal wildlife penalty assessment within five years of a prior gross misdemeanor or felony conviction under this title; or

(b) When the person killed the protected wildlife in question with the intent of bartering, selling, or otherwise deriving economic profit from the wildlife or wildlife parts.
[2012 c 176 § 14; 1998 c 190 § 14.]

POL-5301 DESIGNATING STATE CANDIDATE SPECIES

This policy applies to all WDFW employees and volunteers. However, if policies or procedures are in conflict with or are modified by a bargaining unit agreement, the agreement language shall prevail.

Definitions:
State Candidate Species: Species that WDFW reviews for possible listing as state endangered, threatened, or sensitive.

1. Species are Considered for Designation as State Candidate if Specific Criteria are Met

A species will be considered for designation as a State Candidate species if sufficient evidence suggests that its status may meet the listing criteria defined for State Endangered, Threatened, or Sensitive in WAC 232-12-297, Section 3.3: “When populations are in danger of failing, declining, or are vulnerable, due to factors including, but not restricted to, limited numbers, disease, predation, exploitation, or habitat loss or change.”

2. State Candidate Species are Also Included as Priority Species and are Incorporated into WDFW’s Priority Habitats and Species (PHS) Program, Per PHS Criteria

3. State Candidate Species Shall be Managed by the WDFW as Needed to Help Ensure the Long-Term Survival of Populations in Washington

4. The List of State Candidate Species is Reviewed Annually

The list of state candidate species will change with new status conditions of species’ populations. The state candidate species list may be revised annually to reflect these changes (see PRO-5301).

5. The Wildlife Program Maintains the List of State Candidate Fish, Wildlife, and Shellfish Species.

The Endangered Species Section of the Wildlife Program is responsible for maintaining the candidate species list and system for annual review.

Appendix D. Locations and numbers of bat specimens from Washington held in museums. Records were primarily found through a search of the MaNIS database (http://manisnet.org) on 21 January 2010.

Museum	No. of Specimens
Burke Museum of Natural History and Culture, University of Washington, Seattle, Washington	1,033
Slater Museum of Natural History, University of Puget Sound, Tacoma, Washington	265
National Museum of Natural History, Washington, D.C.	181
Museum of Vertebrate Zoology, University of California, Berkeley, California	166
Charles R. Conner Museum, Washington State University, Pullman, Washington	148
American Museum of Natural History, New York, New York	108
Natural History Museum, University of Kansas, Lawrence, Kansas	98
Museum of Zoology, University of Michigan, Ann Arbor, Michigan	58
Donald R. Dickey Collection of Birds and Mammals, University of California at Los Angeles, Los Angeles, California	23
Museum of Southwestern Biology, University of New Mexico, Albuquerque, New Mexico	21
Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts	12
Natural History Museum of Los Angeles County, Los Angeles, California	9
Michigan State University Museum, East Lansing, Michigan	6
California Academy of Sciences, San Francisco, California	4
Louisiana State University Museum of Natural Science, Baton Rouge, Louisiana	2
Sternberg Museum of Natural History, Fort Hays State University, Hays, Kansas	2
University of Alaska Museum of the North, Fairbanks, Alaska	1
Total	**2,137**

Washington State Status Reports and Recovery Plans

Status Reports

2007	Bald Eagle	√
2005	Mazama Pocket Gopher, Streaked Horned Lark, Taylor's Checkerspot	√
2005	Aleutian Canada Goose	√
2004	Killer Whale	√
2002	Peregrine Falcon	√
2001	Bald Eagle	√
2000	Common Loon	√
1999	Northern Leopard Frog	√
1999	Olympic Mudminnow	√
1999	Mardon Skipper	√
1999	Lynx Update	
1998	Fisher	√
1998	Margined Sculpin	√
1998	Pygmy Whitefish	√
1998	Sharp-tailed Grouse	√
1998	Sage-grouse	√
1997	Aleutian Canada Goose	√
1997	Gray Whale	√
1997	Olive Ridley Sea Turtle	√
1997	Oregon Spotted Frog	√
1993	Larch Mountain Salamander	
1993	Lynx	
1993	Marbled Murrelet	
1993	Oregon Silverspot Butterfly	
1993	Pygmy Rabbit	
1993	Steller Sea Lion	
1993	Western Gray Squirrel	
1993	Western Pond Turtle	

Recovery Plans

2012	Columbian Sharp-tailed Grouse	√
2011	Gray Wolf	√
2007	Western Gray Squirrel	√
2004	Greater Sage-Grouse	√
2003	Pygmy Rabbit: Addendum	√
2002	Sandhill Crane	√
2004	Sea Otter	√
2001	Pygmy Rabbit: Addendum	√
2001	Lynx	√
1999	Western Pond Turtle	√
1996	Ferruginous Hawk	√
1995	Pygmy Rabbit	√
1995	Upland Sandpiper	
1995	Snowy Plover	

Conservation and Management Plans

2013	Bats	√

√: These reports are available in pdf format on the Department of Fish and Wildlife's web site:
http://wdfw.wa.gov/wlm/diversty/soc/concern.htm. or
http://wdfw.wa.gov/wlm/diversty/soc/concern.htm