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Biology and Management of Old-Growth Forests

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Biology of Bats in Douglas-Fir Forests

Robin E. Christy and Stephen D. West

Abstract

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Twelve species of bats occur in Douglas-fir forests of the Pacific Northwest, of which nine are known to roost in tree cavities, bark crevices, or foliage, and several are closely associated with old-growth forests. Thus bat populations may be detrimentally affected by forest management practices involving the removal of large, old trees and snags. We review the life history characteristics and habitat relations of bats in the Pacific Northwest and provide information useful in managing forests for the persistence of native bat populations.

Keywords: Bats, Pacific Northwest, natural history, old-growth forests.

Preface

Information about old-growth Douglas-fir forests and the wildlife species associated with them is critical to forest managers in the Pacific Northwest. Management of these forests has become a major public policy issue. Extremely high levels of concern have been expressed for a broad variety of values associated with old-growth forests, including ecological, social, and religious values as well as commodity values derived from timber production. Forest managers are faced with a need to devise balanced strategies that retain all these values at levels acceptable to the public and consistent with the National Forest Management Act.

Forest acreage in an "old-growth" stage of development has declined rapidly in the Pacific Northwest since the 1950s. This has caused increasing concern about species' associations with old forests and maintenance of viable populations for the most closely associated species. Decisionmakers need to know which species show strong associations with old-growth forests and to understand the ecological requirements of those species. Methods and tools are needed to effectively manage and monitor these species and their habitat.

The purpose of this series of publications on the "Biology and Management of Old-Growth Forests" is to summarize the life history characteristics and habitat relations of species showing strong associations with old-growth forests in Washington, Oregon, and northern California, and to suggest options for their management. University and Federal scientists who collaborated in the USDA Forest Service, Pacific Northwest Research Station, old-growth research program have produced a comprehensive list of associated species. Their technical research results were presented at a symposium in March 1989 in Portland, OR, and published in a book, "Wildlife and Vegetation of Unmanaged Douglas-Fir Forests." We offer this series of management publications as a sequel to that research and to address other issues related to the management of late seral ecosystems. The series is funded by the Wildlife Habitat Relationships Program, Pacific Northwest Region, USDA Forest Service. The goal is to provide timely information to managers so they can make well-informed decisions about the management of old-growth forests.

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Introduction

As a group, bats have unique adaptations and occupy a specialized niche. They are the only mammals capable of true flight and have developed echolocation to a remarkable degree, capabilities making them the preeminent foragers of nocturnal flying insects. Bats belong to the order Chiroptera, meaning "hand wing." Their wings are actually hands, each finger functioning as a wing bone with the thumb as a claw at the leading edge of the wing. A thin sheet of skin connects the finger bones to form the wing, and in most species, an additional flight membrane stretches between the two hindlegs. Individuals of some species are capable of flying long distances; migratory species of the Pacific Northwest may fly from British Columbia to Mexico each year. Of the three families of bats found in North America, only one family, the Vespertilionidae (evening bats), occurs in the Pacific Northwest.

The objectives of this paper are to describe the basic biology of bats inhabiting Douglas-fir forests in the Pacific Northwest and to discuss their ecological relations with old-growth forests¹. Relatively little is known about many aspects of the ecology or population dynamics of bats in this region. To the extent possible, we will describe their natural history characteristics and habitat requirements. The best sources of information on Pacific Northwest bat populations are Cross (1976a) and Maser and others (1981). Fortunately, several bat species have distributions extending beyond the Pacific Northwest where they have been studied in greater detail; much of the available information pertains to populations in the Eastern United States and Canada. As appropriate, we have integrated this information into our discussion. Much of the general life history information we report comes from three sources: Barbour and Davis (1969), van Zyll de Jong (1985), and the Mammalian Species Series of the American Society of Mammalogists (Fenton and Barclay 1980, Kunz 1982a, Kunz and Martin 1982, Kurta and Baker 1990, Manning and Jones 1989, O'Farrell and Studier 1980, Shump and Shump 1982, Warner and Czaplewski 1984).

The USDA Forest Service's Old-Growth Forest Wildlife Habitat Research Program (Ruggiero and others 1991) was designed to evaluate the degree to which terrestrial vertebrates, including bats, are associated with old-growth Douglas-fir forests in the Pacific Northwest. This study is of particular importance because bats generally have been overlooked in vertebrate surveys, and very few studies have focused on the association of bats with different seral stages. According to echolocation and capture studies performed during this study, 12 species of bats inhabit Douglas-fir forests in the Washington Cascade and Oregon Coast Ranges (Thomas and West 1991). Certain species, such as the western small-footed myotis, generally are not regarded as forest-dwelling. Because they were captured during the old-growth study, however, they are included here. We caution that this list is based on limited data and should be considered interim until additional information on distribution and habitat requirements of forest-dwelling bats becomes available.

Eight of the 12 species occurring in Douglas-fir forests of the Pacific Northwest are in the genus *Myotis*, the mouse-eared bats. These bats are small, weighing 4 to 9 grams with wingspans of 22 to 26 centimeters (see "Glossary"). Individual species of *Myotis* are similar to one another and can be difficult to identify (table 1). In addition to the *Myotis* bats, four other species belonging to separate genera occur in Douglas-fir forests: the big brown, silver-haired, Townsend's big-eared, and hoary bats. These species generally are larger than the *Myotis* bats, weighing 9 to 27 grams, and are identified easily: silver-haired and hoary bats are very distinctively colored, big brown bats are the largest brown species (much larger than the *Myotis* species), and Townsend's big-eared bats have relatively large ears and prominent glandular lumps on the nose (table 1).

¹ Scientific names for all species are given at the end of the text.

Table 1-Diagnostic characteristics of bats found in Douglas-fir forests in Washington and Oregon

Diagnostic Characteristics ^{a,b}	Myotis bats							Non-Myotis bats				
	California	Western small-footed	Keen's	Yuma	Long-eared	Little brown	Fringed	Long-legged	Silver-haired	Townsend's big-eared	Big brown	Hoary
Relative size:												
Weight (grams)	small 4-5	small 3-6	small 5	small 4-5.5	small-medium 5-8	small-medium 6.5-9.5	small-medium 5-7	small-medium 6.5-8.5	medium 9-13	medium 9-12	medium-large 15-21	large 25-30
Wings:												
Membrane color	almost black	black	almost black	brown	black	dark brown	black	almost black	black	brown	almost black	black and brown
Wingspan (centimeters)	22-23	21-25	21-26	22-27	25-29	22-27	27-30	25-27	27-31	29-31	32-39	38-41
Membrane hair	hairless	hairless	hairless	sparse hair	hairless	sparse hair	hairless	dense hair	hairless	hairless	hairless	dense hair upper edge
Fur characteristics:												
Sheen	nonglossy	nonglossy	glossy	nonglossy	glossy	glossy	variable	nonglossy	glossy	nonglossy	glossy	9~Y
Dorsal color	dark brown-red brown	yellow brown-blond	dark brown	black, red, light brown	light brown-yellow dorsal colors	black and brown-yellow	light brown	red brown-black	black with white tips	gray brown-dark brown	red brown-dark brown	dark brown with yellow-white
Ventral color	paler	buff-white	tan-buff	paler	paler	paler	paler	dorsal colors	paler	paler	light/paler	paler/yellow
Relative length	long	long	average	average	long	long	average	average	average	average	long	long
Ear:												
Color	almost black	black	dark brown	brown	black	dark brown	black	almost black	black	brown	almost black	black
Relative size ^c (millimeters)	long (2-4)	long (2-4)	long (2-4)	short (m1)	very long (>5)	short (t1)	long (3-5)	short (t1)	short (t1)	very long(>5)	short (t1)	short (t1)
Foot:												
Size ratio to tibia ^d	very small 0.37-0.46	small 0.48	medium 0.50	large 0.53-0.56	medium 0.50	large 0.53-0.56	medium 0.50	very small 0.41	medium 0.50	medium 0.50	medium 0.50	medium 0.50
Calcar:	keeled	keeled	small keel	unkeeled	unkeeled	unkeeled	unkeeled	keeled	unkeeled	unkeeled	keeled	small keel
Tail membrane:												
Edge hair	hairless	hairless	sparse	sparse	small-fine	sparse	large-stiff	hairless	moderate	hairless	hairless	thick fur
Dorsal hair	hairless	hairless	hairless	light furring	hairless	light furring	hairless	hairless	moderate	hairless	hair on upper 1/4	thick fur
Echolocation call:												
Frequency (kHz)	67-37	55-41	110-38 ^e	80-40 ^f	97-54	80-40 (25) ^g	49-31	89-40	30-25	50-20	48-27	39-26
Duration (milliseconds)	6	5	3 ^e	5 ^f	5	5	8	10	10	5	10	15
Other diagnostic characteristics:		striking black face	dark shoulder spots	difficult to distinguish from little brown myotis	dark shoulder spots; keel not reliable character; longest ears of any <i>Myotis</i>		notch on ear		ear shape broad and short	prominent lumps on nose	chatter in flight; largest brownish bat in North America	chatter in flight; tufts tan fur at thumbs, elbow and wrist; brown in forearm

^a The smaller species of *Myotis* are difficult to identify and a specialist should be consulted whenever possible.

^b Bats sometimes bite when handled and some individuals do have rabies. If they must be handled to identify, it is wise to wear gloves, especially when dealing with larger species.

^c Distance ears extend beyond tip of nose when pulled forward.

^d Foot-to-tibia ratio is a relative measure of the size of the foot. Useful in identification of *Myotis* bats.

^e Echolocation frequency and duration assumed to be similar to the northern myotis.

^f Echolocation frequency and duration assumed to be similar to the little brown myotis.

^g Echolocation drops to 25 kHz-"honk"-to avoid intraspecies collisions.

Sources: van Zyll de Jong 1985, Barbour and Davis 1969, Fenton and Bell 1981.

Reproduction and Survival

Bats are an extremely diverse vertebrate group with worldwide distribution. Species range from 2 to 1500 grams and feed on many foods including fruit, insects, other vertebrates, blood, pollen, and nectar (Nowak 1991). In northern temperate regions, due to the seasonality of available resources, bats are insectivorous and nocturnal and either migrate south or hibernate during the winter. Pacific Northwest species comprise a relatively homogeneous group of bats with similar body sizes and diets. Because of this similarity and the limited nature of information available on the ecological relations of many species, we have organized the following discussion by major life history characteristics rather than individual species.

Pacific Northwest bats all have similar reproductive patterns. They mate in autumn or winter (September-February), and females store the sperm until spring (March-May), when ovulation and fertilization occur. Time of parturition differs with latitude (earlier in the south and later in the north) but occurs from late May through mid-July in the Pacific Northwest (Barbour and Davis 1969, Maser and others 1981). *Myotis* species and Townsend's big-eared bats give birth to one offspring per season; big brown, silver-haired, and hoary bats generally have two offspring but may have from one to four (Barbour and Davis 1969).

Most *Myotis* species, big brown bats, and Townsend's big-eared bats are colonial breeders. They form large maternity colonies in the spring, which can range from 12 to 500 individuals but generally contain less than 100. Colonies consist of the females and their young; males and nonbreeding females roost alone or in small groups separate from the maternity roosts. Colonialism reduces the energy costs of thermoregulation because clustering helps pregnant female bats maintain high body temperatures, which promotes rapid fetal growth (McNab 1982; Racey 1973, 1982; Racey and Swift 1981). This energy savings shortens the gestation period, thereby allowing the young to develop sufficiently to survive hibernation or migration. Female bats also may benefit from increased rates of juvenile growth during the gestation and lactation periods: early weaning provides the female with more time to prepare for hibernation or migration, which increases her chances of survival.

Silver-haired and hoary bats are generally considered solitary breeders, although a few nursery colonies of silver-haired bats are reported (Doutt and others 1966, Merriam 1884, Parsons and others 1986, Seton 1907). The young are born and raised in individual day roosts; females and young do not cluster in large colonies. Hoary bats are foliage roosters, and males, nonbreeding females, and breeding females with young generally roost in different levels of the canopy. Roosts of solitary adults often are located in the lower canopy. Clusters of females and their young are located high in the canopy, which reduces the risk of predation when the young are incapable of flight, and allows young bats the space they need while learning to fly (Constantine 1966).

Reproductive activity is influenced by environmental conditions and availability of resources. Females who cannot forage daily because of cold and wet weather will go into torpor if they cannot generate the energy necessary to maintain a high body temperature. Pregnant females who enter torpor during gestation have delayed parturition (Racey 1973, 1982; Racey and Swift 1981), which may result in the death of either the mother or her offspring. Although torpor is not an everyday strategy for male bats and may disrupt spermatogenesis, males and nonreproductive females may be able to withstand cool, wet conditions by entering torpor and conserving energy with little resulting loss in reproductive success (Kurta and Kunz 1988). In the Washington Cascade and Oregon Coast

Ranges, climatic factors apparently affect the spatial distribution of reproductive individuals. Of the females trapped by Thomas and West (1991) at elevations from 300 to 600 meters along the west side of the Washington Cascades, none was pregnant. Pregnant females were common, however, at similar elevations on the east side of the Washington Cascade Range and in the Oregon Coast Range. This difference in the distribution of reproductive females may be due to generally cold and wet conditions occurring during the breeding season (April-July) on the west side of the Washington Cascades. Thomas and West (1991) hypothesize that such conditions reduce the number of suitable foraging days and prevent females from breeding for the energy-related reasons outlined above. Similar patterns of reproductive activity have been found in the Rocky Mountains and the Cascade Range where nonreproductive females and males occupy higher elevations than do reproductive females (Fenton and others 1980, Perkins 1983).

Considering their small body size, bats are extremely long-lived mammals. *Myotis* bats may live from 12 (western small-footed myotis) to 31 (little brown myotis) years, and individual little brown myotis over 10 years old are common (Fenton and Barclay 1980, Humphrey and Cope 1976, Paradiso and Greenhall 1967). Larger bats seem to have a slightly lower potential longevity; the oldest silver-haired bat on record was 12 years old (Schowalter and others 1978a), and big brown and Townsend's big-eared bats generally live from 15 to 20 years (Goehring 1958, Hitchcock 1965, Paradiso and Greenhall 1967). These data represent maximum potential longevity; the average life expectancy of most species is not known.

Pacific Northwest bat species have many predators, but because bats are not a major prey item for any animal group, predation does not seem to be a major mortality factor. Mortality from predation generally occurs while bats are roosting or hibernating rather than when they are active. Most information on predation pertains to the little brown myotis and the big brown bat, the most extensively studied bat species in North America. Small carnivores, raptorial birds, domestic cats, fish, bullfrogs, and snakes have been known to prey on these species (Barbour and Davis 1969, Gillette and Kimbrough 1970, Kirkpatrick 1982). Deer mice often live in the hibernacula of little brown myotis and have been observed eating torpid, injured bats that have fallen from the ceiling (Trevor-Deutsch 1973). Little information exists regarding predation on other bat species, but they probably are subject to similar predation pressures (Barbour and Davis 1969).

Accidents and the influence of people probably kill more bats than predators (see Mohr 1972). Disturbance of hibernacula through cave exploration and bat banding has caused significant declines of bat populations (Gillette and Kimbrough 1970, Mohr 1972). When bats are disturbed, they come out of torpor, which causes them to lose weight and lessens their chances of survival (Davis and Hitchcock 1965). Other human activities also have been linked to widespread declines in bat populations. In the Eastern United States, the establishment of dams has flooded hibernacula (DeBlase and others 1965, Griffin 1953, Hall 1962), and the application of pesticides to control insect populations may affect bats by reducing food supplies and subjecting them to contaminated prey (Clark 1981).

Foraging and Water Intake

Pacific Northwest bats are insectivorous and nocturnal and use echolocation for hunting and orientation. When echolocating, a bat emits pulses of ultrasonic sound (above the upper limit of human hearing-about 20 kHz). When the pulses come into contact with an object, the sound waves are reflected and received by the bat, thus providing it with information about the size, direction, and nature of the object. Echolocation calls consisting predominately of high-frequency sound carry for short distances and are well suited to



(Photo courtesy Merlin Tuttle, Bat Conservation International)

Big brown bats (*Eptesicus fuscus*).

hunting in structurally complex habitats. Low-frequency calls carry longer distances and are efficient in open habitats. There is a rough correlation between the size of bats and the frequency of their echolocation calls; small bats tend to use high frequencies and large bats, low ones. In addition, the echolocation calls of some species have sufficiently unique shapes (patterns of frequency per time) that they can be used to identify individual species. The pattern of the echolocation call for a given species also varies, however, depending on its purpose; for example, as a bat approaches a prey item, the pulse rate of the echolocation call becomes very rapid, thereby creating a sound called a "feeding buzz." Researchers can use the number of feeding buzzes as an index of foraging activity in different habitats.

Most species occurring in this region are aerial foragers, but a few (long-eared and fringed myotis, big brown, and hoary bats) also glean insects from the ground or foliage and rely on vision as well as echolocation when hunting (van Zyll de Jong 1985). Bats consume vast quantities of insect pests; a single *Myotis* bat weighing about 5 grams can consume over 600 mosquito-sized insects in an hour (Griffin and others 1960). Insect prey apparently is selected by size rather than species (Ross 196; small bats tend to eat small insects and large bats eat large ones. Although most bats appear to forage opportunistically, often focusing on swarming or emerging insects, moths are an important component of the diet in many species² (Whitaker and others 1981 a).

Bats feed throughout the night, but many species exhibit two distinct peaks in foraging activity corresponding to peaks in nocturnal insect abundance: one during the first few hours after sunset and the second in the last few hours before sunrise (van Zyll de Jong 1985). The timing of emergence from day roosts differs by species and depends on weather and geographic location (Barbour and Davis 1969, van Zyll de Jong 1985). In the Pacific Northwest, early emergers (California, long-legged, little brown, and Yuma myotis;

² Personal communication. 1991. Stephen P. Cross, professor, Southern Oregon State College, Department of Biology, Ashland, OR 97520.



Photo courtesy Merlin Tuttle, Bat Conservation International

Townsend's big-eared bat (*Plecotus townsendii*).

big brown and silver-haired bats) may be seen well before sunset but generally emerge just at dusk. Late emergers (long-eared myotis; Townsend's big-eared and hoary bats) usually appear from 30 minutes to 1 hour after sunset (Maser and others 1981, Whitaker and others 1977). Emergence times for the western small-footed and fringed myotis in the Pacific Northwest are not known, but information from other parts of the country indicates that western small-footed myotis emerge early (just after sunset) and fringed myotis emerge late (1-2 hours after sunset) (Cockrum and Cross 1964, 1965; van Zyll de Jong 1985; Woodsworth 1981).

After emerging in the evening, bats often seek open water for drinking (Bailey 1936), especially during the breeding season when lactating females have high water requirements. To drink, bats fly close to the water with their mouths open, skimming the surface with the lower jaw. *Myotis* bats may be able to drink from a pool as small as a few centimeters in diameter, whereas larger, less agile species, such as the hoary and big brown bats, need a larger surface area to drink from while in flight (Cross 1986).

Although bats most often are observed foraging over water, many species also forage in forests, and many that occur in urban areas (for example, little brown myotis and big brown bat) commonly forage around street lights, over parks, and along city streets (Barbour and Davis 1969, Furlonger and others 1987, Geggie and Fenton 1985). Thomas and West (1991) found feeding rates of *Myotis* in Douglas-fir forests of Washington and Oregon to be about 10 times greater over water than in the forest interior, and in a Cana-

dian study, little brown myotis were 75 times more active over lakes than in forested habitats (Lunde and Harestad 1986). These findings suggest that open water may provide critical foraging habitat in Pacific Northwest forests.

In upland forests, most foraging appears to occur over clearings and roads, although when gleaning insects, some species may feed within the canopy. Recently harvested areas do not, however, seem to provide suitable foraging habitat; detections of little brown myotis were substantially reduced after clearcutting in British Columbia (Lunde and Harestad 1986). A few species are observed foraging in upland habitats more often than over water. Fringed myotis and hoary and Townsend's big-eared bats commonly feed along forest edges, roads, or open areas within the forest, and western small-footed bats typically forage along cliffs and slopes in dry areas (Barclay 1985, Black 1974, Kunz and Martin 1982, van Zyll de Jong 1985, Whitaker and others 1977). In contrast, Yuma myotis are unique among North American bats in that they forage almost exclusively over water. In addition, their roost sites almost always are located close to open water (Barbour and Davis 1969, Herd and Fenton 1983, van Zyll de Jong 1985).

Many species fly regular circuits while foraging, moving up and down roads and streams or in circular patterns over ponds and lakes (Barbour and Davis 1969, Grinnell 1918, Maser and others 1981, Schwartz and Schwartz 1959, van Zyll de Jong 1985). When foraging, big brown and hoary bats typically fly high over the water or ground surface (up to 50 meters), but most species generally forage below about 10 meters (Barbour and Davis 1969, Whitaker and others 1977).

Migration, Hibernation, and Movement Patterns

Migratory patterns differ considerably in bats, both within and among species, and are difficult to study. Information on migration comes primarily from reports of seasonal appearances and disappearances of species from a given area and from band recoveries (see Fenton and Thomas 1984, Griffin 1970). The majority of temperate bat species migrate relatively short distances (10-500 kilometers) from their summer ranges to winter hibernation sites. A few of the larger species, including the hoary bat, migrate much longer distances and may remain active throughout most of the winter. Some individuals or populations of any of these species may hibernate within their summer range and not migrate at all (Griffin 1970).

Most species in the Pacific Northwest probably undergo relatively short migrations to and from hibernacula each year. Myotis species and Townsend's big-eared and big brown bats begin their migration to hibernation sites in October or November (Dalquest 1948). Adults generally enter hibernation earlier than juveniles, probably because they do not require as much energy for growth and because they are more experienced foragers and can acquire more quickly the fat needed for hibernation (Fenton 1970). Bats emerge from hibernation in the Pacific Northwest with the onset of warmer temperatures in March or April (Maser and others 1981).

In this region, hoary bats and the majority of silver-haired bats are believed to migrate fairly long distances each year, although exact migration routes have not yet been determined (Shump and Shump 1982). A single museum specimen is the only known winter record of the hoary bat in the Pacific Northwest (Perkins and others 1990). Most hoary bats whose summer ranges are in the Pacific Northwest, Canada, and Alaska apparently winter in coastal southern California and Mexico, although they have been found as far north as New York in December and January (Shump and Shump 1982). They generally are not captured in Washington and Oregon until July and apparently leave Washington



Photo courtesy Merlin Tuttle, Bat Conservation International)

Silver-haired bat (*Lasionycteris noctivagans*).

by September, but remain in Oregon until November (Dalquest 1943, Findley and Jones 1964). Sexual segregation of hoary bats in both time and space occurs during migration. Females move north in the spring before the males, beginning their migration to summer ranges in the North-Central and Northeastern United States in May and early June. Males begin their migration later and settle primarily in the Western United States (Findley and Jones 1964, Provost and Kirkpatrick 1952). Generally, only male hoary bats occur in western Oregon and Washington; no females have been found in this region during June and July, when they would be giving birth and rearing young, although records do exist for spring and autumn (Cross 1976a, Dalquest 1943, Perkins 1983, Perkins and Cross 1988, Thomas and West 1991).

Silver-haired bats also seem to be migratory, although a small proportion of the population spends the winter in the Pacific Northwest (Johnson 1953, Perkins and others 1990). No hibernating silver-haired bats were located during cave and mine searches in Oregon and Washington from 1982 to 1989 (Perkins and others 1990) but several individuals, primarily juvenile males, have been found during winter in both States as well as in British Columbia³ (Schowalter and others 1978b). Females apparently migrate farther north than males in the Pacific Northwest, which results in some spatial sequestration of the sexes

³ Perkins, J.M.; Cross, S.P. 1991. Migratory patterns of *Lasionycteris noctivagans* in Oregon and Washington [Austin, TX: 21 st annual American symposium on bat research.] On file with: Bat Conservation International, P.O. Box 162603, Austin, TX 78716-2603.

(Schowalter and others 1978b). Males can be found in Oregon and Washington in May, whereas females do not arrive until June (see footnote 3). Sexual segregation also may occur on an east-west gradient. As with hoary bats, female silver-haired bats seem to dominate numerically in the Eastern United States, whereas males predominate in the West and during migration (Kunz 1982a). Although both males and females occur in western Oregon and Washington (Cross 1976a, Perkins 1983, Perkins and Cross 1988, Perkins and others 1990), reproductive females occupy areas separate from males (see footnote 3). In Washington, females generally occur only east of the Cascades during spring and early summer, but the distribution of sexes becomes more even in August (see footnote 3).

Bats are capable of traveling long distances between roosting and foraging sites, but relatively little is known about this behavior in temperate insectivorous species. Little brown myotis have been observed foraging 2 to 5 kilometers from day roosts (Thomas and West 1991), big brown bats are known to travel up to 4.1 kilometers to foraging habitat (Brigham and Fenton 1986), and adult female Indiana myotis will travel up to 2.5 kilometers from roosts to foraging areas (Gardner and others 1991). Tattle (1976), however, found that growth rates of juvenile gray myotis, which feed almost exclusively on aquatic insects, were inversely proportional to the distance of the maternity colony from water. Lunney and others (1988a) also found that most activity in small, insectivorous bats in Australia was confined to within 1 kilometer of the site of original capture, thereby indicating small foraging ranges. Although bats are capable of traveling long distances to forage, such movements are energetically draining. Foraging therefore apparently occurs within a relatively short distance from roosting sites.

Pacific Northwest bats often feed over water and then return to the forest to roost, thereby transferring nutrients from aquatic to upland habitats and forming an important link between these environments (Cross 1988). No other vertebrate group, with the exception of certain swifts and swallows, exhibits such a movement pattern. Because of their large population numbers, bats may play a unique role in nutrient cycling in forested environments.

Roosts and Hibernacula

Roost sites are a critical resource for bats, and their availability may play a major role in determining population sizes and distributions (see Kunz 1982b). Key requirements of suitable roost sites include proximity to drinking and foraging habitat, protection from predators, and favorable temperature and moisture regimes. Variables such as sex, age, and breeding condition of individuals also play a role in roost selection; for example, breeding females and young generally require different kinds of roosts than males and nonbreeding females.

During the spring and early summer, adult male and nonbreeding female bats are usually solitary roosters, although occasionally they may form small colonies. In late summer, they often join breeding females and juveniles in maternity roosts (van Zyll de Jong 1985). Males and nonbreeding females may or may not roost in the same site each day. Selection of a roost to provide shelter from inclement weather and protection from predators appears to be rather opportunistic for these individuals. Cracks between boards on bridges, crevices in rock cliffs, spaces under tarpaper or siding on buildings, and crevices and cavities in live and dead trees provide suitable day roosts for males and nonbreeding females (Barbour and Davis 1969, Maser and others 1981, van Zyll de Jong 1985) (table 2).

Breeding female and juvenile bats of many species in the Pacific Northwest roost communally in large cavities and crevices, both natural and human-made. Males and nonbreeding

Table Known roost-site characteristics of bats^a

Species	Buildings	Bridges	Hardwood foliage	Conifer foliage	Bark	Rock crevices	Caves and mines	Snags
California myotis	M,S,H	M'S	S		S	S	M,S,H	S
Western small-footed myotis	S				S	S	H	
Long-eared myotis	M,S,H				S	S	M,S,H	S
Keens myotis ^b					S	S		
Little brown myotis	M'S	M'S			S	S	M,H	M
Fringed myotis	M,S,H	S				S,H	M,S,H	
Long-legged myotis	M'S	S			M'S	M'S	H	M
Yuma myotis	M,S,C	M'S					M,H	
Hoary	S ^c		S	S			S	S
Silver-haired ^d	M,S,H				S,H	S,H	S,H	M,S,H
Big brown	M,S,C,H	M'S			S	S	M,S,H	M
Townsend's big-eared	M,H,S	M					M,S,C,H	

^aM = maternity roosts; S = solitary roosts; C = colonial roosts (males and nonbreeding females); H = hibernacula.

^bRoost characteristics not well described.

^cUnusual occurrence from single account (Bowers and others 1968).

^dSome proportion of hibernation accounts may actually be migrating individuals.

females generally are absent from these maternity roosts, but a few males occasionally may be found in the maternity colonies of some species, often roosting separately from the female clusters (Cagle and Cockrum 1943, Davis and others 1965). Temperature and humidity of maternity roosts must remain within certain, narrow boundaries to provide optimal conditions for the development of young. Sites of maternity colonies generally are quite warm, and temperature seems to be a major determinant in the selection of these sites (Fenton and Barclay 1980). Only a limited number of sites are suitable as maternity roosts. Maternity roosts have been found in attics, hollow trees, under large bark flakes, under bridges, in caves, and in other natural and human-made cavities (Barbour and Davis 1969, Maser and others 1981, van Zyll de Jong 1985) (table 2). Although adult females are capable of carrying their offspring in the early stages of development, they rarely do; maternity roosts generally are used throughout the breeding season. Females return to the roost each morning and several times throughout the night to nurse their young. Groups of individuals of some species (for example, little brown myotis, Townsend's big-eared bat) also will frequently return to the same maternity roost year after year (Pearson and others 1952, van Zyll de Jong 1985). After weaning, breeding females and juveniles capable of flight join nonbreeding females and males and roost opportunistically in individual or group roosts.

Environmental conditions also are important in the selection of hibernacula. Only certain cavities, generally caves, provide the proper conditions of temperature and humidity for hibernation, and only specific areas of a cave or cavity will be used. Townsend's big-eared bats prefer cold areas near the entrances of caves as hibernacula (Barbour and Davis 1969, Humphrey and Kunz 1976, Pearson and others 1952), whereas gray myotis only use deep, vertical caves with temperatures from 6 to 11 °C (Tuttle 1979). Different species select different conditions for hibernation and some species require very specific hiber-

hibernacula. The entire North American population of the gray myotis, for example, uses only nine major hibernation caves in the southeastern United States (Lowe and others 1990). Most species in the Pacific Northwest hibernate in caves and abandoned mines although several species use buildings as well (Perkins and others 1990, Senger and others 1974). Some species readily hibernate in human-made structures. Most hibernating California myotis in Washington and Oregon, for example, have been found in buildings (Maser and others 1981, Perkins and others 1990); only a few have been found in caves and mines (Barbour and Davis 1969, Perkins and others 1990, Senger and others 1974, van Zyll de Jong 1985). This apparent preference for buildings as hibernacula may reflect only the difficulty involved in locating hibernating individuals in crevices and other inaccessible areas in caves and mines (Perkins and others 1990).

It is common for bats to forage for a short time and then retire to a roost to rest and digest food or consume large prey items. These roosts are known as night roosts and generally are located at a different site than the day roosts, or in a different area of the same structure. Individual bats may spend from a few minutes to several hours at a time in night roosts, which often are occupied by several bats of different species that ordinarily may not share day roosts. Night roosts have been found in caves and buildings, on porches, and under bridges (Barbour and Davis 1969; Maser and others 1981, van Zyll de Jong 1985). Roosts used at night often are small, with bats packed into confined spaces, but they also may be large and open (for example, porches, barns). The function of night roosts is unknown, but it has been hypothesized that periodically gathering in clusters during the night helps bats maintain high body temperatures, which allows extended periods of activity and increases digestive rates (Fenton and Barclay 1980). Adult male and nonbreeding females use night roosts throughout the spring, summer, and autumn, whereas lactating females and juveniles use them only after weaning in the late summer (Anthony and others 1981, van Zyll de Jong 1985).

Most species use crevices and large cavities for roosting. Crevices include cracks in or under thick bark of trees, spaces between boards in buildings or bridges and under tarpaper or chimney flashing, fissures in rock cliffs, and spaces between rocks in talus slopes. Natural cavities are found in hollow trees and in caves, and human-made cavities include attics, barns, and spaces between wooden bridge supports. Most species will readily roost in artificial structures when natural cavities are unavailable. Almost all Pacific Northwest species have been found roosting in buildings and under bridges (table 2), and some species, such as the big brown bat and the little brown myotis, commonly are encountered in attics and barns (Barbour and Davis 1969, Maser and others 1981, van Zyll de Jong 1985). Big brown bats seem to prefer older buildings to newer ones, and large colonies tend to locate in buildings constructed before 1925 (Perkins 1983, Schowalter and Gunson 1979). Unlike buildings with modern insulation and heating systems, older buildings probably provide conditions that are warm in the summer and cool in winter, which may make such buildings suitable as both summer roosts and winter hibernacula (Schowalter and Gunson 1979). Buildings constructed in the early 1900s also provide more potential roosting sites (that is, in attics and hollow walls) than newer ones (Kunz 1982b). In contrast to natural roost sites, roosts in human-made structures are relatively easily located, which probably accounts for the preponderance of human-made roosts among known sites.

A few species select unique or specialized roost structures. Townsend's big-eared bats roost almost exclusively in cavity roosts, both in human-made structures (that is, buildings, bridges, and mines) and caves (Perkins and Levesque 1987) (table 2). They are



Hoary bat (Lasiurus cinereus).

extremely sensitive to disturbance while roosting, because they hang directly from the ceiling of the roost and do not go into torpor during the day in summer colonies (Barbour and Davis 1969, Dalquest 1948). The hoary bat is the only foliage-roosting bat in the Pacific Northwest and, unlike other species, is not known to roost in human-made structures (table 2). In the Midwest and Eastern United States, hoary bats roost in the foliage of deciduous or coniferous trees and choose sites that are 3 to 12 meters above the ground, open from below, well covered above, and near a clearing (Constantine 1966, van Zyll de Jong 1985). Roost sites have not been found in Douglas-fir forests of the Pacific Northwest, but it has been hypothesized that roost requirements are best met in conifer forests older than 100 years (Perkins and Cross 1988). Older conifers have foliage that begins 10 to 20 meters above the ground and needles that are concentrated around the edge of the canopy, which together provide the proper combination of shelter, open space, and accessibility required by hoary bats for roosting (Perkins and Cross 1988).

Although roost sites are poorly characterized in Pacific Northwest forests, existing information indicates that old-growth forests provide higher quality roost sites than do younger forests. Thomas and West (1991) found activity levels in old-growth Douglas-fir forests to be significantly higher than in young or mature forests for most species. Bat activity within forest stands showed a short peak in the early evening when bats were emerging; few feeding buzzes were recorded during the night, which indicated that bats use old growth for roosting rather than foraging. In other parts of the United States and throughout the world, small forest-roosting bats generally roost in the oldest available trees (Barclay and others 1988, Gardner and others 1991, Lunney and others 1988b). Structural characteristics of old, live trees, such as cracks and crevices in thick bark, bark pulling away from the trunk thus forming crevices, and holes in the bole where limbs have been shed, offer many potential roosting sites. Snags with cracks, peeling bark, bird holes, and hollow interiors also provide ideal sites for the large maternity colonies that *Myotis* bats commonly form in the spring.

Research on Bats in Old-Growth Douglas-Fir Forests

Recent interest in old-growth forest ecosystems of the **Pacific Northwest** has stimulated several studies of the habitat preferences of bats with respect to forest age. According to these studies, bats show a marked preference for old rather than young forests, presumably due to a greater abundance of potential roost sites in large, old, hollow trees compared to small, young trees.

In Oregon, it has been determined that both hoary and silver-haired bats prefer Douglasfir/western hemlock forests more than 200 years old over other forest types and ages (Perkins and Cross 1988). In this study, three forest types were sampled: Douglas-fir/ western hemlock, ponderosa pine/sugar pine, and true fir. These types were further subdivided into three age classes (0-50 years, 51-100 years, and > 100 years). At each sampling site, mist nets were set up over bodies of water to capture bats while they were drinking or foraging. It was assumed that bats were drinking from water sources closest to roosting and foraging areas, following Kunz (1982b). Both hoary and silver-haired bats were captured almost exclusively in old-growth Douglas-fir forests (old growth was defined as stands greater than 100 years of age with most trees over 200 years) and rarely in younger Douglas-fir forests or ponderosa pine forests of any age. Although no roost sites were found, the authors speculated that bats were roosting under large bark flakes and in the foliage of old-growth and mature conifers.

Thomas (1988) and Thomas and West (1991) studied the association of bats with different age classes of Douglas-fir forests in Washington and Oregon as part of the USDA Forest Service's Old-Growth Forest Wildlife Habitat Research Program (Ruggiero and others 1991). Ultrasonic detectors, which record bat echolocation calls, were used to monitor bat activity in young (40-75 years), mature (100-165 years), and old-growth (> 200 years) forest stands on the western side of the southern Cascade Range in Washington and in the Coast Range of Oregon (see Carey and Spies [1991] for additional information on study design). Each detector consisted of an ultrasonic microphone, a divide-by-ten circuit board, a talking clock, and a voice-activated tape recorder (Miller and Andersen 1984, Thomas and West 1989).

Detectors were placed in the canopy and near the forest floor in several stands of each age class, and activity was monitored from dusk until dawn each day. Once reduced to a frequency within the range of human hearing by the divide-by-ten circuit board, calls were recorded on tape along with the time of day from the talking clock (Thomas and West 1989). Recorded calls then were passed through a period meter to convert them into frequency-time spectrograms displayed on an oscilloscope screen (Fenton 1988, Simmons and others 1979, Thomas and West 1989). To identify calls, the minimum frequency, duration, and shape of the calls were compared with recordings from captive bats or previously published characteristics (see Fenton and Bell 1981, Thomas and others 1987).

Several species, especially among the myotis bats, have similar echolocation call characteristics, and it was not possible to distinguish the calls of all species present. Consequently, species whose calls overlapped were classified into groups for analysis: *Myotis* A (little brown and Yuma myotis); *Myotis* B (California, Keens, long-eared, and western small-footed myotis); and big brown bat (big brown bats and fringed myotis) (table 3). Echolocation calls could be individually distinguished for the long-legged myotis, silver-haired, hoary, and Townsend's big-eared bats. With additional research, further resolution of the groups into constituent species may be possible.

Table 3-Detection rates of bats in old-growth, young, and mature stands in the southern Washington Cascade and the Oregon Coast Ranges

Species or groups ^a	Old-growth	Mature and young	Old-growth/younger ^b	P ^c
Washington:				
<i>Myotis A</i>	1.23 t 0.27 ^d	0.33 t 0.09	3.73	<0.005
<i>Myotis B</i>	2.41 t 1.75	.91 t .25	2.65	< .001
Long-legged	.34 t .08	.06 ± .02	5.67	< .01
Silver-haired	.27 .27:t .11	.15 :t .64	-	Ns
Oregon:				
<i>Myotis A</i>	6.29 t 1.98	2.48 t 1.13	2.54	< .001
<i>Myotis B</i>	6.54 ± 1.81	1.48 ±	.50	4.42 < .001
Long-legged	1.46 t .50	.53 t	.30	2.75 < .01
Silver-haired	2.73 t 1.15	.28 ±	.22	9.75 < .005
Big brown	.53 ± .26	.16 ±	.08	3.31
	< .05			

Ns = not significant.

^a *Myotis A* includes the little brown and Yuma myotis; *Myotis B* includes the California, long-eared, Keens, and western small-footed myotis; big brown includes the big brown bat and fringed myotis.

^b Detection rates are expressed as a ratio of old-growth to younger stands.

^c Differences between detection rates in old-growth and younger stands were tested by a Mann-Whitney test; P is the resulting probability.

^d Detection rates as bats per 100 sample minutes ($x \pm SE$).

Source: Thomas and West 1991.

Although not all bat species are readily captured in mist nets, some idea of the relative abundances of species within each group was obtained by using mist nets in areas censused by echolocation call. Captures within each group were dominated numerically by one species. Among the *Myotis A* group, most captures were of the little brown myotis; the *Myotis B* group was dominated by California myotis; and big brown bats comprised the majority of the big brown bat group.

The main peak in activity was short and predictable and generally occurred in the first 15 minutes after dusk; a second activity peak occurred at dawn (Thomas and West 1991). Feeding rates in old-growth forests, determined by counting the number of feeding buzzes, were low. Low feeding rates, combined with high detection at dawn and dusk, indicated that bats were using old-growth forests primarily for roosting rather than feeding (Thomas and West 1991).

Because activity levels did not differ significantly between young and mature stands, the calls in these age classes were combined for further analysis. Most groups had significantly higher abundances in old-growth forest (table 3). Although detection rates for the silver-haired bat did not differ significantly between age classes in the Washington Cascades, detection rates were higher in old growth than in young and mature forests (table 3). Detection rates for big brown bats or fringed myotis were too low to be included in the analysis for the Washington Cascades.

As part of the old-growth research program, relations between activity levels and vegetative parameters were examined to determine habitat characteristics of importance to forest-dwelling bats (Thomas and West 1991). The density of damaged or diseased trees, snag size and decay class, elevation, and stand age were all weakly associated with higher activity levels. These regression variables did not explain observed associations with old growth because 83 percent of the total among-sample variation was not accounted for in the regression. The relation between measured vegetative characteristics and activity levels was too weak to draw any conclusions. According to Thomas and West (1991), the weakness of the association indicates that critical habitat variables associated with natural roost-site characteristics were not measured and remain unknown. This information gap severely constrains our ability to describe the habitat relations of bats in the Pacific Northwest.

Regional differences in abundance and reproductive activity were clearly evident in the Washington Cascade and Oregon Coast Ranges. Population sizes of all species (except the long-legged myotis) in old-growth forests of the Washington Cascades seem to be much lower than in the Oregon Coast Range (Thomas and West 1991). Along the west side of the Washington Cascades, only 11 percent of the bats captured were female and none of these females was reproductively active. In contrast, along the east side of the Washington Cascades and in the Oregon Coast Range, breeding females and juveniles were much more abundant. These results suggest that in the Pacific Northwest, only relatively warm environments provide suitable conditions for reproduction in bats.

Review of Other Bat Studies in the Pacific Northwest

In general, few studies have been done on the bat fauna of the Pacific Northwest, especially in Washington. Previous work consists primarily of population surveys in southern (Cross 1976a) and northwestern (Perkins 1983) Oregon. In each of these surveys, roost sites were located through public input gathered through radio and newspaper requests for roost locations, as well as information from various State and Federal land management agencies. Species composition and relative abundances of bats in different habitats were determined by capture with mist nets. In southern Oregon, habitat variables (for example, vegetation types, number of snags, amount of available rimrock) also were measured to identify habitat characteristics of importance to different bat species.

In southern Oregon, the fringed myotis, big brown, hoary, and silver-haired bats were found most commonly in the west, whereas the western pipistrelle, western small-footed myotis, and little brown myotis were more common in the east. The pallid bat, long-legged myotis, and long-eared myotis were caught most frequently in ponderosa pine forests but were found across the State. Townsend's big-eared bats, California myotis, and Yuma myotis occurred in equal frequency throughout the study area. Captures of both the big brown and silver-haired bats were most frequent in areas of high snag density and forest cover. A single spotted bat was captured in a ponderosa pine forest during this study. This species is most common in the Southwestern United States and is found as far north as the Okanagan Valley of British Columbia but has been neither captured nor sighted in Washington; this account represents the only record of the species from Oregon.

In northwestern Oregon, the little brown bat was the most common and widespread species, and big brown bats, California, long-eared, fringed, long-legged, and Yuma myotis also were distributed widely. Other species were more restricted in distribution: silver-haired, hoary, and Townsend's big-eared bats were caught only in old-growth or mature Douglas-fir forests, and the pallid bat was found only in oak-woodland habitats.



(Photo courtesy Merlin Tuttle, Bat Conservation International)

Long-eared myotis (*Myotis evotis*).

Roost sites and capture locations for all bat species occurring in Oregon have been mapped in relation to habitat and physiography (Maser and Cross 1981). Data on bat distribution were collected from 1970 to 1980 by using mist nets, shooting, and collecting bats from day and night roosts. Range maps of Oregon bats were compiled from this data and previously published accounts.

Bats at Oregon Caves National Monument in southwestern Oregon have been surveyed several times from 1958 to 1989 (Albright 1959; Cross 1976b, 1977; Cross and Schoen 1989). A mark-recapture technique, in which bats were captured in Tattle traps (Tattle 1974) at the main cave entrance and marked on the wings with punchmarks, was used to estimate numbers of bats using the caves. Eight species were captured: Townsend's big-eared and big brown bats, long-eared, Yuma, little brown, California, fringed, and longlegged myotis. The caves most commonly were used as night roosts although a few individuals used them during the day or for hibernation. Confidence limits for population estimates were large and, although it appeared that a decline has occurred since 1958, this could not be verified.

The distribution, status, and habitat affinities of Townsend's big-eared bat in Oregon are described by Perkins and Levesque (1987). A distribution map was constructed by using data from captures, museum specimens, and literature sources. The total Oregon population was estimated at 2,300-2,600 bats, with a fragmented distribution centering around areas with suitable cave or cavelike habitat. Comparison of counts at known hibernacula with historical records suggested that population declines may have occurred in some areas. Management recommendations included habitat protection, population monitoring, and public education.

Bats are most easily censused in their hibernacula, and several researchers have compiled winter records of bats in the Pacific Northwest from cave, mine, and house searches and museum specimens (Perkins and others 1990, Senger and others 1974). Over-wintering California, long-eared, little brown, fringed, and long-legged myotis as well as

Townsend's big-eared and Mexican free-tailed bats were found in caves or mines, or both, in Washington and Oregon. Winter records from museum specimens of the aforementioned species plus big brown, silver-haired, and hoary bats also were listed. The number of bats in a given hibernaculum generally was less than 10. California myotis and big brown and Mexican free-tailed bats were found most commonly in buildings; little brown myotis were found with equal frequency in buildings and in caves or mines; Townsend's big-eared bats and long-eared, western small-footed, fringed, and long-legged myotis were found primarily in caves and mines; and silver-haired bats rarely were found

The food habits of bats in western and eastern Oregon have been studied by stomach or scat analysis (Whitaker and others 1977, 1981 a, 1981 b). Several species showed similar patterns of prey selection across the State. Townsend's big-eared and silver-haired bats and long-legged, long-eared, and fringed myotis ate primarily moths; little brown myotis and western pipistrelles ate flies; big brown bats ate beetles; and silver-haired bats and western small-footed myotis did not specialize but fed on a wide variety of insects. A few species showed a different pattern for the west than for the east side of the State, possibly reflecting differences in prey availability. Yuma and California myotis ate flies in western Oregon, whereas the Yuma was a generalist and the California ate primarily moths on the east side. The pallid bat fed heavily on beetles in western Oregon but ate mainly moths and grasshoppers in the east.

The effects of pesticide application on bats were studied in the Pacific Northwest by examining the residue patterns from a 1974 spray application of DDT to forests in northeastern Oregon, eastern Washington, and northern Idaho (Henny and others 1982). Levels of DDT in the control group were extremely low or absent. Four of five species showed significant changes in DDT residues after the forests were sprayed. California and longlegged myotis showed the highest residues, silver-haired and big brown bats showed a moderate increase in residues, and long-eared myotis exhibited no postspray change. Three years after spraying, only California and long-legged myotis exhibited DDT levels above control levels. Although it was not determined whether these elevated levels of DDT had adverse effects on the bats in this study, insecticides have been linked with population declines and toxicity in other areas (Clark and others 1978, Geluso and others 1976; see review in Clark 1981).

Conclusion and Research Needs

Biologists suspect that bat populations have been declining in recent years, but this is difficult to document because few data exist on historic population sizes. The status of only 3 percent of bats worldwide is well known (Stebbing 1980) but 7 of the approximately 40 species in the United States are listed Federally as endangered (Lowe and others 1990). None of the Federally listed species are found in the Pacific Northwest; however, the Townsend's big-eared bat has been nominated for federal listing, and both the Washington State Department of Wildlife and the Oregon Department of Fish and Wildlife have listed it as a Species of Concern or Sensitive Species. Documented population declines of bats worldwide are due primarily to disturbance in maternity colonies and hibernacula and loss of habitat (Cockrum 1969, Edgerton and others 1966, Mohr 1948, Tuttle 1979). Forest harvest in particular has been shown to have detrimental effects on populations of little brown myotis in that activity is substantially reduced after clearcutting (Lunde and Harestad 1986). Because most Pacific Northwest bat species are closely associated with old-growth Douglas-fir forests (Thomas and West 1991), the recent, rapid decline in old-growth forests on the west coast probably has had detrimental effects on bat populations.



(Photo courtesy Merlin Tuttle, Bat Conservation International)

Yuma myotis (*Myotis Yumanensis*).

Mitigation for the effects of forest harvest on bat populations is difficult to prescribe because critical aspects of their basic ecology are poorly understood. Conservation of bat species in the Pacific Northwest should center on preserving suitable roost sites and foraging areas, but attaining this goal is hampered by our rudimentary knowledge of these requirements. Recent advances in miniaturization of radiotelemetry components have now made radio tracking of bats feasible. This technique holds promise for gathering significant new information on roost characteristics and home range sizes. Three studies involving radio tracking of *Myotis* bats currently are underway in Washington State. They should provide significant new information on natural roost sites in second-growth and old-growth forests of the Pacific Northwest. Although radio-tracking studies are expensive and time consuming, they are the only practical means of gathering information on roosting behavior in forest-dwelling bats. More studies of this kind are necessary.

Bats often have been excluded from general vertebrate surveys because they are difficult to study; specialized equipment and expertise are required. Responses of bat populations to various forest management practices (for example, riparian buffer strips, clearcutting) and habitat variables (for example, forest fragmentation) therefore are virtually unknown. Two large-scale studies of vertebrate responses to logging practices and landscape patterns recently have begun in Washington. Automated ultrasonic detectors are being used to assess bat activity patterns in both studies. Inclusion of bats in other vertebrate studies in the Pacific Northwest would provide valuable information both on the effects of forest practices on bat populations and the distribution and habitat preferences of individual species.

The lack of information on basic geographic distributions, habitat associations, and the population status of Pacific Northwest bat species is a major factor hindering the development of alternative forest management procedures that might protect bat populations. General bat surveys to document distribution and estimate population sizes have been performed in various areas in Oregon (Cross 1976x, Perkins 1983), and fairly current distribution maps exist for the State (Maser and Cross 1981). The bat fauna of Washington

remains virtually unstudied, however; no recent distribution maps have been published for the State and localized trapping efforts and cave exploration provide the only information. General surveys (consisting of cave and building searches, trapping efforts, and ultrasonic detection) in state parks, national forests, and wildlife refuges would greatly enhance the current information base. Although we lack critical information for all bat species, this deficit is most acute for Keen's myotis⁴. Virtually no research has been conducted on the basic ecology of Keen's myotis since it was proposed as a distinct species by van Zyll de Jong (1979). It is found exclusively in the Pacific Northwest and occupies a restricted range within western Washington and western British Columbia. It is considered a forestdwelling species and most likely has a strong association with old-growth forests, as it was part of a group of Myotis species identified as closely associated with old-growth Douglas-fir forests (Thomas and West 1991). Keen's myotis has not been found roosting in human-made structures and may rely entirely on natural roost sites, such as bark flakes and rock crevices. Forested habitat within the range of this species has declined substantially in the past two decades. Basic information on population sizes, roost sites, migration, and feeding habits of Keen's myotis will be necessary to assess the status of this species and ensure its long-term survival.

To evaluate the effects of forest management on bat populations of the Pacific Northwest, we need to accurately describe current geographic distributions, monitor population sizes, and determine the habitat characteristics of sites used for roosting, maternity colonies, and foraging. Distributional records for many species are incomplete and information on population sizes for most species is virtually nonexistent. Some progress is now being made in understanding habitat-use patterns, but this work has only begun. Critical habitat elements, especially the characteristics of naturally occurring roost sites and the size and variation in foraging ranges, need to be described. Until key characteristics of roost sites and foraging areas are known, it will be very difficult to manage forests for the persistence of native bat populations.

⁴ A recent taxonomic revision separated Keen's myotis into two species: Keen's myotis (Western United States) and the northern myotis (Eastern United States).

Scientific Names⁵

Common name	Scientific name
Bats:	
California myotis ⁶	<i>Myotis californicus</i>
Western small-footed myotis ⁶	<i>Myotis ciliolabrum</i> ⁷
Long-eared myotis ⁶	<i>Myotis evotis</i>
Gray myotis	<i>Myotis grisescens</i>
Keen's myotis ⁶	<i>Myotis keenii</i>
Little brown myotis ⁶	<i>Myotis lucifugus</i>
Northern myotis	<i>Myotis septentrionalis</i>
Indiana myotis	<i>Myotis sodalis</i>
Fringed myotis ⁶	<i>Myotis thysanodes</i>
Long-legged myotis ⁶	<i>Myotis volans</i>
Yuma myotis ⁶	<i>Myotis yumanensis</i>
Hoary bats	<i>Lasiurus cinereus</i>
Silver-haired bats	<i>Lasionycteris noctivagans</i>
Spotted bat	<i>Euderma maculatum</i>
Big brown bats	<i>Eptesicus fuscus</i>
Townsend's big-eared bat ⁶	<i>Plecotus townsendii</i>
Pallid bat	<i>Antrozous pallidus</i>
Western pipistrelle	<i>Pipistrellus hesperus</i>
Mexican free-tailed bat	<i>Tadarida brasiliensis</i>
Other animals:	
Deer mouse	<i>Peromyscus spp.</i>
Bullfrog	<i>Rana catesbeiana</i>
Vegetation:	
Douglas-fir	<i>Pseudotsuga menziesii</i> (Mirb.) Franco
Western hemlock	<i>Tsuga heterophylla</i> (Raf.) Sarg.
Ponderosa pine	<i>Pinus ponderosa</i> Dougl. ex Laws.
Sugar pine	<i>Pinus lambertiana</i> Dougl.
True fir	<i>Abies spp.</i>

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⁵ All taxonomy of North American species follows Jones and others (1992). s

⁶ Bat species occurring in Douglas-fir forests in the Pacific Northwest. 7

⁷ Previously known as *M. lebiii* or *M. subulatus*.

Literature Cited

- Albright, Ray. 1959.** Bat banding at Oregon caves. *Murrelet*. 40: 26-27.
- Anthony, E.L.P.; Stack, M.H.; Kunz, T.H. 1981.** Night roosting and the nocturnal time budget of the little brown bat, *Myotis lucifugus*: effects of reproductive status, prey density, and environmental conditions. *Oecologia*. 51: 151-156.
- Bailey, Vernon. 1936.** The mammals and life zones of Oregon. North American Fauna 55. Washington DC: U.S. Department of Agriculture, Bureau of Biological Survey. 416 p.
- Barbour, Roger W.; Davis, Wayne H. 1969.** Bats of America. Lexington: University of Kentucky Press. 286 p.
- Barclay, Robert 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, Robert M.R.; Faure, Paul A.; Farr, Daniel R. 1988.** Roosting behavior and roost selection by migrating silver-haired bats (*Lasionycteris noctivagans*). *Journal of Mammalogy*. 69: 821-825.
- Black, Hal L. 1974.** A north temperate bat community: structure and prey populations. *Journal of Mammalogy*. 55: 138-57.
- Bowers, J.R.; Heidt, G.A.; Baker, R.H. 1968.** A late autumn record for the hoary bat in Michigan. *Jack-Pine Warbler*. 46: 33.
- Brigham, R. Mark; Fenton, M. Brock 1986.** The influence of roost closure on the roosting and foraging behavior of *Eptesicus fuscus* (Chiroptera: Vespertilionidae). *Canadian Journal of Zoology*. 64: 1128-1133.
- Cagle, Fred R.; Cockrum, Lendell. 1943.** Notes on a summer colony of *Myotis lucifugus lucifugus*. *Journal of Mammalogy*. 24: 474-92.
- Carey, Andrew B.; Spies, Thomas A. 1991.** Sampling design of the Old-Growth Forest Wildlife Habitat Program. In: Ruggiero, Leonard F.; Aubry, Keith B.; Carey, Andrew B. [and others], tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 9-16.
- Clark, Donald R., Jr. 1981.** Bats and environmental contaminants: a review. *Special Rep.-Wildl.* 235. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 27 p.
- Clark, Donald R.; Laval, Richard K.; Swineford, Douglas M. 1978.** Dieldrin-induced mortality in an endangered species, the gray bat (*Myotis grisescens*). *Science*. 199: 1357-1359.
- Cockrum, E. Lendell. 1969.** Migration of the guano bat *Tadarida brasiliensis*. In: Contributions in mammalogy. University of Kansas Museum of Natural History Misc. Publ. 51. Lawrence, KS: University of Kansas Printing Service: 303-336.
- Cockrum, E. Lendell; Cross, Stephen P. 1964.** Time of bat activity over water holes. *Journal of Mammalogy*. 45: 635-636.
- Cockrum, E. Lendell; Cross, Stephen P. 1965.** Time of bat activity over water holes. *Journal of Mammalogy*. 46: 356.

- Constantine, Denny 6.1966.** Ecological observations on lasiurine bats in Iowa. *Journal of Mammalogy*. 47: 34-41.
- Cross, S.P., ed. 1976a.** A survey of bat populations and their habitat preferences in southern Oregon: a student originated studies project of the National Science Foundation. Ashland, OR: Southern Oregon State College. 40 p.
- Cross, Stephen P.1976b.** A survey of the bats of Oregon Caves National Monument. [Place of publication unknown]:[Publisher unknown]; contract report; NPS contract CX-9000-6-0051. 25 p. Available from: Stephen P. Cross, Department of Biology, Southern Oregon State College, Ashland, OR.
- Cross, Stephen P. 1977.** A survey of the bats of Oregon Caves National Monument. [Place of publication unknown]: [Publisher unknown]; contract report; NPS CX-90006-0051. 40 p. Available from: Stephen P. Cross, Department of Biology, Southern Oregon State College, Ashland, OR.
- Cross, Stephen P. 1986.** Bats. In: Cooperidge, Allen Y.; Boyd, Raymond J.; Stuart, Hanson R., eds. Inventory and monitoring of wildlife habitat. Denver, CO: U.S. Department of the Interior, Bureau of Land Management Service Center: 297-517.
- Cross, Stephen P.1988.** Riparian systems and small mammals and bats. In: Raedeke, Kenneth J., ed. Streamside management: riparian wildlife and forestry interactions. Seattle, WA: University of Washington Press: 93-112.
- Cross, Stephen P.; Schoen, Curtis. 1989.** Bats at Oregon Caves: 1988 status report. [Place of publication unknown]: [Publisher unknown]; contract report; NPS CX-90006-0051. 25 p. Available from: Stephen P. Cross, Department of Biology, Southern Oregon State College, Ashland, OR.
- Dalquest, Walter W.1943.** Seasonal distribution of the hoary bat along the Pacific Coast. *Murrelet*. 24: 21-24.
- Dalquest, Walter W. 1948.** Mammals of Washington. Lawrence, KS: University of Kansas: Publication of the Museum of Natural History: 1-444.
- Davis, W.H.; Hassell, M.D.; Rippy, C.L. 1965.** Maternity colonies of the bat *Myotis lucifugus* in Kentucky. *American Midland Naturalist*. 73: 161-165.
- Davis, Wayne H.; Hitchcock, Harold B. 1965.** Biology and migration of the bat, *Myotis lucifugus*, in New England. *Journal of Mammalogy*. 46: 296-313.
- DeBlase, Anthony F.; Humphrey, Stephen R.; Drury, K. Susan. 1965.** Cave flooding and mortality in bats in Wind Cave, Kentucky. *Journal of Mammalogy*. 46: 96.
- Doutt, J.K.; Heppenstall, C.A.; Guilday, J.E. 1966.** Mammals of Pennsylvania. Harrisburg: Pennsylvania Game Commission. 273 p.
- Edgerton, H.E.; Spangle, R.F.; Baker, J.K.1966.** Mexican free-tailed bats: photography. *Science*. 153: 201-203.
- Fenton, M.B. 1970.** Population studies of *Myotis lucifugus* (Chiroptera: Vespertilionidae) in Ontario. *Life Sciences Contributions of the Royal Ontario Museum*. 77: 1-34.
- Fenton, M.B.; Bell, G.P. 1981.** Recognition of species of insectivorous bats by their echolocation calls. *Journal of Mammalogy*. 62: 233-43.

- Fenton, M.B.; van Zyll de Jong, C.G.; Bell, G.P. [and others]. 1980.** Distribution, parturition dates and feeding of bats in south-central British Columbia. *Canadian Field-Naturalist*. 94: 416-20.
- Fenton, M. Brock. 1988.** Detecting, recording, and analyzing vocalizations of bats. In: Kunz, T.H., ed. *Ecological and behavioral methods for the study of bats*. Washington, DC: Smithsonian Institution Press: 91-104.
- Fenton, M. Brock; Barclay, Robert M.R. 1980.** *Myotis lucifugus*. *Mammalian Species* 142. New York, NY: American Society of Mammalogists. 8 p.
- Fenton, M. Brock; Thomas, Donald W. 1984.** Migrations and dispersal of bats (Chiroptera). In: Checkley, D.; Cullen, J.; Kitting, C. [and others], eds. *Migrations: mechanisms and adaptive significance*. *Contributions in Marine Science*. 27: 409-424.
- Findley, James S.; Jones, Clyde. 1964.** Seasonal distribution of the hoary bat. *Journal of Mammalogy*. 45: 461-470.
- Furlonger, C.L.; Dewar, H.J.; Fenton, M.B. 1987.** Habitat use by foraging insectivorous bats. *Canadian Journal of Zoology*. 65: 284-288.
- Gardner, James E.; Garner, James D.; Hofmann, Joyce E. 1991.** Summer roost selection and roosting behavior of *Myotis sodalis* (Indiana bat) in Illinois. Twin cities, MN: U.S. Department of the Interior, Fish and Wildlife Service; final report; [contract no. unknown]. 56 p.
- Geggie, J.F.; Fenton, M.B. 1985.** A comparison of foraging by *Eptesicus fuscus* (Chiroptera: Vespertilionidae) in urban and rural environments. *Canadian Journal of Zoology*. 63: 263-267.
- Geluso, Kenneth N.; Altenbach, J. Scott; Wilson, Don E. 1976.** Bat mortality: pesticide poisoning and migratory stress. *Science*. 194: 184-186.
- Gillette, David D.; Kimbrough, John D. 1970.** Chiropteran mortality. In: Slaughter, B.H.; Waltin, D.W., eds. *About bats*. Dallas, TX: Southern Methodist University Press: 262-283.
- Goehring, H.H. 1958.** A six year study of big brown bat survival. *Proceedings of the Minnesota Academy of Science*. 26: 222-24.
- Griffin, Donald R. 1953.** Deluge underground. *Bulletin of the National Speleological Society*. 15: 34-37.
- Griffin, Donald R. 1970.** Migrations and homing of bats. In: Wimsatt, W.A., ed. *Biology of bats*. New York: Academic Press: 233-64. Vol. 1.
- Griffin, Donald R.; Webster, Frederic A.; Michael, Charles R. 1960.** The echolocation of flying insects by bats. *Animal Behaviour*. 8: 141-154.
- Grinnell, Hilda Wood. 1918.** A synopsis of the bats of California. *University of California Publications in Zoology*. 17: 223-404.
- Hall, J.S. 1962.** A life history and taxonomic study of the Indiana bat *Myotis sodalis*. *Scientific Publications of the Reading Public Museum and Art Gallery*. 12: 1-68.

- Herd, Robert M.; Fenton, M. Brock. 1983.** A genetic, morphological and ecological investigation of a putative hybrid zone between *Myotis lucifugus* and *Myotis yumanensis* (Chiroptera: Vespertilionidae). *Canadian Journal of Zoology*. 61: 2020-2050.
- Henny, Charles J.; Maser, Chris; Whitaker, John O., Jr.; Kaiser, T. Earl. 1982.** Organochlorine residues in bats after a forest spraying with DDT. *Northwest Science*. 56: 329-337.
- Hitchcock, Harold H. 1965.** Twenty-three years of bat banding in Ontario and Quebec. *Canadian Field-Naturalist*. 79: 4-14.
- Humphrey, S.R.; Cope, J.B. 1976.** Population ecology of the little brown bat, *Myotis lucifugus*, in Indiana and southcentral Kentucky. Stillwater, OK: American Society of Mammalogists. 81 p.
- Humphrey, Stephen R.; Kunz, Thomas H. 1976.** Ecology of a Pleistocene relict, the western big-eared bat (*Plecotus townsendii*) in the southern great plains. *Journal of Mammalogy*. 57: 470-484.
- Johnson, Murray L. 1953.** Fall and winter record of the silver-haired bat for Washington State. *Murrelet*. 31: 32.
- Jones, J. Knox, Jr.; Hoffmann, Robert S.; Rice, Dale W. [and others]. 1992.** Revised checklist of North American mammals north of Mexico. Occasional Papers of the Museum of Texas Tech University 146. Lubbock: Texas Tech University Press. 23 p.
- Kirkpatrick, Ralph D. 1982.** *Rana catesbeiana* (bullfrog) food. *Herpetological Review*. 13: 17.
- Kunz, Thomas H. 1982a.** *Lasiurus noctivagus*. *Mammalian Species* 172. New York, NY: American Society of Mammalogists. 5 p.
- Kunz, Thomas H. 1982b.** Roosting ecology of bats. In: Kunz, Thomas H., ed. *Ecology of bats*. New York, NY: Plenum Press: 1-55.
- Kunz, Thomas H.; Martin, Robert A. 1982.** *Plecotus townsendii*. *Mammalian Species* 175. New York, NY: American Society of Mammalogists. 6 p.
- Kurta, Allen; Baker, Rollin H. 1990.** *Eptesicus fuscus*. *Mammalian Species* 356. New York, NY: American Society of Mammalogists. 10 p.
- Kurta, Allen; Kunz, Thomas H. 1988.** Roosting metabolic rate and body temperature of male little brown bats (*M. lucifugus*) in summer. *Journal of Mammalogy*. 69: 645-651.
- Lowe, David W.; Matthews, John R.; Moseley, Charles J., eds. 1990.** The official world wildlife fund guide to endangered species of North America. Washington, DC: Beacham Publishers. 1180 p.
- Lunde, Robert E.; Harestad, Alton S. 1986.** Activity of little brown bats in coastal forests. *Northwest Science*. 60: 206-209.
- Lunney, D.; Barker, John; Leary, Tanya. 1988a.** Movements of banded bats (*Microchiroptera: Vespertilionidae*) in Mumbulla State Forest near Beqa, New South

- Lunney, Daniel; Barker, John; Priddel, David; O'Connell, Micheal. 1988b.** Roost selection by Gould's long-eared bat, *Nyctophiius gouldi* Tomes (Chiroptera: Vespertilionidae) in logged forest on the south coast of New South Wales. Australian Wildlife Research. 15: 375-384.
- Manning, Richard W.; Jones, J. Knox, Jr. 1989.** *Myotis evotis*. Mammalian Species 329. New York, NY: American Society of Mammalogists. 5 p.
- Maser, Chris; Cross, Stephen P. 1981.** Notes on the distribution of Oregon bats. Research Note PNW-379. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 31 p.
- Maser, Chris; Mate, Bruce R.; Franklin, Jerry F.; Dyrness, C.T. 1981.** Natural history of Oregon Coast mammals. Gen. Tech. Rep. PNW-133. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 496 p.
- McNab, Brian K. 1982.** Evolutionary alternatives in the physiological ecology of bats. In: Kunz, Thomas H., ed. Ecology of bats. New York: Plenum Press: 151-200.
- Merriam, Clinton Hart. 1884.** Mammals of the Adirondack region. New York: Press of L.S. Foster. 316 p.
- Miller, Lee A.; Andersen, Bent Bach. 1984.** Studying bat echolocation signals using ultrasonic detectors. Zeitschrift fur Säugetierkunde. 49: 6-13.
- Mohr, Charles E. 1948.** Texas bat caves serve in three wars. Bulletin of the National Speleological Society. 14: 3-13.
- Mohr, Charles E. 1972.** The status of threatened species of cave-dwelling bats. Bulletin of the National Speleological Society. 34: 33-47.
- Nowak, Ronald M. 1991.** Walker's mammals of the world. Baltimore: Johns Hopkins University Press. 642 p. Vol. 1.
- O'Farrell, Micheal J.; Studier, Eugene H. 1980.** *Myotis thysanodes*. Mammalian Species 137. New York, NY: American Society of Mammalogists. 5 p.
- Paradiso, John L.; Greenhall, Arthur M. 1967.** Longevity records for American bats. American Midland Naturalist. 78: 251-252.
- Parsons, Harold J.; Smith, Donald A.; Whittam, Robert F. 1986.** Maternity colonies of silver-haired bats, *Lasionycteris noctivagans*, in Ontario and Saskatchewan. Journal of Mammalogy. 67: 598-600.
- Pearson, Oliver P.; Koford, Mary R.; Pearson, Anita K. 1952.** Reproduction of the lump-nosed bat (*Corynorhinus rafinesquh*) in California. Journal of Mammalogy. 33: 273-320.
- Perkins, J. Mark. 1983.** Northwest Oregon bat survey. Portland, OR: Oregon Department of Fish and Wildlife; draft report; contract 82-0-4. 51 p.
- Perkins, J. Mark; Barss, John M.; Peterson, Joshua. 1990.** Winter records of bats in Oregon and Washington. Northwestern Naturalist. 71: 59-62.

- Perkins, J. Mark; Cross, Stephen P. 1988.** Differential use of some coniferous forest habitats by hoary and silver-haired bats in Oregon. *Murrelet*. 69: 21-24.
- Perkins, J. Mark; Levesque, Connie. 1987.** Distribution, status and habitat affinities of Townsend's big-eared bat (*Plecotus townsendii*) in Oregon. Portland, OR: Oregon Department of Fish and Wildlife, nongame wildlife program; technical report 86-5-01. 49 p.
- Provost, Ernest E.; Kirkpatrick, Charles M. 1952.** Observation on the hoary bat in Indiana and Illinois. *Journal of Mammalogy*. 33: 110-113.
- Racey, P.A. 1973.** Environmental factors affecting the length of gestation in heterothermic bats. *Journal of Reproduction and Fertility Supplement*. 19: 175-189.
- Racey, P.A. 1982.** Ecology of bat reproduction. In: Kunz, Thomas H., ed. *Ecology of Bats*. New York: Plenum Press: 57-104.
- Racey, P.A.; Swift, Susan M. 1981.** Variations in gestation length in a colony of pipistrelle bats (*Pipistrellus*) from year to year. *Journal of Reproduction and Fertility*. 61: 123-129.
- Ross, Anthony. 1967.** Ecological aspects of the food habits of insectivorous bats. *Proceedings of the Western Foundation of Vertebrate Zoology*. 1: 205-63.
- Ruggiero, Leonard F.; Aubry, Keith B.; Carey, Andrew B. [and others], tech. coords. 1991.** Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 533 p.
- Schowalter, David B.; Dorward, William J.; Gunson, John R. 1978a.** Seasonal occurrence of silver-haired bats (*Lasionycteris noctivagans*) in Alberta and British Columbia. *Canadian-Field Naturalist*. 92: 288-291.
- Schowalter, David B.; Gunson, John 1979.** Reproductive biology of the big brown bat (*Eptesicus fuscus*) in Alberta. *Canadian Field-Naturalist*. 93: 243-251.
- Schowalter, David B.; Harder Lawrence D.; Treichel, Bruce H. 1978b.** Age composition of some vespertilionid bats as determined by dental annuli. *Canadian Journal of Zoology*. 56: 355-358.
- Schwartz, Charles Walsh; Schwartz, Elizabeth Reader. 1959.** The wild mammals of Missouri. Columbia: University of Missouri Press and Missouri Conservation Commission. 339 p.
- Senger, Clyde M.; Senger, Robert; Senger, David; Senger, Stuart. 1974.** Winter records of myotis bats in western Washington. *Murrelet*. 55: 13-14.
- Seton, Ernest Thompson. 1907.** Life-histories of northern animals. New York: Charles Scribner's Sons. 1264 p.
- Shump, Karl A., Jr.; Shump, Ann 0. 1982.** *Lasiurus cinereus*. *Mammalian Species* 185. New York, NY: American Society of Mammalogists. 5 p.
- Simmons, James A.; Fenton, M. Brock; Ferguson, William R. [and others]. 1979.** Apparatus for research on animal ultrasonic signals. *Life Sciences Misc. Publi.* Toronto, ON: Royal Ontario Museum. 31 p.

- Stebbing, R.E.1980.** Conservation of European bats. Kent, United Kingdom: Christopher Helm, Ltd. 246 p.
- Thomas, Donald W.1988.** The distribution of bats in different ages of Douglas-fir forests. *Journal of Wildlife Management*. 52: 619-626.
- Thomas, Donald W.; Bell, Gary P.; Fenton, M. Brock. 1987.** Variation in echolocation call frequencies recorded from North American vespertilionid bats: a cautionary note. *Journal of Mammalogy*. 68: 842-847.
- Thomas, Donald W.; West, Stephen D. 1989.** Sampling methods for bats. Gen. Tech. Rep. PNW-243. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 20 p. (Ruggiero, Leonard F.; Carey, Andrew B., tech. eds.; *Wildlife-habitat relationships: sampling procedures for Pacific Northwest vertebrates*).
- Thomas, Donald W.; West, Stephen D. 1991.** Forest age associations of bats in the Washington Cascade and Oregon Coast Ranges. In: Ruggiero, Leonard F.; Aubry, Keith B.; Carey, Andrew B. [and others], tech. coords. *Wildlife and vegetation of unmanaged Douglas-fir forests*. Gen. Tech. Rep. PNW-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 295-303.
- Trevor-Deutsch, B. 1973.** The role of hibernating bats in the winter diet of *Peromyscus* spp. (Rodentia: Cricetidae) in Ontario. Ottawa, ON: Carleton University. 127 p. Ph.D. thesis.
- Tuttle, Merlin D. 1974.** An improved trap for bats. *Journal of Mammalogy*. 55: 475-477.
- Tuttle, Merlin D. 1976.** Population ecology of the gray bat (*Myotis grisescens*): factors influencing growth and survival of newly volant young. *Ecology*. 57: 587-595.
- Tuttle, Merlin D. 1979.** Status, causes of decline and management of endangered gray bats. *Journal of Wildlife Management*. 43: 1-17.
- van Zyll de Jong, C.G. 1979.** Distribution and systematic relationships of long-eared *Myotis* in western Canada. *Canadian Journal of Zoology*. 57: 987-94.
- van Zyll de Jong, C.G.1985.** Handbook of Canadian mammals: Volume 2: Bats. Ottawa: National Museums of Canada. 212 p.
- Warner, Richard M.; Czaplewski, Nicholas J.1984.** *Myotis volans*. Mammalian Species 224. New York, NY: American Society of Mammalogists. 4 p.
- Whitaker, John O., Jr.; Maser, Chris; Keller, Laurel E. 1977.** Food habits of bats of western Oregon. *Northwest Science*. 51: 46-55.
- Whitaker, John O., Jr., Maser, Chris; Cross, Stephen P.1981 a.** Food habits of eastern Oregon bats, based on stomach and scat analysis. *Northwest Science*. 55: 281-92.
- Whitaker, John O., Jr.; Maser, Chris; Cross, Stephen P. 1981 b.** Foods of Oregon silver-haired bats. *Northwest Science*. 55: 75-77.
- Woodsworth, G.C. 1981.** Spatial partitioning by two species of sympatric bats, *Myotis californicus* and *Myotis leibii*. Ottawa, ON: Carleton University. M.S. thesis.

Glossary

Calcar-Extension of heel bone that supports the tail membrane between the foot and the tail.

Day roosts-Structures used by bats to sleep or rest in during the day.

Glean-To pick insects from the ground or foliage rather than from the air.

Hibernacula-Sites used by bats for hibernation in winter months (for example, caves, mines, hollow trees, attics).

Hibernation-Long-term decrease in metabolic rate during winter in response to seasonal changes in environmental conditions and resource availability.

Keel-Ridgelike expansion of the calcar, which gives added support to the tail membrane.

Kilohertz (kHz)-Unit of sound frequency equal to 1000 cycles per second. The human ear can pick up sounds from 0.05 to 20 kHz. Bat echolocation frequencies range from 10 to 180 kHz. Species in the Pacific Northwest echolocate at 20 to 100 kHz.

Maternity roosts-Structures used by colonial female bats and their young during the spring and summer months. Males often join females and young in maternity roosts in autumn after young are weaned.

Mist netting-Capture of bats (or birds) in fine nylon nets.

Night roosts-Structures used briefly by bats at night. Bats will retreat to night roosts to rest between feeding periods or to feed on large insects that cannot be eaten while in flight. Night roosts usually are found in different locations than day roosts.

Torpor-Short-term decrease in metabolic rate for energy conservation that may occur during any season of year.

Vespertilionidae-Evening bats or plain-nosed bats. Taxonomic family that includes all Pacific Northwest bats.

Wingspan---Length of wing spread. Measured from wing tip to wing tip, including width of the body.

Christy, Robin E.; Stephen D. West. 1993. Biology of bats in Douglas-fir forests. Gen. Tech. Rep. PNW-GTR-308. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 28 p. (Huff, Mark H.; Holthausen, Richard M.; Aubry, Keith B., Tech. coords. Biology and management of old-growth forests).

Twelve species of bats occur in Douglas-fir forests of the Pacific Northwest, of which nine are known to roost in tree cavities, bark crevices, or foliage, and several are closely associated with old-growth forests. Thus bat populations may be detrimentally affected by forest management practices involving the removal of large, old trees and snags. We review the life history characteristics and habitat relations of bats in the Pacific Northwest and provide information useful in managing forests for the persistence of native bat populations.

Keywords: Bats, Pacific Northwest, natural history, old-growth forests.

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