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MATERNITY ROOST SITE SELECTION OF LONG-EARED MYOTIS, *MYOTIS EVOTIS*

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Bat conservation is hindered by a lack of geographic-specific knowledge of characteristics of roost sites used by reproductive females. We examined roost selection by reproductive female *Myotis evotis* (long-eared myotis) in the Channeled Scablands of northeastern Washington. We used radiotelemetry to locate 35 roosts of reproductive female *Myotis evotis*. Habitat variables were measured for each roost itself and at a 0.1-ha microplot and 78-ha macroplot surrounding each roost. We measured habitat variables at random 0.1-ha microplots in the vicinity of each roost and at general random 0.1-ha microplots and 78-ha macroplots. Thirty-four roosts were found in crevices in small basalt rock formations. All radiomarked bats switched roosts at least once and roost switching apparently involved the entire colony. The average number of switches was 3.3 with an average of 2 days between roost switches. The distance traveled between day roosts averaged 148.9 m. Compared to random plots, roosts were in more open, rocky habitats, closer to edge of forest stands, and relatively distant from sources of permanent water.

Key words: Channeled Scablands, habitat selection, long-eared myotis, maternity roosts, rock crevices, roost switching

Maternity roost sites are an important resource for bats and their availability can be a major determinant of population size and distribution in temperate latitudes (Kunz 1982). Roost selection is mediated by factors that vary regionally, reflecting differences in availability, climate, potential predators, thermoregulatory requirements, and proximity to foraging habitat and water (Barbour and Davis 1969; Barclay and Brigham 1996; Brigham 1991; Chruszcz and Barclay 2002; Nagorsen and Brigham 1993). *Myotis evotis* (long-eared myotis) is generally considered to roost in snags and stumps (Kunz and Lumsden 2003; Rabe et al. 1998; Vonhof and Barclay 1996, 1997, Waldien et al. 2000, 2003), but it also roosts in rocks (Chruszcz and Barclay 2002), and human-made structures (Manning and Jones 1989). An understanding of how roost-site selection varies across different habitats is a prerequisite for bat conservation. Moreover, similar to many other species of bats (e.g., Kunz and Lumsden 2003; Lewis 1995; Sherwin et al. 2000), individual *Myotis evotis* are known to switch roost sites periodically (Rabe et al. 1998; Vonhof and Barclay 1996). As Barclay and Brigham (2001) noted, frequent roost-switching behavior means that conservation of roosting habitat must be on a larger scale than an individual roost site.

We examined maternity roost selection of *Myotis evotis* in the Channeled Scablands of northeastern Washington. The Scablands area is comprised of stands of ponderosa pine (*Pinus ponderosa*) and quaking aspen (*Populus tremuloides*) forests intermixed with basalt rock outcrops and cliffs, numerous wetlands, shrub-steppe, and buildings that provide a full spectrum of possible roost and foraging sites. This juxtaposition of potential roosting and foraging habitat provides an opportunity to investigate selection of specific roost sites as well as broader habitat conditions. Specifically, our objectives were to identify the types of roosts used by reproductive female *Myotis evotis* and to determine site and habitat characteristics of these roosts.

MATERIALS AND METHODS

Study area.—Our research was conducted on Turnbull National Wildlife Refuge in northeastern Washington State. The 6,307-ha study area is located amidst the Channeled Scablands on the eastern edge of the Columbia Basin Plateau. Elevations range from 670–720 m. A modified maritime climate of warm, dry summers ($\bar{X}$ = 27°C) and cool moist winters (−4 to −1°C) is typical of the region. Topographic variations across the refuge result in a 10–15°C difference among microclimatic pockets. Average annual precipitation is 42 cm, occurring primarily as rain or snow in winter and early spring (National Oceanic and Atmospheric Association 1997).

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Numerous wetlands comprised of vernal pools, pothole basins, and larger permanent ponds constitute 20% of the landscape (United States Fish and Wildlife Service 1999). The 130 wetland basins within the refuge were formed by volcanic activity and several massive floods that occurred at the end of the Pleistocene Epoch (Allen et al. 1986). Two important ecological zones make up the study site, a Ponderosa Pine Zone and a remnant of the Palouse Zone. Second-growth pine forests cover approximately 40% of the study area and are represented by 2 plant associations. Ponderosa pine–Idaho fescue (*Festuca idahoensis*) association is found on shallower, drier soil with a more open canopy, and ponderosa pine–snowberry (*Symphoricarpos albus*) association typically occurs in topographic depressions and near wetlands (Daubenmire 1952). The 2,307 ha of Palouse habitat on the refuge is dominated by meadow and shrub-steppe plant communities within a landscape consisting of shallow rocky soils interspersed with regularly occurring soil mounds. This area is often referred to as "biscuit and swale" topography (Daubenmire 1970). Idaho fescue, bluebunch wheatgrass (*Agropyron spicatum*), and common snowberry form the dominant native cover of the mounds that range from 1–1.3 m high and 6–9 m across. Shallow, rocky soils of intermound areas support a community dominated by scabland sage (*Artemesia rigida*), Sandberg's bluegrass (*Poa sandbergii*), and snow buckwheat (*Eriogonum niveum*). Edges of wetland basins, channels, and meadows are dominated by quaking aspen with an understory of red-osier dogwood (*Cornus stolonifera*), thinleaf alder (*Alnus tenuifolia*), water birch (*Betula occidentalis*), black hawthorne (*Crataegus douglasii*), and snowberry, but constitute less than 2% of the study area.

Bat capture and telemetry.—We trapped bats at 17 harp trap (constructed following Tidemann and Woodside [1978]) sites and 50 mist net (Avinet, Inc., Dryden, New York) sites at different wetland, road, and forest areas distributed throughout the refuge from June through September of 1996 and 1997. All bats captured were identified to species and sex, age, and reproductive condition were recorded (Anthony 1988; Racey 1988). This project was reviewed and approved by Eastern Washington University's Institutional Animal Use and Care Committee and followed the guidelines of the Animal Care and Use Committee (1998).

Radiotransmitters (LB-2, Holohil Systems Ltd. Carp, Ontario, Canada) weighing approximately 0.45–0.51 g were attached to 14 pregnant or lactating *Myotis evotis*. Following a 1-day waiting period, a 3-element Yagi antenna and a TRX-2000S (Wildlife Materials, Inc., Carbondale, Illinois) receiver were used to locate radiotagged bats at day roosts. Bats were located daily until the transmitter terminated output (10–21 days). Individual roost sites were revisited at night with the assistance of night vision equipment to determine specific location of the roost, verify its status as a maternity colony, and record emergence time and number of individuals in the colony. Use of night vision equipment reduced potential disturbance. If a radiotagged bat switched roosts, we revisited the old roost site for 3 consecutive nights to verify that no bats remained at the old roost. We visited the new roost sites nightly while they were in use to count individuals emerging. Although not all bats were radiotagged, the switch was assumed to include the entire colony when no individuals were observed emerging from the old colony and the number emerging from the new roost was the same as that emerging from the old roost.

Habitat sampling.—To characterize the roost site, we measured habitat characteristics at 3 different spatial scales: 1) the roost itself, 2) a 0.1-ha (17.8 m radius) circular microplot centered on the roost (hereafter termed roost microplot), and 3) a 78-ha (500 m radius) landscape-level macroplot (hereafter termed roost macroplot). We selected 500 m because it is approximately one-half the longest recorded distance between roosts of individual *Myotis evotis* in this study.

To examine whether habitat characteristics of roost sites and randomly available areas differed, we measured habitat variables at 2 categories of random plots: vicinity and general. The 1st category was a random plot located in the roost vicinity, hereafter referred to as vicinity-random plots. We selected vicinity-random plots by measuring 50 m from the roost in a random direction. We then used the closest rock that was similar to the roost rock as the center of the vicinity-random plot. To locate the general random plots, we selected 72 points throughout the study area using a random number generator and plotted those using ARCVIEW GIS (ESRI, Redlands, California). We used these 72 points as the center for 0.1-ha microplots and 78-ha landscape-level macroplots. We refer to these general random plots as general-random microplots and general-random macroplots, respectively. We measured a total of 41 habitat variables (Appendix I) to characterize roost, roost microplots and macroplots, vicinity-random microplots, and general-random microplots and macroplots.

Statistical analysis.—We compared habitat variables between 1) roost microplots and vicinity-random microplots, 2) roost microplots and general-random microplots, and 3) roost macroplots and general-random macroplots using a Kruskal-Wallis test (Sokal and Rohlf 1995). We used multivariate logistic regression to determine the relative importance of habitat variables in discriminating between roost sites and random sites. Because our sample included measurements of multiple roost sites for individual bats, roost macroplots potentially overlapped and observations of variables in roost microplots of individual bats might have lacked statistical independence. To compensate for this, we used a modified estimate of variance in the logistic regression analysis that takes advantage of the fact that although observations are not independent, there are sets or aggregations of observations that are (White 1980; Williams 2000). We aggregated roost observations by individual bats. By summing over the aggregations, a modified estimate of variance is constructed using the independent sums such that the resulting estimate is robust to within-cluster correlation. At microplot scale we used stepwise logistic regression with backwards selection to identify which of 25 variables best predicted selected roosts. Variables were included in the model at $P = 0.05$. We did this separately for both vicinity-random and general-random microplots. To examine which of 7 land cover variables best predicted selected roosts at macroplot scale we used a logistic regression. For each logistic regression we report the estimate, odds ratio, and 95% confidence interval of each odds ratio. The odds ratio compares the probability that a given variable is associated with a roost to the probability that it is not. An odds ratio >1 means that a variable has a higher predicted probability of being associated with a roost, whereas if the odds ratio is <1, the odds of the variable being associated with a roost are decreased (Hair et al. 1998). All statistical tests were conducted with SAS statistical software (SAS Institute 1995). We used $P \leq 0.05$ for all statistical tests.

Results

By tracking the 14 radiotagged *Myotis evotis*, we located 35 roosts. The mean number of roosts located per individual was 3.2 ± 0.2. The mean number of individuals in 13 colonies for which we could obtain accurate counts was 4.0 ± 0.5 *SE*. All radiomarked bats switched roosts at least once, and roost switching involved the entire colony. The average number of roost switches for 9 *Myotis evotis* females that were followed ≥10 days was 3.3 ± 0.6 and days between roost switching averaged 2.0 ± 0.3. Individual *Myotis evotis* returned to a previous roost site once in 1996 and twice in 1997. The average

Fig. 1.—Rock roost of *Myotis evotis* in foreground with ponderosa pine and aspen behind. Arrow indicates vertical crevice.

distance traveled between day roosts was 148.9 ± 46.3 m ($n = 26$).

Roost characteristics.—Thirty-four of 35 day roosts used by reproductive female *Myotis evotis* were found in 2-cm wide crevices in small, isolated rocks or, less commonly, basalt cliff faces (Fig. 1, Table 1). Twenty-six crevices were vertical, 6 were horizontal, and 2 were diagonal. Twenty-one observations of roosts with lactating females were in vertical crevices and 9 observations of roosts with lactating females were in horizontal or diagonal crevices ($\chi^2 = 4.8$; $d.f. = 1$; $P < 0.005$). Sample size of roosts with pregnant females (4) was insufficient for comparison. Significantly more crevices were orientated skyward ($n = 13$; $\chi^2 = 27.4$; $d.f. = 4$; $P < 0.001$) than in any of the individual 4 cardinal directions (6 north; 5 south; 4 east; 6 west). Seventeen crevices had an overhang and the distance to the overhang and width of the overhang was highly variable. The distance to the 1st obstruction to the roost crevice averaged 10.4 ± 2.76 m. One roost was located under the bark of a 2.1-m ponderosa pine snag with a dbh of 29.2 cm for 1 day; then the colony switched to rock crevices.

Table 1.—Characteristics of rock roosts used by *Myotis evotis* in Channeled Scablands of northeastern Washington.

		Dimension (cm)							
		Height		Width		Length		Depth	
Characteristic	*n*	$\bar{X}$	*SE*	$\bar{X}$	*SE*	$\bar{X}$	*SE*	$\bar{X}$	*SE*
Roost substrate									
Isolated rock or knoll size	30	55.8	8.5	76.6	6.4	113.4	12.5		
Basalt cliff size	4	320.8	37.2						
Crevice size	34			2.2	0.1	37.1	9.8	31.2	2.8

Comparison of the habitat characteristics between roost microplots and vicinity-random microplots revealed that roosts were located further from permanent water bodies, had fewer seedlings, less grass and sedge cover, and had greater rock cover than random plots (Table 2). These same 4 variables plus an additional 11 variables differed between roost microplots and general-random microplots (Table 3). Roosts were located in areas characterized by less basal area, less canopy cover, fewer seedlings, fewer saplings, smaller trees, more dispersed shrubs, and greater moss cover. There was less distance to habitat transitions (edges) on roost microplots as compared to general random plots. These comparisons indicate that at microplot scale, roosts sites were characterized by open, rocky habitats close to forest edge but removed from permanent water bodies. At landscape level, comparison of roost macroplots to general random macroplots revealed that roosts were located in areas with a greater proportion of grassland and aspen habitat and lower proportion of permanent or semi-permanent wetlands (Table 3).

At roost vicinity scale, we found percentage rock cover, distance to permanent water, and distance to any water type best discriminated *Myotis evotis* roost from near random sites (Table 4). Odds of a rock outcrop being used as a roost increased with increasing amount of rock cover, with increasing distance from a permanent water body, and with decreasing distance from any water source (Table 4). Percentage rock cover and distance to permanent water were also the best predictors when roost microplots were compared to general-random microplots (Table 4). At the landscape level, likelihood of roost selection increased with proportion of grassland habitat and decreased with the proportion of permanent water in the 78-ha plots (Table 4).

Table 2.—Comparison of habitat variables between 0.1-ha plots at 35 *Myotis evotis* roost sites and 35 vicinity-random plots in Channeled Scablands of northeastern Washington. Variables defined in Appendix I.

	Roost		Random		Kruskal-Wallis	
Variable	$\bar{X}$	*SE*	$\bar{X}$	*SE*	χ^2	*P*
Slope	10.69	2.83	8.14	1.24	0.0155	0.90
Distance to edge	15.74	4.29	13.59	2.19	0.0139	0.91
Distance to water	247.70	28.01	246.05	9.24	0.0167	0.90
Distance to permanent water	406.49	30.91	281.99	29.04	6.3795	0.01
Nearest canopy	12.66	1.40	12.56	2.11	0.4808	0.49
Average stem dbh	17.87	1.06	10.57	1.577	1.2186	0.27
Average stem height	8.62	0.52	19.54	1.42	0.7969	0.37
Basal area	7.94	1.23	9.84	0.66	2.6086	0.11
Seedlings (# per ha)	1134.00	561.38	1784.29	855.66	6.8063	0.01
Saplings (# per ha)	52.29	19.46	142.57	74.51	0.8373	0.36
Canopy cover (%)	25.18	3.71	25.19	4.09	0.0795	0.78
Large shrub cover (%)	16.20	2.55	22.04	3.94	0.4821	0.49
Distance to nearest shrub	26.23	6.20	26.30	6.35	2.0399	0.15
Nearest shrub height	0.61	0.13	0.42	0.07	0.3998	0.53
Distance to nearest tree	10.77	1.04	10.86	1.17	0.0311	0.86
Nearest tree dbh	22.65	1.24	23.34	1.72	0.0068	0.93
Nearest tree height	10.15	0.64	10.54	0.71	0.0068	0.93
Moss ground cover (%)	19.88	2.25	18.75	1.72	0.0006	0.98
Grass and sedge ground cover (%)	17.57	1.69	23.5	2.0	4.9009	0.027
Forbs ground cover (%)	3.05	0.48	4.42	0.68	1.6334	0.20
Small shrub ground cover (%)	2.45	0.61	3.94	0.96	1.6334	0.20
Litter ground cover (%)	25.48	2.48	26.85	2.54	0.1163	0.73
Coarse woody debris (%)	3.52	0.58	4.47	0.86	0.1393	0.71
Rock cover (%)	23.58	2.12	12.56	1.39	15.5332	<0.001
Bare ground (%)	4.05	0.76	3.58	0.72	0.0529	0.82

Discussion

Many studies in forested areas have found that *Myotis evotis* uses loose bark of snags or stumps as roosts (Nagorsen and Brigham 1993; Rabe et al. 1998; Vonhof and Barclay 1996, 1997; Waldien et al. 2000, 2003) and Kunz and Lumsden (2003) classify *Myotis evotis* as a tree roosting bat. In contrast, we found all but 1 roost of reproductive females in rock crevices. Despite this difference in roost site, colony characteristics we observed fit Kunz and Lumsden's (2003) categorizations of *Myotis evotis* with respect to small colony size (<10), low roost fidelity (shifting sites every 1–2 days), and small roost area (distance between consecutive roosts <400 m).

The almost exclusive selection of rock structures, despite availability of snags and stumps, suggests that rock roosts might provide several benefits that increase reproductive fitness over other roost types. These benefits might include reduction of potential competition for roost sites from larger-bodied bats known from the refuge, thermodynamic advantages, and predator evasion.

Rock roosts might provide a better thermal environment than tree roosts. Although we did not measure roost temperatures, the greater thermal conductivity of rocks compared to wood (Curtis 1983) and the reduced forced convective losses in smaller cavities (Kurta 1985) likely provided warmer roost temperatures for reproductive female bats (Racey 1973). Chruszcz and Barclay (2002) radiotracked reproductive female *Myotis evotis* and monitored body temperatures and roost temperatures. Pregnant females were observed in horizontal rock crevices that warmed quickly during the morning, facilitating the bats' arousal from torpor. Lactating females were observed in vertical crevices that exhibited a temperature gradient allowing bats to move up and down the crevice to thermoregulate (Chruszcz and Barclay 2002). Although we did not monitor temperature, we also observed lactating females using vertical more than horizontal cracks.

Table 3.—Comparison of habitat variables at 35 *Myotis evotis* roost micro- and macroplots and 72 general-random micro- and macroplots in Channeled Scablands of northeastern Washington. Variables defined in Appendix I.

Scale and variable	Roost $\bar{X}$	Roost *SE*	Random $\bar{X}$	Random *SE*	Kruskal-Wallis χ^2	*P*
Microplot						
Slope	10.69	2.82	7.59	0.80	0.005	0.95
Distance to edge	15.74	4.30	25.88	4.02	4.497	0.03
Distance to any water	247.70	28.01	102.61	8.64	19.989	<0.001
Distance to permanent water	406.49	30.91	200.20	15.72	29.242	<0.001
Average stem dbh	17.87	1.06	21.62	1.53	1.762	0.18
Average stem height	8.62	0.52	11.52	0.75	4.863	0.03
Basal area	7.94	1.24	17.79	1.62	16.017	<0.001
Saplings (# per ha)	52.29	19.46	340.71	64.87	17.232	<0.001
Seedlings (# per ha)	1134.00	61.39	2080.71	486.88	5.811	0.02
Canopy cover (%)	25.18	3.71	42.03	3.37	7.379	0.01
Large shrub cover (%)	16.20	2.55	24.34	3.26	0.718	0.40
Distance to nearest shrub	26.23	6.20	21.29	3.97	4.475	0.03
Nearest shrub height	0.59	0.13	0.48	0.09	0.172	0.69
Distance to nearest tree	10.78	0.04	17.29	4.83	2.381	0.12
Nearest tree dbh	22.65	1.24	31.64	1.61	13.952	<0.001
Nearest tree height	10.15	0.64	14.97	0.75	17.937	<0.001
Moss ground cover (%)	19.88	2.25	15.81	1.93	5.244	0.02
Grass and sedge ground cover (%)	17.57	1.69	30.49	2.10	14.872	<0.001
Forbs ground cover (%)	3.05	0.49	9.24	1.18	10.559	0.001
Small shrub ground cover (%)	2.45	0.61	4.18	0.67	2.829	0.09
Litter ground cover (%)	25.48	2.48	31.17	2.13	1.689	0.19
Coarse woody debris (%)	3.52	0.58	2.63	0.48	3.633	0.057
Rock cover (%)	23.58	2.12	3.37	0.59	59.494	<0.001
Bare ground (%)	4.05	0.76	2.33	0.46	5.612	0.01
Macroplot						
Seasonal wetland	8.15	0.97	9.58	0.68	2.298	0.13
Semi-permanent wetland	1.85	0.48	3.76	0.37	20.016	<0.001
Permanent wetland	1.09	0.34	4.65	0.78	15.689	<0.001
Grassland and scrubland	42.56	2.25	36.42	1.82	7.505	0.01
Closed ponderosa	27.05	1.77	23.05	1.31	2.617	0.11
Aspen	1.70	0.09	1.53	0.16	4.165	0.04
Open ponderosa	18.27	1.87	21.17	1.43	1.625	0.20

Rock crevices might also provide greater security from predators. Rock is more resistant than wood to being broken apart by a predator. The skyward aspect of roost entrances and the general lack of obstructions provide a panoramic view of potential dangers before emergence. On several occasions, we observed *Myotis evotis* coming to the surface of the rock and pausing at the crevice's entrance prior to flight. These narrow and deep crevices would exclude most potential mammalian predators known to prey on bats. Although rock crevices are relatively secure from mammalian predators, snakes would be able to enter crevices and are known predators of *Myotis evotis* (McIntosh and Gregory 1976).

Avoidance of such predators might also be associated with the bats' roost-switching behavior. Similar to other studies (e.g., Chruszcz and Barclay 2002), we observed that female *Myotis evotis* routinely switched roosts. In addition to predator avoidance, disturbance, minimizing travel distance to foraging areas, response to parasite levels, and selection of microclimates have been proposed as likely explanations for frequent roost switching (Lewis 1995). Because roosts were relatively short distances apart, frequent switching by *Myotis evotis* was not likely related to changing prey availability. Although females do switch roost crevice types depending upon reproductive state, almost all the females we observed switching roosts were already lactating. Roosts used by these maternity colonies were very similar in size of the rock structure and depth and width of crevice. The similarity between roosts and the generally stable weather conditions during the period of observation makes it unlikely that roost microclimate was the primary motivation for roost switching.

Although *Myotis evotis* routinely switched roosts, individuals were faithful to a particular area. High patch fidelity could reduce energy expenditures associated with locating new roosts (Lewis 1995). This fidelity further underscores the importance of understanding habitat selection at a larger scale than the roost (Barclay and Brigham 2001). *Myotis evotis* selected relatively open, rocky habitats in close proximity to forest edges and removed from permanent water.

The increased solar radiation of the more open habitat types with less canopy cover and lower tree basal area might provide a better thermal environment than rock roosts in heavier forest cover. Waldien et al. (2003) observed that *Myotis evotis* was the most likely bat found using stumps as maternity roosts in open clearcut forest in western Oregon. The selection of roosts in close proximity to the edges of forest stands, especially aspen, might be explained by *Myotis evotis*' foraging strategy. *Myotis evotis* is known as a substrate gleaner that often forages near dense tangled vegetation or in forested areas (Faure and Barclay 1992, 1994; Manning and Jones 1989; Maser et al. 1981). This foraging strategy could also explain the apparent affinity for roosts near small wetlands, because these are typically ringed with aspen. Similar to other studies of habitat selection by bats in the Pacific Northwest (e.g., Betts 1998; Campbell et al. 1996), distance to permanent water did not appear to be a factor in roost-site selection. Given that wetlands comprise approximately 20% of the area on Turnbull National Wildlife Refuge (United States Fish and Wildlife Service 1999), access to water was not a limiting factor. The greater distance from roost to water than the general random sites reflected the location of rock roosts on ridges that are farther from water occurring in channels and depressions between ridges.

Understanding regional differences in roost and roost-habitat selection is a critical component in managing habitats for bat conservation. Because we found that *Myotis evotis* selected rock structures in open habitats, selective thinning and prescribed burning of ponderosa pine stands, especially those containing rock outcrops, will benefit this species. In addition, the restoration and maintenance of aspen stands in this area is a management priority because of the selection for this habitat at the landscape level.

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TABLE 4.—Parameter coefficients for logistic regression on habitat variables at 3 spatial scales for *Myotis evotis* maternity roosts in Channeled Scablands of northeastern Washington, 1996–97.

Scale	Variable	*d.f.*	*P*	Estimate	95% CI	Odds ratio
Microplot: Roost–Vicinity Random	Distance to any water	1	0.002	−0.012	0.981–0.996	0.988
	Distance to permanent water	1	<0.001	0.012	1.006–1.019	1.012
	Rock cover (%)	1	<0.001	0.135	1.053–1.243	1.144
	Intercept	1	<0.001	−3.558		
Microplot: Roost–General Random	Distance to permanent water	1	0.003	0.010	1.003–1.017	1.010
	Rock cover (%)	1	<0.001	0.2973	1.186–1.528	1.346
	Intercept	1	<0.001	−6.641		
Macroplot: Roost–General Random	Permanent wetland	1	0.029	−0.2852	0.582–0.972	0.752
	Grassland and scrubland	1	0.05	0.1030	0.999–1.229	1.108
	Intercept	1	0.06	−8.8940		

ing helpful suggestions. We thank adjacent landowners for their cooperation. We thank I. C. Napier, R. A. Napier, C. R. Rule, R. P. Rule, J. R. Alto, L. A. Koll, and J. M. Connor for help in habitat measurement. We thank our pilot, G. Beck. This project was funded by United States Fish and Wildlife Service and through grants from Bat Conservation International, Northwest Scientific Association, and the Department of Biology, Eastern Washington University.

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Appendix I

Definitions and methods of measurement of habitat variables used to characterize *Myotis evotis* roost sites and random plots in Channeled Scablands of northeastern Washington State.

Scale and habitat variable	Method
Roost variables	
Crevice configuration	Crevices classified as horizontal, vertical, or diagonal.
Rock type	Rock types classified as isolated rock or boulder, rocky knoll, or large cliff face (>1.5 m high).
Rock dimensions	Length, width, and height (cm) of rock structures.
Roost crevice	Length, width, and depth (cm) of roost crevices.
Cavity orientation	Cardinal direction of cavity entrance.
Horizontal obstruction	Distance to 1st obstruction (branch, overhang, shrub, tree, etc.) at 90° intervals from roost entrance (m).
Vertical obstruction	Distance (m) and type of cover above and below roost entrance.
Distance between roosts	Distances between roost sites for individual bats measured using GIS.
Roost microplot and general-random microplot	
Slope	Slope recorded using a clinometer.
Aspect	Aspect recorded as flat, north, south, east, or west.
Upland habitat type	Microplots classified into 1 of 5 general upland habitat types: grassland and scrubland, closed ponderosa pine forest (>50% cover), open ponderosa pine forest (<50% cover), aspen, or mixed ponderosa pine and aspen.
Distance to edge	Distance (m) to change in habitat type.
Distance to water	Distances (m) to nearest available water and to permanent body of water determined from aerial maps of study site and by using GIS.
Water type	Nearest water types classified as vernal pool, seasonal wetland, semi-permanent wetland, permanent wetland, streambed, or channel.
Shrub density and height	Shrub density and height (m) measured using the point center quarter method (Dix 1961).
Large shrub cover	Percentage of shrub (>1 m tall) cover estimated for each microplot by 2 observers and the average used in analysis.
Ground cover	Ground cover recorded for points at 1 m intervals along a transect extending from the center to the edge of the each microplot in each of the 4 cardinal directions. Categories of ground cover were: mosses, ferns, grasses and sedges, forbs, small shrubs (≤1 m tall), seedlings, litter, slash and logs, rocks, bare ground, and live tree.
Distance to nearest tree	Within the roost and the near random microplots, the distance to nearest tree (m) from the rock as well as its dbh (cm) and height (m) in 4 quadrants.
Seedlings and saplings density	All seedlings (<1 m tall) and saplings (>1 and <2 m) counted within each plot. Densities converted to stems per ha.
Canopy cover	Percentage of canopy cover (measured with concave spherical densiometer) at 9 m (one-half radius of the microplot) from the center of both the roost and random plots in 4 cardinal directions (Lemmon 1956). The 4 estimates averaged.
Basal area	Species, dbh, height, and configuration of all stems within the microplot. Basal area (m^2 per ha) calculated from stem data.
Roost macroplot and general-random macroplot	
Cover of wetland type	GIS overlays of vegetation cover were used to determine the composition (%) of 3 wetland types: seasonal, semi-permanent, and permanent.
Cover of upland habitat type	GIS overlays of vegetation cover were used to determine the composition (%) of 4 upland habitat types: grassland and scrubland, open ponderosa pine forest (<50% cover), closed ponderosa pine forest (>50% cover), and aspen.