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Roost Environments for Bats Using Abandoned Mines in Southwestern Montana: A Preliminary Assessment

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Prepared by:

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Executive Summary

Roost environments of ten abandoned mine workings known to be used by bats were studied in detail during 1998-1999 to expand on scant knowledge of underground roost requirements for bats in Montana. Objectives were to: 1) document daily mine ambient temperature and relative humidity during winter and summer using electronic dataloggers, especially at underground microsites where evidence of bat use was found, 2) document the seasons when mines were used for roosting, and identify the bat species using the mines, and 3) determine mine characteristics obtained from external surveys that might be useful for identifying underground environments suitable for bat roosts in abandoned mines. Special attention was paid to Townsend's Big-eared Bat (*Corynorhinus townsendii*), a Montana animal species of special concern, a Montana BLM Special Status species, and a species of high conservation concern throughout its range.

Four bat species were identified using these mines. Townsend's Big-eared Bat (*Corynorhinus townsendii*) was present at six mines, Western Small-footed Myotis (*Myotis ciliolabrum*) at five mines, Western Long-eared Myotis (*M. evotis*) at one mine, and Big Brown Bat (*Eptesicus fuscus*) at one mine.

Summer ambient mine temperature was generally too cold (usually < 10 °C) to be suitable for maternity roosts. However, suitable sites were present in some underground workings, and one *C. townsendii* maternity roost averaged 11.9 °C during June and July. Maximum mean daily temperature recorded in any mine was 14.6 °C.

Ambient mine temperature decreased significantly as elevation increased, and summer and winter mine temperatures were highly correlated and relatively predictable using time-series data. However, complex mines at higher elevations may contain internal microsites, not detectable from external surveys, with temperature and relative humidity regimes suitable at all seasons for roosting bats.

Relative humidity fluctuated dramatically in many mines, and tended to be lowest and least stable in winter, when means in some mines were < 50%. At two known Townsend's Big-eared Bat hibernation roosts, winter mean relative humidity was 74.0% and 83.4%, while respective ambient mine temperatures averaged 7.5 °C and 4.4 °C.

Mine suitability for roosting bats was not apparent from external variables, such as portal size, number of portals, detectable airflow, or even elevation. The most useful information obtained during external visual inspections was the presence or absence of obstructions at portals and the extent of underground workings, if visible from the portal.

All mines should first be evaluated for use by bats before reclamation takes place. Useful information about the potential for roost use can be gathered from external inspections and monitoring (visual, auditory, trapping) at mine portals. However, where possible and safe, the best method for assessing mine structure and use by bats is underground survey. Identifying mines suitable for hibernating bats requires underground inspection. Trapping at mine portals for pregnant and lactating females may be effective in identifying mines used as maternity roosts, but even here internal inventory is the best survey method. Mines that are used for night and day roosts can be effectively monitored on multiple visits without mine entry, preferably during different seasons, but even a single underground visit can reveal if there is any evidence of more extensive use by bats.

Acknowledgements

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We were aided in the field by Sam Martinez, Tom O'Shea, Michelle Brown, and Janelle Corn. Tom O'Shea (USGS-BRD) kindly provided on loan some of the data loggers used during this study. We also thank Lee Flath (Lewis and Clark Caverns State Park) for granting access to the Gypsum adits, and Marian and Max Johnson (Ravalli) for permission to visit the McDonald Mine adits. Cedron Jones (MTNHP) produced the map.

The report was reviewed and edited by John Carlson (MTNHP) and Joy Lewis (MTNHP), and produced with the help of Katrina Scheuerman (NRIS).

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INTRODUCTION

Because bats spend much of their lives in roosts (Kunz 1982), knowledge of their roosting requirements provides important life-history information for understanding habitat use and seasonal presence of most species. Furthermore, suitable summer and winter roosts may limit local and regional distribution and relative abundance of many temperate-zone bats (Humphrey 1975, Dobkin et al. 1995), especially cave-dwelling taxa. Thus conservation and protection of roosts are critical long-term management activities for the perpetuation of many North American bat species (Sheffield et al. 1992).

Bat populations in many natural caves have declined or disappeared because of a variety of human-induced disturbances (LaVal and LaVal 1980, Richter et al. 1993, Tuttle and Taylor 1994). Abandoned and undisturbed mines now serve as principle summer and winter roosts for many cave-dwelling species (Tuttle and Taylor 1994) because mines offer a variety of subterranean microclimates similar to those present in natural caves (Tuttle and Stevenson 1978). Concern about the status of North American bat populations increased dramatically in recent decades (Pierson 1998) when it was recognized that significant numbers of abandoned mines were being barricaded, backfilled, and blasted shut for safety and liability reasons, without prior biological survey to determine their significance for roosting bats.

We conducted a survey of abandoned mines on BLM lands in southwestern Montana during the summers of 1997 and 1998 (Hendricks et al. 1999) to assess and characterize their use by bats prior to potential reclamation activity. We anticipated that our work would help managers identify sites currently used by bats, and that the information characterizing used abandoned mines might guide future mine survey and reclamation activity. We gathered long-term climate data from used abandoned mines because roost climate is a major influence on roost site use. Roost environment descriptions (especially temperature and relative humidity at roost microsites) are very limited for bats in Montana, and most available data pertain to roosts in caves (Worthington 1991, Madson and Hanson 1992, Hendricks 2000, Hendricks et al. 2000).

For each mine inspected internally in 1998 and considered safe for reentry we placed electronic data loggers to record daily mine temperature and relative humidity over a 6-12 month period. Our objectives for this phase of the study were to: 1) document daily mine ambient temperature and relative humidity during winter and summer, especially at underground microsites where we found evidence of bat use, 2) determine the seasons when mines were used for roosting, and identify the bat species using the mines, and 3) determine mine characteristics documented from external surveys that might be useful for identifying underground environments that are suitable for bat roosts in abandoned mines. Of special interest were mines used by Townsend's Big-eared Bat (*Corynorhinus townsendii*) because this bat is a Montana animal species of special concern, a Montana BLM Special Status species, and a species of high conservation concern throughout its range (Pierson et al. 1991, Pierson et al. 1999, Sherwin et al. 2000).

METHODS

We concentrated our study on ten mines between 45°10' N and 47°16' N latitudes in southwestern Montana (Figure 1), six mines in Beaverhead, Madison, and Silver Bow counties, supplemented with four mines in Jefferson and Lake counties known or suspected to be used by Townsend's Big-eared Bat. Elevation of mines ranged from 853 m to 2249 m (Table 1). Mines used by bats were identified first from historical records or by external inspection during summer, and through use of electronic bat detectors (ANABAT II, Titley Electronics, Ballina, Australia) and mist-net or harp trap sampling at portals.

We surveyed each mine internally at least twice to the fullest extent possible where deemed safe. No vertical workings (shafts) were entered during this study. At least two people entered each mine during surveys. We recorded presence, number, location, and identity of bat species when possible. During surveys, we recorded the following "structural" habitat variables: vegetation cover at the mine, portal elevation, number and size of portals, length of underground workings, presence of standing water, cross-section dimensions of main tunnels, and number of levels. We ranked mine complexity as simple (main passage with non-branching side tunnels), moderate (main passage with branching side tunnels or < 3 levels), or complex (main passage with multiple branching side tunnels or > 2 levels).

We gathered time-series temperature and relative humidity data by installing at least one data logger (HOBO H8, Onset Computer Corporation, Pocasset, Massachusetts) in each mine, usually near microsites where bats or bat sign were observed. In two shallow mines data loggers were placed where we considered the mine environment likely to be the most stable. Fifteen data loggers were placed in the mines; only two mines contained more than one data logger. Data loggers were attached to an extendable aluminum rod and positioned < 30 cm below the tunnel ceiling. Data loggers were set to record temperature and relative humidity every six hours. We calculated daily means from these data and used daily mean values in the analyses we present in this report.

Because of the small sample of mines studied our analyses are largely inferential. Where statistical analyses were performed we followed standard procedures (Sokal and Rohlf 1981) using Statistix version 2.0 (Analytical Software, Tallahassee, Florida).

RESULTS

Mine habitat features. Use by bats of abandoned mines in our sample did not appear related in any obvious way to vegetation cover, mine size or complexity (Table 1), size or number of portals, or availability of standing water. All mines were in sagebrush or sagebrush intermixed with scattered conifers, and all mines had either one or two functional portals with dimensions that ranged from 1.2-2.1 m high by 1.2-2.0 m wide. Five of the mines contained standing water. Six mines (McDonald Adits #1 and #2, Gypsum Adits #1 and #2, Union, Hendricks) had some form of gate at their portals.

Mine temperature and relative humidity. We placed data loggers in six mines in September and retrieved them the following August (Table 1). At four mines we placed data loggers in December or January and retrieved them the following July. Data loggers failed to record for the duration of installation at two mines; in the Gypsum Adit #1 the logger failed to record any data, and in the Unnamed Adit #3 the logger became wet and ceased operation by March, 174 days after installation. Continuous temperature and relative humidity profiles are shown in Appendix 1 for all loggers that recorded any data.

Maximum daily temperature recorded among the mines (Table 1) was 14.6 °C in late July at the Unnamed Adit #2. However, portions of some mines never achieved temperatures > 6 °C, even in summer (Appendix 1). The lowest mine temperature, –15.9 °C, was recorded in late December; in general mine temperatures dropped below freezing only in mines or portions of mines where there was significant movement of air. In several mines, relative humidity reached lowest values near or below 30% during December or January while maximum values (85-100%) were recorded in July or September (Appendix 1).

Table 2 shows mean temperature and relative humidity data from each mine for the same winter and summer time periods, thereby making comparisons among mines the most meaningful. Mean temperatures for January through April varied from –1.4 °C to 11.8 °C, depending on the mine and location within the mine. Interestingly, the extremes were found in the same mine, the

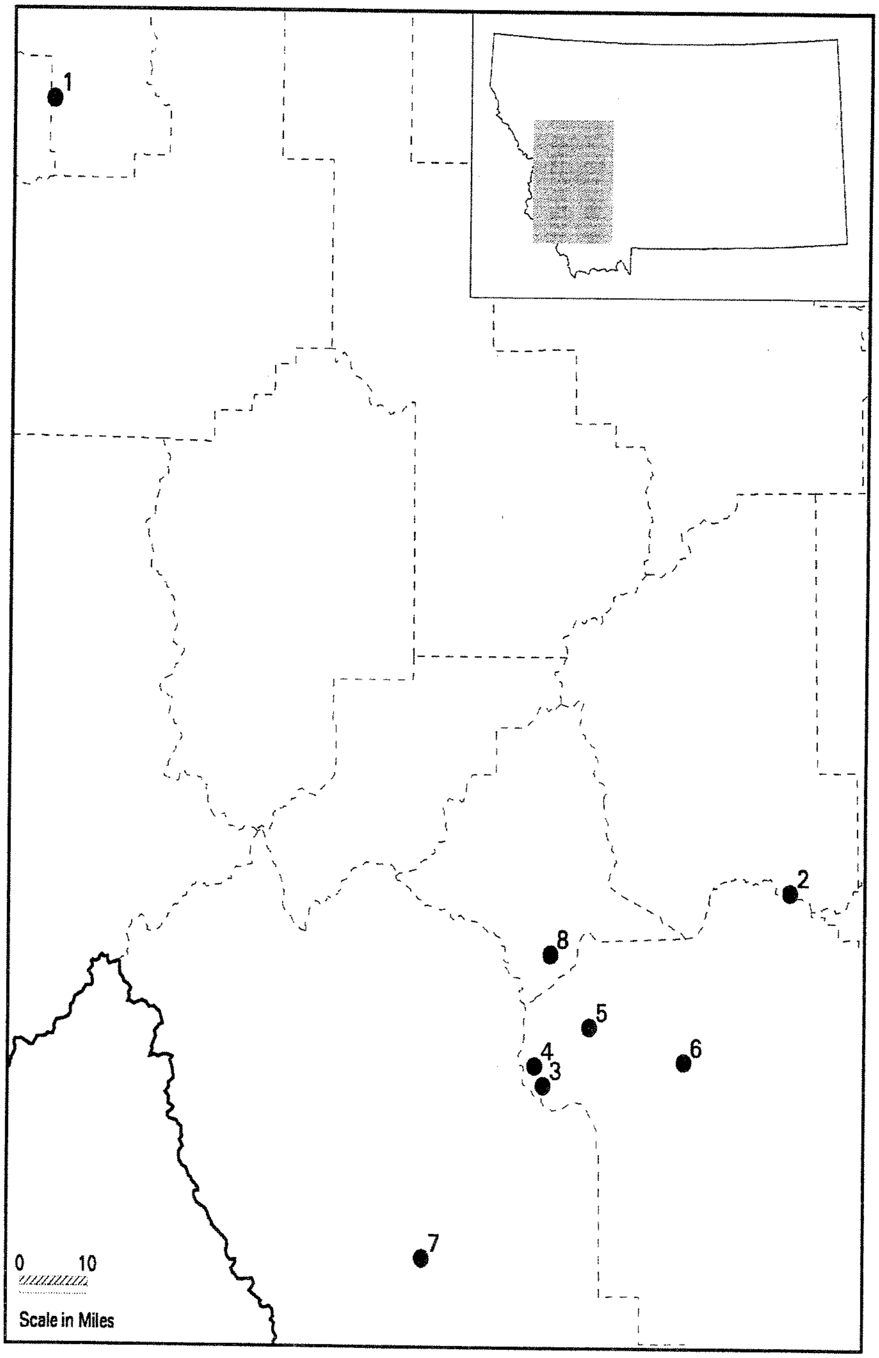


Figure 1. Location of abandoned mines in southwestern Montana where mine climates were studied during 1998-1999.

Table 1. Summary of physical and climatological characteristics of abandoned mines used by bats in southwestern Montana during 1998-1999. Dates are the periods when daily mine temperature (T, in degrees Celsius) and relative humidity (RH) were continuously recorded. Numbers preceding mine names correspond to locations shown in Figure 1.

Mine	Elev m	Mine complexity	Mine size m	Logger[a] m	T min	T max	RH min	RH max	Dates (n days)
1. McDonald Adit #1 (shallow)	853	moderate	>200	40	-0.1	11.0	32.1	100	7 Dec-12 Jul (218)
" (deep)	"	"	"	107	7.8	11.7	90.1	100	"
1. McDonald Adit #2	853	simple	50	13	9.0	13.5	78.0	96.9	"
2. Gypsum Adit #2	1390	simple	44	8	0.8	7.0	72.1	98.7	7 Jan-12 Jul (188)
2. Gypsum Adit #1	1432	simple	22	16	---	---	---	---	---
3. Unnamed Adit #2	1719	simple	83	24	-8.0	14.6	34.3	86.8	10 Sep-25 Aug (350)
4. Unnamed Adit #3	1768	simple	81	60	7.1	9.4	67.2	100	10 Sep-28 Feb (174)
5. Unnamed Adit #1	1786	simple	57	46	5.0	11.0	39.9	98.1	10 Sep-25 Aug (349)
6. Union	1817	complex	>150	108	-4.8	13.1	30.0	94.9	"
7. Hendricks First Drift	1859	complex	>700	103	-9.1	5.0	34.3	98.0	"
" Graeter Tunnel	"	"	"	76	-15.9	5.1	30.8	97.5	"
" Main Drift	"	"	"	143	8.6	9.8	72.5	88.7	"
" Solution Cavity	"	"	"	201	11.8	12.2	26.4	75.8	"
" West Drift	"	"	"	164	10.2	11.0	26.5	78.5	"
8. Ruth & Copper Bottom	2249	simple	56	41	3.0	5.4	92.0	100	10 Sep-25 Aug (350)

[a] Distance from the data logger to the portal.

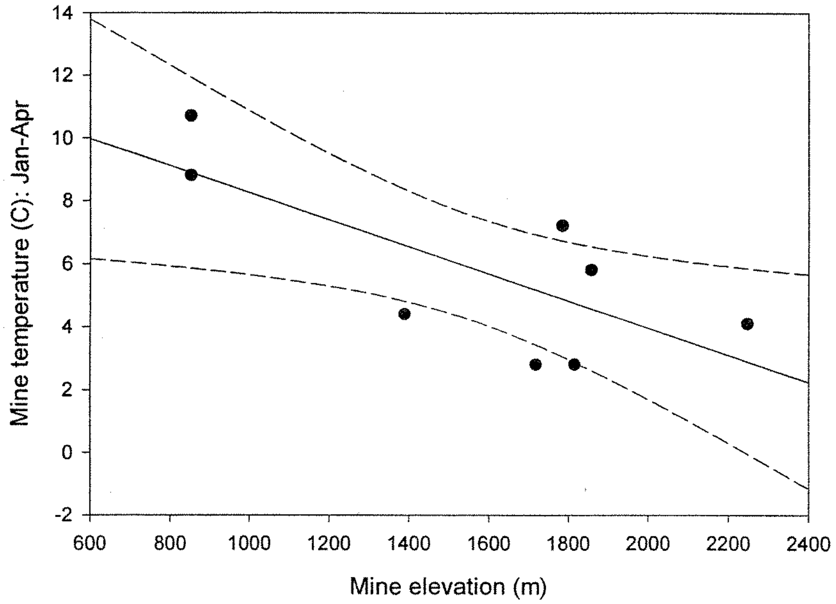
Hendricks. The June to mid-July extremes in mean temperature (3.6 °C and 12.2 °C) also occurred in the Hendricks Mine. Extreme values occurred in this mine because of significant air movement through parts of the workings, while other parts experienced very little air movement. For all data logger locations, summer mean temperatures were 2.5 ± 2.1 °C warmer than in winter. The same pattern was evident for relative humidity; summer means were 12.1 ± 9.2% greater than in winter. However, in the Main Drift of the Hendricks Mine summer relative humidity was actually a few percent lower than in winter (Table 2), the only data logger location where this occurred.

Mean mine temperature tended to decrease with increased elevation in both winter and summer (Figure 2), but relative humidity did not show a significant elevation trend for either period (winter: $r = -0.364$, $P = 0.376$; summer: $r = -0.308$, $P = 0.458$). For both temperature and relative humidity, summer means were highly and positively correlated with winter means (Figure 3). However, variation (measured as the standard deviation) in temperature and relative humidity for the winter and summer periods at each data logger location was only weakly correlated ($r = 0.387$, $P = 0.191$ and $r = 0.165$, $P = 0.591$).

We noted significant airflow in three mines, the Union, Hendricks, and Unnamed Adit # 2, and slight airflow in the shallow location of the McDonald Adit #1. In the Union and Hendricks mines, we never saw bats or concentrations of droppings where airflow was greatest (the first level of the Union, Graeter Tunnel and First Drift in the Hendricks), although scattered droppings were present in these portions of the mines (Table 2). Mean temperature difference between winter and summer was larger at locations where there was significant air movement (4.88 ± 1.26 °C versus 1.03 ± 0.70 °C: $t = 7.19$, df = 11, $P < 0.001$). Air movement did not have a similar effect on the mean difference in winter and summer relative humidity ($t = 0.79$, $P = 0.444$).

Table 2. Daily mine temperature (°C) and relative humidity (%) for winter (10 Jan-30 Apr) and summer (1 Jun-13 Jul). Values are means ± 1 standard deviation. Asterisk indicates location is a known bat hibernation site (winter) or a maternity/day roost site (summer).

Mine	Winter (n = 111 days)		Summer (n = 43 days)	
	Temp	RH	Temp	RH
McDonald Adit #1 (shallow)	7.5 ± 0.9*	74.0 ± 9.4	10.5 ± 0.4*	97.4 ± 2.7
" (deep)	10.0 ± 0.4	98.2 ± 1.4	11.3 ± 0.2*	100.0 ± 0.4
McDonald Adit #2	10.7 ± 0.2	89.0 ± 2.0	11.9 ± 0.5*	91.7 ± 4.7
Gypsum Adit #2	4.4 ± 0.9*	83.4 ± 4.2	6.7 ± 0.2	97.8 ± 0.6
Gypsum Adit #1	---	---	---	---
Unnamed Adit #2	2.8 ± 1.7	56.1 ± 6.9	9.2 ± 1.5	63.0 ± 13.0
Unnamed Adit #3	---	---	---	---
Unnamed Adit #1	7.2 ± 0.4	49.9 ± 3.4	8.7 ± 0.5	69.2 ± 12.6
Union	2.8 ± 1.1	59.2 ± 7.6	7.9 ± 1.5	74.4 ± 14.7
Hendricks First Drift	-0.9 ± 1.4	71.7 ± 9.6	3.6 ± 0.3	84.5 ± 2.1
" Graeter Tunnel	-1.4 ± 2.7	69.8 ± 9.9	3.9 ± 0.3	86.2 ± 1.7
" Main Drift	9.1 ± 0.2*	77.5 ± 2.0	9.7 ± 0.2	74.7 ± 0.4
" Solution Cavity	11.8 ± 0.1	42.6 ± 6.2	12.2 ± 0.0*	65.2 ± 2.0
" West Drift	10.6 ± 0.0	44.0 ± 6.8	10.7 ± 0.1*	67.3 ± 1.9
Ruth & Copper Bottom	4.1 ± 0.4	98.7 ± 2.0	4.9 ± 0.2	100.0 ± 0.0



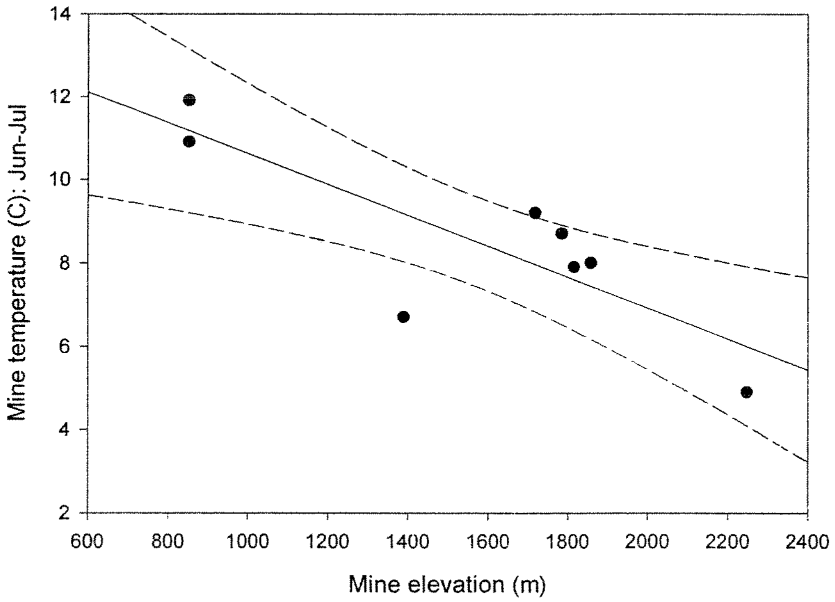
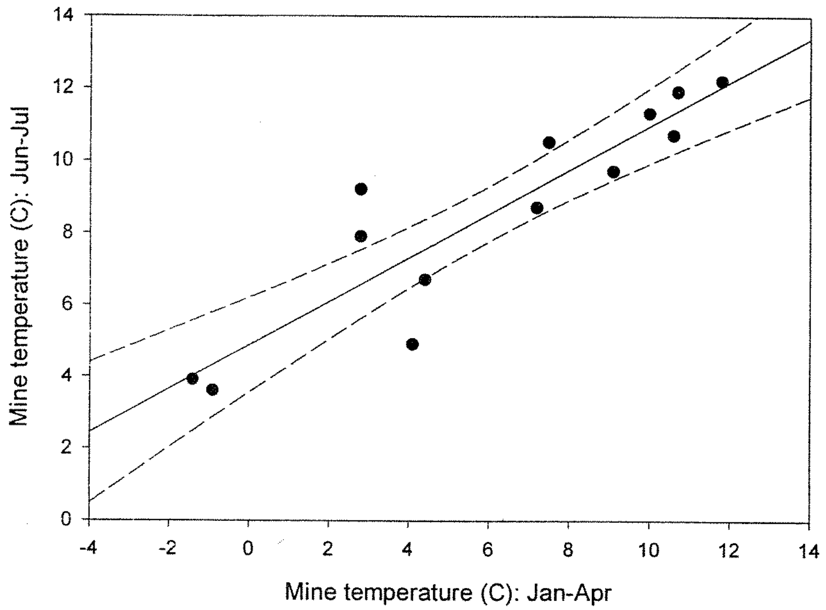


Figure 2. Mean mine temperature decreases with increased elevation in winter (Jan-Apr: *r* = -0.744, P = 0.034) and summer (Jun-Jul: *r* = -0.828, P = 0.011) in southwestern Montana. Points are mean values for individual mines, using data from Table 2. Dashed line is the 95% confidence interval.



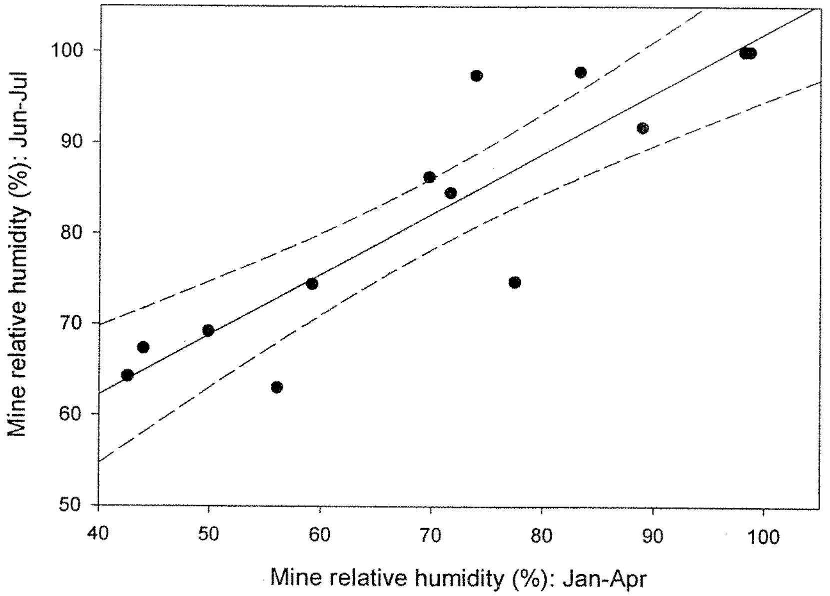


Figure 3. Winter (Jan-Apr) and summer (Jun-Jul) mine ambient temperature (top: $Y = 0.608X + 4.874$, $R^2 = 0.823$) and relative humidity (bottom: $Y = 0.657X + 36.201$, $R^2 = 0.792$) are highly correlated ($P < 0.001$) in southwestern Montana. Points represent individual datalogger locations, using the data from Table 2. Dashed line is the 95% confidence interval.

Bat use of mines. We observed four species of bats at the ten mines (Table 3). *Corynorhinus townsendii* was present at six mines, *Myotis ciliolabrum* at five mines, and *M. evotis* and *Eptesicus fuscus* at one mine each. In all cases, we observed only small numbers of individuals.

Three of the mines (McDonald Adit #1, Gypsum Adits #1 and #2) were hibernacula for *C. townsendii*, with number of hibernating individuals ranging from 1-8. All *C. townsendii* in the McDonald Adit #1 were roosting singly on the walls < 1.0 m above the floor within 40 m of the portal. In the Gypsum Adit #1 a single *C. townsendii* was on the wall <1.0 m above the floor and 13.8 m from the portal. In the Gypsum Adit #2 we found torpid bats (1 unidentified *Myotis* and 7 *C. townsendii*) between 6.0-25.5 m from the portal; all bats were <1.0 m above the floor and roosting singly. In the only other mine entered during winter (Hendricks) we found single *M. ciliolabrum* and *E. fuscus*, both about 1.5 m above the floor 143 m from the portal. A maternity roost of 25 *C. townsendii* in the McDonald Adit #2 was the largest number of bats we found in a single mine; these were in a tight cluster on the wall near the ceiling about 1.5 m above the floor and 14 m from the portal. We found no other maternity roosts.

The remaining bats we observed or captured (Table 3) appeared to be using the mines as day or night roosts. The single *M. ciliolabrum* we found in June in the Hendricks Mine was a female fully exposed on the wall near the ceiling about 1.5 m above the ground. Three of five *M. ciliolabrum* we captured at the portal of the Unnamed Adit #1 on 11 June were non-lactating females (teats visible, however). The two *M. evotis* we captured in August at the Unnamed Adit #2 were lactating females, the only reproductive female bats we captured. All the other individuals that we handled were males.

We were unable to fully survey the three largest mines, McDonald Adit #1, Hendricks Mine, Union Mine, although we investigated 60-70% of the workings in each. Therefore, it is possible, even probable, that we missed seeing some bats during summer in the McDonald Adit #1, and in

Table 3. Bats observed during 1998-1999 at abandoned mines in southwestern Montana. An asterisk following a mine name indicates bats were captured at the mine portal.

Mine	Bat species[a]
McDonald Adit #1 (shallow)	8 *Corynorhinus townsendii* (7 Dec), 1 *Myotis* species (13 Jul)
" (deep)	1 *C. townsendii* (13 Jul)
McDonald Adit #2	25 *C. townsendii* (13 Jul)
Gypsum Adit #2	7 *C. townsendii* (6 Jan), 1 *Myotis* species (6 Jan)
Gypsum Adit #1	1 *C. townsendii* (6 Jan)
Unnamed Adit #2*	5 *M. ciliolabrum* (6 Aug, 17 Aug), 1 *M. evotis* (6 Aug, 17 Aug)
Unnamed Adit #3*	2 *M. ciliolabrum* (7 Aug)
Unnamed Adit #1*	1 *C. townsendii* (11 Jun), 8 *M. ciliolabrum* (11 Jun)
Union*	1 *C. townsendii* (11 Jul), 2 *M. ciliolabrum* (11 Jul)
Hendricks First Drift	None (scattered droppings)
" Graeter Tunnel	None (scattered droppings)
" Main Drift	1 *M. ciliolabrum* (4 Dec), 1 *Eptesicus fuscus* (4 Dec)
" Solution Cavity	None (concentrated droppings)
" West Drift	1 *M. ciliolabrum* (13 Jun)
Ruth & Copper Bottom	None (few droppings)

[a] Townsend's Big-eared Bat *Corynorhinus townsendii*, Western Small-footed Myotis *Myotis ciliolabrum*, Western Long-eared Myotis *Myotis evotis*, Big Brown Bat *Eptesicus fuscus*.

the Hendricks Mine during summer and especially in winter. Low netting success at the portal of the Union Mine, coupled with our internal survey, suggests to us that this mine is unlikely to support relatively large numbers of bats even in areas we did not reach.

Bats were present during winter at locations with mean winter temperatures of 4.4-9.1 °C and mean relative humidity between 74-84% (Table 2). Mine sites where we observed bats during the day in summer (either maternity or day roosts) were the warmest (10.5-12.2 °C) among the data logger locations ($t = 4.89$, $P < 0.001$; adjusted for unequal variances). However, occupied sites in summer were not necessarily the most humid. Microclimate conditions at *C. townsendii* roosts (Tables 2 and 3, Appendix 1) were cold during winter (averages of 4.4 and 7.5 °C), but relatively warm during summer (11.3 and 11.9 °C). Relative humidity at *C. townsendii* roosts averaged 74.0 and 83.4% in winter, 91.7 and 100% in summer.

DISCUSSION AND RECOMMENDATIONS

Roost environments: Abandoned mines provide suitable environments for a variety of roosting purposes for bats (Pierson et al. 1991, Tuttle and Taylor 1994, Betts 1997, Sherwin et al. 2000). Abandoned mines in northwestern North America are often used as hibernacula and day or night roosts rather than maternity roosts because mine temperatures are too cold and energy-expensive for normal rates of development of young bats (Dwyer 1971). The results of our study in southwestern Montana of mine features and microclimates favored by bats, particularly *C. townsendii*, conform to general patterns for western North America. Our study was hampered by lack of visits to each mine during the four seasons to determine with certainty the seasonal use of each by bats. Nevertheless, we documented the long-term climate of several abandoned mines over an elevation gradient, and several preliminary conclusions regarding roost use by bats in this portion of Montana are possible.

We found only one mine (McDonald Adit #2) used as a maternity roost, by *C. townsendii*, and it was at the lowest elevation of the mines studied (Table 1). Mean June-July temperature near this colony was about 12 °C (Table 2), which is much colder than at maternity sites in California (Pierson et al. 1991). It is possible the McDonald Adit #2 maternity roost moved after our July visit to warmer temperatures nearer the mine portal. Similar behavior has been documented for California maternity aggregations after young are born in late July and early August (Pierson et al. 1991). We did not get close enough to the McDonald colony to determine if young bats were present when we retrieved our data logger on 13 July. There are few temperature and relative humidity data for other *C. townsendii* maternity roosts in Montana. Temperature was 18 °C beneath a maternity roost of about 75 *C. townsendii* in a ceiling dome of Toeckes Cave (1524 m elevation) on 23 August 1999 (S. Martinez personal communication). Temperature was likely at least a few degrees warmer closer to the roost.

Summer bat use of mines declined with increased elevation in southwestern Montana (Hendricks et al. 1999). The most plausible explanation for this pattern is that mean mine temperature declined significantly as elevation increased (Figure 2), making higher elevation mines less attractive to bats for roosting. This is especially true for female bats (Cryan et al. 2000) because of increased energy demands related to reproduction. Bats found at high elevations in western North America tend to be males or non-reproductive females (Storz and Williams 1996, Cryan et al. 2000). Currently, little is known about the upper elevation limit for caves and mines used by bats in Montana. Little Ice Cave (2493 m elevation) is the highest known hibernation roost in the state (Madson and Hanson 1992). There is also considerable activity by several species of *Myotis* at the mouth of this cave in summer, although cave temperature throughout is 3.3 °C (Worthington 1991) making it too cold for use as a maternity roost.

As our data across a range of elevations show (Table 2, Appendix 1), mines in western Montana generally provide relatively cold roost environments for bats regardless of season. Greatest use of abandoned mines by bats in western Montana is for day/night roosts and hibernacula. Many abandoned mines in southwestern Montana present bats with a variety of summer microclimates (Table 2) and are used briefly as night roosts (Hendricks et al. 1999), where meals are digested in relative safety. However, hibernacula are the best-documented roost climates in Montana, although data are usually point (single date) samples, and bat species found hibernating often are unidentified to species. Fortunately, the exception is *C. townsendii*, because it is relatively easy to identify, even when torpid and undisturbed.

In Montana, *C. townsendii* use caves and mines across a broad range of elevations for hibernation roosts (Table 4). Torpid *C. townsendii* have been found from November through April in sites where the respective ranges of temperature and relative humidity are –1.0-8.0 °C and 50-100% (see also Table 2). Number of hibernating individuals at each of these sites (Table 4) was < 20, although larger winter numbers have been reported in appropriate winter roosts in the lower-elevation plains of eastern Montana (Swenson 1970), where few surveys have been conducted. The data presented in Table 4 suggest that roosts below 2000 m elevation may routinely support larger winter aggregations of *C. townsendii*. This pattern could arise because arid landscapes often favored by this species (Sherwin et al. 2000) are found at lower elevations in the region, or because maternity roosts are often < 20 km from hibernacula (Humphrey and Kunz 1976, Kunz and Martin 1982, Dobkin et al. 1995) and are probably more abundant at lower elevations. Microclimates for Montana hibernacula of *C. townsendii* are similar to those reported in the literature from a number of western and midwestern states (Pearson et al. 1952, Twente 1955, Twente 1960, Humphrey and Kunz 1976, Genter 1986, Pierson et al. 1991, Webb et al. 1996, Choate and Anderson 1997, Kuenzi et al. 1999), with winter

Table 4. Summary of point-sample (single date) microclimate data for Townsend's Big-eared Bat (*Corynorhinus townsendii*) hibernacula in Montana. Temperature (T) and relative humidity (RH) data were recorded near hibernating bats using a sling psychrometer.

Locality	Elev (m)	Date	No. bats	T (°C)	RH (%)	Source[a]
McDonald Adit #1	853	7 Dec	8	8.0	57-64	1
Azure Cave	1361	12 Nov	6	6.0-7.0	90-100	2
Gypsum Adit #2	1390	6 Jan	7	3.5-4.5	80	1
Gypsum Adit #1	1432	6 Jan	1	6.0	54	1
Tate-Poetter Cave	1487	19 Apr	4	2.0-3.0	76-86	3
Toeckes Cave	1524	12 Feb	9	-1.0-3.0	50-85	4
Four-eared Bat Cave	1536	26 Feb	15	6.5-7.0	61-73	5
Frogg's Fault Cave	1835	28 Feb	10	6.5-7.0	90	5
Dandy Mine	1856	4 Mar	4	5.0	100	5
Lisbon Mine	2012	4 Mar	1	6.5	100	5
Big Ice Cave	2295	18 Mar	2	-0.5	100	5
Mystery Cave	2384	20 Mar	3	3.5	85	5

[a] 1) this study, 1998-1999; 2) Hendricks et al. 2000; 3) Hendricks 2000; 4) unpublished data, 2000; 5) Madson and Hanson 1992.

roost temperature typically ranging between –1.5-10.0 °C. However, in some California locations roost temperature near torpid individuals may reach 21.0-25.0 °C (Pierson et al. 1991, Webb et al. 1996), much warmer than for any Montana hibernaculum.

***Management Implications*:** There are two major approaches for assessing abandoned mines for bats: external and internal surveys (Altenbach 1995, Navo 1995). During external surveys data are gathered on the number and dimension of all entrances (portals), airflow, outside air temperature, presence of standing water, and visual sign of bats (carcasses, roosting bats, droppings); one portal survey in spring, one in summer, and two in fall are recommended (Navo 1995). Use of electronic bat detectors can aid in portal surveys. Internal surveys allow direct measurement of mine temperature and relative humidity, and also an assessment of the extent of underground workings and their configuration as well as evidence of bats at specific locations within the mine. Cold season internal surveys can determine both summer and winter use, whereas warm season surveys can determine only summer use.

Our analysis identified few mine characteristics measurable from external surveys that are good predictors of mine suitability for bats, with the exception of obstructions across portals that inhibit or preclude bat access (Hendricks et al. 1999). Mine temperature is an important feature for roost selection by bats (Dwyer 1971, Humphrey 1975), and relative humidity may also be important (Betts 1997). We found a significant negative relationship between elevation and summer or winter mine temperature (Figure 2), but not between elevation and relative humidity; mines at higher elevation were colder year round, but not necessarily less humid. Mean mine temperature during both summer and winter was highly correlated (Figure 3), indicating that temperature taken during one season is a good predictor of temperature during the other season in the same mine; this pattern was also found for relative humidity. Nevertheless, obtaining these measurements required going underground. Furthermore, we found considerable short-term variation in temperature and/or relative humidity in most of the mines we monitored (Appendix 1), making questionable the characterization of their year-round climate from data obtained during a single visit (Sherwin et al. 2000). If surveys are restricted to one or two visits because of monetary or logistical limitations, the potential for significant short-term variation should be kept in mind when characterizing the mine climates.

We also found that mines with climates largely unsuitable for use by bats may contain areas within them that can be and are used (Table 2, Appendix 1). It is not possible to identify these internal microsites from external surveys, with the possible exception of the shallowest mines with workings completely visible from the portal. Identification of hibernacula, the most likely mine roosts to be used over several continuous months in Montana, is impossible from external survey alone. Furthermore, internal survey is the quickest and least labor/time intensive method for determining mine suitability for bats in all seasons (Pierson et al 1999). We therefor suggest that, where safe, internal survey is the preferred method for assessing mine use and suitability for bats. Where mine entry is impossible or unsafe, external survey at the portal must suffice. In these cases it is critical that surveys are conducted at the appropriate time. Possible hibernation activity is detected best in fall (September and October) when bats swarm at their hibernation roosts. Maternity use of mines is detected best in summer (July and August) when females are pregnant or lactating.

We recommend that all abandoned mines scheduled for reclamation on public lands receive proper evaluation as bat habitat prior to closure, whether by external or internal survey. Protocols for mine evaluation are presented in the conservation assessment and strategy for the Townsend's Big-eared Bat, *C. townsendii* (Pierson et al. 1999), as well as Altenbach (1995) and Navo (1995), and are appropriate for all mine-dwelling bat species in Montana.

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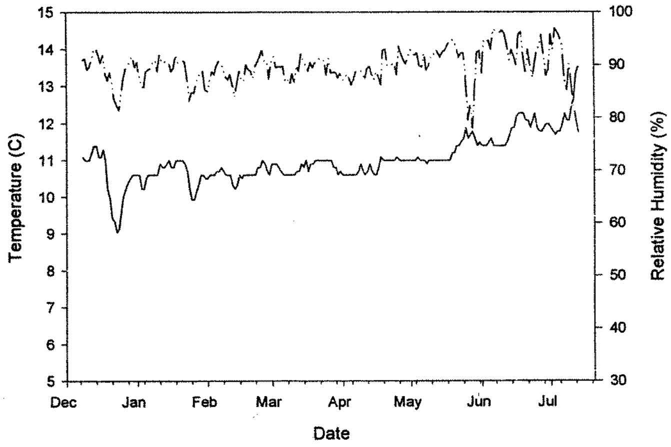
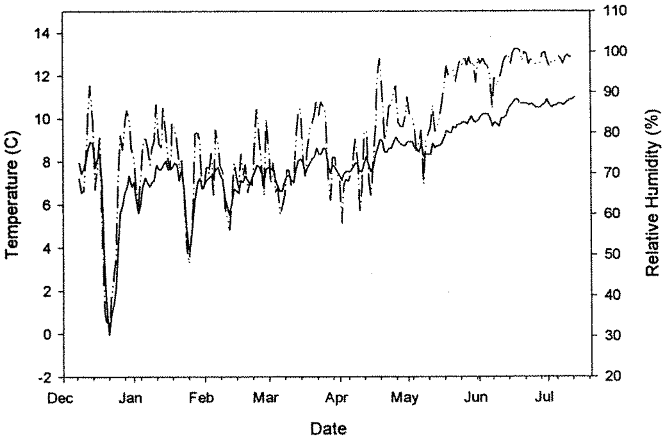
Appendix 1. Continuous temperature (solid line) and relative humidity (broken line) profiles for 1998-1999 from nine mines in southwestern Montana (see Table 1 for additional details). Note that scales vary from figure to figure and that time periods of continuous recordings also vary. Townsend's Big-eared Bat (*Corynorhinus townsendii*) was documented underground at the first four locations (McDonald Adit #2, McDonald Adit #1 both sites, Gypsum Adit #2) and captured in summer at the portals of the next two locations (Unnamed Adit #1, Union Mine). McDonald Adit #2 was a maternity site.

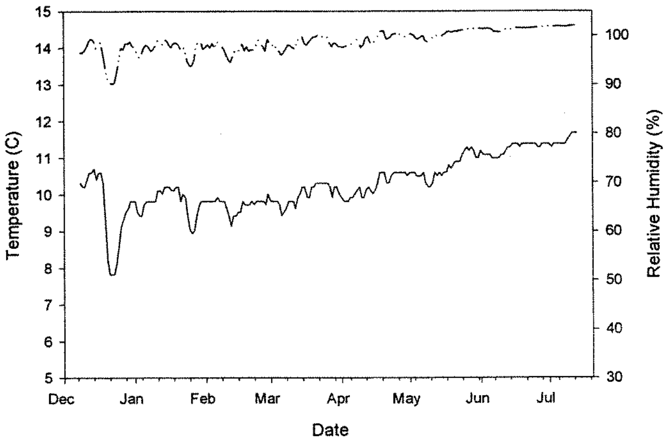
McDonald Adit #2



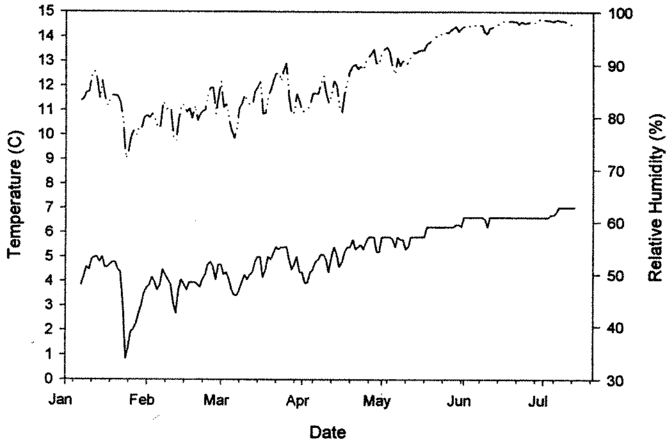
McDonald Adit #1 (Shallow)



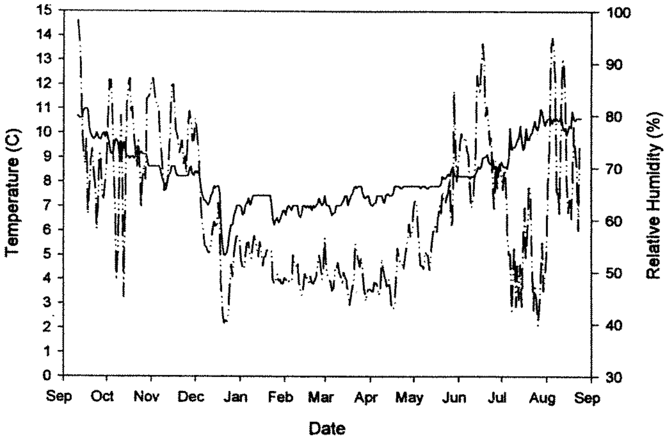
McDonald Adit #1 (Deep)



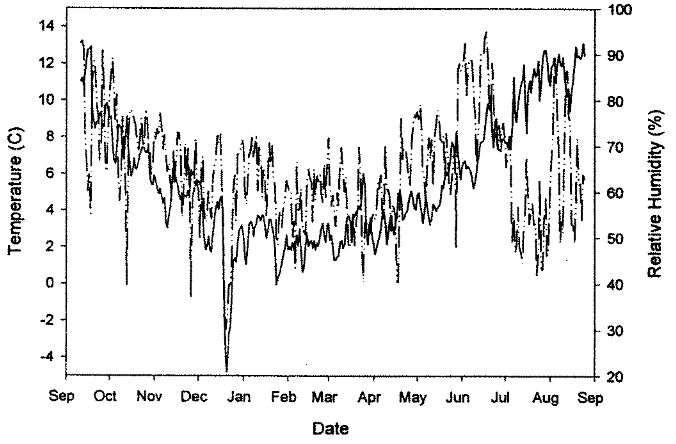
Gypsum Adit #2

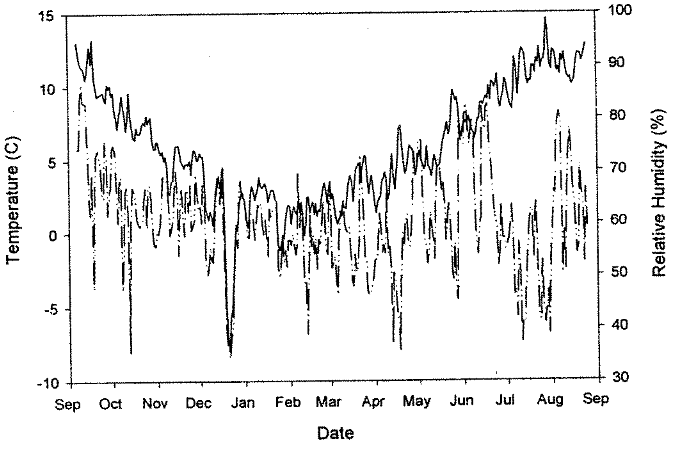


Unnamed Adit #1



Union





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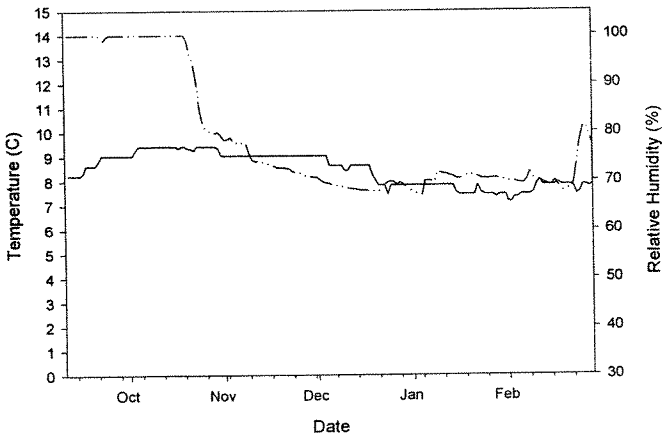
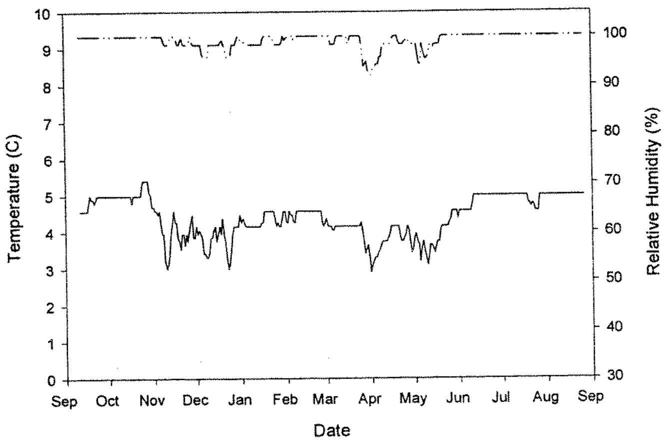
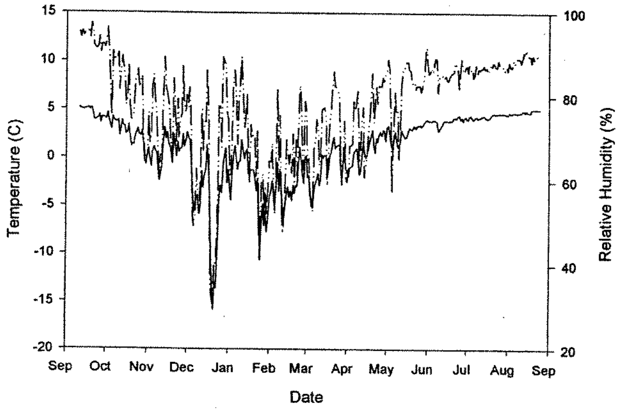
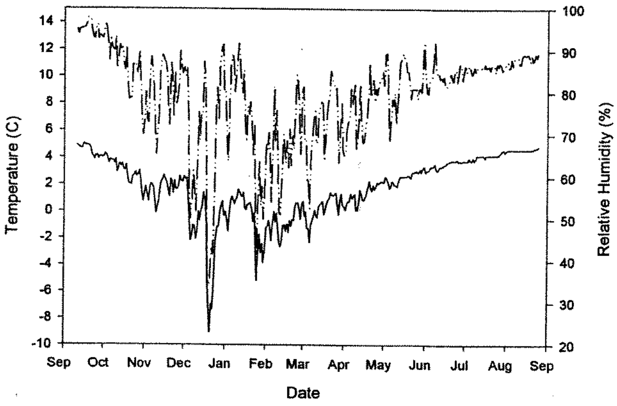


Unnamed Adit #3



Ruth & Copper Bottom


Hendricks Graeter Tunnel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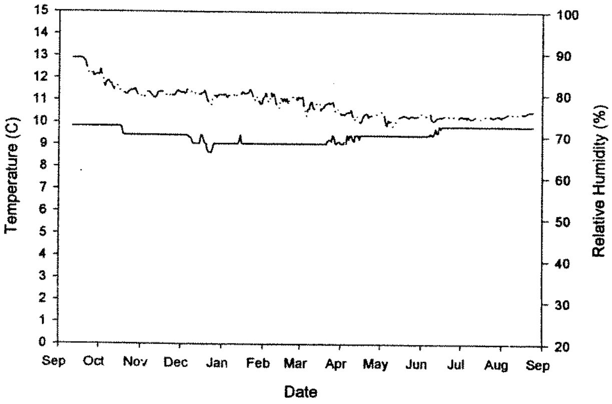
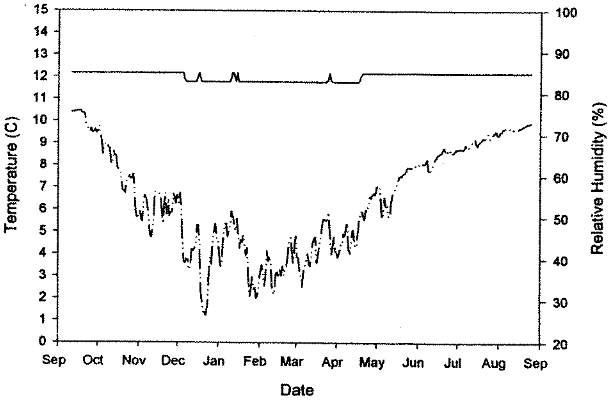
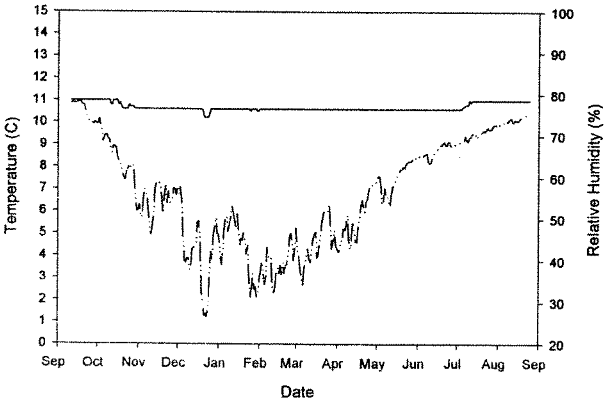

Hendricks Main Adit


Hendricks Solution Cavity


Hendricks West Drift