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Research Article

Hibernacula Selection by Townsend's Big-Eared Bat in Southwestern Colorado

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ABSTRACT In western United States, both mine reclamations and renewed mining at previously abandoned mines have increased substantially in the last decade. This increased activity may adversely impact bats that use these mines for roosting. Townsend's big-eared bat (*Corynorhinus townsendii*) is a species of conservation concern that may be impacted by ongoing mine reclamation and renewed mineral extraction. To help inform wildlife management decisions related to bat use of abandoned mine sites, we used logistic regression, Akaike's information criterion, and multi-model inference to investigate hibernacula use by Townsend's big-eared bats using 9 years of data from surveys inside abandoned mines in southwestern Colorado. Townsend's big-eared bats were found in 38 of 133 mines surveyed (29%), and occupied mines averaged 2.6 individuals per mine. The model explaining the most variability in our data included number of openings and portal temperature at abandoned mines. In southwestern Colorado, we found that abandoned mine sites with more than one opening and portal temperatures near 0°C were more likely to contain hibernating Townsend's big-eared bats. However, mines with only one opening and portal temperatures of $\geq$10°C were occasionally occupied by Townsend's big-eared bat. Understanding mine use by Townsend's big-eared bat can help guide decisions regarding allocation of resources and placement of bat-compatible closures at mine sites scheduled for reclamation. When feasible we believe that surveys should be conducted inside all abandoned mines in a reclamation project at least once during winter prior to making closure and reclamation recommendations.

KEY WORDS Colorado, *Corynorhinus townsendii*, Four Corners region, hibernacula, mines, Townsend's big-eared bat.

Townsend's big-eared bat (*Corynorhinus townsendii*) is a species of conservation concern in western North America (Adams 2003, O'Shea and Bogan 2003). Two of the 5 subspecies (*C. t. virginianus* and *C. t. ingens*) are listed as endangered under the United States Endangered Species Act (U.S. Fish and Wildlife Service 1994) and concern about this species in western North America led to the development of a collaborative conservation strategy (Pierson et al. 1999). The goal of this strategy is to "identify, protect, and restore important habitats and viable *C. townsendii* populations throughout the species' range..." (Pierson et al. 1999:37). Although this species is found in a variety of habitats, from deserts to conifer forests and riparian communities it exists in low densities throughout its range (Humphrey and Kunz 1976, Kunz and Martin 1982, Pierson et al. 1999). Townsend's big-eared bats roost in caves, abandoned mines, rock crevices, and man-made structures such as buildings, tunnels, and bridges (Kunz and Martin 1982, Pierson et al. 1999). Townsend's big-eared bats are highly sensitive to disturbance at roost sites and loss of roosting resources may be a limiting factor (Humphries and Kunz 1976, Pierson et al. 1999). The Colorado Bat Conservation Plan (Ellison et al. 2003) ranks Townsend's big-eared bat as the species of highest concern in the state and this plan emphasizes that a key research priority is to define the microhabitat requirements of cave and mine roosting bats.

The Four Corners region of Colorado, Arizona, New Mexico, and Utah is an area of rapid environmental modification, which includes current large-scale abandoned mine reclamation projects and a dramatic increase within the last decade in renewed mining activities associated with raising mineral ore commodity prices (United States Bureau of Land Management and United States Fish and Wildlife Service, 2007, Environmental Working Group 2008). These environmental changes are altering the availability of abandoned mines as roosting habitat for Townsend's big-eared bats. For example, between 2000 and 2007, the Bureau of Land Management inventoried 5,500 abandoned mines in the western United States and initiated reclamation efforts at many of these sites (US BLM and USFS 2007). Also, active mine claims at new and formerly abandoned sites in Colorado increased from 5,430 in 2003 to >23,400 in January 2008 (Environmental Working Group 2008). Thus, reclamation activities and renewed mining operations have the potential to eliminate a substantial proportion of available Townsend's big-eared bat roosts.

The Colorado Division of Wildlife's Bats/Inactive Mines Project has been conducting surveys throughout Colorado since 1991 to document and protect important bat roosts in abandoned mines (Navo and Krabacher 2005). This project has documented Townsend's big-eared bats hibernating in abandoned mines throughout the western and mountainous parts of the state (Navo et al. 1991, Navo and Krabacher 2005). Conducting surveys inside abandoned mines, however, is dangerous and resource intensive (Burghardt 1996, 2003; Navo 2001). Being able to predict where this species hibernates using surface and near-surface features of mines would reduce the hazards biologists are exposed to in the field and reduce the resources required to identify mines that provide adequate hibernation conditions.

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Our purpose was to describe and model winter use of abandoned mines by Townsend's big-eared bat in southwestern Colorado. We compared differences between abandoned mines occupied by Townsend's big-eared bat and abandoned mines where this species was not found during winter bat surveys. We evaluated the evidence for multiple competing hypotheses on 2 scales: one that included mine-site variables and a second that included elevation and climate variables.

STUDY AREA

We compiled and analyzed data collected by the Colorado Division of Wildlife's Bats/Inactive Mines Project (BIMP) from abandoned mines in southwestern Colorado. The study area was within the Colorado Plateau physiographic province of the Rocky Mountain region and included portions of the Uncompahgre Plateau and La Plata Mountains. Mine sites in the study area were located in sagebrush (*Seriphidium tridentatum*) and piñon-juniper (*Pinus edulis* and *Sabina* spp.) woodlands of the benchlands and canyonlands of southwestern Colorado. Two sites were located in montane forest in the La Plata Mountains. Elevation of abandoned mine sites range from approximately 1,400 m to >3,000 m.

METHODS

Mine Surveys

During January, February, and March from 1999 to 2007, BIMP biologists conducted bat surveys inside abandoned mines within the study area (Navo 2001). Biologists surveyed mines scheduled for reclamation by Colorado Division of Reclamation, Mining and Safety; BLM; and USFS.

Biologists collected the following information at each mine: bat presence (by visual inspection, no bats were handled), species (when possible from visual inspection), number of bats of each species, whether bats roosted singly or in groups, elevation at the mine portal, size of the portal opening (m^2), ceiling temperature at the portal entrance using an infrared thermometer (Raynger ST2, Raytek Corporation, Santa Cruz, CA), minimum depth of the mine, and minimum number of openings or portals. When possible, air temperature was measured near hibernating Townsend's big-eared bats. We estimated mean annual temperature (MAT) and length of winter (LOW) at mine sites using historic climate data from 7 weather stations within the study area (Western Regional Climate Center 2009). We defined LOW as the period when average daily minimum temperatures were <0°C (Humphries et al. 2002). We estimated MAT and LOW from climate data centers within 32 km and within 75 m elevation of mine locations. Where there was an elevation difference of >75 m between the weather station and the mine site, we calculated a local terrestrial lapse rate and used this rate to adjust MAT and LOW values (Gottfried et al. 1999).

Sites included in our analysis were not selected randomly. Project areas were chosen for survey work based on priorities of state and federal agencies (Colorado Division of Reclamation, Mining and Safety; BLM; and USFS) and private landowners. Several mines were surveyed twice during our study and in such cases we only used data from the first survey. Mines that were too difficult or dangerous to reach during winter were not surveyed. Because sites were not selected randomly, there may be some potential bias. However, we believe that our results are applicable to other abandoned mines in southwestern Colorado that will be scheduled for reclamation and that are reasonably accessible during winter.

Modeling and Data Analysis

We compiled data collected during 9 years of BIMP surveys inside mines conducted during January, February, and March 1999–2007. We excluded 20 mines from the analysis because data for these sites were incomplete. We used 7 variables to model Townsend's big-eared bat presence at abandoned mines: portal area (m^2), portal temperature (°C), number of openings, minimum depth (m), elevation at portal (m), MAT (°C), and LOW (months). We used the square of portal temperature (portal temperature^2) because we expected a parabolic response between portal temperature and presence of hibernating Townsend's big-eared bats. For example, we suspected that a mine with a stable internal temperature of 5°C would be more likely to be occupied by Townsend's big-eared bats than would a mine with stable internal temperatures of −5°C or 15°C.

Abandoned mines in Colorado are often clustered within mining districts and it would be helpful if biologists and managers could prioritize abandoned mines within and among these districts. We therefore developed 2 balanced model sets, one that included mine-site variables and a second that included elevation and climate variables. We developed the mine-site model set to provide information about characteristics of individual mines that may influence hibernacula selection by Townsend's big-eared bats. Such information might help identify suitable hibernation sites within a mine reclamation project. We developed elevation and climate models to provide information about landscape variables that may influence hibernacula selection by this species.

We analyzed data using logistic regression and the logit link function (MiniTab, Inc., State College, PA). We assessed each global model's fit using Pearson Chi-square goodness of fit test (Burnham and Anderson 2002). We calculated variation inflation factors ($\hat{c}$) for each global model to determine if data were over-dispersed (Burnham and Anderson 2002). We compared models using Akaike's information criterion for small sample sizes (AIC_c; Burnham and Anderson 2002). We ranked models using AIC_c weights (w_i) and we calculated a cumulative AIC_c weight (w_+) for each predictor variable. We then calculated unconditional parameter estimates ($\tilde{\bar{\beta}}_i$) and 95% confidence intervals for the regression coefficient for each model variable. We considered variables with a 95% confidence interval around $\tilde{\bar{\beta}}_i$ that did not overlap zero to have a strong effect (Burnham and Anderson 2002). We then used the highest-ranked model and associated unconditional parameter estimates to estimate the probability of an abandoned mine in southwestern

Table 1. Variables at abandoned mines occupied by hibernating Townsend's big-eared bat (hibernacula) and abandoned mines not unoccupied by this species (non-hibernacula) shown as mean, standard error, and associated 95% confidence interval. Data were collected at 133 abandoned mine sites ($n = 38$ hibernacula and $n = 95$ non-hibernacula) in southwestern Colorado during January, February, and March, 1999–2007. All variables are continuous variables.

	Hibernacula			Non-hibernacula		
Variable	$\overline{X}$	**SE**	**95% CI**	$\overline{X}$	**SE**	**95% CI**
Portal area (m^2)	4.7	0.6	3.5–5.8	4.6	0.3	4.0–5.2
Portal temp (° C)	4.3	0.5	3.3–5.4	5.8	0.4	5.0–6.7
Portal temp^2	29.4	5.4	18.7–40.0	51.7	7.5	36.9–66.4
No. of openings	1.9	0.2	1.5–2.3	1.3	0.1	1.2–1.4
Min. depth (m)	69.7	10.5	49.1–90.3	61.4	11.1	39.8–83.1
Elevation at portal (m)	1898	24	1851–1946	1896	17	1863–1930
Length of winter (mo)	6.9	0.1	6.7–7.0	6.9	0.05	6.8–7.0
Mean annual temp (° C)	8.4	0.2	8.0–8.9	8.7	0.2	8.4–9.0

Colorado being occupied by Townsend's big-eared bats during winter.

RESULTS

Surveys were conducted inside 133 abandoned mines from 1999 to 2007 (1999 = 34 sites; 2000 = 0 sites; 2001 = 2 sites; 2002 = 3 sites; 2003 = 7 sites; 2004 = 9 sites; 2005 = 36 sites; 2006 = 29 sites; and 2007 = 13 sites). Townsend's big-eared bats occupied 38 of the 133 mines surveyed (28.6%). Surveyors found 99 Townsend's big-eared bats. Average number of Townsend's big-eared bats in occupied mines was 2.6 (range = 1–8, SD = 2.14; Table 1). All Townsend's big-eared bats were roosting singly, except one group of 2 bats and 2 groups of 3 bats. Air temperature measured near 78 hibernating Townsend's big-eared bats ranged from −2.6°C to 8.9°C ($\bar{x} = 4.0$°C, SD = 2.8°C).

The chi-square goodness-of-fit test suggested that data adequately fit the mine-site global model ($\chi^2 = 135.607$, df = 128, $P = 0.306$). The estimated variation inflation factor ($\hat{c} = 1.06$) suggested data were not over-dispersed (Burnham and Anderson 2002). The model that incorporated number of openings and squared temperature at the main portal's ceiling (openings + squared portal temperature) had the most support ($w_i = 0.43$; Table 2). The next most parsimonious models incorporated depth, number of openings, and squared portal temperature ($w_i = 0.15$) and number of openings, portal area, and squared portal temperature ($w_i = 0.15$; Table 2).

The Chi-square goodness of fit test suggested that data adequately fit the elevation and climate global model ($\chi^2 = 93.916$, df = 85, $P = 0.238$). The estimated variation inflation factor ($\hat{c} = 1.10$) suggested data may be slightly over-dispersed (Burnham and Anderson 2002); however, we did not modify AIC$_c$ values for over-dispersed data because there was not a distinct lack of fit in the global model (i.e., $P \leq 0.15$; Burnham and Anderson 2002). The model that incorporated LOW and MAT had the most support ($w_i = 0.32$; Table 3). The next most parsimonious models used MAT ($w_i = 0.19$) and LOW, MAT, and elevation ($w_i = 0.12$; Table 3).

Of the variables used in the mine-site models, number of openings received the highest cumulative AIC$_c$ weight ($w_+ = 0.99$), followed by squared portal temperature ($w_+ = 0.79$), portal area ($w_+ = 0.26$), and minimum mine depth ($w_+ = 0.26$; Table 4). Of the mine-site variables, the 95% confidence interval for the unconditional parameter estimates for the intercept (−2.0021, −1.4301), number of openings (0.6592, 0.7725), and squared portal temperature (−0.0154, −0.0014) did not overlap zero. Of the variables used in the climate and elevation models, MAT received the

Table 2. Log-likelihood, number of parameters (K), Akaike's Information Criterion adjusted for small sample size (AIC$_c$), AIC$_c$ difference (Δ_i), and AIC$_c$ weight (w_i) for each model used in the mine-site balanced model comparison using data collected at 133 abandoned mine sites ($n = 38$ Townsend's big-eared bat hibernacula and $n = 95$ non-hibernacula) in southwestern Colorado during January, February, and March, 1999–2007. Abbreviations are number of openings (Openings), squared portal temperature (Portal temp^2), and minimum depth (Depth).

Model	Log-likelihood	K	AIC$_c$	Δ_i	w_i
Openings + portal temp^2	−71.48	3	149.14	0.00	0.43
Depth + openings + portal temp^2	−71.45	4	151.21	2.07	0.15
Openings + portal area + portal temp^2	−71.45	4	151.21	2.07	0.15
Openings	−73.86	2	151.80	2.66	0.11
Depth + openings + portal area + portal temp^2	−71.41	5	153.30	4.16	0.05
Depth + openings	−73.85	3	153.89	4.75	0.04
Openings + portal area	−73.81	3	153.80	4.66	0.04
Depth + openings + portal area	−73.81	4	155.92	6.78	0.01
Portal temp^2	−77.16	2	158.42	9.28	0.00
Depth + portal temp^2	−77.15	3	160.48	11.34	0.00
Portal area + portal temp^2	−77.16	3	160.51	11.36	0.00
Depth + portal area + portal temp^2	−77.15	4	162.60	13.46	0.00
Depth	−79.16	2	163.04	13.90	0.00
Portal area	−79.56	2	163.21	14.07	0.00
Depth + portal area	−79.47	3	165.13	15.99	0.00

Table 3. Log-likelihood, number of parameters (*K*), Akaike's Information Criterion adjusted for small sample size (AIC_c), AIC_c difference (Δ_i), and AIC_c weight (w_i) for each model used in the climate and elevation balanced model comparison using data collected at 133 abandoned mine sites ($n = 38$ Townsend's big-eared bat hibernacula and $n = 95$ non-hibernacula) in southwestern Colorado during January, February, and March, 1999–2007. Abbreviations are length of winter (LOW), mean annual temperature (MAT), and elevation at portal (ELEV).

Model	Log-likelihood	*K*	AIC_c	Δ_i	w_i
LOW + MAT	−77.457	3	161.10	0.00	0.32
MAT	−79.045	2	162.18	1.08	0.19
LOW + MAT + ELEV	−77.393	4	163.10	2.00	0.12
LOW	−79.547	2	163.19	2.09	0.11
ELEV	−79.568	2	163.23	2.13	0.11
MAT + ELEV	−78.618	3	163.42	2.32	0.10
LOW + ELEV	−79.529	3	165.24	4.14	0.04

Table 4. Cumulative AIC_c weight (w_+), unconditional parameter estimate ($\tilde{\tilde{\beta}}_i$), unconditional standard error, and 95% confidence interval for variables used in the mine-site balanced model set and the elevation and climate balanced model set using data collected at 133 abandoned mine sites ($n = 38$ Townsend's big-eared bat hibernacula and $n = 95$ non-hibernacula) surveyed in southwestern Colorado during January, February, and March, 1999–2007.

				95% CI	
Variable	w_+	$\tilde{\tilde{\beta}}$	SE	Lower	Upper
Mine site variables					
Intercept		−1.7161	0.1459	−2.0021	−1.4301
No. of openings	0.99	0.7159	0.0289	0.6592	0.7725
Squared portal temp	0.79	−0.0084	0.0036	−0.0154	−0.0014
Min. depth	0.26	−0.0001	0.0002	−0.0005	0.0003
Portal area	0.26	0.0044	0.0069	−0.0090	0.0179
Elevation and climate variables					
Intercept		2.3131	8.6636	−14.6676	19.2937
Mean annual temp	0.73	−0.3557	0.2914	−0.9268	0.2155
Length of winter	0.60	−0.4483	0.8828	−2.1786	1.2819
Elevation	0.37	−0.00007	0.00034	−0.00075	0.00060

highest cumulative AIC_c weight ($w_+ = 0.73$), followed by LOW ($w_+ = 0.60$) and elevation at portal ($w_+ = 0.37$). All 95% confidence intervals for the elevation and climate unconditional parameter estimates overlapped zero.

The model that included number of openings and squared portal temperature provided the best model for predicting Townsend's big-eared bat occupancy at mines. Number of openings and squared portal temperature were not correlated, using the Pearson product moment correlation calculation ($\rho = -0.044$, $P = 0.617$).

DISCUSSION

Townsend's big-eared bats were found hibernating in low densities and almost all bats were found hibernating independently and hanging pendant, not in crevices. These observations are consistent with studies of this species' use of abandoned mines in other parts of the western United States (Kunz and Martin 1982; Pierson et al. 1999; Sherwin et al. 2000, 2003). In our study, Townsend's big-eared bats were found hibernating in 29% of mines surveyed (38 of 133). Mines with more openings were more likely to be occupied by hibernating Townsend's big-eared bats. Mines with multiple openings generally have greater air exchange with the surface than do mines with one opening (Vutukuri and Lama 1986, Sherwin et al. 2003, King 2004). More openings may thus create a greater range of temperatures within the mine, providing Townsend's big-eared bats with a suite of thermal conditions from which to choose hibernation locations. Unlike other bat species found in abandoned mines in southwestern Colorado, which hibernated inside crevices and bore-holes, Townsend's big-eared bats were found hanging pendent from the ceiling of internal mine workings. This roosting behavior likely exposes Townsend's big-eared bats to a broader range of internal mine temperatures. Mines with more openings may contain multiple areas that provide temporally and spatially dynamic optimal hibernating temperatures for Townsend's big-eared bats. Also, mines with multiple openings may be easier for bats to detect; mines with one opening may be less conspicuous to bats. Mines are inherently unstable subterranean structures and rock falls, cave-ins, and other forms of deterioration are common. In mines with multiple openings, bats may be able to find their way out or in if one opening becomes blocked. Therefore, mines with more than one opening may be of higher conservation priority because they have a higher likelihood of being occupied by Townsend's big-eared bat and these mines will tend to provide alternative escape routes for bats in the event of cave-ins where one exit is blocked.

Mines with portal temperatures close to 0°C were more likely to house hibernating Townsend's big-eared bats. Temperatures inside mines during the winter months tend to be warmer than average ambient surface temperatures and the temperature at a mine portal will tend to be colder than temperatures in the internal workings of a mine (King 2004). Portal temperatures we used were recorded just prior to entering mines to conduct bat surveys. Portal temperatures should vary at the same mine, depending on the weather conditions and time of day the portal temperature is measured. The predictive power of portal temperatures might be substantially improved by taking a series of portal temperatures over a period of time, allowing estimation of the distribution of winter portal temperatures for each mine site. For example, placing a temperature data logger on the ceiling of a portal and recording portal temperatures over a longer period of time during the winter would be a safe way to gather more information about the variability of internal mine temperatures during the hibernation period. Incorporating portal temperature variation into future surveys and modeling efforts may improve on the current mine-site modeling effort.

Number of openings and portal temperature provided the best model for predicting Townsend's big-eared bat occupancy at abandoned mines in southwestern Colorado. This model predicts that the probability of finding Townsend's big-eared bat in an abandoned mine within our study area in southwestern Colorado is highest when the mine has ≥ 3 openings and the portal temperature is approximately $0^{\circ}C$ (Fig. 1). For example, estimated probability ($\hat{\psi}$) that a mine will be occupied by Townsend's big-eared bat if the portal temperature is $0^{\circ}C$ is higher for a mine with 3 openings ($\hat{\psi} = 0.60$) than for a mine with 1 opening ($\hat{\psi} = 0.27$). Similarly, the estimated probability of a mine being occupied if there are 2 openings is higher if the portal temperature is $0^{\circ}C$ ($\hat{\psi} = 0.43$) than if the portal temperature is $5^{\circ}C$ ($\hat{\psi} = 0.38$). Although the model that included number of openings and squared portal temperature had the most support (Fig. 1), mines with only one opening and high portal temperatures of $\geq 10^{\circ}C$ (see Figs. 2 and 3) were occasionally occupied by Townsend's big-eared bat. Therefore this model should be used with caution. Furthermore, we based occupancy estimates on single surveys conducted inside mines. Future studies of Townsend's big-eared bat occupancy inside mine sites might be improved by conducting multiple visits to mine sites by ≥ 2 biologists and incorporating detection probability estimates into occupancy estimation models (MacKenzie et al. 2006).

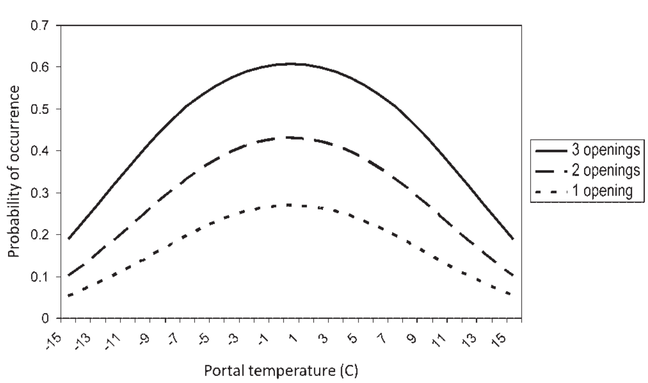

Figure 1. Estimated probability of Townsend's big-eared bat hibernating in abandoned mines in southwestern Colorado using the model "Openings + Portal Temperature^2." This model had the most support using the data set of 133 mine sites ($n = 38$ hibernacula and $n = 95$ non-hibernacula) surveyed in southwestern Colorado during January, February, and March, 1999–2007.

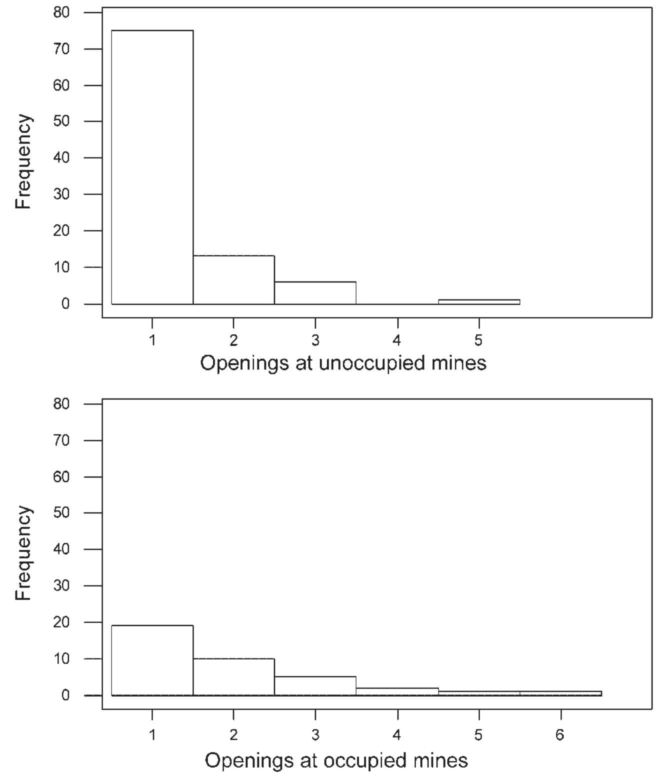

Figure 2. Number of openings at 95 abandoned mines not occupied (top) and 38 abandoned mines occupied (bottom) by hibernating Townsend's big-eared bats in southwestern Colorado during January, February, and March, 1999–2007.

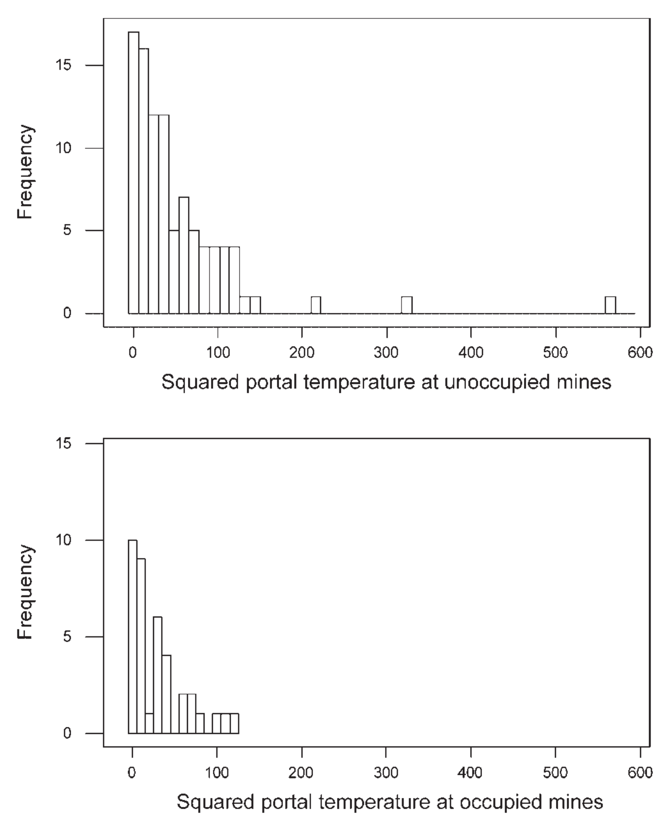

Figure 3. Squared portal temperature at 95 abandoned mines not occupied (top) and 38 abandoned mines occupied (bottom) by hibernating Townsend's big-eared bats in southwestern Colorado during January, February, and March, 1999–2007.

Although the elevation and climate model that incorporated LOW and MAT received the highest AIC_c weight, we are skeptical that this model provides insight into hibernacula selection by Townsend's big-eared bat. Sherwin et al. (2003) found that hibernating Townsend's big-eared bats in Nevada and Utah often moved among roost sites during winter. In southwestern Colorado, this species may be moving up and down elevation or climatic gradients to take advantage of preferred microclimates within abandoned mine sites, caves, or other roosts, in a manner that has little to do with elevation or local climate. Mean elevation of both occupied and unoccupied mines was approximately 1,900 m. However, 2 Townsend's big-eared bat hibernation sites were located at approximately 3,050 m, where MAT was lower and winters were longer than at most other hibernation locations. These sites serve as a caution not to dismiss high elevation sites as inadequate hibernacula for Townsend's big-eared bat. Szewczak et al. (1998) also found Townsend's big-eared bats hibernating at high elevation (3,200 m) in the White and Inyo Mountains in California. Because all elevation and climate unconditional parameter estimates overlapped zero, we conclude that these factors did not have a significant effect on hibernacula selection by Townsend's big-eared bat. Finer-scale data than what we collected could be incorporated into future research by using data loggers to collect ambient winter temperature data.

There are >23,000 abandoned mines in Colorado (Colorado Division of Minerals and Geology 2002). Of these abandoned mines, we estimate that roughly 6,000 occur in southwestern Colorado. Thus, our 133 mine surveys from 1999 to 2007 represent a small fraction (approx. 2%) of abandoned mines in southwestern Colorado. Conducting surveys inside abandoned mines is dangerous, resource intensive, and requires specialized training and equipment (Altenbach 1995, Navo 2001, Sherwin et al. 2009). Yet there is no more effective tool for documenting mine resource use by bats. Whenever possible, managers and biologists should incorporate winter and warm-season surveys, as well as proximity to suitable drinking water and foraging habitat, in mine closure decisions. Furthermore, estimation of population parameters, such as age and sex structured abundance, survival, and fecundity will be required to model population dynamics and estimate population growth rates of Townsend's big-eared bat in southwestern Colorado and other areas occupied by this species (O'Shea et al. 2003).

MANAGEMENT IMPLICATIONS

The ability to reliably predict where Townsend's big-eared bats hibernate using surface and near-surface mine features would reduce the hazards to which biologists are exposed and reduce the resources required to identify mines that should be prioritized for conservation. In southwestern Colorado, we found Townsend's big-eared bat hibernating in 29% of mines surveyed, but almost all bats were found hibernating independently. Thus, ongoing mine reclamation activities and renewed mining operations in the Four Corners region have the potential to impact or eliminate a substantial proportion of abandoned mines available for use as winter roosts by this species. In this study, abandoned mine sites with more than one opening and portal temperatures near 0°C were more likely to contain hibernating Townsend's big-eared bats. However, mines with only one opening and portal temperatures of ≥10°C were occasionally occupied by Townsend's big-eared bat. When feasible we believe that surveys should be conducted inside all abandoned mines in a reclamation project at least once during winter prior to making closure and reclamation recommendations.

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