SPECIES ASSESSMENT FOR FRINGED MYOTIS (*MYOTIS THYSANODES*) IN WYOMING

prepared by

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Summary

The fringed myotis (*Myotis thysanodes*) is recognized by several federal and state agencies as a sensitive species that is apparently rare and threatened, but for which relatively little is known regarding the current status of local, regional, or national populations. Primary threats to *M. thysanodes* are roost disturbance, habitat alteration, and toxic chemicals. Roost disturbance (especially of maternity roosts and hibernacula) can take the form of direct human contact or alternation of the roost environment. Habitat alteration refers to modification of any component of the required habitat mosaic (i.e. open water, conifer forest, and roost structures) or modification of how those components relate to each other spatially. Chemicals refer primarily to pesticides and toxic impoundments from industry and resource extraction, which can cause direct bat mortality and reduce populations of insect prey.

To conserve *M. thysanodes* it is of primary importance to delineate local populations and insure that 1) key life history stages are not disturbed; 2) once disturbance has been minimized, the necessary habitat mosaic is present for persistence of those populations, 3) given appropriate habitat suitability, exposure to potentially detrimental chemicals is eliminated, and 4) populations are non-invasively monitored to determine trends. More specific issues of conservation concern are discussed in greater detail later in this assessment. Fulfilling the information needs listed at the end of this document will clarify population status and contribute to refining these conservation goals.

Introduction

This assessment addresses the biology, ecology, and conservation status of fringed myotis throughout its current range, with particular attention given to that portion occurring within and

near Wyoming. Our goal is to provide a summary of published information and expert

interpretation of this information that can be used by the Bureau of Land Management (BLM) to

develop management plans. *M. thysanodes* was selected for assessment because it occurs on the

Wyoming BLM sensitive species list due to the rarity and potential sensitivity to disturbance of

the species as a whole, and the probable isolation of the subspecies in particular.

Relatively little is known about most *M. thysanodes* populations and virtually none about those

in Wyoming. Therefore, this assessment summarizes information from throughout its North

American range and, where possible, attempts to relate this specifically to aspects of Wyoming.

Information was obtained from peer reviewed literature, agency reports, and acknowledged bat

experts.

There is uncertainty in all scientific inquiries, and the data described in this assessment is no

exception. Herein, the strength of evidence from research is noted and alternative explanations

assessments of observational data and expert inference are described when appropriate. Peer-

reviewed literature represents the strongest set of data and is therefore used preferentially to draw

conclusions regarding *M. thysanodes*. Hypotheses and inferences are noted with appropriate

qualifications. Where possible, when there is little or no quantitative research to back up specific

ideas, expert opinion was obtained independently from several sources.

As with all pieces of literature synthesized from disparate data, this assessment has some

limitations. Since most data presented herein come from specific studies with restricted research

areas, interpolation and extrapolation of this data must be done with caution. It seems that aspects

of fringed myotis biology, ecology, and conservation vary over the geographic extent of its range.

Therefore, the information in this assessment should not be taken as definitive of fringed myotis in

any particular area. Rather, it should be used as a guide to the range of biological parameters and

behaviors possible for *M. thysanodes*, which can then help direct specific investigation to clarify

the status of local populations as a prelude to major management action.

Natural History

Morphological Description

Unlike all other myotis in North America, *M. thysanodes* has a conspicuous fringe of hair

along the posterior border of the interfemoral membrane (Fig. 1) that extends 1.0 to 1.5 mm

beyond the uropatagium (e.g., Jones and Genoways 1967). Other morphometric characteristics of

M. thysanodes are reported in Table 1. There seems to be geographic variation in fur color, with

darker animals occurring in the northern portions of *M. thysanodes* range (Miller and Allen 1928

in O'Farrell and Studier 1980). The dorsal fur varies in color from yellowish brown to dark brown

with olive tones (O'Farrell and Studier 1980) or reddish tones (Barbour and Davis 1969). The

ventral fur is usually somewhat paler and can be touched with ochre (Barbour and Davis 1969),

but there may not be much color difference between the dorsal and ventral surfaces (O'Farrell and

Studier 1980). The Black Hills subspecies, *M. t. pahasapensis*, is brownish to tawny olive or

ochraceous buff above and pale to light ochraceous buff below (Jones and Genoways 1967).

Bats can often be identified by the frequency modulation of their echolocation calls. The

pattern of *M. thysanodes* echolocation calls begins with a variable downward sweep in frequency

to 28-33 kHz in 1-3 milliseconds (Fig. 2). Although generally having no constant frequency

portions, *M. thysanodes* calls can sometimes terminate in a nearly constant frequency tail lasting

2-7 milliseconds.

Although not diagnostic, the wing and tail membranes of *M. thysanodes* are thick and

puncture-resistant compared to many other bat species, presumably to mitigate injury while

gleaning insects on the ground or in thorny vegetation (Wilson and Ruff 1999, O'Farrell and

Studier 1980). The aspect ratio (wing span^2/wing area $\cong$ 6) is low, which is typical of slow, highly

maneuverable bats that forage by gleaning (O'Farrell and Studier 1980).

The sexes are generally distinguished based on external genitalia. In the non-breeding season,

sexual differentiation is more difficult. Females tend to have slightly, but significantly, larger

heads, bodies and forearms (Williams and Findley 1979 in O'Farrell and Studier 1980). The

baculum of *M. thysanodes* was described as 0.77 mm long and dumbbell shaped with a ventral

groove (Vaughan 1955 in O'Farrell and Studier 1980).

M. t. pahasapensis has been confused with *M. evotis* where they co-occur. They can be

distinguished based on external characteristics, most notably the conspicuous uropatagial fringe.

Also, *M. t. pahasapensis* has smaller ears (average 18.7 versus 20) and longer forearms (average

about 41.1 versus 38.6). In other areas, *M. evotis* has either no or a poorly developed uropagatial

fringe and longer ears can be evidenced by the fact that the ratio of ear length to forearm length is

greater than 0.5 (unlike *M. thysanodes*) (Genter and Jurist 1995).

Taxonomy and Distribution

Taxonomy

M. thysanodes is part of a group of bats sometimes referred to as the "long-eared" *Myotis* (*M.*

thysanodes, *M. auriculus*, *M. evotis*, and *M. keenii*), which seem to have a high taxonomic affinity

based on morphology and chromosomal characteristics that differ from other North American

vespertilionids (Bickham 1979). A similarly close affinity between "long-eared" myotis in the

southwestern United States has been assigned to *M. auriculus, M. evotis, M. milleri, and M.*

thysanodes (Reduker et al. 1983).

There are three recognized subspecies of fringed myotis (Fig. 3). *M. thysanodes thysanodes*

occurs in the main part of the species range. *M. t. aztecus* occurs in Oaxaca, Mexico (Wilson and

Ruff 1999). *M. t. pahasapensis* occurs only in the Black Hills of South Dakota, Wyoming, and

Nebraska (Barbour and Davis 1969; Jones and Genoways 1967; Bole 1935). According to Jones

and Genoways (1967), *M. t. pahasapensis* has slightly larger ears (average 18.7 mm versus 16.2

mm in *M. t. thysanodes*), a shorter forearm (41.1 mm versus 43.0 mm), smaller skull (see

measurements in Jones and Genoways 1967), and darker ears and membranes that contrast in

color with the dorsal pelage. A fourth subspecies, *M. t. vespertinus* (the Pacific fringe-tailed bat),

has been suggested to occur west of the Cascade mountains, along the pacific coast, from

southwestern Washington south through Oregon and into northwestern California as far south as

Humboldt and Shasta counties (Maser and Cross 1981, Manning and Jones 1988). It is tracked

separately by the Washington Natural Heritage Program, although it is not universally recognized

as a valid subspecies.

Range

    M. thysanodes is predominantly a western species occurring from southern British Columbia,

Canada (where it is only known from a few specimens), south through southern Mexico (Fig. 3;

O'Farrell and Studier 1980; Rasheed et al. 1995; Hall 1981). It occurs west to the Pacific coast

and east to the Rocky Mountains, with an isolated population in the Black Hills of South Dakota

and Wyoming. Populations in Mexico don't reach either coast, being found predominantly in the

central highlands. Occurrences have been documented in 14 states (Arizona, California, Colorado,

Idaho, Nebraska, New Mexico, Montana, Nevada, Oregon, South Dakota, Texas, Utah,

Washington, Wyoming).

    Two subspecies (*M. t. aztecus* and *M. t. vespertinus*) do not occur in Wyoming. *M. t.*

thysanodes, however, occurs over much of the state and the Black Hills subspecies (*M. t.*

pahasapensis) occurs only in the Black Hills of South Dakota and Wyoming. *M. t. pahasapensis*

is also reliably found in extreme northwestern Nebraska where it borders the Black Hills of South

Dakota and Wyoming, but questionable records exist farther east (Czapleqski et al. 1979).

M. thysanodes distribution does not seem to be substantially impacted by major topographic

features, as evidenced by a study on the Unita Mountains of Utah and Wyoming, where, unlike

many species whose range was partially defined by this east-west mountain range, it occurred

throughout the region with minimal geographic variation (Kirkland 1981).

Abundance

Rangewide, *M. thysanodes* appears to be quite rare, since is usually represents a small fraction

of bats detected in survey efforts, averaging ~ 7.5% ± 3.2% (range: 1.3% – 22.8%) of bats

identified (Table 2). The high end of this range was an outlier that occurred in northern Arizona,

where *M. thysanodes* was nearly twice as abundant as documented in any other study (Herder

1999). Without this outlier, the mean frequency of occurrence decreases to ~ 6.3% ± 2.3% of

identified bats (range: 1.3% – 13.7%), and the highest densities appear to be in the Black Hills of

South Dakota and in northern Arizona (e.g., Czaplewski et al. 1979, Herder 1998). In one Black

Hills study, they represented 13.7% of 1,699 mist net captures over 4 years (Cryan 1997); only *M.

volans* and *Eptesicus fuscus* were more abundant. However, they accounted for only 7% of 405

mist net captures for study in Badlands National Park, South Dakota, ranking 4th in relative

abundance among the 9 species captured (Bogan et al. 1996). Similarly, they were the 4th most

captured species during bat surveys of Jewel Cave National Monument, South Dakota (35

captured out of 587 total, or 6% of captures), and a few individuals were documented hibernating

in the cave during several winters (Choate and Anderson 1997). Thus, it appears that although

relatively rare, *M. thysanodes* can be locally abundant for reasons that are not fully understood.

Population Trend

To our knowledge, no monitoring efforts have targeted fringed myotis on a local or regional scale, much less rangewide, so no statistically valid trend data is available. Anecdotal evidence suggests increases in some areas and decreases in others, possibly confounded by short-term fluctuations. The range in Wyoming may have contracted over the last 50 years. Population trends are discussed more thoroughly in the trends portions of the Biological Conservation Status section (see below).

Habitat Requirements

General

Habitat types: *M. thysanodes* appear to frequent a fairly broad range of habitats (e.g., Cryan 1997). The most common habitat in which to find them appears to be oak, pinion, and juniper woodlands or ponderosa pine forest at middle elevations (O'Farrell and Studier 1980, Barbour and Davis 1969, Cockrum et al. 1996, Wilson and Ruff 1999, Davis 1966). They also seem to use deserts (Cockrum et al. 1996), grasslands, and other woodlands. Some specific studies have indicated the following (see also Table 2):

- A two year survey effort in northern Arizona suggested ponderosa pine forest was used preferentially over pinion and juniper (Herder 1998). This study resulted in 142 *M. thysanodes* captured in mist nets, harp traps, and trip lines placed over open water sources, of which 135 were captured in ponderosa pine forest, 6 in pinion-juniper woodlands, and 1 in desert scrub-sagebrush. This occurred despite the fact that the highest overall capture success for all species combined was in pinion-juniper woodland. These habitats were roughly attitudinally segregated, with shrub communities being predominantly below 4500 ft (~ 1400 m), pinion and juniper being 4,500 ft to 6,000 ft (~ 1400 - 1800 m), and ponderosa pine being over 6,000 ft (1800 m).

- In the Tonto National Forest, Agyagos et al. (1994) found *M. t. thysanodes* to be much more abundant in montane conifer forest (particularly ponderosa pine) than in all other habitat types.

- The Arizona Game and Fish Department (AGFD 1997) stated that those desert and shrubland areas used by fringed myotis were invariably within an hour flight of forested or riparian areas, including oak and pinion woodlands.

- Ellinwood (1978) reported limited M. thysanodes captures, all of which were located in pinion and juniper woodlands.

- Davis (1966) reported foraging activity in oak forest in Texas.

- O'Farrell and Studier (1980) reported captures over water troughs in creosote and burro bush shrubland in southern Nevada.

- Jones (1965) showed evidence of use in a variety of evergreen forests in New Mexico and Arizona.

- Williams (1968) reported use of sagebrush grasslands in Washington.

- Genter and Jurist (1995) documented use of open semi-desert areas to dry ponderosa pine forest.

- Brown and Berry (1998) and Miner et al. 1996 reported telemetered *M. t. thysanodes* roosting in cliff faces in dry chaparral and flying to foraging sites in pine/oak woodland.

- Brown and Berry (2000) documented a maternity colony of over 200 *M.thysanodes* in a mine in the Mojave Desert in creosote bush scrub at 600m elevation.

Elevation: *M. thysanodes* seems to range in elevation between roughly 1,200 m and 2,100 m (4,000 ft and 7,000 ft), and can be found up to 2,850 m (9350 ft) in spruce-fir forest in New Mexico (Barbour and Davis 1969, AGFD 1997). A similar elevation range of 1340 m to 1890 m (4,400 ft to 6,200 ft) was reported for *M. t. thysanodes* in Arizona (Agyagos et al. 1994). They have occasionally been reported from elevations of less than 150 m (< 500 ft) in coastal areas of California (Orr 1956), including at sea level on San Clemente Island off the Southern California Coast (Brown 1980; Von Bloeker 1967) .

Mistnetting activities in the southern Black Hills conducted by Cryan (1997, 2000) indicated mean elevations of capture for male *M. t. pahasapensis* (mean = 1,573 ft; STDV = 110 ft; N = 202) were slightly but significantly higher than for reproductive females (mean = 1,338 ft; STDV = 215 ft; N = 22; P<0.001). This is a trend suggested for other bats and is likely related to the energetic advantages gained by raising young in relatively warmer and insect-rich lowland environments (see citations in Cryan 1997).

Water Resources: Daily water loss in bats is extreme in comparison to other mammals, largely due to the respiratory demands imposed by flight (Studier and O'Farrell 1980). Perhaps partially for this reason, insectivorous bats as a group seem to have renal function that allows greater urine concentrating ability than suggested simply by their size and habitat use and within this group of bats, renal function seems well correlated with the relative aridity of the predominant habitat (Geluso 1980). Bats in arid environments have kidneys with more prominent medullae than those in more mesic regions. Although found in a variety of habitats, *M. thysanodes* seems to have a urine concentrating ability lower than most bats (Geluso 1980), that suggests a predisposition to relatively more mesic environments or environments where sources of drinking water are readily available. Dependence on nearby water sources is also supported by the fact that roost sites have been shown to be located closer to stream channels than expected by chance (Weller and Zabel 2001). Desert populations of *M. thysanodes* may have less dependence on proximate drinking water, perhaps due to physiological adaptations, as evidenced that no open water existed within 16 km (10 miles) of their roost in creosote bush scrub (Brown and Berry 2000).

The size and nature of flight for individual bat species relative to the size and vegetative cover of the water body can determine which bats are likely to be encountered at a given site. Large,

fast-flying bats, usually with limited maneuverability, are more likely to be encountered at large, uncluttered bodies of water, because they need long, open "swoop zones" and cannot effectively navigate through dense overhanging vegetation. Smaller bats, such as *M. thysanodes*, can be seen at a wider variety of water bodies, because they need a minimal swoop zone and can maneuver through vegetative clutter. Such species can regularly use water sources as small as cattle stock tanks (e.g., Herder 1998).

   Roosts: Suitable roosting sites are a critical habitat component, the availability of which can determine population sizes and distributions (e.g., Kunz 1982, Humphrey 1975). Maternity roosts, diurnal roosts, nocturnal roosts and winter hibernacula must all be considered. *M. thysanodes* seem to use caves, mines, and buildings as maternity colonies, solitary day and night roosts, and hibernacula (see list of references in O'Farrell and Studier 1980, Davis 1966, Musser and Durrant 1960, Perkins et al. 1990; Easterla 1966; Judd 1967). They will also use bridges and rock crevices (Brown and Berry 1998, Davis 1966, Herder 1998, Miner et al. 1996) as solitary day and night roosts and may hibernate in crevices as well (Christy and West 1993). They regularly use tree snags, particularly ponderosa pine (Chung-MacCoubrey 2001, Kurtzman 1994, Morell et al. 1994, Murphy 1994, Rasheed et al. 1995 in Cryan 1997) and have been shown to use lava flows on at least one occasion (Herder 1998).

   There is undoubtedly geographic variation in roost selection, but the pattern of this variation and its underlying causes are unclear. They likely result from a combination of factors including roost quality and availability, prevailing temperatures, proximity to water and foraging areas, and predator avoidance (e.g., Kunz 1982, Lewis 1995). One of the most important factors is likely thermal regime (Kunz 1982) and it is possible that, at the distributional scale, *M. thysanodes* varies its roost choices on this basis. For instance the prevalence of crevice roosting found in arid

climates may be a partial function of the high daytime temperatures in such areas, making

maintenance of high daytime roost temperatures less restrictive. All of 8 *M. thysanodes* from the

Black Hills that were radio-collared in the summer where recorded roosting in rock crevices in or

near rock ridges or steep-walled canyons (Cryan 1997). These roost sites typically had southern

exposure (maximizing thermal heating) and were located in low-elevation forests (e.g., ponderosa

pine) bordering oak and juniper woodlands.

In some regions it appears that males and females both use exclusively tree snags for day

roosts (Weller and Zabel 2001). In areas were tree roosting is the norm, vegetative structural

complexity of habitat around roost sites is likely more important than plant species composition or

general topographic features in determining local *M. thysanodes* distribution. These bats choose

areas with a high density of snags ≥ 30 cm diameter at breast height (i.e., not just a high density of

snags, but a high density of large snags) and lower canopy cover than surrounding forest, which

are likely correlated variables. The best model in a comparison of habitat models for predicting bat

presence in an area contained only two variables; the number of snags ≥ 30 cm DBH combined

with percent canopy cover, where increasing numbers of snags and decreasing canopy cover

increased the probability of bat occurrence (Weller 2000). Abundance of large snags and low

canopy cover allows more thermal heating of roosts, easier flight access to roosts, and the ability

to readily switch roosts in the event of roost collapse, for predator avoidance, or to find more

suitable microclimates (Lewis 1995, Weller 2000, Kunz 1982). In such circumstances, *M.

thysanodes* have been known to switch roosts several times a week (e.g., every 1.72 ± 0.23 days;

Weller and Zabel 1999). Roost snags also tended to be taller relative to the surrounding canopy

than random snags, have a higher diameter at breast height than random snags, and were nearer to

stream channels than randomly selected points. Most roost snags were in decay classes 2 - 4

(Thomas 1979), since fringe myotis in this study tended to roost under loose bark. These snags

were Douglas fir, ponderosa pine, and sugar pine used in approximate proportion to their availability (the largest snags in the study area were predominantly Douglas fir).

Microhabitat requirements of *M. thysanodes* within cave and mine roosts, the suitability of which largely determines occupancy, have not been well studied. It seems that they tend to roost in open areas in tightly packed groups (AGFD 1997, Wilson and Ruff 1999) often in shallow pockets in the ceiling. In houses, maternity roosts usually occur in tightly packed clusters in open areas of attics (e.g. along ceiling joists), but may also occur in cracks between beams (O'Farrell and Studier 1980) or crevices between the chimney and building (P. Brown pers. obs).

As with other bats, fringed myotis likely selects roosts based on temperature regimes. Maternity colonies are generally quite warm, to minimize thermoregulatory expenditures of pregnant and lactating females and developing young. Groups of roosting *M. thysanodes* often switch locations within roost sites, probably in order to find appropriate microclimates for thermoregulatory purposes. In attics reproductive females appeared to seek out warm (not hot) microclimates throughout the summer, but shifted to cooler microclimates with the approach of fall migration (O'Farrell and Studier 1980). Ideal day roosts for large numbers of bats often have a variety of microclimates within them, so bats are able to behaviorally thermoregulate by moving to different locations within the same roost structure.

Few hibernacula have been well documented, but those that have are generally cool and usually in caves or mines with little temperature fluctuation throughout the winter, which facilitates hibernation at a uniformly low metabolic rate. A few bats were reported hibernating in mines in Arizona (Cockrum et al. 1996) that were cool (e.g., 16.7°C and 21.7°C) and damp (no indices given). They have also been discovered hibernating in buildings and mines along the coast range north of San Francisco Bay (Pierson 1998). Unlike other bats that may aggregate in high

numbers to hibernate, *M. thysanodes* has been shown to hibernate in small numbers, at least in the Black Hills (Martin and Hawks 1972, Tigner 1997 in Cryan 1997).

Roost site fidelity varies among bats, but is likely to be inversely related to roost availability and directly related to roost permanence (Weller and Zabel 2001, Kunz 1982, Lewis 1995 in Cryan 1997). The roost site fidelity of *M. thysanodes* appears to vary across its range and is likely related to the main roosting structures in a given geographic area. Roosts in relatively permanent structures, such as caves, buildings, and rock crevices, seem to elicit high fidelity while roosts in trees do not (Lewis 1995, Weller and Zabel 2001). Bats using spatially abundant but impermanent roosts (e.g., tree foliage or snags) are more closely tied to a home range in which a variety of roosts are used, than are bats that roost in relatively permanent but sparse habitat features (e.g., caves). This is suggested by the studies in California that showed low fidelity to individual roost snags, but consecutive roosts snags that were relatively proximate to each other (i.e., 254 ± 61 m; Weller and Zabel 2001). In such an area, shifting between roosts occurs on a daily basis (Weller 2000), so specific roost trees, although heavily used over a longer period of time, may not be used at all on a given night (Weller 2000). Additionally, Cryan (1997) found evidence that some myotis species roosted in a variety of structures, making assignment of optimal roosting habitat complex.

Nursery colonies likely remain more stable, since lactating females with pups are less likely to shift day roosts. Chung-MacCoubrey (1996) investigated roosting habits of pregnant or lactating female *M. thysanodes* captured in pinion-juniper habitat in New Mexico. This study suggested that maternal *M. thysanodes* showed roost fidelity to colonial roosts in living and dead ponderosa pine trees with lightening or wind damage. Such trees were generally located near the boundary of ponderosa pine stringers in pinion-juniper habitat.

Aside from the fact that they roost separately, males are likely to choose summer roosts with different characteristics than females, a trait that may be true of many bat species. Specifically, females may choose warmer roost sites because they have more thermoregulatory demands, since they must maintain a relatively high metabolism during gestation and lactation (Kunz and Nagy 1988). In contrast, males can use daily torpor as a means of energy conservation and so may use cooler roost sites. There is some evidence from different portions of their range that male *M. thysanodes* roost at higher elevations than females during the spring and summer months (e.g., Cockrum et al. 1996).

Seasonal and Life History Shifts

In the temperate portion of its range, *M. thysanodes* likely migrates short distances to winter hibernacula that are lower in elevation and/or more southern than summer roosts. In southern desert areas, the bats may actually move to higher elevations in search of cooler temperatures for hibernation. Migration events are relatively quick, synchronous, and closely tied to breeding, although spring migration is probably more so than fall migration and there is likely variation related to seasonal weather patterns. In New Mexico, bats will usually arrive at their maternity roost from mid to late April and depart sometime in September (O'Farrell and Studier 1975). It has been suggested that *M. thysanodes* does not generally have sufficient fat reserves at the end of the breeding season to enter hibernation immediately after vacating maternity roosts and that they therefore may remain periodically active in the fall, or even all winter in temperate climates such as locations in New Mexico (O'Farrell and Studier 1976, 1975). This is supported by the ability of this species to fly at reduced body temperature (Studier and O'Farrell 1972 in O'Farrell and Studier 1975).

Given that fetal development is closely tied to spring thermoregulatory history of pregnant females, O'Farrell and Studier (1975) suggest that the uniformity of spring migration and parturition dates are evidence that *M. thysanodes* roosting groups are annually coherent. In other words, all members of a given maternity colony likely roost in the same hibernacula, or at least congregate in a common location prior to spring arrival at the maternity colony. This suggests potentially low mixing between roost groups, and when combined with high interannual roost area fidelity, has implications for isolation of fringed myotis populations.

Area Requirements

Very little data is available on home range requirements for insectivorous bats, and none for *M. thysanodes* in particular. Moreover, the concept of home range is not clearly applicable to bat ecology, given the mobility of bats and the apparent plasticity of foraging areas with respect to prey abundance (e.g., de Jong 1994). Nightly activity areas for individual *M. evotis* (similar in form and function to *M. thysanodes*; e.g., Bickham 1979, Reduker et al. 1983) were approximately 38.3 ha (SE = 7.3 ha; n = 11) based on radio telemetry in late summer (Waldien and Hayes 2001). However, *M. thysanodes* may travel farther from roosts than *M. evotis* (Miner et al. 1996).

It is likely that area requirements can change over the course of a season. In a similar study over an entire season, de Jong (1994) showed that *Eptesicus nilssoni* "home range" increased substantially (from ~ 12 ha to over 700 ha) as insect abundance decreased over the course of a summer. With high insect abundance, bats hunted close to their day roost, but foraged farther a field as abundance decreased. This was mitigated somewhat by reproductive status, because lactating females remained relatively close to the roost regardless of prey availability. It may also be biased by availability of water, since bats seem to forage preferentially near, but not necessarily

over, water (Waldien and Hayes 2001). This is likely driven as much by the relative availability

of prey in these locations as any other factor.

A somewhat inverse way of conceptualizing the area requirements of bats is to consider the

distance they will travel from a roost to a foraging area (see also the discussion below on

landscape context). Such distances vary depending on the species. Strong, direct fliers (e.g.,

Lasiurus cinereus) may be capable of longer commuting flights than slow, agile fliers (e.g., *M.

evotis*) for the same relative energy expenditure. However, the distance any one species will travel

seems to be fairly plastic and similar species may range over different distances. For instance, as

summarized by Pierson (1998), recorded one-way distances from roost to foraging areas ranged

from about 40 km (*M. grisescens*) to less than one km (*M. evotis*). Given their wing morphology,

M. thysanodes would likely fall on the short end of this scale, although one telemetered female did

commute at least 8 km one way to a foraging area (Miner et al. 1996, Brown and Berry 1998).

The main message to remember is that the farther a roost is from a foraging area, the greater are

the energetic demands placed on the bats and (all else being equal) the less suitable the habitat

mosaic. The point at which this distance becomes critical depends on a host of factors (e.g.,

species, habitat structure, forage quality, etc), but there is undoubtedly some distance at which the

energetic cost of commuting to foraging sites outweighs feasible energy intake and makes a site

unsuitable for supporting a viable bat population.

Landscape Context

The significance of the spatial relationship of foraging, night-roosting, and day-roosting sites

is poorly understood for most bats. Generally speaking, roost sites are near, but geographically

separate from, foraging sites (e.g., Waldien and Hayes 2001). The fact that bats don't necessarily

forage around the roost makes intuitive sense, because these two areas are selected for different

qualities. Roost sites are chosen for roost qualities (e.g., thermal regime, accessibility, predator avoidance) and foraging areas are chosen for prey availability (e.g., insect abundance, vegetative structure, access to drinking water). However, the extent to which roosting and foraging areas are geographically proximate contributes to the quality of those sites for supporting viable bat populations, because the delicate energy balance of bats is impacted most significantly by time spent in flight, which is directly related to time spent foraging and commuting to foraging areas (Studier and O'Farrell 1980). Thus, ideal areas for *M. thysanodes* (and many other bats) will contain a mosaic of foraging habitat, still water sources, and roost structures that are proximate to each other over a large enough area to accommodate shifts in local prey abundance, as noted in the previous section on area requirements (Pierson 1998).

Movement and ActivityPatterns

Seasonal Movements

The migratory patterns of *M. thysanodes* are not well known. *M. thysanodes* maintain a constant, low level of body fat throughout the spring and summer and put on additional fat rapidly in late summer and early fall, suggesting that colonies migrate to winter hibernacula (Wilson and Ruff 1999). It is not known how far these hibernacula are from breeding grounds, but the distance is not likely to be great given the generally slow, maneuverable, energetically demanding flight of this species. It is therefore likely that fringed myotis spend both summer and winter in Wyoming. On a small scale in their northern range (e.g., South Dakota, Wyoming, and northern Colorado), it is generally thought that hibernacula are at lower elevations and/or further south than summer roosts. However, desert populations might actually migrate to higher locations in desert mountain ranges to hibernate, because the temperatures are too warm at lower elevations (P. Brown, unpublished data).

M. thysanodes arrive at maternity roosts rapidly from mid-April to mid-May, after which

populations become stable throughout the summer until a more gradual exodus in September

(O'Farrell and Studier 1975).

Daily Activity and Energy Budgets

Most insectivorous bats exhibit a bimodal activity pattern each night, actively foraging early in

the evening and again before dawn (Erkert 1982). On the whole, *M. thysanodes* appears to be

most active for the first 1 – 2 hours after sunset, up to about 4.5 hours after sunset (O'Farrell and

Studier 1980). Weller (2000) found that mean emergence time from day roosts (generally in tree

snags) was 30.8 ± 1.9 minutes after sunset. O'Farrell and Studier (1975) suggest that the time of

peak emergence is about 23 ± 0.6 minutes (range 12 - 32) minute after sunset and is most closely

related to time of sunset, rather than light intensity, rate of change in light intensity, or weather

conditions. However, other external factors may greatly influence nightly activity patterns, so

such estimates should be viewed with caution. Studies have suggested that weather, particularly

wind and rain, can greatly reduce overall nightly activity of small bats (e.g., Ekert 1982, Kunz

1982, Grindal 1995, O'Farrell and Bradley 1970), although this is not uniformly supported for *M.

thysanodes* (O'Farrell and Studier 1975). Time of first emergence may be effected by factors such

as weather, with overcast conditions sometime resulting in early first emergence while not

affecting times of peak emergence (O'Farrell and Studier 1975). Bat researchers should be aware

that even if weather conditions such as wind and rain do not greatly impact activity patterns, they

can negatively impact observed activity, for instance by reducing capture rates by traditional

survey methods such as mist-netting.

The daily energy budget for fringed myotis, like most bats, is dominated by the requirements

of flight, which comprise roughly 50% of daily energy use but account for only 8% of the time

budget (Studier and O'Farrell 1980). Thus, small variations in time spent foraging have large

repercussions on energy expenditures, which must then be compensated for by increased energy

intake and/or decreased energy expenditure during roosting. Thus, the distance from roosting sites

to foraging and drinking areas can have large repercussions on daily energy balance. Bats adapted

to flight and foraging in cluttered areas, as is *M. thysanodes*, often forage and commute along

habitat edges where cluttered areas (e.g., forests) abut open areas (e.g., meadows) (Fenton 1990,

Grindal 1995). Since fringed myotis have been shown to be gone from maternity roosts all night,

they are probably finding night-roosts proximate to foraging sites rather than making multiple

round-trips in one evening. This was the case for the radio-tagged female *M. thysanodes* in the San

Diego County study. She commuted each evening from a rock crevice roost in chaparral to

Jeffrey pine forest 1000 feet higher in elevation and 12.8 km (8 miles) distant, returning at dawn

(Simons et al, 2000; Miner et al.1996).

    M. thysanodes may lose about 16% of its body weight during a day (12 hours) of normal

roosting (Studier et al. 1970). Bats roosting in groups expend less energy to thermoregulate and

consequently exhibit less weight loss during roosting periods (10.1 – 11.5% of body mass with a

mean of 10.9%) than those roosting singly (9.0 – 21.8%, mean = 15.8%; Studier et al., 1970).

Weight loss during roosting is partially due to defecation and urination early in the roosting period

and to evaporative water loss that is related to environmental conditions in the roost, especially

ambient temperature (T_a). Water turnover was estimated to be nearly half the total body weight

per day. In addition to energy balance issues, this results in large daily fluctuations in wing

loading and presumably, by extension, flight ability and energy expenditure during flight, over the

course of 24 hours. The lowest wing loading occurs during the first flight of evening and the

highest wing loading usually occurs after the initial foraging/drinking bout. Female body

composition (e.g., fat content, water content, lean dry body weight, and embryo/fat-free body

weight), and thus wing loading and energy expended on flight, also fluctuates significantly over reproductive stages (O'Farrell and Studier 1976).

Evidence suggests that *M. thysanodes* may be a facultative homeotherm, since patterns of thermoregulation can vary with breeding status and T_a (Studier and O'Farrell 1976, O'Farrell and Studier 1980). Also, these bats can fly at low T_a and body temperature (T_b; Wilson and Ruff 1999). The thermoneutral zone appeared to be at T_a's of 32.5ºC to 34.5ºC (O'Farrell and Studier 1970 in O'Farrell and Studier 1980). T_b is regulated more during mid-pregnancy and lactation and at times when the energy required for thermoregulation is not excessive (i.e., closer to the thermoneutral zone). Altenbach (pers.comm.) has observed torpid female *M. thysanodes* in late stages of pregnancy roosting in cool mines. Energy demands, and thus physiological stress, of female bats is much higher during lactation (346 cal/day) than late pregnancy (78 cal/day; O'Farrell et al. 1971). Individual bats frequently shift from regulating to conforming and vice versa depending on environmental and physiological conditions. They can cut energy costs during roosting in half by shifting to thermo-conforming at temperatures below 16ºC. Further, since minimum T_b required for flight seems to be relatively low (on the order of 24ºC), *M. thysanodes* might be capable of some winter flight and potentially migrates to suitable habitat when weather becomes inhospitable, but no formal estimate of the energetic costs of flying are available.

Reproduction and Survivorship

Breeding Phenology

In New Mexico, *M. thysanodes* probably mates after females leave the maternity roost in the fall (O'Farrell and Studier 1973). Sperm are stored over-winter and ovulation, fertilization, and implantation occurs in late April to mid-May. Gestation lasts 50 to 60 days and young are born over about a two week period in late June to early July (e.g., between about June 28 and July 3;

Barbour and Davis 1969, O'Farrell and Studier 1975). Although no formal studies have

investigated *M. thysanodes* breeding phenology in other parts of the country, captures of pregnant

and lactating bats elsewhere in their range suggest that the timing of reproduction may be fairly

similar throughout their range (Miller and Allen 1928, Dalquest 1947, Cockrum and Ordway

1959, Easterla 1973, Barbour and Davis 1969). For instance, lactating females where captured

between about July 4 to July 23 in northern Arizona and young of the year began to be captured

after the middle of July (Herder 1998).

   Young are capable of limited flight 16.5 days after parturition and flight becomes

indistinguishable from adults by 20.5 days (O'Farrell and Studier 1973, O'Farrell and Studier

1980). Young achieve full adult body dimensions by 21 days of age, at which point they are

indistinguishable from adults except by epiphysial closures. A complete relation of age to body

measurements is given by O'Farrell and Studier (1973). Juvenile *M. thysanodes* leave the

maternity roost soon after weaning, while the adult females may remain until late summer or early

fall departure to hibernacula (O'Farrell and Studier 1975).

   Due to the high energetic demands of flight, small body size, their restrictive nocturnal feeding

habits, and thermoregulation in temperate climates, *M. thysanodes*, and bats in general, face

difficulties in maintaining a positive daily energy balance. This is particularly true of pregnant

and lactating females, who have the substantial added burden of fetal growth and milk production

respectively. One common way for bats to maintain a positive energy balance is by periodically

becoming heterothermic while roosting (McNab 1982). This strategy entails special tradeoffs in

breeding females, since fetal development and milk quality are directly affected by parental

metabolism and body temperatures (e.g., Tuttle and Stevenson 1982, McNab 1982). Pregnant *M.*

thysanodes females maintain homeothermy during early and middle pregnancy, but shift to

heterothermy about 37 days into pregnancy to conserve energy, which appears to be shunted

directly to the fetus, resulting in a period of rapid fetal growth prior to birth (Studier et al. 1973).

This postponement of fetal growth makes sense in an energy-limited species whose ability to fly,

and consequently ability to forage effectively, is directly dependent on fetal size. Altenbach (pers.

comm..) has observed females in later pregnancy stages in full torpor in what he describes as

embryonic diapause. Somewhat less intuitively, lactation is even more energetically demanding

for bats than any point during pregnancy (Studier et al. 1973).

Breeding Behavior

Maternity colonies are usually found in caves, mines, and sometimes buildings (Wilson and

Ruff 1999) and appear to consist entirely of adult females and pups, ranging in size from dozens

of adult bats to several hundred or more (Agyagos et al. 1994, O'Farrell and Studier 1975,

O'Farrell and Studier 1980, Barbour and Davis 1969). During the weeks prior to parturition, *M.

thysanodes* females become very secretive and difficult to find in the roost (O'Farrell and Studier

1973), which may have important ramifications for timing of survey work. Whereas they

normally roost in fairly open areas within the roost structure, prior to birth they form small,

isolated groups in smaller cracks. O'Farrell and Studier (1973) reported a resident cluster of 60 or

more suddenly "disappearing" and further searching revealed this isolation behavior. Also, during

this pre-parturition period, they become even more sensitive to disturbance, making them very

difficult to approach and accurately count.

Males usually roost separately from maternity colonies (O'Farrell and Studier 1975, O'Farrell

and Studier 1980) and singly or in small groups. Males are completely segregated from females

for all of the non-hibernating year, except for a brief mating period after young have been weaned.

In studies conducted in Mohave County, Arizona, male bats segregate to form different and

smaller spring and summer colonies than female, maternity colonies, and these male aggregations occur at higher elevations that female roosts (Cockrum et al. 1996). In the temperate Black Hills of South Dakota, all *M. thysanodes* maternity roosts (and those of all other myotis species in the study) where found at relatively low elevations to which they likely migrated from higher, cooler hibernacula sites (Cryan 1997, 2000). A similar trend was found among other *Myotis* species in the Washington Cascades and the Oregon Coast range (Thomas 1988).

   M. thysanodes appear to exhibit high breeding site fidelity, returning to the same geographic areas year after year (Easterla 1973, Cockrum et al. 1996, Tigner 1997 in Cyran 1997), but may change specific roosts within an area multiple times within a given season (Cyran 1997), theoretically to find optimal thermoregulatory or prey conditions (see further discussion under the roosts section above)

   Adult females seem to roost in a separate cluster from the juveniles, although they fly into the juvenile cluster regularly to nurse (O'Farrell and Studier 1973). Some level of communal care for young appears to occur in *M. thysanodes* maternity colonies. During each night when adults leave the roost to forage, several females remain in the roost with the pups (O'Farrell and Studier 1980). These individuals occasionally suckle pups and retrieve those that fall from the roost.

Fecundity and Survivorship

   M. thysanodes have only one young per year per female (Cockrum 1955, Barbour and Davis 1969), because daily energy balances of pregnant and lactating female bats, including *M. thysanodes*, appear to be very restrictive, and may preclude the development of more than one offspring per litter (Studier et al. 1973). A large portion of breeding females become pregnant every year (O'Farrell and Studier 1975). In New Mexico, the adult-to-young parturition ratio in a maternity colony was nearly one (O'Farrell and Studier 1975). Age at first breeding is uncertain.

There is no direct evidence to determine whether young breed the fall after parturition, but lack of testicular activity in male young of the year suggests *M. thysanodes* may not breed until their second year (O'Farrell and Studier 1980).

Neonate mortality may be as low as 1% (O'Farrell and Studier 1973), but no data exists on adult or juvenile survivorship. Banding studies indicate life spans for *M. thysanodes* of up to 11 years (Paradiso and Greenhall 1967, Wilson and Ruff 1999), but due to the difficulties associated with band-recapture estimates and the fact that other North American myotis have been recorded at up to 34 years old (Wilkinson and South 2002), maximum longevity is likely somewhat longer.

Population Demography

No studies have been conducted regarding the metapopulation dynamics or genetic differentiation among *M. thysanodes*. This would pose an interesting question for future research, since although bats are highly mobile, they are also closely tied to limited roosting and foraging areas, thus limiting potential distribution and dispersal. For instance, the relative level of sympatry between the black hills subspecies (*M. t. pahasapensis*) and *M. t. thysanodes*, and thus the extent and validity of the subspecies, is largely unknown. Dewey (2000) is investigating inter and intraspecific variation in mitochondrial DNA for several species of myotis, including *M. thysanodes*, but does not have results at this time.

Food Habits

Diet

Generalized food habits from Black (1974) are summarized by O'Farrell and Studier (1980). Some studies have suggested that *M. thysanodes* consumes mostly beetles (Black 1974; Rainey and Pierson 1996), but others in the Pacific Northwest have suggested mainly moths (Whitaker et al. 1981 and 1977). Anecdotal information supports a diet largely of beetles and moths (AGFD

1997, Turner and Jones 1968) and fly larvae are eaten in captivity (Banfield 1975). A more detailed diet analyses (Warner 1985) suggested that *M. thysanodes* was somewhat opportunistic, feeding on a variety of insect classes when they became abundant, but that beetles always comprised a large portion of the diet. Of 68 diet samples collected over two summers, 90% contained the remains of coleopterans, followed by lepidopterans (62%), dipterans (53%), neuropterans (24%), hymenopterans and homopterans (9% each), and others (9%). Most species in this study regularly consumed moths, but *M. thysanodes* and *Antrozous pallidus* were the only two bats with less than a 50% frequency occurrence of moths in their diets. In a limited sample, Whitaker et al. (1977) found a variety of insect classes in stomachs of *M. thysanodes*, with nearly 50% of total volume accounted for by potentially flightless taxa (Phalangida, Araneida, and Gryllidae). All things considered, it is distinctly possible that there is geographic variation in *M. thysanodes* diet at both the distribution and local levels, likely due to variation in prey availability (e.g., Kunz 1982), but not enough information has been collected and reported to draw any conclusions.

Foraging

O'Farrell, et al. (1971) estimate that *M. thysanodes* must assimilate 4.39 kcal/day to maintain caloric balance. A higher assimilation is required to gain needed fat deposits in preparation for winter hibernation, perhaps on the order of 4.58 kcal/day, which is what bats in this study assimilated in late September. *M. thysanodes* seems to emerge late in the evening compared to other bats; generally 1 – 2 hours after sunset (Cockrum and Cross 1964, 1965). In desert areas, a maternity colony of *M. thysanodes* emerged within an hour of sunset (Brown and Berry 2000) which was consistent with a radio-telemetry study of this species in Southern California mountains (Miner et al, 1996).

Based on early studies, Banfield (1975) suggested that *M. thysanodes* hunts insects on the wing. However, the wing morphology of *M. thysanodes* suggests dexterous, low-speed flight suitable for foraging in areas with much vegetative clutter, which suggests that these bats may glean insects from vegetation (O'Farrell and Studier 1980), probably near the top of the forest canopy (Miner et al. 1996). Flight speeds of *M. thysanodes* in restricted environments have been estimated at roughly 8.6 miles per hour (Range: 8.0 – 9.8), which is slightly lower than expected based on forearm length (Hayward and Davis 1964). This reduced speed to size ratio also suggests a gleaning mode of foraging wherein slow-speed maneuverability is necessary for capturing prey and is seen in other gleaning bats, most notably the pallid bat (*Antrozous pallidus*).

It has been suggested that *M. thysanodes* has other physiological adaptations suggesting a gleaning mode of foraging, including a larger brain to facilitate highly maneuverable flight and dexterous control of the tail membrane for capturing prey (Findley 1972, Findley and Wilson 1982). The fringe of uropatagial hairs may also aid in such prey capture, as they are connected to a muscle in the tail membrane that is unique to *M. thysanodes* and that may allow the hairs to flare perpendicular to the uropatagium, thus preventing escape of insects once they are ensnared in the tail membrane (Glass and Gannon 1994). It is also possible that such hairs may help gleaning insects by adding tactile sensitivity to the tail (Glass and Gannon 1994).

Many species of bats, including *M. thysanodes*, forage over bodies of water, since insect abundance (e.g., mosquitoes) is often much greater in these areas (e.g., Grindal et al. 1999, Thomas and West 1991 in Christy and West 1993). Also, it has been shown that many bats preferentially forage along forest or field edges (Fenton 1990, Furlonger 1987, Grindal 1995), which makes ecological sense because forests and forest edges have been shown to have more insect biomass, abundance, and richness than adjacent open areas (Grindal 1995, Grindal and

Brigham 1999, Lewis 1970), while edges have low spatial complexity relative to interior forest.

Edge-foraging has been demonstrated for *M. thysanodes* in a radiotelemetry study in the Laguna

Mountains of Southern California (Miner et al. 1996; Brown and Berry 1998). Given their wing

morphology, echolocation patterns, and purported gleaning mode of foraging, it is likely that they

are adapted to forage and fly in vegetatively cluttered environments, which means they probably

forage in interior forest and/or along forest edges. Further, Coleopterans, which are their chief

prey taxa (see above), may be less abundant in clearcuts and clearcut edges than in forested

landscapes where which they are otherwise prevalent (Grindal and Brigham 1999). If prey

distribution at least partially determines foraging patterns of *M. thysanodes*, it stands to reason that

these bats would preferentially forage in the forest, where beetles may be most abundant.

Water

   In addition to foraging near water (see information above on foraging), most bats need open,

still bodies of water to drink. Bats in general drink water by skimming the surface of open, flat

bodies of water while in flight. It has been estimated that captive *M. thysanodes* on a mealworm

diet experience a water turnover of almost half the total body water per day (O'Farrell et al. 1971),

likely due in part to high dietary protein loads and high rates of evaporative water loss due to

flight (McNab 1982). Therefore, *M. thysanodes* must drink water shortly after emerging from day

roosts each evening (Cross 1986 in Christy and West 1993). Given their flying agility, it is likely

that even very small watering holes have sufficient open surface area for them to drink. However,

desert populations of bats may receive necessary water from prey and not have the same

requirements for open drinking water as those in mesic environments, as evidenced by maternity

colonies located in low desert scrub not near open water (Brown and Berry 2000).

Community Ecology

Few studies have looked at the actual consumption rate of wild insectivorous bats (none at *M. thysanodes* in particular), but those that have suggest rapid consumption of insects (e.g., Kunz 1982), with some consuming perhaps half their body weight in insects each night (Whitaker 1988). Therefore, they represent major predators of nocturnal insects and, depending on their abundance and concentration of in a given area, could have ecologically significant impacts on local insect communities.

Many bats, including *M. thysanodes*, forage in specific areas, particularly near water, and roost in areas that are geographically separate from those foraging areas. Digestion and defecation generally occur during roosting, so bats could potentially play a role in nutrient distribution in forested ecosystems (Grindal 1995), particularly given the typically high nitrogen concentration of their feces (Rainey et al. 1992).

Predators and Competitors

Surveys of roost sights and watering holes in a variety of habitats has shown that *M. thysanodes* coexists with a wide variety of other bat species including *Myotis evotis, M. volans, M. californicus, M. ciliolabrum, M. lucifugus, M. velifer, M. yumanensis, M. auriculus, Eptesicus fuscus, Pipistrellus Hesperus, Lasioniycteris noctivagans, Corynorhinus townsendii, Idionycteris phyllotis, Euderma maculatum, Lasiurus borealis, L. cinereus, Antrozous pallidus, Tadaria braziliensis,* and *T. macrotis* (O'Farrell and Studier 1980). This list partially reflects the wide distribution and habitat selection of *M. thysanodes*. It appears that competition with these species is minimized in part through niche partitioning in which fringed myotis forages in cluttered areas and may glean from vegetation rather than capture insects in the air.

Although a variety of animals can prey upon bats, bats are not a focal prey item for any carnivore group, so it is unlikely that predation is a significant mortality factor in many areas (e.g., Grindal 1995). Most predation occurs when bats are roosting or when those bats that forage by gleaning land to capture insects. Predators might include small mammalian carnivores (e.g., raccoons, weasels), small raptors, owls, domestic cats, fish, bullfrogs, snakes, and deer mice (Christy and West 1993).

Parasites and Disease

M. thysanodes can host a variety of ectoparasites, which have been summarized by O'Farrell and Studier (1980), but have very few endoparasites (Cain and Studier 1974 in O'Farrell and Studier (1980). It is possible for such parasites to have severe effects on individuals with extreme infestations, but no literature has related any of these parasites to population-level declines in *M. thysanodes*. As with other bats, high parasite levels in communal roosts may cause *M. thysanodes* populations to change roosts (Lewis 1995).

There have been a few reports of individual *M. t. thysanodes* infected with the rabies virus, but, as with other bats, the incidence of this is likely very low and poses minimal threat to humans (Constantine 1979, Constantine et al. 1979) and no threat to the persistence of the species.

Symbiotic and Mutualistic Interactions

There are no documented symbiotic or mutalistic interactions between *M. thysanodes* and non-Chiropteran species. However, fringed myotis have been found roosting with many other species of bats (O'Farrell and Studier 1980) and it is possible that some thermoregulatory and anti-predation (is there a citation for this?) advantage is gained from this behavior.

Many bats have a commensal relationship with beaver, since beaver create small bodies of open water from which bats can drink. Further, beaver ponds promote vegetative growth around their edges and may alter local insect abundance.

Conservation

Conservation Status

Federal Endangered Species Act

Neither *M. thysanodes*, nor any subspecies or population segments thereof, are currently listed or being considered for listing under the United States Endangered Species Act (ESA). However, prior to modification of the ESA process (USFWS 1996), it was listed as a Category 2 Candidate Species. Category 1 species were those for which the U. S. Fish and Wildlife Service (USFWS) had sufficient information to support a proposed listing, and Category 2 species were those for which USFWS had some information indicating that the species may be in trouble but not enough to determine whether listing was appropriate. Currently, USFWS recognize as candidates for listing only species that would have been included in the former Category 1, and they no longer maintain a Category 2 list with legal status.

Bureau of Land Management

The State Offices of the Bureau of Land Management (BLM) in California, Colorado, Idaho, Montana, Nevada, and Wyoming list *M. thysanodes* on their sensitive species lists (e.g., USDOI BLM Wyoming 2001). As stated in the BLM Manual 6840, this designation is meant to provide protection for species with respect to BLM land management actions that is at least equivalent to the federal policy for candidate species under the ESA. This generally means that the BLM must review programs and activities to determine their potential effect on these species.

Forest Service

Region 2 of the Forest Service currently lists the Black Hills subspecies (*M. t. pahasapensis*) on its sensitive species list (USDA Forest Service 1994).

State Wildlife Agencies

M. thysanodes is recognized as of special management concern by several state wildlife agencies including Idaho (Species of Concern), Oregon (Sensitive, Vulnerable), Utah (Species of Special Concern due to Limited Distribution), California (proposed Species of Concern) , and Wyoming (Native Species Status 2). By virtue of being on the Idaho Fish and Game Species of Special Concern list, state officials have determined fringed myotis to be either low in numbers, limited in distribution, or having suffered significant habitat losses. As a result, it is classified as a protected non-game species for which it is illegal to collect, harm, or otherwise remove from its natural habitat. The Oregon Department of Fish and Wildlife lists a Sensitive Species as one which may become threatened or endangered, as defined in the Oregon Administrative Rules (635-100-0001), throughout all or part of its range in Oregon.

The Wyoming Game and Fish Department (WGFD) assigns *M. thysanodes* a state special concern rank of NSS2 (Native Species Status 2). The NSS2 rank is based on WGFD estimates that fringed myotis populations in Wyoming are restricted in numbers and experiencing ongoing significant loss of habitat, although extirpation is not deemed imminent (Oakleaf et al. 2002). WGFD ranks native species on a scale of NSS1 to NSS7, with NSS1 representing critically imperiled species and NSS7 representing stable or increasing species. These ranks are assigned by WGFD biologists as a way to roughly prioritize wildlife concerns in the state, but they carry no legal, regulatory, or management weight per se.

Natural Heritage Ranks

The Natural Heritage Network assigns range-wide and state-level ranks to species based on established evaluation criteria (e.g., Keinath and Beauvais 2002a,b, Master et al. 2000). *M. thysanode*s merits a global rank of G4-G5, which means that rangewide it is deemed by Heritage scientists to be Apparently Secure. This is based on a synthesis of state ranks and biological evidence that suggests it is "widespread in western North America [with] well over 100 occurrences; abundance is apparently low; protected at a minimum of three locations; appears to be moderately threatened" (NatureServe Explorer 2001).

Sixteen western states and provinces have assigned a State Rank to *M. thysanodes*, and 8 of these states rank it as S2 (imperiled) or S1 (critically imperiled). In general, state ranks are assigned bases on the assessed risk of extinction within a state, where S1 species are deemed critically imperiled and S5 species are deemed demonstrably secure. These assessments are based on biological information on population status, natural history, and threats at the state level. Specific State Ranks are as follows: Arizona (S3-S4), California (S4), Colorado (S3), Idaho (S1?), Montana (S3), Nebraska (S1), Nevada (S2B), New Mexico (S5), Oregon (S2?), South Dakota (S2), Texas (S3), Utah (S2B,SZN?), Washington (S3?), Wyoming (S1B,S1N), and British Columbia (S2-S3). Question marks (?) indicate that the rank is uncertain, generally due to lack of information on population status. SB and SN designations refer to breeding and non-breeding populations respectively, and are generally used for species whose conservation concerns vary with season (e.g., migratory animals).

Western Bat Working Group

The Western Bat Working Group (1998) ranked *M. thysanodes* as of high conservation concern in 4 out of 10 ecoregions in which it occurs and as Moderately High priority in 4 others

(Fig. 4). All of Wyoming is encompassed by the regions for which *M. thysanodes* was listed as

High or Moderately High priority.

Biological Conservation Issues

Extrinsic Threats

Roost Disturbance

Human disturbance of known bat roosts has been shown to cause abandonment of roost sites

for many species (e.g., Wilson and Ruff 1999, Brown and Berry 1991), but documentation of

abandonment by *M. thysanodes* in particular is scarce and largely anecdotal (P. Brown pers.

comm., E. Person pers. comm.). Often this disturbance is intentional and people are actively

trying to exterminate the bats, usually due to uninformed opinions regarding the nature of bats,

particularly with relation to disease such as rabies. This is especially true of bats roosting in

human structures, such as attics and barns, where they more frequently come into contact with

people. However, it also occurs in other areas where bats congregate, most notably in caves and

mines.

A less evident, but no less destructive, form of disturbance is the recreational entry into

roosting structures. It has been clearly documented that several bat species, including *M.*

thysanodes, are sensitive to the presence of humans while they are roosting and may abandon

roosts is sufficiently disturbed (O'Farrell and Studier 1973). This is especially true of caves and

mines, which can to receive heavy human traffic and often bring humans in close contact with the

bats due to the confined nature of the environment.

Any habitat alteration that modifies the airflow and/or thermal regime in roosts can have

substantial impacts on bats (e.g., Currie in press, Tuttle and Stevenson 1977). As discussed above,

daily energy budgets of bats are in delicate balance and anything that alters this balance can result

in lowered fecundity, mortality, or roost abandonment. For instance, physical modification of cave and mine entrances, including substantial vegetative alterations outside the entrances or improperly constructed gates, can alter thermal and airflow characteristics of roosts, resulting in population declines. This also applies to non-permanent roosts such as tree snags. Modification of the forest around snags can alter solar and wind exposure, thereby making an otherwise suitable roost unfit for bat occupancy because it is too hot or cold to allow bats to effectively thermoregulate.

Habitat Alteration

As suggested above, in some areas, particularly where primary roost structures are tree snags, *M. thysanodes* selects areas of high roost density rather than specific roost sites per se (e.g., Lewis 1995, Cryan 1997). Therefore, a reduction of old forest and snag density from harvest activities can have negative impacts on local populations, and there is some evidence that such impacts may increase with decreasing elevation (Grindal 1995, Cryan 1997).

The importance of open-water impoundments in suitable habitat and proximate to roost sites has been clearly stated (see above discussions in the Habitat section). Factors that alter water flow or persistence (e.g., irrigation, draught, beaver activity) can greatly impact bat distributions and, perhaps more importantly, alter critical daily energy balances of bats by shifting their foraging patterns.

Since *M. thysanodes* optimally requires a habitat mosaic with several key features (see Landscape Context above), disturbances that act to homogenize the landscape at the scale of typical bat foraging areas (see Area Requirements above), will likely lead to a reduction in suitable habitat. However, increased forest fragmentation has been shown to decrease the occurrence of some bats (e.g., Ekman and de Jong 1996, Walsh and Harris 1996) so caution should be taken

when considering the suitability of complex landscapes. There is likely an optimal range habitat

proportions and configurations (e.g., forest and roosting habitat, versus open habitat, versus

water), but there are no quantitative guidelines available.

The impact of fire on bat populations has not received sufficient study. However, since bats

require specific environmental components (i.e., roost structure, water source, foraging habitat), it

can be assumed that to the extent fire reduces one or more of these components, it will have a

negative impact on local bat populations. Depending on the nature of the fire, however, it may

increase bat habitat suitability; for example, by increasing snag density and habitat heterogeneity

in a patchily burned timber stand. It should be noted that these positive effects are not likely to

become beneficial until several years after the fire incident, when regeneration progresses, while

negative effects are immediate.

Chemicals

No studies have been done specifically addressing the effects of chemical pollutants, most

notably insecticides, on *M. thysanodes*. Moreover, very little research has investigated impacts of

these chemicals on any North American bats. However, it is likely that such chemical pollutants

could be responsible for bat declines in some areas (Rainey and Pierson 1996). The impact on

bats is via two mechanisms. First is by significantly reducing the abundance of bat prey. Second,

chemicals could accumulate in the surviving invertebrate prey that make the bulk of North

American bat diets and then become concentrated in bat tissues once these invertebrates are

consumed. Studies have shown that bats accumulate very high concentrations of organochlorines

(e.g., DDT, DDE) and other contaminants in their tissues, which are often many times above those

of other taxa, such as birds (Clark and Shore 2001, Russell 1976, Jeffries 1972, O'Shea, et al.

2001). For instance, in a study downstream from a DDT manufacturing plant "residues in nestling

red-wing [black bird] carcasses had declined to trace amounts, averaging 0.28 mg kg^{-1} DEE with

no DDD or DDT detected, in birds collected 20 km downstream from the DDT source, whereas

juvenile gray bats at this same point contained 34 mg kg^{-1} DDE, 12 mg kg^{-1} DDD, and 0.34 mg

kg^{-1} DDT. Furthermore, this contaminant was recognizable in gray bat colonies at least 140 km

downriver" (Clark and Stone 2001).

Probable reasons for this elevated bioaccumulation in bats and other factors related to

increased bat sensitivity to environmental contaminants are summarized by Clark and Shore

(2001) from which the following were derived:

- High metabolic demands. High metabolic rates associated with small size and flight
  demand greater rates of food intake, which increases the intake and potential accumulation
  of chemicals.

- Pronounced fat cycles: Most bioaccumulation of lipophyllic contaminants occurs in fat.
  Bats risk mobilization of stored contaminants through extreme shifts in fat depletion
  resulting from migration and/or hibernation. It also suggests that bats are most susceptible
  to such compounds when fat stores are low, which is most pronounced in the spring, after
  winter hibernation.

- Lactation: Chemicals tend to concentrate in milk, exposing young to large doses and
  potentially resulting in reduced fecundity.

- Behavior: Bats forage on insects most heavily in twilight hours, which is when insects are
  most abundant and when pesticides are often applied to avoid drift, so bats may be prone to
  encounter pesticides directly.

- Life Cycle: Bats have long life spans, allowing more time for contact with and potential
  accumulation of contaminants. They also have low reproductive rates, which would
  restrict the ability of bat populations to rebound from mortality events associated with
  increased contaminant levels.

- Roosting: Roosting can increase bat exposure in two ways. First, bats that roost in
  buildings that are exposed to chemicals that are used as timber treatments (e.g., fungicides,
  lindane, dieldrin), some of which have been shown to be quite toxic to bats in such

circumstances. Second, roosts concentrate bats in small areas, making incidental exposure of large groups more likely.

Despite bioaccumulation studies, contaminant-induced mortality and morbidity to the range of chemicals to which bats are commonly exposed has not been well studied, and no studies have been conducted specifically for *M. thysanodes*. A summary of mean lethal concentrations in the brain for some chemicals and bat species is provided by Clark and Shore (2001). Further, well documented impact on wild bats is rarely available and would in fact be difficult given the problems associated with observing bats. For instance, lethal insecticide doses for some bat species are above those of laboratory mice, suggesting low susceptibility to environmental application of such chemicals (Clark and Shore 2001). However, it has been shown that doses well below such levels can induce loss of coordination that completely prevents flight and alters energy metabolism (Clark and Shore 2001). In the wild, the proximate cause of death in such cases would likely be predation and therefore would not be correctly attributed to toxins. Another example is that total tissue concentrations are not necessarily an indication of immediate lethality of contaminants. Lipophillic organochorines are toxic via impact on the brain of vertebrates, but as noted above these chemicals can be stored in fat. Therefore, even sub-lethal concentrations can accumulate over time, resulting in lethal concentrations when the fat is metabolized, such as during hibernation. Mortality could occur over winter, when nearly all fat in metabolized, and not be temporally or spatially proximate to chemical application.

Commensurate with these difficulties, very few population-level impacts have been studied (see Clark and Shore 2001 for summary data). Of these, two studies documented substantial declines in local populations resulting from organochlorine application (aldrin and DDT). Population-level effects have also occurred via intentional or incidental application of acutely toxic pesticides to bats in their roosts that caused direct adult mortality, and via application of

pesticides (e.g., lindane, dieldrin, PCP) to roost structures, the residues of which caused increased

adult mortality and reduction of successful breeding for years afterward. Other contaminants with

demonstrated toxicity to bats include PCB's, lead, cadmium, blue-green algal toxins, effluent from

cyanide extraction gold mines, and impounded sewage.

Abundance and Abundance Trends

   As noted in the Biology and Ecology section above, *M. thysanodes*, seems to be relatively rare

rangewide. Trends in abundance of *M. thysanodes* are largely unknown. In addition to numerous

difficulties in monitoring bat populations (see Inventory and Monitoring below) the fact that

fringed myotis area relatively rare makes trend estimation particularly problematic. The few long-

term studies of abundance, which looked at a variety of bats, occurred in New Mexico in the

1960s and 1970s. They demonstrated both positive and negative fluctuations over the course of 5

and 10 years that resulted in largely unclear trends, possibly showing a net increase (Jones and

Suttkus 1972, Easterla 1973). Potentially confounding estimates of population size, particularly

those based on once or twice-annual visits, are monthly changes in local abundance (Jones 1966)

and roosting shifting over the course of the summer (Cryan 1997, Lewis 1995).

   The Arizona Game and Fish Department lists the populations in Arizona as apparently stable

based on limited survey data (AGFD 1997). The Nevada Bat Conservation Plan (Altenbach et al.

2002) states that, in Nevada records are relatively few but suggest an apparent increase in numbers

or area occupied over the last 20 years, which may be a result of increased survey efforts with

better techniques. No trends in abundance were evident, but Ramsey (1998) reported that *M.*

thysanodes was recorded in a broader range of habitats in the Gila National Forest, New Mexico,

that previously reported, which may have had as much to do with structural changes in the

environment and water sources than habitat type per se.

In California, museum records suggest that the fringed myotis is widely distributed across California, although it is always one of the rarest species in netting and night roost surveys in a number of localities (Pierson et al. 1996). Historic records document only six maternity sites: two in Kern County (including the type locality at Old Fort Tejon) and one each in Marin, Napa, Tuolumne, and Tulare counties. Surveys by Pierson (1998) since 1990 at four of these sites have shown that although the roost structures are still available, they are no longer occupied by fringed myotis. The limited data available suggest serious population declines. Not only have historic maternity colonies disappeared, but those remaining appear to contain significantly fewer animals (Pierson, 1998). For example, a Napa County roost documented by Dalquest (1947) to contain about 50 animals in July 1945 (of which 40 were collected at that time), in June 1987 had only 10-15 animals, and in August 1988 none were found. The building which housed the bats was near a new winery and had increased human activity in the vicinity. This species appears to be extremely sensitive to disturbance at roost sites and to human handling, more so than other species of *Myotis* (like the Yuma myotis). Another maternity colony of 40-50 bats in a mine in the Kern River Canyon is no longer occupied by fringed myotis, probably due to increased human entry (P. Brown, pers. comm.). A roost of over 200 adults located by P. Brown (pers. obs.) in 1991 in a house in Big Bear was subsequently excluded by the owners.

Distribution Trends

Peripheral areas and population connectivity have been better defined as researchers have increased bat survey efforts and become knowledgeable regarding accurate identification of *M. thysanodes*. Despite this, the overall extent of distribution of the species does not seem to have changed greatly since comprehensive North American range maps have been published (this assessment, Wilson and Ruff 1999, O'Farrell and Studier 1980, Barbour and Davis 1969, Jones and Genoways 1967). However, very few survey sites have been revisited with any degree of

regularity, so geographic trends in presence are largely unknown. Also, the proportion of *M. thysanodes* range that is actually occupied is unknown for large areas. Virtually no information is available for any populations in Mexico.

Although the total continental extent has not drastically changed, it is possible that local populations have fluctuated and perhaps contracted, becoming smaller and more isolated in recent decades. This seems to be true for Wyoming (Fig. 3b). There have been no current sightings of fringed myotis in the northerwestern portion of the state, where there are several historical records, despite relatively recent surveys (Wyoming Natural Diversity Database, Laramie, Wyoming unpublished data).

Habitat Trends

Information on habitat trends is not readily available. As suggested in previous sections, one must consider trends in roosting habitat, foraging habitat, and water sources. Estimating trends in the area of suitable habitat for each of these three categories is in itself a difficult task. Even more problematic is estimating trend in the juxtaposition of all three habitat components at a both the fairly fine spatial scale of individual bat colonies (i.e., on the order of 100's of hectares) and at the landscape scale. The discussion in the following paragraphs is therefore largely conjecture based on limited information and expert opinion.

Cliff roosts can be destroyed by dam and road construction in canyons and impacted by rock climbing activities. Also, large cliff complexes often draw tourists, so the habitat around such areas has likely been impacted to some extent by recreational development. However, the extent of such alteration and disturbance is undocumented. Relative to other roost structures (especially caves and mines) cliff roosting habitat has probably not decreased greatly in abundance over the last century. This is due largely to the relative permanence of cliffs and the difficulty with which

roosting substrate thereon is accessed my humans. Whether existing disturbance has resulted in a net decrease in useable cliff roosts is unclear.

Trends in forest roosting habitat (i.e., aggregations of large, old snags) are also fairly unclear. A recent analysis of the historic range of variability (HRV) for forest stand dynamics in the Bighorn National Forest, Wyoming (Romme 2002, unpublished data) suggested that prior to European settlement the Bighorn landscape might have contained 15 - 30% old-growth forests. Rough estimates of current old growth are more on the order of 10 - 15% (Jon Warder, USFS, Bighorn National Forest, pers. comm.). Some areas, such as the Black Hills National Forest, have substantially less old growth than this while others undoubtedly have more. However, if this general trend holds true, the available forest roosting habitat for *M. thysanodes* has decreased over the last century by a potentially large amount. Further, if the currently proposed Healthy Forest initiative (President of the United States 2002) is widely adopted and implemented, there will be a major emphasis on reducing fuel loads in older stands, and the amount of forest meeting the needs of roosting bats will likely continue to decrease as this fuel, such as dead snags, is removed.

Suitable cave roosting habitat has likely decreased over the last century due to human disturbance of cave systems. Large cave complexes are particularly vulnerable to such disturbance because they attract tourists and have often be established as part of national or state parks. In recent decades, however, awareness of the importance of caves to bats has increased and actions (such as seasonally limiting access to caves) are slowly being taken to protect key cave complexes from undue disturbance. If this trend continues and is supported by land management agencies, we expect the downward trend in cave roosting habitat to stabilize in the next decade. Additionally, the availability of abandoned underground mines may somewhat mitigate the loss of cave habitat, but there are several reasons why this is not fully compensating. First, some mines

are not suitable for roosting bats. It has been estimated that 80% of abandoned mines may be used

by bats, and 10% receive substantial use (P. Brown pers. comm.). Second, many mines have or

are planned to be closed for human hazard abatement without regard to bat use. Renewed mining

in historic districts also destroys abandoned mines. Third, locations of mines are not necessarily

conducive to bat colonization due to the lack of proximal, suitable foraging and drinking habitat.

Despite these drawbacks, abandoned mines can have a significant positive impact on local bat

populations and should be considered (Altenbach and Pierson 1995; Tuttle and Taylor 1994;

Riddle 1995).

The trend in human structures suitable for use by roosting bats is similarly unclear, so we can

only make educated guesses. Public persecution of bats, due largely to a misunderstanding of

their nature and fear of disease such as rabies has probably caused a decrease in available building

roosts during most of the 20th century, despite nearly continuous growth in construction. This

trend may have abated somewhat in the last decade, as extensive efforts to educate the public

regarding bats and provide ecologically sound methods to deal with "pest bats" have become

established (e.g., French et al 2002). Thus, the current trend in building roosts is probably stable,

but will continue to be so only as long as public outreach persists.

Trends in available foraging and water habitat are much harder to estimate than trends in

roosts. Not only are such areas are more diffuse in the landscape, but the foraging habits of most

bats is not nearly as well understood. For instance, it is not known exactly what elements of

habitat *M. thysanodes* selects, although based on the variety of forest types occupied, it appears

that vegetative structure and stand age may play a more important role than plant species

composition. Application of chemical treatments, such as pesticides and herbicides can also make

otherwise good foraging habitat unsuitable either by direct impacts or via reduction of insect prey.

Drought, events, such as that currently occurring in much of the Rocky Mountains, can reduce the number of wetlands, as can declining trends in beaver impoundments. Increased channelization of streams, which limits slow-flowing wetlands and narrows riparian corridors, may also have negative effects on bats.

Intrinsic Vulnerability

Bats in general and *M. thysanodes* in particular, are fairly vulnerable to extirpation by virtue of their life history. An interagency expert evaluation panel considered fringed myotis to be more vulnerable to alteration of mature forest ecosystems than most bat species because it is dependent on old-growth conditions, "is rare, occurs in a restricted elevation zone, and has strong site fidelity" (Forest Ecosystem Management Assessment Team 1993). We can add sensitivity to roost disturbance, restrictive hibernation requirements, and low reproductive capacity to this list.

M. thysanodes are widespread, like many bats, and therefore tend to be overlooked in conservation efforts that often focus inordinate value on distribution extent as a criterion for sensitivity (Pierson 1998). In fact, although their range is large, they are rare and patchily distributed within that range, making them vulnerable to local extirpation where recolonization is unlikely. More explicitly, *M. thysanodes* require a specific and restrictive combination of habitat characteristics (discussed above), and if any part of this system is disturbed it could result in local extirpation. This is especially true given that site fidelity has been shown for *M. thysanodes* both at the stand and roost scales (e.g., Cryan 1997, Forest Ecosystem Management Assessment Team 1993, Weller and Zabel 2001). Particularly maternal female *M. thysanodes*, show high preference for specific roost caves to which they return over the course of a summer and from one summer to the next, although some movement between proximal day roosts has been shown by banding

studies (Cockrum et al. 1996). A similar preference is shown for specific watering places

(Cockrum et al. 1996).

While in the roost, fringed myotis appear easily disturbed by human presence, particularly in

maternity colonies when females are near parturition (Studier and O'Farrell 1973). Disturbance at

hibernacula could be even more detrimental for several reasons. First, the margin by which bats

survive winter hibernation is often very small, so any even that causes them to rouse from torpor

can expend energy sufficient to cause over-winter mortality. Second, due to the relative scarcity

of suitable hibernacula, bats from wide areas tend to concentrate on only a few sites, causing the

elimination of one such site to be potentially far-reaching (Pierson 1998).

Finally, the low reproductive rate of *M. thysanode*s (see the above discussion on breeding),

means that populations cannot easily recover after crashes.

Conservation Action

Existing or Future Conservation Plans

To date, there are no management plans or conservation strategies pertaining explicitly to *M.

thysanodes* in any portion of its range. However, non-regulatory conservation strategies have been

drafted for other, bat species, such as Townsend's big eared bat (*Corynorhinus townsendii

townsendii* and *C. t. pallescens*; Pierson et al. 1999). Also, several states are in the process of

drafting bat conservation plans designed to provide conservation guidance for the suite of bats

present within their boundaries. The only completed plan thus far is the Nevada Bat Conservation

Plan (Altenbach et al. 2002), but plans for Arizona and Colorado are nearing completion (Vicki

Herren, Western Bat Working Group, pers. comm.). The Nevada Plan (presumably other plans

will be similar) provide general guidance and also offer recommendations pertaining to specific

species relevant to their habitat use in Nevada. Although portions of these plans are not pertinent

to *M. thysanodes* in Wyoming, they contain substantial guidance that is directly applicable and will also aid a broad range of other bat species.

Since the largest conservation concern for most bats is lost of suitable habitat, the core of all such plans is preservation of roosting structures and foraging habitat, which is generally approached on a species and habitat-specific basis. Objectives pertinent to *M. thysanodes*, drawn in part from the above-noted conservation plans, have been highlighted in the management sections of this assessment. If these conservation guidelines are rigorously followed, we believe adequate protection will be afforded *M. thysanodes* within Wyoming, given that future information (see Information Needs) does not uncover additional issues. However, it should be noted that these plans are designed by independent experts (usually members of Western Bat Working Groups and representatives of wildlife management agencies) and they therefore carry no legal weight. They will only be effective to the extent that they are officially adopted and implemented by land management agencies such as the Forest Service and BLM. Ideally, listing *M. thysanodes* as a sensitive species and incorporating such guidelines as the vehicle by which it is managed will insure effective conservation. This will only happen if the guidelines, through agency sensitive species policies, are allowed to impact land and timber management actions and mine reclamation policies.

Conservation Elements

Implications and Potential Conservation Elements

There has been no study explicitly investigating implications of environmental change on *M. thysanodes*, but studies have been conducted on bat communities and the similarity of those communities to *M. thysanodes* populations can be estimated. Five main conservation elements are needed for *M. thysanodes*, and many other bat species (Specific approaches that have been

proposed to address these conservation elements are provided in the following section on tools and practices.):

1. **Protection of roost sites** - Roosts are very sensitive, and any disturbance to roost sites can potentially extirpate bats from that site, particularly if such a disturbance is long lasting or results in a long regeneration time. Where tree roosting is prevalent, roost protection requires more planning, since the local abundance and spatial distribution of current and future snags must be considered.

2. **Protection of foraging areas** - Foraging areas are suitable based on a combination of prey (insect) availability and habitat structure and may be able to absorb more disturbance than roost sites without markedly impacting bat populations. However, the range and magnitude of tolerated disturbance at foraging areas is not clearly known. It can be assumed that any decrease in insect abundance, particularly of beetles and moths, will have a direct negative effect on *M. thysanodes*, but the "critical level" below which insect numbers fall before significant declines in bat use are seen is not known. Similarly, we do not know the exact amount of cover preferred by foraging, forest-dwelling bats. We can be fairly certain that elimination of cover altogether (e.g., in large clearcuts) will have a negative impact on clutter-adapted bats like *M. thysanodes*, although it may also create suitable edge habitat, which is preferred by some species (see references in Grindal and Brigham 1999).

3. **Protection of still-water wetland areas** - Open water sources may be necessary for bats to drink on the wing and as insect breeding areas. If wetlands are eliminated (e.g., by draining, draught, shifts in the water table) local bat populations will suffer, depending on the availability of other nearby water sources.

4. **Maintenance of a landscape** that contains the above three habitat elements in geographic proximity. All of the above components must occur in fairly close proximity (e.g., less than several km) in order for bats to efficiently use them.

5. **Elimination of exposure to toxic chemicals** - Man-made water sources are often used by bats, so preventing bat use of toxic impoundments, such as cyanide ponds, oil reserve pits, and wastewater facilities is important (e.g., . Pierson et al. 1999; Rainey and Pierson 1996). Also, it is necessary to investigate the impacts of modern pesticides on bat populations,

both through direct effects and reduction of prey, and eliminate use of those that are found

to be detrimental.

Inventory and Monitoring

Detailed accounts of bat monitoring techniques are presented in several sources (e.g.,

Altenbach et al. 2002, O'Shea and Bogen 2000, Kunz 1998, MELP 1998). The following is a list

of some key ideas and pitfalls that managers should consider when designing such surveys, but is

not a complete accounting of how to establish such a program.

Multiple sites and site types - Monitoring plans ideally should include both roost structures

(hibernacula, night and maternity roosts) and known, persistent foraging and watering habitat

(Pierson et al. 1996). Nevada (Altenbach et al. 2002) recommends employing a 100 km grid

system to select at least 60 wetland habitat sites throughout the state for annual monitoring. These

sites should be stratified by the surrounding habitat types and elevation zones, and emphasis

should be placed on unique sites (e.g., large complexes, exceptional habitat heterogeneity) and

sites with historic bat data where the long term viability of the water source known.

Multiple visits – For adequate monitoring, sites should be sampled four times per year,

maintaining consistency in survey dates and possibly moon phase over time. Some roosts,

although heavily used over a longer period of time, may not be used at all on a given night (Weller

2000), so visiting a roost or a watering hole one-time is insufficient for accurate survey and

monitoring work. Comprehensive monitoring of roost sites would ideally include surveys during

at least three periods: pre-maternity (April – May), maternity (June – August), and post maternity

(late August – September) (Herren and Luce 1997).

Capture over water - Bats are most easily captured around still, open water, from which they

drink water while on the wing and around which many species forage due to increased insect

abundance. In one study in arid areas of Arizona, the majority of bats captured in mist nets over

water sources were in the month of July, with some also being captured in June and August, but

virtually none being captured in any other months (Cockrum et al. 1996). This is in part

attributable to the increased water requirements of lactating females. There is undoubtedly local

geographic variation in the seasonal pattern of mist net captures.

Exogenous factors - Bat activity may vary with precipitation, temperature, wind, phase of the

moon, and cloud cover, so survey efforts must take these factors into account. The effects of each

of these factors are uncertain at best, but rough ideas are presented in Table 3.

Monitoring roosts - Monitoring of roost sites is critical to effective management of bats.

However, a detailed account of how to monitor roosts, and all the statistical sampling attention

that entails, is beyond the scope of this assessment. Survey methods have been covered above and

in other documents (e.g., e.g., Kunz 1998, MELP 1998, O'Shea and Bogan 2000) and general

monitoring tips can also be derived from Pierson et al. (1996 and 1999), Altenbach et al. (2002),

and local bat experts.

In short, the three biggest monitoring problems typically faced by managers are: method of

surveys, timing of surveys, and minimizing disturbance to roosting bats. Monitoring surveys

should be conducted at least bi-annually on nearly the same date and moon phase each year, and

since roosts are typically very sensitive to disturbance such activities must be minimized and

conducted using the least intrusive method that will yield appropriate results. A combination of

acoustic and night vision surveys at roost openings are least invasive, since roosts are not entered

and bats are not handled, so colony counts can be made every year. However, they do not often

give accurate species identification or species specific numbers. A reduced visitation schedule

(e.g., every other year or more) should be considered if actually entering the roost is required, and

such visitations should follow established guidelines to minimize disturbance to roosting bats

(e.g., ASM 1992). Capture of bats at roost openings is more disruptive and should be done with

great care and on a greatly reduced schedule (e.g., no more than on a triennial basis).

It is generally assumed that nursery exit counts of adult females are most reliable 2-3 weeks

prior to parturition, but unless precise dates of parturition are known this is somewhat risky for *M.*

thysanodes. Fringed myotis females become highly secretive about one and a half weeks

preceding parturition and established roost clusters break up during this period (O'Farrell and

Studier 1973). This could result in undercounting if survey visitation occurs during this time

period. Exit counts might best be conducted around the time of parturition, and prior to when the

juveniles begin to fly.

Population and Habitat Management

It is not sufficient for bat conservation to simply draw buffer zones around potential roosts.

The spatial arrangement of foraging and roosting sites, as well as their connectivity with suitable

commuting habitat, needs to be carefully considered (e.g., Pierson 1998). Unfortunately there are

no quantitative figures to guide such action. The following are some examples of guidelines that

have been suggested for conservation of *M. thysanodes* and similar bats. Most of the buffers and

times noted are expert suggestions and are not based on specific scientific studies per se. They

may not in fact be adequate and may differ with different habitats and types of disturbance.

Therefore, numbers presented should not be viewed as minimum recommendations, not fixed

guidelines. Also, since most of these guidelines are fairly recent, it is too soon to obtain data on

their impacts. Therefore it is critical that any such actions taken by the Forest Service incorporate

an initial inventory and thorough, long-term, post treatment monitoring of the affected bat

populations in order to determine management impacts.

- Maintain wetland habitats within a 10 mile (16 km) radius of maternity roosts and other roost complexes to achieve year-round water and suitable vegetative structure (e.g., Pierson et al. 1999).

- Areas of timber management (e.g., prescribed burning, thinning, harvesting) should be thoroughly searched for roosts.

- Where there are tree-based roost complexes, roost trees should not be modified and day roost habitat should be managed to maintain groups of large, tall snags in early to medium stages of decay (Weller and Zabel 2001).

- For other roost structures (e.g., caves, mines, buildings), no prescribed burning or major forest alteration (e.g., clearcutting) should be conducted within a 0.25 mile radius of maternity roosts or hibernacula. Further, no more than half of a 1.5 mile radius buffer around roost should be subject to such action in a given decade (e.g., Pierson et al. 1999).

When forest management actions occur near roosts, they should be conducted only when the roost is unoccupied or else not within a 0.25 mile buffer of the roost. Whenever activities occur within this buffer zone (i.e., even when the roost is unoccupied) a minimum intact forest buffer of 500 feet should be left around all roost entrances, so as not to alter air flow and thermal regimes in the roost. Similarly, roost entrances should not be visible from a road, to minimize human visitation (Pierson et al. 1999). The Nevada Bat Working Group suggests providing a 10 km radius buffer zone around maternity roosts in pinion-juniper and subalpine conifer habitats to protect foraging sites near those roosts (Altenbach et al. 2002). These buffer zones should receive high priority for fire suppression in fire management plans and timber management should be minimized, particularly when the roost is occupied. Additionally, they suggest a smaller buffer of 2.5 km radius of known roosts in which no burning or vegetative alternation should take place.

When forest roosting is thought to occur, the abundance and spatial distribution of roost snags on the landscape is important. Moreover, if local populations are to persist, the maintenance of appropriate snag densities in perpetuity is necessary. Thus, forest managers need to consider snag

recruitment, which effectively means retaining green trees of various sizes to serve as future snags

(Pierson 1998). Policies, such as the "Healthy Forest Initiative" (President of the United States

2002) that permit intensive logging and selective removal of dead and dying trees are detrimental

to maintenance of such a landscape. For woodland foraging species, such as *M. thysanodes*, The

Nevada Bat Working Group suggests that at least 90% of existing canopy be conserved within

those watersheds where bats are likely to occur, in order to provide sufficient foraging habitat

(Altenbach et al 2002).

Several bat working groups suggest closing hibernation sites to public access between

November 1 and April 1 each year, and maternity sites from April 1 to October 1, in order to

minimize lethal disturbance to roosts (e.g., Altenbach et al. 2002). For caves and mines, this

means installing bat-friendly gates (e.g., Vories and Throgmorton 2002) and for buildings the

installation of locks and or fences to prevent human disturbance of roosting areas. Clearly visible

interpretive signs that don't block air flow can educate the public of the reasons for the action and

hopefully avoid vandalism by uninformed parties.

Captive Propagation and Reintroduction

No captive propagation or reintroduction is currently underway, nor is such action

recommended at this time. Unless *M. thysanodes* populations undergo substantial crashes that

threaten imminent extirpation, conservation effort is more fruitfully spent in roost and habitat

preservation and restoration.

Targeted Areas

Although it is important throughout Rocky Mountains, within Wyoming the Black Hills is the

obvious focal point for *M. thysanodes* conservation. More specifically, it contains a large portion

of the locally endemic *M. t. pahapsensis* subspecies, which is questionably isolated from the

populations in the main range.   When considered in light of the extensive harvesting and minimal

old-growth left in the Black Hills, the importance of conservation efforts become even more

evident.

Information Needs

Relatively little is known about several key aspects of *M. thysanodes* biology that are relevant

to management of the species. The following is a list of information needs that we deem most

important to establishing effective conservation strategies for this species.

1. **Pesticides** - Research the impacts of the modern pesticides that are most likely to affect
   bats (i.e., those that are most likely to impact their prey and those that they are most likely
   to come in contact with either via consumption of contaminated prey or direct exposure).
   Two avenues of research are important. First, determine what the toxicological impacts to
   bats are through environmental exposure to such chemicals. The most likely exposure
   pathways are through direct contact during foraging flights or while roosting and through
   consumption of insects that contain high concentrations of chemicals. Second, determine
   how reductions in insect populations resulting from pesticide application affect bat
   populations indirectly via a reduction in the local prey base.

2. **Management impacts** – Very little monitoring of bat populations has occurred. What has
   been done was usually short-term, localized, and focused primarily on direct roost
   disturbances. Therefore, limited good data on the effects of specific habitat management
   practices on bats. For instance, we don't have data on fire effects, timber harvest effects,
   or forest treatment effects (e.g., thinning). Research seeking to answer these questions
   would be invaluable to forest managers seeking to conserve bat populations.

3. **Local Roosting Habits and Roost and Habitat Suitability** – Research needs to be
   conducted to find where *M. thysanodes* are roosting on a local basis, including what
   structures they are using across Wyoming. Once basic roosting areas are documented,
   research is needed to clarify the characteristics of existing maternity and hibernation sites
   so that those characteristics can be maintained and the suitability of currently unused sites
   can be evaluated. Similarly, more explicit delineation of optimal *M. thysanodes* foraging

habitat is needed. This information can be obtained through radio-telemetry and acoustic surveys.

4. **Metapopulation Structure** – More information is needed on the metapopulation dynamics of *M. thysanodes*, particularly where subspecific issues are concerned. This is important for defining conservation units. Genetic variation studies would prove useful. Although bats are mobile, they are also closely tied to limited roosting and foraging areas, thus limiting potential dispersal. For instance, the relative level of sympatry between the black hills subspecies (*M. t. pahasapensis*) and *M. t. thysanodes*, and thus the extent and validity of the subspecies, is largely unknown. Moreover, we don't know if or how long it might take for local populations to be recolonized after extinction events.

Tables and Figures

Table 1: Reported morphometric measurements of *M. thysanodes*.

Source [(Location)]	Forearm Length (mm)	Wing-span (mm)	Ear Length (mm) [a]	Total Length (mm)	Tail Length (mm)	Weight (g)	Pelage
Banfield 1975; Cowan and Guiguet 1956			16-18 (5 b.s.)	89 (86-93)	38.5 (36-41)		Pale buffy-brown; Pale sandy-brown
Boyce 1968 [b]	42.3		14.0	74.1	24.9		
Christy and West 1993		270-300	long			5-7	Light brown dorsal fir, paler below with black membranes
Barbour and Davis 1969	39-46	265-300	16-20	91-96			Reddish to dark brown above, pale below
Davis 1966	43		16.5	86	35		"… full and about 9mm long on the back. Upperparts uniform warm buff, tips of hares shiny, bases fuscous black; underparts dull whitish."
Genter and Jurist 1995	41.4	270-300		89.8	41.5	7.0	"Dorsal pelage varies from medium brown to pale buff with individual hairs being grayish plack basally; ventral pelage is paler"
Jones and Genoways 1967	39.2-43.3		17-21		40-44	6-7	Buckthorn brown and tawny-olive to light ochraceous buff above, pale to light ochraceous buff below.
Jones and Webb 1952 [b]	44		15	87			
Musser and Durrant 1960 [Utah]	42.5 [41.5-44.5]		17.4 [16-19]	85.6 [80-92]			Same as Miller and Allan 1928 but "some specimens which possess lighter, buffy-tipped hairs"
O'Farrell and Studier 1980	40-47		16-20	43-59 (nose to vent)	34-45		yellowish to olive brown above, same below
Wilson and Ruff 1999	40.3-45.3			80-99 (total length)	35-45	6.0-11.8	

[a] Lengths in parenthesis refer to how far, in millimeters, the ear extends beyond the snout (b.s.) when laid forward. [make sure this is extracted from all the references in this table.]

[b] Measurement by Boyce (1968) were taken from a dried study skin (Specimen Number UW2269). Measurements of ear and forearm by Jones and Webb (1952) were also from a study skin.

Table 2: Selected occurrence reports of *M. thysanodes* across its range. This table reports only the results of surveys that identified *M. thysanodes*, so it reflects relative abundance in currently occupied habitat. There are many surveys within *M. thysanodes* range that don't identify any individuals of this species.

Source	MYTH Encounters			Species Identified	Rank [a]	Location	Notes
	M/F	% of Total	Hourly Rate [b]				
Agyagos et al. 1994	287	6	3.7 [b]	18	10	Tonto Rim, Central Arizona	Dates: 1993. Habitat: Ponderosa Pine, Pinion-Juniper, Mixed conifer. Elevation: 1,200 m – 1,900 m.
Bogan et al. 1996	24/5	7	nr	9	4	Badlands National Park, South Dakota	Dates: 1992 – 1993. Habitat: Cottonwood and cedar. Elevation: nr
Choate and Anderson 1997	35	6.0	nr	~8	4	Jewel Cave South Dakota	Dates: 1989. Habitat: Clearings bordered by ponderosa pine. Elevation: 1,580 m – 1,664 m.
Cockrum et al. 1996	379/786	9		21	5	Mohave County, Arizona	Dates: 1959 1964. Habitat: Oak and pine forests. Elevation: nr.
Cryan 1997	202/30	13.7	nr	10	3	Southeastern South Dakota	Dates: Habitat: Unspecified, probably ponderosa pine. Elevation: 1,037 m – 1,768.
Ellinwood 1978	3	1.3	nr	14	10	Southeastern Colorado	Dates: 1977 – 1978. Habitat: Pinion-juniper near cliffs and canyons. Elevation: 1,097 m – 2,934 m.
Fenton et al. 1980	6	1.4	nr	11	8	Southern British Columbia	Dates: 1979. Habitat: nr. Elevation: < 700 m.
Herder 1998	67/75	12.3	nr	17	3	Northern Arizona	Dates: 1996 – 1997. Habitat: Ponderosa pine and pinion-juniper. Elevation: 1,600 m – 2,100 m.
Herder 1999	75	22.8	0.5 – 2.2 [e]	13	2	Northern Arizona	Dates: 1998. Habitat: Ponderosa pine and pinion-juniper. Elevation: 1,600 m – 2,100 m.
Morrell et al. 1999	49/52	9.0	8.7 [c]	11	5	Coconino National Forest, Arizona	Dates: 1993 – 1995. Habitat: Ponderosa pine. Elevation 2,000 m – 2,500 m.
"	8/13	3.8	1.2 [c]	15	7	"	Dates: 1993 – 1995. Habitat: Mixed ponderosa pine – oak. Elevation 2,000 m – 2,500 m.
Simons et al. 2000	21	2.2	7.0 [d]	9	16	Coastal mountains, Southern California	Dates: 1996 – 1998. Habitat: Montane conifer and montane desert. Elevation 1,500 m – 2,400 m.
Weller 2000	15/15	8.5	nr	7	3	Northwestern California	Dates: -. Habitat: Mature Douglas-fir and white fir. Elevation 950 m – 1,320 m.

Table 2 footnotes:

nr = not reported

[a] "Rank" represents the ordinal abundance rank of *M. thysanodes* among the species captured in a given survey. For instance, a rank of 5 indicates that *M. thysanodes* was the 5th most abundant species of bat captured.

[b] Hourly encounter rate given as number of *M. thysanodes* per 100 net-hours.

[c] Hourly encounter rate given as number of *M. thysanodes* per 1000 linear net-meter-hours.

[d] Hourly encounter rate given as number of *M. thysanodes* per 100 hours.

[e] Hourly encounter rate estimated from total bat capture success and given as number of *M. thysanodes* per hour per 10 m^2 of nets.

Table 3: Potential effects of exogenous factors on activity of free-ranging bats. This information was extracted largely from discussions in Ekert (1982) and Kunz (1982), with more recent additions from Grindal (1995).

Factor	Suggested Effects	Possible Mechanism
Cloud Cover (Light)	Heavy cloud cover that noticeably darkens the sky can cause early emergence from day roosts.	Light-mediated inhibition of locomotor activity. Predator (owl) avoidance.
Phase and rising of moon (Light)	Activity is generally reduced as the moon becomes fuller and during those portions of the night when the moon is in the sky.	Light-mediated inhibition of locomotor activity. Predator (owl) avoidance.
Temperature	Decreasing temperature results in decreased bat activity.	Lower temperatures result in increased metabolic demands of activity. Insect activity decreases with decreasing temperature (e.g., Grindal 1995).
Precipitation	Activity response varies with intensity of precipitation. Light rain probably has no impact. Heavy rain can prevent flight entirely. Moderate rain can reduce or alter patterns of activity.	Precipitation can interfere with echolocation, flight, and thermoregulation. Precipitation can also decrease insect activity.
Wind	Activity response varies with strength of wind. Light or moderate wind probably has little impact. Strong or gusty wind can prevent flight entirely.	Wind can interfere with prey capture, flight, and thermoregulation. Wind can also decrease insect activity.
Food Supply	Abundant recourses can result in reduced foraging time and consequently more strongly bimodal peaks of activity related to peaks in insect abundance that often occur in twilight periods.	Like most animals, bats forage until energy demands are met and then rest.
Reproductive Phase	Pregnant and lactating females are often very active because they have high energy demands. However, pregnant bats can become less active the closer they are to parturition.	Wing loading becomes higher with more advanced pregnancy, thus making foraging more difficult and energy intensive.
Elevation	Given the same habitat types, activity can be greater at lower elevations (e.g., Grindal 1995).	Temperature and insect abundance decrease with increasing elevation.

Fig. 1: Photographs of *M. thysanodes* showing general appearance and the uropatagial fringe (©
   Merlin Tuttle, Bat Conservation International, Austin, Texas).

Fringe

Fig. 2: Example of a *Myotis thysanodes* echolocation call from California, recorded and displayed via Anabat[©]. The vertical axis is frequency in kHz. Note the upper end of the call's range (~70 kHz), the lower end of the range (~28 to ~33 kHz), and the rapid downward sweep between these frequencies, with no constant frequency tail. This combination of features is typical of *M. thysanodes*, but other bats (e.g., *M. volans*) can have similar calls.
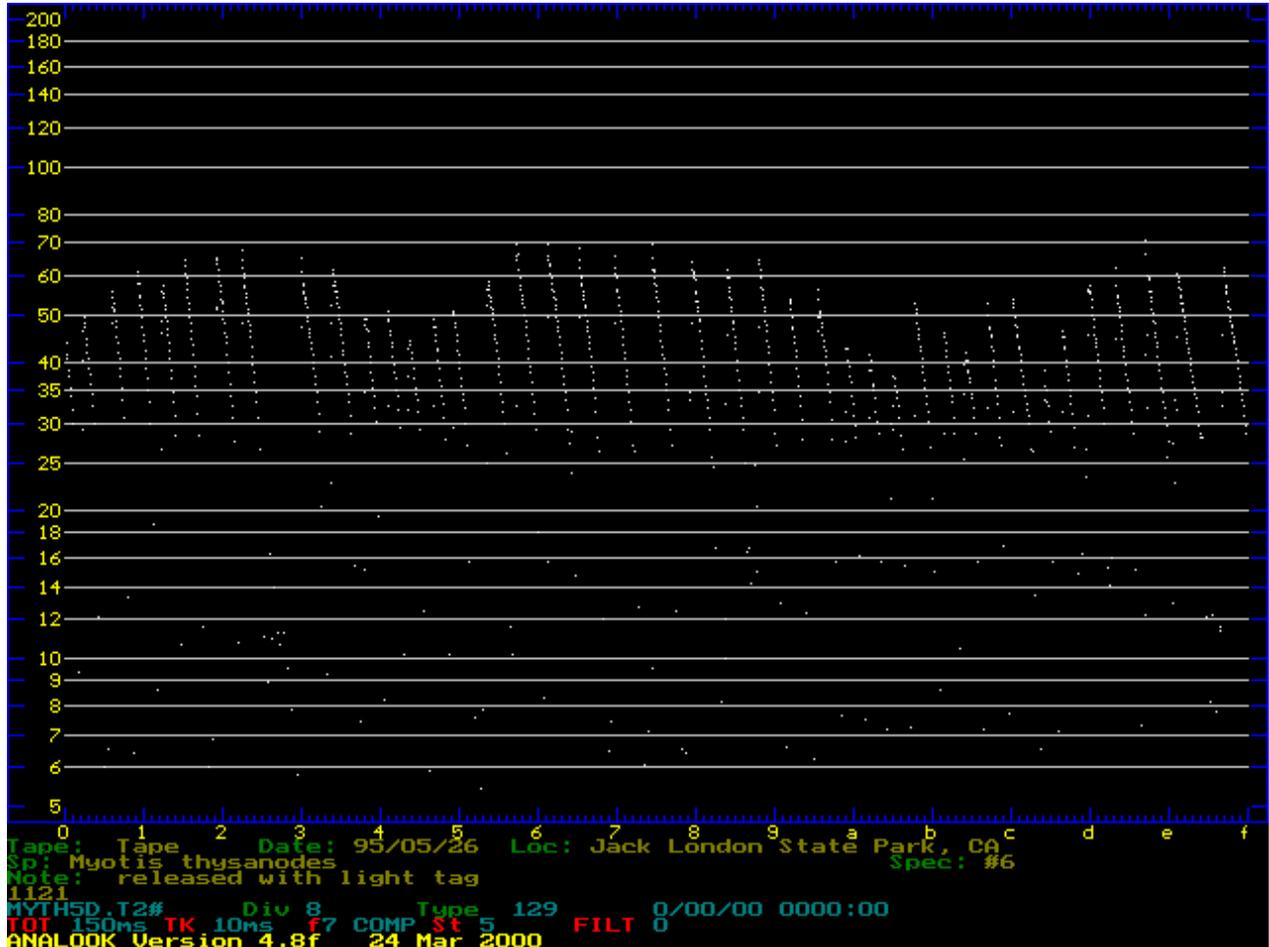
Fig. 3a: North American range of *Myotis thysanodes* adapted from range maps compiled by Bat
Conservation International, Austin, Texas, O'Farrell and Studier (1980), and Manning and
Jones (1988). Current estimated year-round range is shaded in light green. Approximate
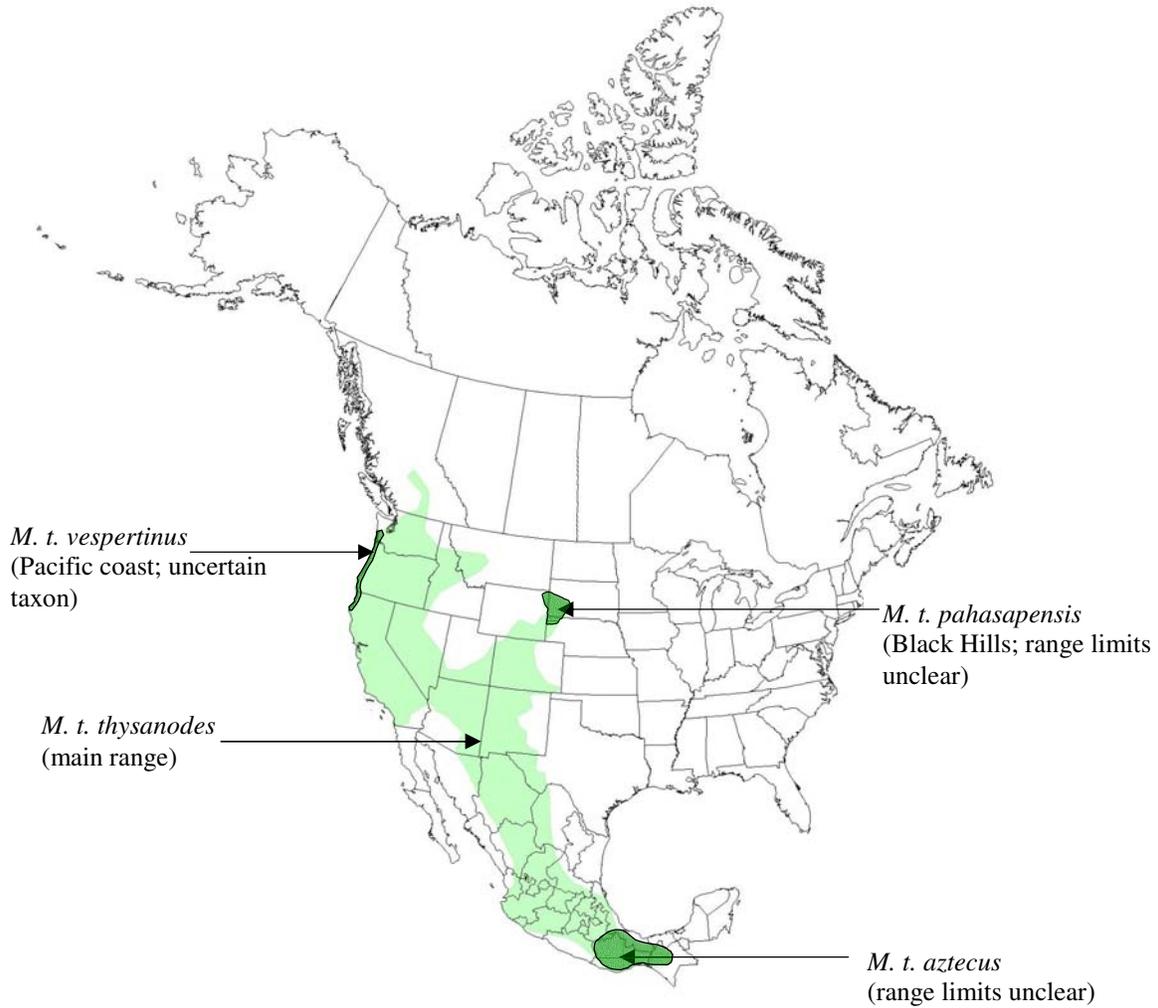subspecies locations are in darker green.

Fig. 3b: Potential distribution of *M. thysanodes* in and near Wyoming. Black squares represent
current (more recent than 1990) observational records. Black triangles represent historic
(older than 1990) observational records. Solid green polygon represents estimated current
distribution based on observations and national distribution maps (O'Farrell and Studier 1980,
Manning and Jones 1988, Bat Conservation International). Dashed green line represents the
probable historic range in Wyoming based on observational records, which are mostly
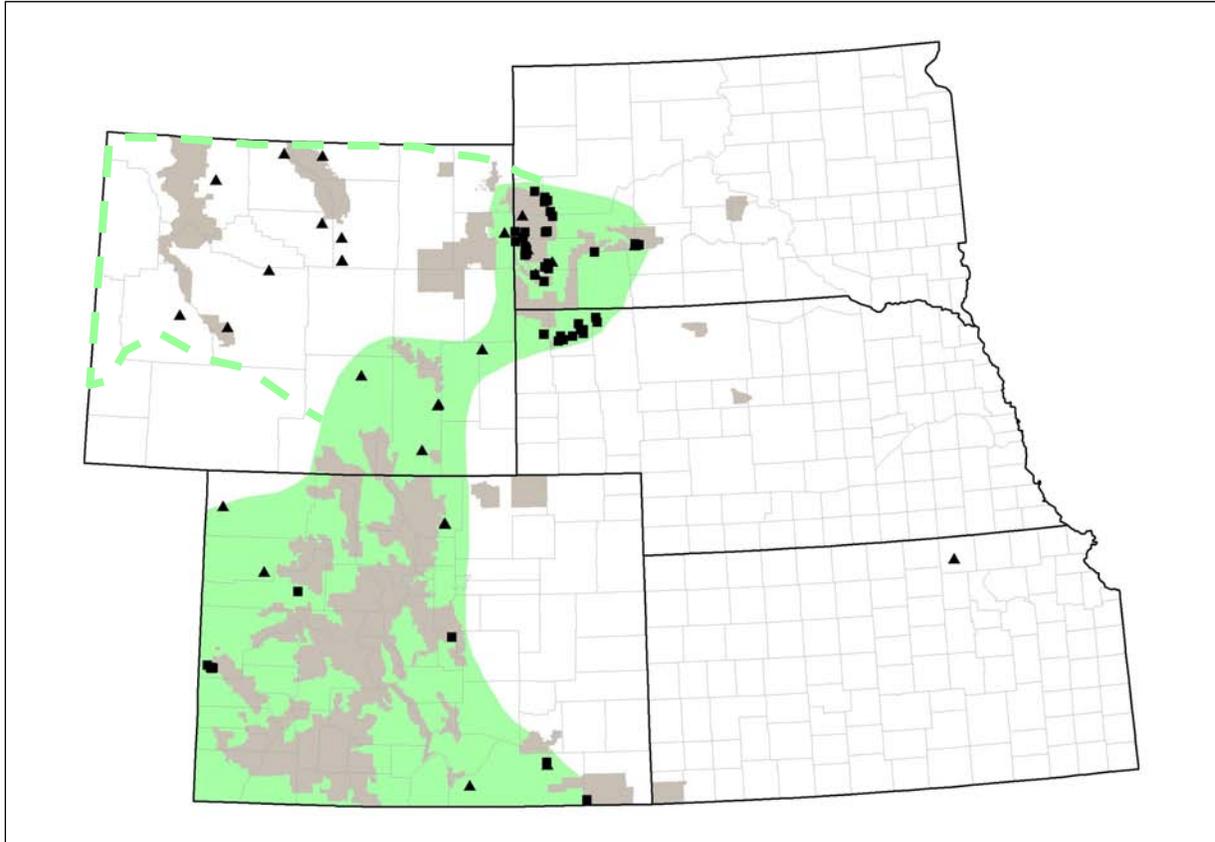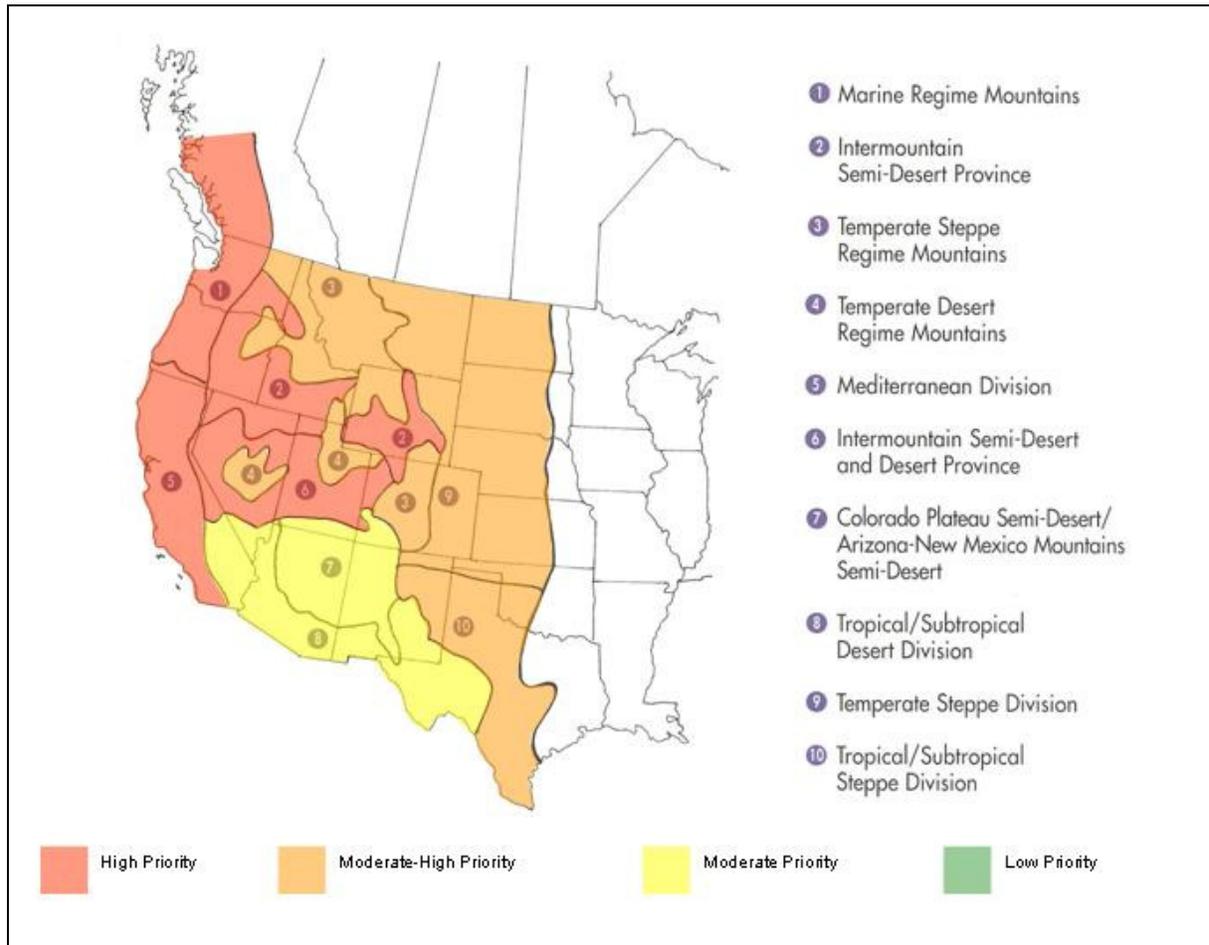museum specimens.

Fig. 4: Regional Conservation Priority of Myotis thysanodes throughout its range as defined by
the Western Bat Working group. Image adapted from Western Bat Working Group (1998).

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