Hibernaculum potential of rock outcrops and associated features in eastern Montana

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Introduction

Understanding the types of hibernacula commonly used by bats and evaluating both landscape level attributes and microclimates within these hibernacula can prioritize habitat conservation and other management actions in the face of White-Nose Syndrome (WNS). However, inferring the impact of habitat structures and attributes on transmission and pathogenicity of *Pseudogymnoascus destructans* (*PD*) may be problematic without prior knowledge of the system before introduction of the pathogen. Montana is in a unique position to understand the life history of western bats and use of non-cave and mine hibernacula. We have a network of state and federal agencies, tribes, non-governmental organizations, and private companies all committed to understanding the bats within the state and helping our native species survive the threat of WNS. Furthermore, Montana has a large and comprehensive acoustic data set focused on year-round activity at water sources, counts and microhabitat attributes of roosts such as caves, bridges, and buildings, and over 25 years of capture data from mist netting efforts (see Bachen et al. 2018 and Bachen et al. 2019). However, we still lack adequate information on the types of hibernacula used by species that are presumed to over-winter in our state.

Although Montana has comprehensive data on certain biological aspects of bats, significant gaps in our understanding of the natural history of all species exists. Of the 15 bat species present in Montana, four are thought to migrate out of state in the winter. The remaining nine species have been detected acoustically during winter and spring suggesting that these species over winter in Montana (Bachen et al. 2018). Caves and mines are currently the best studied hibernacula in Montana. However, use of caves by bats in Montana appears to be low for most caves. Of 106 caves surveyed, 46 had at least one bat present. However, use was typically very low and only 9 caves had more than 20 bats of any species counted. In total approximately 4,000 individual bats have been counted across all surveyed caves. Seven species of bats have been observed in caves with Townsend's Big-eared Bat (*Corynorhinus townsendii*) and *Myotis* species the most commonly encountered. There are unsubstantiated reports of the use of basements and buildings, but these are anecdotal and lack evidence to confirm the presence of any species of bat (MTNHP point observation database, 2020).

Similar to Montana, infrequent use of caves and mines common across the northwestern United States and little is known about where bats in this region overwinter (Weller et al. 2018). The use of active season roosts during the period directly before hibernation is becoming better studied and may provide insight into the selection of hibernaculum. In Yellowstone National Park, Little Brown Myotis (*M. lucifugus*) and Big Brown Bats (*Eptesicus fuscus*) have been documented using cracks and crevices in cliffs or talus (rock outcrops) during the active season and during the fall (Johnson et al. 2017). In other regions, Eastern Small-footed Myotis (*M. lebii*) have been tracked using radio telemetry to rock outcrops preceding hibernation (Moosman et al. 2015) and have been found over-wintering in these features (Lemen et al. 2016). In Colorado, Little Brown Myotis were found to use buildings, trees, and rock crevices during the autumn and to make short-distance elevational changes rather than longer distance movements during this time (Neubam 2018).

Due to relatively high levels of winter activity in topographically rugged areas (Bachen et al. 2018), we suspect many species rely on features such as rock outcrops and badlands for overwintering. Potential differences in abiotic hibernacula attributes such as humidity, temperature, and the stability of these microclimates across the year may affect the dynamics of how WNS is transmitted. Similarly, numbers of bats using these features and aggregation sizes are unknown. Thus, we currently have little information on the types of hibernacula that could be used to assess WNS impacts and spatial spread. We need to first identify those sites and features currently used for over-wintering and baseline indices for populations, aggregation sizes and species communities in order to properly assess the impacts of WNS in Montana, prioritize the conservation of important features, implement treatment if developed, and identify hibernacula with attributes that minimize the lethal effects of WNS on bats. If we attempt to assess these features after WNS spreads to Montana, we will not only lose the opportunity to learn more about the natural history of our bats prior to expected declines, but any information on preference for non-cave roosts may be biased and effects of hibernacula type on surviving populations may be difficult or impossible to determine. Although WNS has not been detected in Montana, we likely have limited time to identify and assess alternative hibernacula. This has become a high priority as *Pd* was detected approximately 300 miles from our western border in Washington in 2016 (Lorch et al. 2016). Since then *Pd* has been detected in additional areas of Washington as well as Wyoming, North Dakota and South Dakota (White-Nose Syndrome Response Team: WNS Spread Map 2020). To address these information needs, we conducted surveys to identify non-cave and mine hibernacula sites for *Pd* positivity and WNS susceptible bat species.

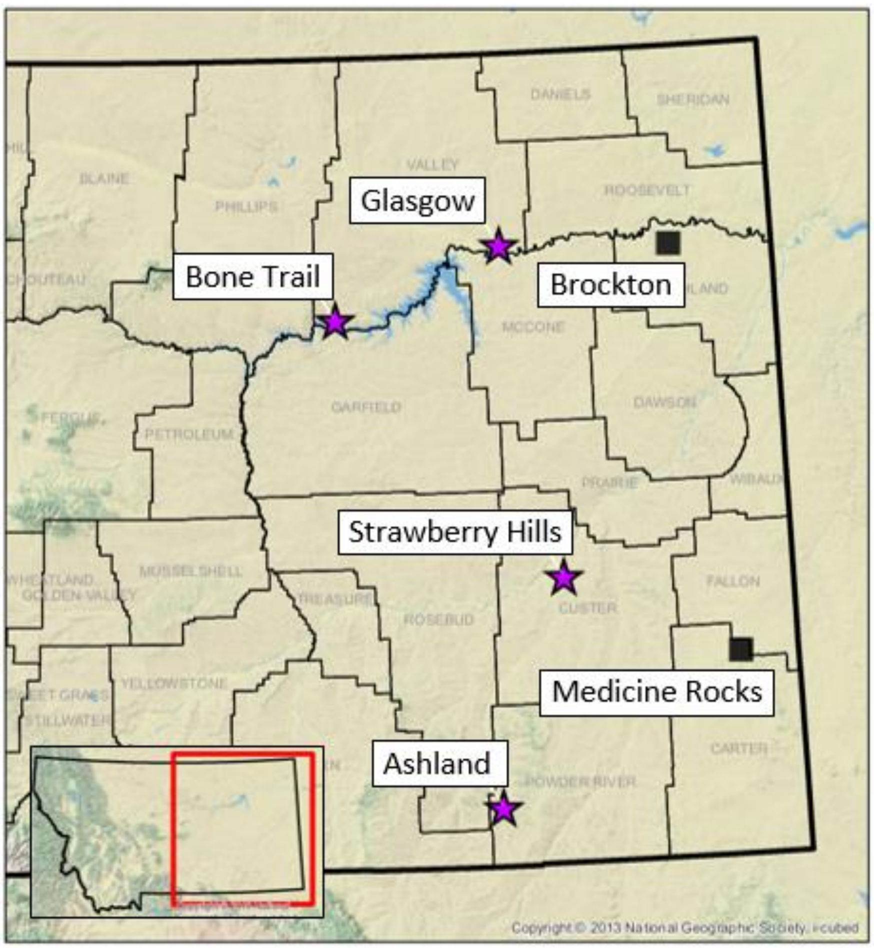

Figure 1. Survey locations across eastern Montana. Areas that were assessed with acoustic detectors but not surveyed due to low winter activity are shown with black squares. Areas where telemetry work was conducted to locate fall transitional roosts are shown with purple stars.

Study Area & Methods

Data collected as part of a statewide acoustic surveillance project conducted by MTNHP in collaboration with state, federal, and NGO partners across Montana allowed us to narrow our focus for this work. Between 2011 and present we have placed long-term acoustic monitoring stations at 87 sites, which have been deployed for an average of 2.3 years and was used to assess winter activity across the state. Based on these data, we chose 6 sites within eastern Montana (Figure 1) in regions with high activity levels of 40 kHz bats (*Myotis* species) during winter months (November – March). Within these regions we chose areas that had features suspected to support overwintering, and separation from known cave or mine hibernacula.

As this work was exploratory in nature, we used several strategies to assess site suitability, locate roosts, and assess activity and microclimate within these roosts. At some areas with suitable roost features we deployed acoustic detectors to confirm winter activity. In areas with good activity, we used mist nets to capture bats and radio transmitters to find their roosts. We also opportunistically captured bats at roosts to increase sample size. For roosts that were accessible and appeared to have potential for use as hibernation we used microclimate data loggers and acoustic detectors to gather information and infer use as hibernacula.

To capture bats, we deployed mist nets at water sources and within flight corridors during the fall transition season (October and November). Additionally, we opportunistically hand captured bats based on public reports and found while looking at rock outcrops. Upon capture, we fixed a radio tag (Holohil, Carp, Ontario, Canada) to any *Pd* or WNS susceptible species of bat and then released these individuals (White-Nose Syndrome Response Team: Bats Affected by WNS 2020). We used standard radio telemetry tracking methods for the life of the tag hoping for at least 5 relocations to identify the specific features that are used by bats (*sensu* Johnson et al. 2017 and Moosman et al. 2015).

To confirm presence of bats during the winter, we placed an acoustic detector (SM2Bat+, Wildlife Acoustics, Maynard, Massachusetts) in proximity to suspected roost features where either an individual had been relocated during the transition season or that otherwise appeared to be suitable for hibernation if no fall roosts were located in that area. Each detector/recorder was run off a marine grade 12v battery, charged with a 30-Watt solar panel, for continuous data collection over the winter. Units were set to collect data from 0.5 hours before sunset to 0.5 hours after sunrise in order to record emergence and immergence periods. All recordings were analyzed following standardized MTNHP protocols (Maxell 2015). All recordings are housed in the Montana Natural Heritage Program Call Library for future analysis if desired.

Microclimates of potential hibernacula were assessed with a HOBO temperature and humidity logger (Onset Computer Company, Bourne, Massachusetts). Units were deployed in November 2018 or later and run through to the following active season. Sensors were placed as deeply as possible in each feature (1-2m). To assess the temperature and humidity profile we examined low, high and average temperatures including the standard deviation as a measure of temperature variation. Data were limited to November through March. To assess temperatures outside of the roost we used the temperature logger in the SM2 BAT+ acoustic detector.

Acoustic and microclimate data were then used to assess whether a feature could be used as a winter roost. We evaluated similarities in species use, bat activity patterns, roost temperature and humidity, and variation in microclimate attributes to known cave and mine hibernaculum. We sought to identify roosts with consistent activity close to sunset and sunrise, cool stable temperatures and high relative humidity as these attributes are similar to known hibernaculum. Activity was assessed as the number of calls at each site between November and March, the total number and distribution of calls within 4 hours of sunset by month and site. To assess temperature we quantified the minimum, maximum, and variation in roost temperature from the HOBO logger deployed at the roost. To assess the difference between temperatures within and outside of each roost we compared data from the roost logger with temperature data collected from acoustic monitoring stations deployed at each site.

Results

In response to variable activity levels and capture success we used a combination of survey methods at seven areas across eastern Montana. At areas with what appeared to be good features, we deployed detectors, but two we found low activity. As such we did not continue our efforts to locate roosts using telemetry or deploy microclimate loggers. These areas include Medicine Rocks and Brockton. At others with robust winter activity (Ashland, Strawberry Hills, and Bone Trail areas) we captured bats and deployed microclimate loggers at roosts within suitable roosts. Finally we telemetered bats found in roost searches in Glasgow, but these animals did not roost in features suitable for hibernation so we did not deploy loggers at these sites. We also did not deploy loggers at the Bone Trail roost as this was an exposed rock crevice unlikely to be used during the winter.

Telemetry

We tracked captured bats across 4 areas using telemetry (Figure 1, Table 1). Sites were netted 3-4 nights each resulting in a total of 11 capture nights. Eight bats were captured and 6 were radio-marked (Table 2). We additionally hand captured and radio-marked another 4 bats at roosts. Species varied between sites (Table 2) and included Big Brown Bat, Western Small-footed *Myotis (M. ciliolabrum)*, Townsend's Big-eared Bat, and Long-eared Myotis (*M. evotis)*. Relocating bats proved challenging with some bats never located and others tracked daily up to 12 days. We identified 11 independent roosts. The number of roosts found per bat ranged from 1 to 4. Roost structures included rock outcrops of sandstone and clinker (fused sedimentary rock created as a byproduct of coal fires), soil erosion cavities in mudstone, and abandoned houses.

Table 1. Bat species captured and radio tagged by site. Species captured were Eptesicus fuscus (EPFU), Myotis ciliolabrum (MYCI), M. evotis (MYEV), and *Corynorhinus townsendii (COTO).*

Area	Species							
	EPFU		**MYCI**		**MYEV**		**COTO**	
	Captured	**Tagged**	**Captured**	**Tagged**	**Captured**	**Tagged**	**Captured**	**Tagged**
Bone Trail	2	2	1	1	1	1	0	0
Glasgow*	3	3	0	0	0	0	0	0
Ashland	2	2	1	0	0	0	0	0
Strawberry Hills	0	0	1	0	0	0	1	1
TOTAL	**7**	**7**	**3**	**1**	**1**	**1**	**1**	**1**

*Bats were hand-captured at this site

ǂ1 bat was captured during a rock outcrop survey while radio tracking another bat

Table 2. Number of roosts and structure type identified by individual radio-tagged bats.

Area	Bat	Species	Sex	Tracked (# days)	# Roosts	Roost Structure(s)
BoneTrail	EPFU1	*Eptesicus fuscus*	M	1	0	Not relocated
	EPFU2	*Eptesicus fuscus*	F	1	0	Not relocated
	MYCI1	*Myotis ciliolabrum*	M	4	1	Shale Rock
	MYEV1	*Myotis evotis*	F	1	0	Not relocated
Glasgow	EPFU3	*Eptesicus fuscus*	F	7	1	Abandoned House
	EPFU4	*Eptesicus fuscus*	F	7	1	Abandoned House
	EPFU5	*Eptesicus fuscus*	F	7	2	Abandoned House(s)
Ashland	EPFU6	*Eptesicus fuscus*	Female	12	1	Rocky Outcrop - Clinker
	EPFU7	*Eptesicus fuscus*	Male	12	3	Rocky Outcrop - Sandstone
Strawberry Hills	COTO1	*Corynorhinus townsendii*	Male	12	4	Erosion Cavity

Acoustic activity

While capture and radio marking only occurred during the fall of 2019, acoustic detector/recorders were deployed at 5 areas in fall 2017 through spring 2019. Each site was associated with roosting bats detected during telemetry work or areas similar to sites assessed in previous projects with relatively high winter activity (Figure 1, Bachen et al. 2018). Of these detectors, 6 recorded bat calls for some or all the deployment period (Table 3, Appendix A)

The detectors deployed at Timber Creek, Brocton Reservoir, and Medicine Rocks did not provide sufficient evidence of winter activity to justify further survey and recorded just 18, 0, and 1 sequences respectively (Table 3). Detectors placed in the Strawberry Hills demonstrated robust local populations of overwintering animals. The detector deployed at the Strawberry Hills Site 1 had the greatest amount of activity or any detector with 1,224 call sequences recorded in November through March. The Otter Creek Drainage near Ashland had previously been shown to have robust winter activity (Bachen et al. 2020) so we did not deploy a detector to assess the site. Rather both detectors were deployed at roosts found during telemetry work. Ashland Site 1 had a relatively large number of calls November through March (978). Ashland Site 2 had 166 sequenced during the same time period. Across all detectors we were only able to definitively identify two species: Silver-haired Bat and Western Small-footed Myotis.

We assessed hourly activity for all detectors but it was of particular interest for the Ashland and Strawberry Hills sites as these were placed at (Ashland) or near (Strawberry Hills) fall roosts. As with total activity, the timing of nightly activity varied by detector and month in the winter. As most detectors recorded data for only part of the winter, proximity to a suspected hibernaculum is difficult to assess based on activity patterns (Appendix A). Of the detectors with sufficient data the Ashland 1 detector recorded consistent activity within one half hour of sunset across the winter and appears to have been placed at or very close to a hibernaculum.

Table 3. Species confirmation by month across the winter using acoustic recordings. Species are noted by their four-code based on genus and species names. For example, MYCI is Western Small-footed Myotis, EPFU is Big Brown Bat, LANO is Silver-haired Bat, and LACI is Hoary Bat. Where uncertainty in species identity exists we report the most specific group possible. 20kHz bats are typically Sliver-haired or Big-brown Bats, 50 kHz are typically Myotis species. Total call sequences recorded at a given site are noted in brackets next to the site name. Periods when a detector was not deployed or not functioning are noted with an "X".

Detector Site (call sequences recorded)	November		December		January		February		March	
	2017	2018	2017	2018	2018	2019	2018	2019	2018	2019
Ashland 1 (978)	X	MYCI 20kHz Bat	X	MYCI 20kHz Bat	X	MYCI	X		X	MYCI 20kHz Bat
Ashland 2 (166)	X	MYCI, 20kHz Bat	X	MYCI, 20kHz Bat	X	20kHz Bat	X		X	
Brockton (0)	X		X		X		X		X	
Medicine Rocks (1)	X	x		X						X
Strawberry Hills 1 (1,224)	X	X		X	20kHz Bat 50kHz Bat	X			LANO 20kHz Bat	X
Strawberry Hills 2 (2)	X		X	X	X	X	X		X	X
Strawberry Hills 3 (0)	X	X	X	x	X	X	X		X	X
Strawberry Hills 4 (47)	X	20kHz Bat 50kHz Bat	X	20kHz Bat 50kHz Bat	X	X	X		X	X
Timber Creek (18)	X		X		X		X		X	

Microclimate

Across all but one roost the HOBO loggers recorded nominally higher and more variable temperatures than the sensors in the detector/recorder units (Table 4, Appendix A). This is unexpected as we presume that the roost features would mitigate the effects of temperature variation. Relative humidity was also variable, but most roost features measured moderate to high average relative humidity (Table 5). Only the logger placed at the Strawberry Roost 4 recorded humidity levels that were similar in value and stability to cave and mine roosts that have been monitored in Montana (see Bachen et al. 2019 and Appendix A).

Table 4. Temperature profiles of fall transition roosts. Roost temperatures are measured using HOBO loggers placed in the roost feature. Site temperatures are measured using the internal sensor within the SM2 BAT+ acoustic detector/recorder units deployed outside roosts. All temperatures are in degrees Celsius. Note that some detectors did not record for the entire period of interest, and recorded temperature may not accurately reflect true conditions. As such all detectors with incomplete data are greyed. Some detectors were placed on the landscape rather than at roost features, so roost profiles were not assessed. These are noted with NA. Note that Ashland1 had two HOBO loggers deployed at the site in different parts of the outcrop.

Roost	Minimum Roost Temp.	Maximum Roost Temp.	Minimum Site Temp.	Maximum Site Temp.	SD Roost Temp.	SD Site Temp.
Ashland 1	-16.8, -14.0	18.8, 18.3	-7.9	21.4	5.9, 6.8	4.9
Ashland 2	-16.32	18.93	-10.9	23.9	5.9	4.7
Strawberry Hills 1	-4.7	23.7	-16.7	5.9	6.9	5.5
Strawberry Hills 2	-11.1	5.38	-5.6	20.8	4.7	5.0
Strawberry Hills 3	-14.0	11.0	0.9	16.6	6.6	4.1
Strawberry Hills 4	-14.4	2.53	-3.4	16.1	4.5	3.8

Table 5. Relative Humidity (RH) measured at fall transition roosts. Sites without HOBO loggers deployed were removed from the table. Note that 2 loggers were deployed at Ashland 1 and values for each unit are given.

Roost	Minimum RH	Maximum RH	Mean RH	SD RH
Ashland 1	33, 27	97, 97	63, 63	10.7, 11.1
Ashland 2	28	98	64	11.9
Strawberry Hills 1	17	89	32	19.6
Strawberry Hills 2	44	77	62	9.0
Strawberry Hills 3	56	85	73	5.7
Strawberry Hills 4	80	100	95	6.0

Potential hibernacula

Ashland Roost 1

The Ashland 1 roost was within a south-facing outcrop of clinker on a ridge in sparse Ponderosa Pine (*Pinus ponderosa*) forest (Figure 2). One female Big Brown Bat was observed using the outcrop as a roost in the fall. The detector placed next to the outcrop, recorded high activity of both high frequency (*Myotis spp.*) and low frequency bats (indeterminate Big Brown Bat or Silver-haired Bat (*Lasionycteris noctivagans*) across the winter. Activity of both groups was associated with sunrise and sunset. Between November and January and in March, the earliest recorded bat calls in each month were at 20, 17, 24, and 17 minutes after sunset respectively. No calls were recorded within 4 hours of sunset in February. Western Small-footed Myotis was confirmed at this site across the winter. Recorded sequences were likely made by Big Brown Bats, but due to similarity with other species could not be attributed with certainty. Temperature and humidity profiles as measured by the HOBO logger differed from typical cave and mine hibernacula. However, based on the amount and timing of activity we feel that this outcrop or a closely associated feature is likely used as a hibernaculum for both Western Small-footed Myotis and Big Brown Bat. To confirm use, future surveys should seek to capture or observe animals leaving or entering this roost feature in the winter.

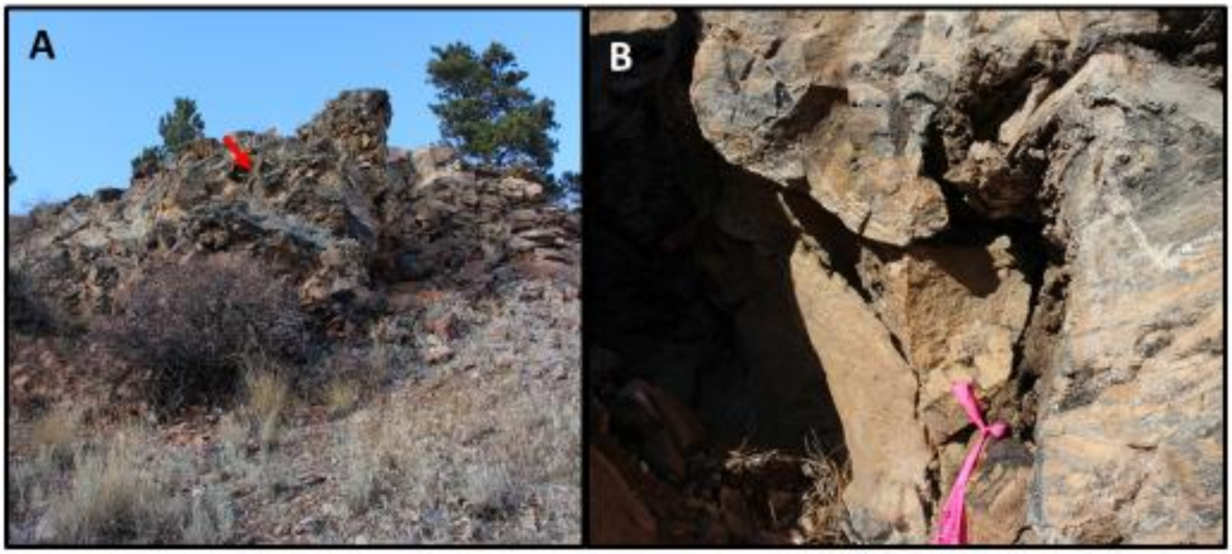

Figure 2. Roost used by a female Big Brown Bat fall 2019. This outcrop of clinker was approximately 4 meters high and located on a south facing ridge in sparse Ponderosa Pine forest (panel A). The animal was roosting in a deep crack (B) near the pink flagging.

Sites near hibernacula

Ashland Roost 2

The detector at Ashland 2 was placed near a complex of sandstone cliffs on a south facing hillside used by a male Big-Brown Bat during the fall (Figure 2). This detector had consistent nightly activity across the winter similar to Ashland 1, but typically had less activity than that site. Both high and low frequency bats were recorded, but passes were typically later in the evening than at the Ashland 1 site. The only species confirmed from acoustic data at the site was Western Small-footed Myotis. Temperature and humidity profiles as measured by the HOBO logger differed from typical cave and mine hibernacula. The consistent activity in proximity to the detector indicates that hibernacula are within the local area. However, few calls were recorded near sunset, and activity was generally later than at the Ashland 1 detector. These patterns indicative that these cliffs are fall transition roosts, and are near hibernacula but not actually but are not actually used to overwinter.

Figure 3. The location of roost used by a male Big Brown Bat on a south facing hillside in the Ashland area (Panel A). The animal was captured during a rock outcrop search under a bolder (C), and was relocated in the outcrops uphill (B). Red arrows show where the animal was located within each outcrop. Other cliffs on the same hillside were used, but are not shown.

Strawberry Hills Roost 4

During fall telemetry work, a Townsend's Big-eared Bat was tracked to this feature. As a detector was not placed directly at this feature we could not assess activity in relation to sunset and sunrise. However both high and low frequency bats were recorded in the local area. The microclimate logger was only deployed from late February through March due to inclement conditions at the site. Relative humidity was always over 80% and stabilized at 100% during much of March. Temperature was variable between 0 ˚C and -15 ˚C for the first period of deployment, but then stabilized near 0 ˚C for approximately 2 weeks. This fluctuation between variability and stability in microclimate is atypical across other deployments. However, the stability may be due to snow or ice deposition on the sensor. Nevertheless, even in the variable period, relative humidity values were within the range observed at cave and mine hibernacula. Temperature stabilized at zero or slightly above zero degrees Celsius, which is also consistent with some hibernaculum. During periods of variability, the temperature was significantly lower than temperatures selected by bats elsewhere in the state. As the logger was placed in the entrance and not deep in the feature, temperature and humidity may be suitable further in the roost. The pattern of activity associated with this feature is not consistent with those observed at hibernaculum elsewhere, but the presence of active bats demonstrates the potential for hibernating bats within the broader area.

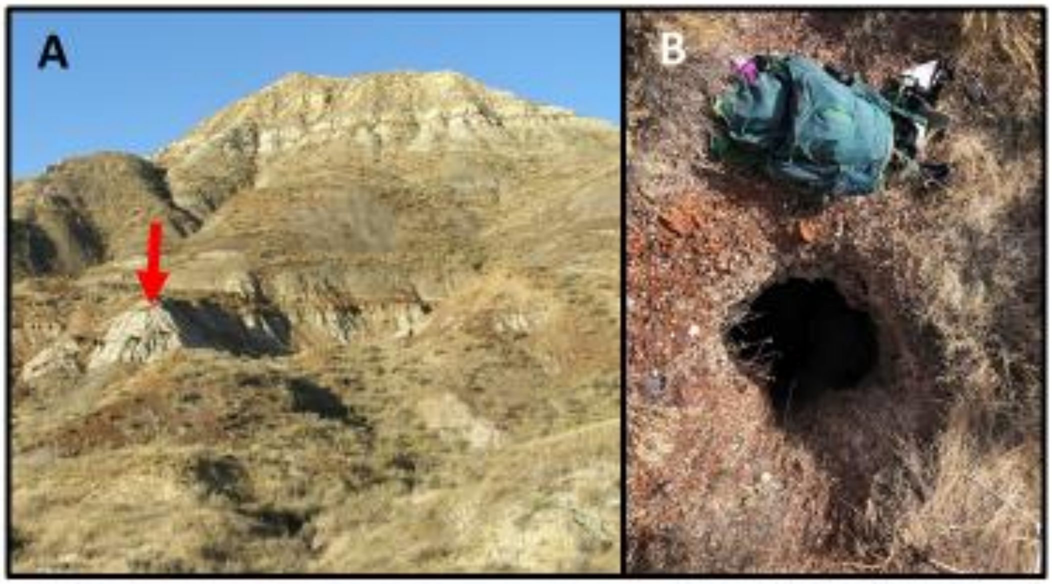

Figure 4. The location of a roost used by a Townsend's Big-eared Bat in the Strawberry Hills area. The roost was within an area of badlands on a south facing hillside (A). The animal was located in an erosion cavity (B). This individual also use 3 other erosion cavities in this same area (not shown).

Discussion

As expected based on previous experience, it was difficult to capture bats in the fall. Even though data from previous acoustic detector deployments were used to select capture sites with relatively high activity levels, few bats were seen flying during netting efforts and even fewer were captured at sites. Crews prioritized capture for evenings with low wind and temperatures at least or above 40^{o} F as these conditions were previously linked with increased activity (Bachen et al. 2018). For future efforts a large crew that could increase survey effort by trapping at more locations for more nights would likely yield more captures. In addition, a more effective triple high net was not obtained until after the field season but has proven effective in capture efforts since. Use of this net may also yield more captures. Identifying the roost locations of the bats that were captured proved especially challenging. Our inability to track bats to roosts was likely caused by the short distance of signal transmission making it difficult to acquire a signal when bats were roosting far from the foraging site at which they were captured, and bats roosting far into rock cracks and crevices which may block the signal and make acquisition difficult. Additionally migration in many of Montana's bat species is poorly understood and tagged individuals may have been traveling to distant over-wintering sites and moved outside of our study area and beyond our abilities to relocate. Although tracking crews hiked and drove wide circles around capture sites and detection sites, relocations were often very close to the initial site of capture and soon after capture. Additional dollars for aerial telemetry simultaneous to ground monitoring may increase the ability to find roosts as would tracking at night when animals may be active and the signal not blocked by the roost structure. We are unable to draw many conclusions on fall movements and fall/winter roosts from radio tracking alone due to these challenges and our low sample size.

Collecting acoustic data across the winter is also challenging. Detector units powered by solar panels need adequate solar exposure, which limits deployment locations to those that have an unobstructed view of the southern sky. Four of the seven detectors functioned intermittently between November and March. Although general equipment failure could be responsible in some of these cases, intermittent functioning and recording for only a few weeks to a month after deployment is indicative of inadequate solar charge or solar panel failure. During future work, efforts to deploy detectors at sites that maximize solar exposure, and if necessary, using a long microphone cable to sample near the roost, will increase the likelihood that detectors function across the winter.

Microclimate within roosts is difficult to assess, due to the inaccessibility of specific roost areas within features. We were unable to place the sensor very deep within any of the roosts. Therefore, it is likely that the recorded data do not reflect temperature and relative humidity of the exact areas used by bats. Assessment of microclimate within roost would be improved by developing a method to place the sensor further into the roost. We had hoped to demonstrate a mitigating effect of the roost structure on the ambient air temperature through comparison to the internal temperature of the acoustic detector placed at the roost. Unexpectedly, the temperatures recorded by the acoustic detectors showed little difference in the range of temperatures even though temperatures throughout the winter surely varied widely. The sensor in the detector was within the plastic housing so was not exposed to airflow and the housing may have provided some insulation, resulting in less variability in temperature. Comparison of these inaccurate ambient temperatures to roost temperatures would lead to inaccurate conclusions. Comparison of roost temperature with local weather station data may improve the assessment of the actual difference in variability in future work.

Relative humidity was variable within the few roosts where it was measured, but most roost loggers measured moderate to high average relative humidity. Only one logger recorded humidity levels that were similar in value and stability to cave and mine roosts. Similar to temperature, the relative the sensors may not have been placed deep enough within the roosts to accurately assess microclimate where bats were choosing to roost. A larger sample size and multiple years of data collection are needed to prove the assumption that non-cave and non-mine hibernacula may not provide adequate conditions for *PD* persistence due to their temperature and humidity. From our limited data it is difficult to say with certainty that the roosts we located serve as hibernacula although acoustic data show bats were in the area of most roosts throughout the winter.

Acoustic data was useful for assessing proximity of hibernacula to detectors. As bats continue to avoid activity during daylight, assessing how soon animals were recorded after sunset can be useful for assessing how close the detector is to a hibernaculum. At the Ashland 1 site, we recorded consistent activity at dusk or about 20 minutes after sunset. This demonstrates that animals are emerging from hibernacula within the immediate vicinity of the detector. Unfortunately acoustic data cannot be used to locate specific hibernacula, so further survey using emergence counts or other methods is necessary to conclusively demonstrate use of the outcrop for overwintering.

Although we encountered challenges over this project, we were able to begin to collect data to better understand overwintering in areas without caves and mines. We were able to identify a rock outcrop that we suspect is a hibernaculum in the Ashland area based on the high levels of winter activity and activity at or just after sunset. Although our assessment did not conclusively demonstrate the use of this feature, we were able to show that two species were roosting in very close proximity to the detector across the winter. With further refinement, these methods may be able to better identify hibernacula across Montana and help inform conservation and management of the states' bat species.

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Appendix A

Acoustic and microclimate data from detector sites and roosts

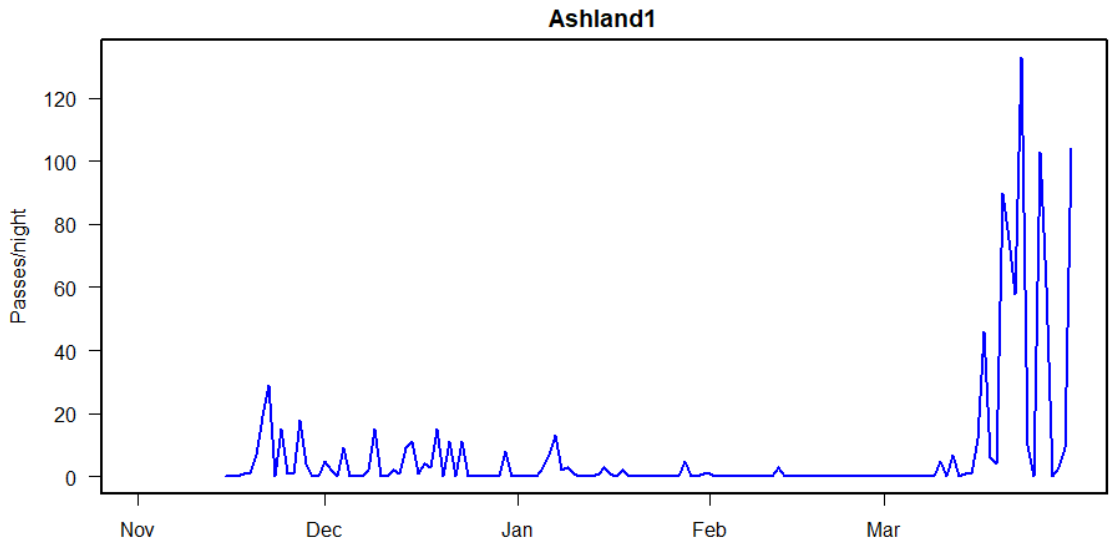


Figure A-1. Winter activity at the Ashland 1 detector. Number of passes by bats per night across the November 2018 through March 2019 deployment period..

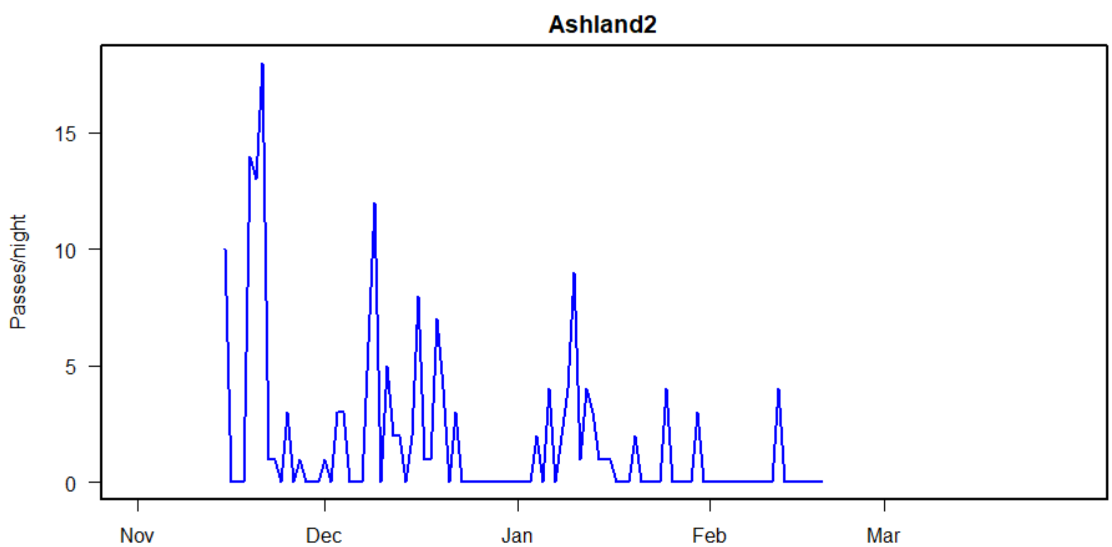


Figure A-2. Winter activity at the Ashland 2 detector. Number of passes by bats per night across the November 2018 through March 2019 deployment period. Line is only shown when the detector was functioning correctly and could record data. Note that unit did not function from late February through March.

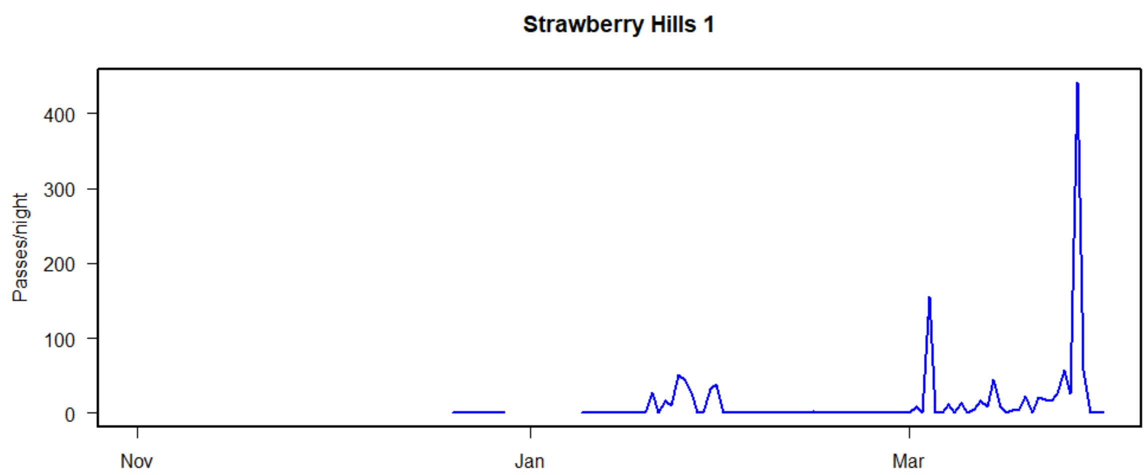


Figure A-3. Winter activity at the Strawberry Hills 1 detector. Number of passes by bats per night across the November 2017 through March 2018 deployment period. Line is only shown when the detector was functioning correctly and could record data. Note that unit worked infrequently during the initial deployment period.

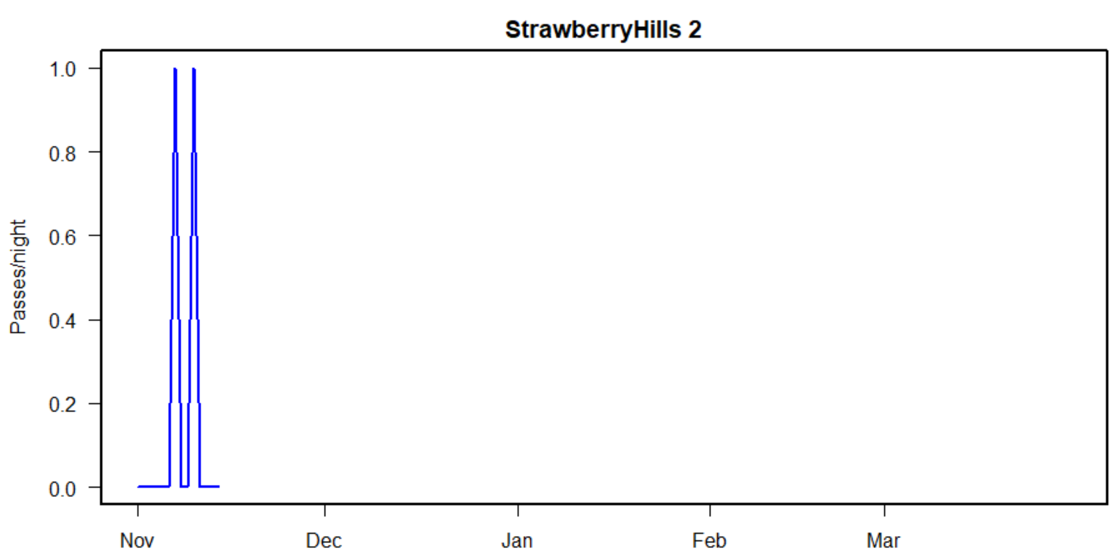


Figure A-4. Winter activity at the Strawberry Hills 2 detector Number of passes by bats per night across the November 2018 through March 2019 deployment period. Line is only shown when the detector was functioning correctly and could record data. Note that the unit did not function from mid-November through March. This likely resulted from battery not charging properly because the unit was not receiving adequate sunlight or equipment failure.

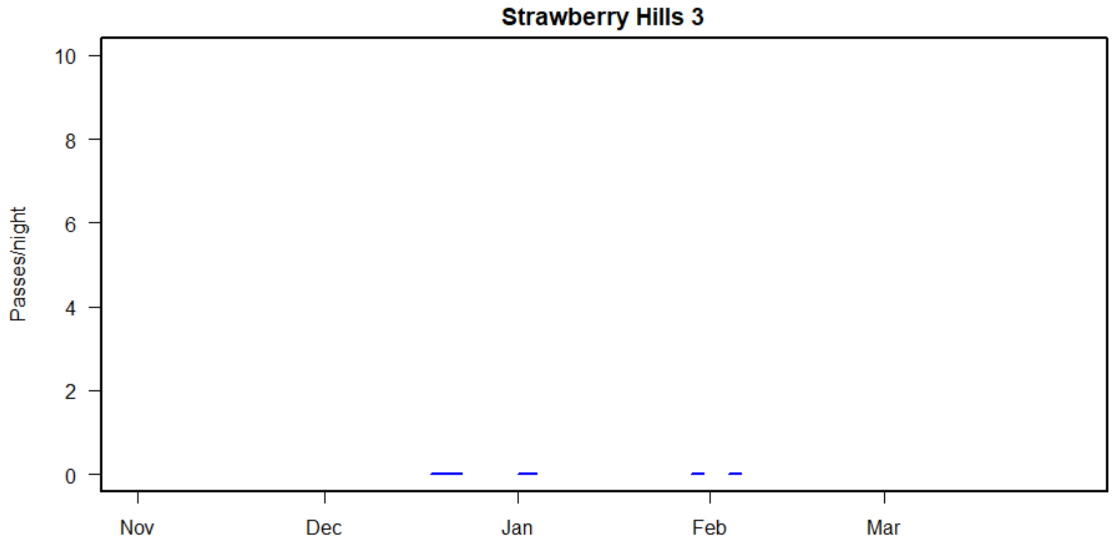


Figure A-5. Winter activity at the Strawberry Hills 3 detector. Number of passes by bats per night across the November 2018 through March 2019 deployment period. Line is only shown when the detector was functioning correctly and could record data. Note that the unit functioned sporadically across the deployment period. This was likely due to the battery not charging properly because the unit was not receiving adequate sunlight. The detector placed at the Strawberry Hills Site 3 did not record bat calls. Almost all areas have some bat activity; therefore, the lack of recordings may be related to issues with the detector, microphone, or both.

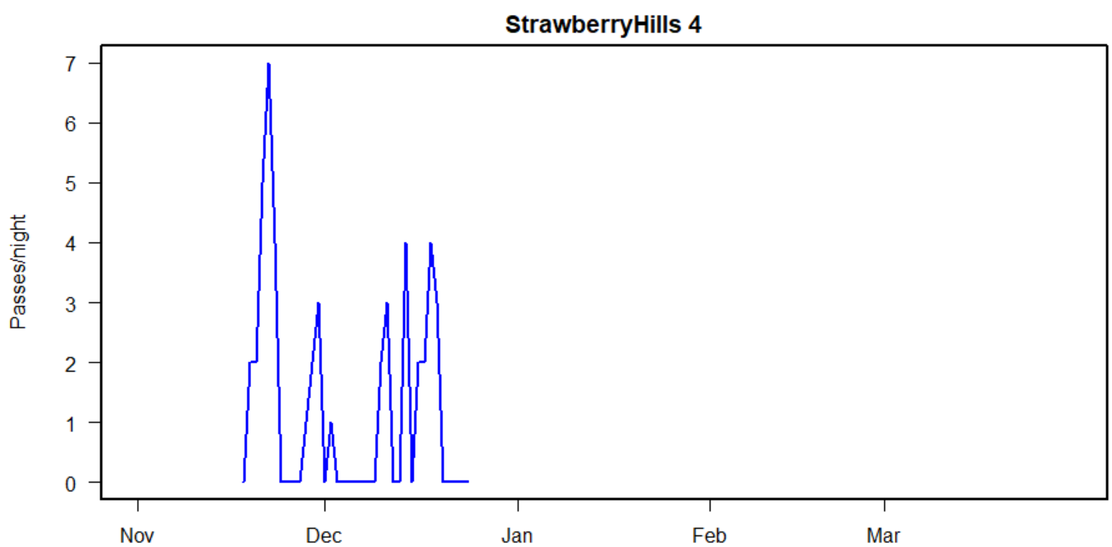


Figure A-6. Winter activity at the Strawberry Hills 4 detector. Number of passes by bats per night across the November 2018 through March 2019 deployment period. Line is only shown when the detector was functioning correctly and could record data. Note that the unit did not function from late-December through March. This was likely due to the battery not charging properly because the unit was not receiving adequate sunlight or equipment failure.

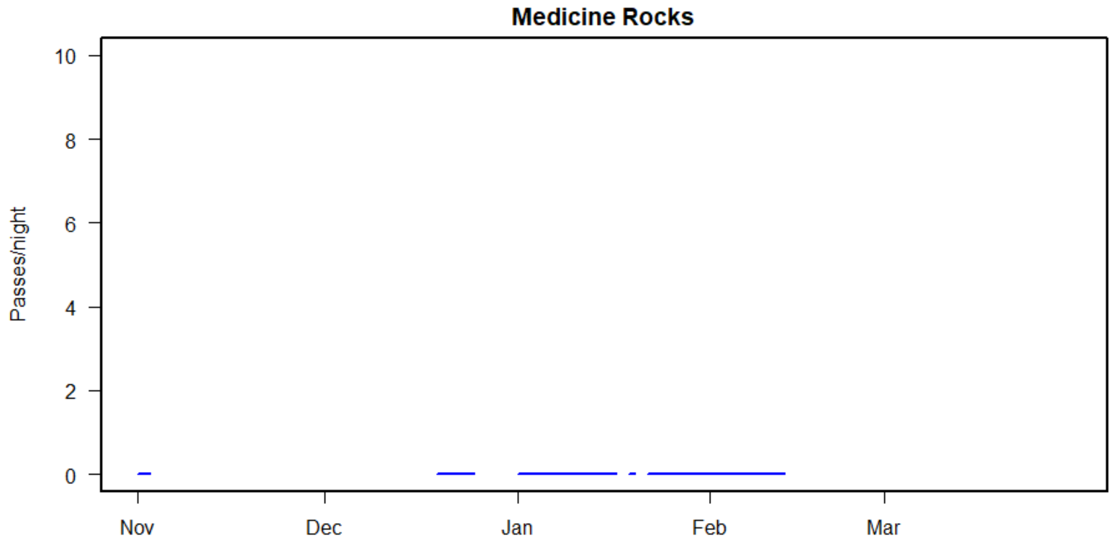


Figure A-7. Winter activity at the Medicine Rocks detector, 2018 to 2019. Number of passes by bats per night across the November 2018 through March 2019 deployment period. Line is only shown when the detector was functioning correctly and could record data. Note that the unit functioned sporadically across the deployment period. This was likely due to the battery not charging properly because the unit was not receiving adequate sunlight.

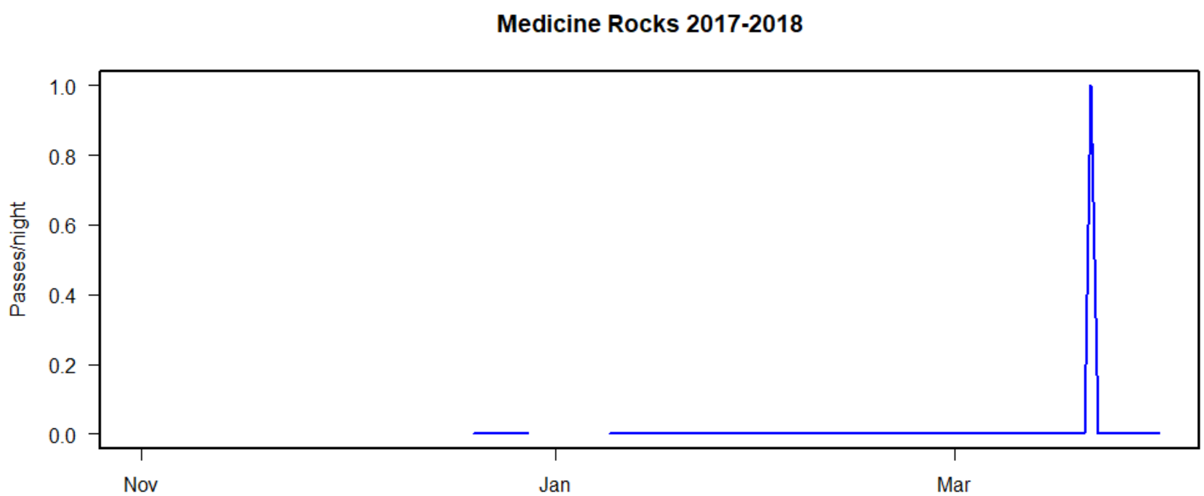


Figure A-8. Winter activity at the Medicine Rocks detector, 2017 to 2018. Number of passes by bats per night across the November 2017 through March 2018 deployment period. Line is only shown when the detector was functioning correctly and could record data. Note that the unit functioned across much of the 2018 period but only recorded a single call in March.

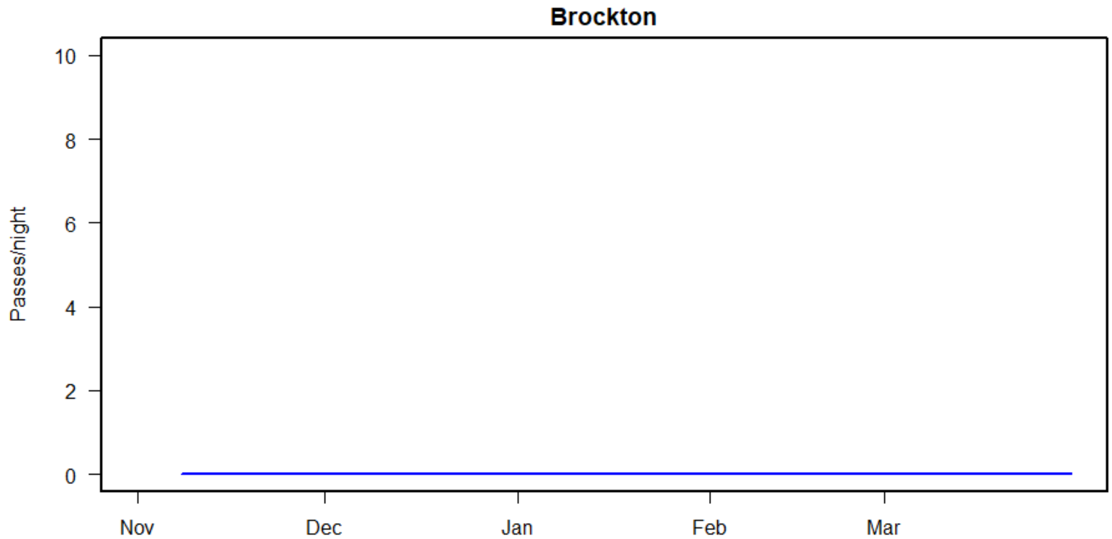


Figure 5. Winter activity at the Brocton detector. Number of passes by bats per night across the November 2018 through March 2019 deployment period. Line is only shown when the detector was functioning correctly and could record data. Note that the unit functioned during the recording period but did not record any calls.

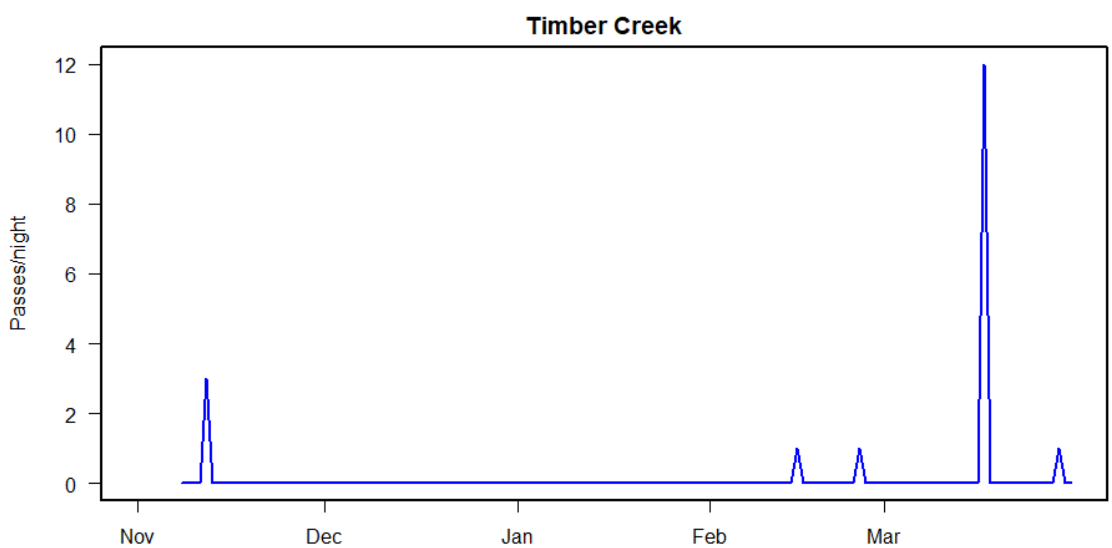


Figure A-10. Winter activity at the Timber Creek detector. Number of passes by bats per night across the November 2018 through March 2019 deployment period. Note that the unit functioned during the recording period but recorded few calls which likely indicates few bats roosting in the area during the winter.

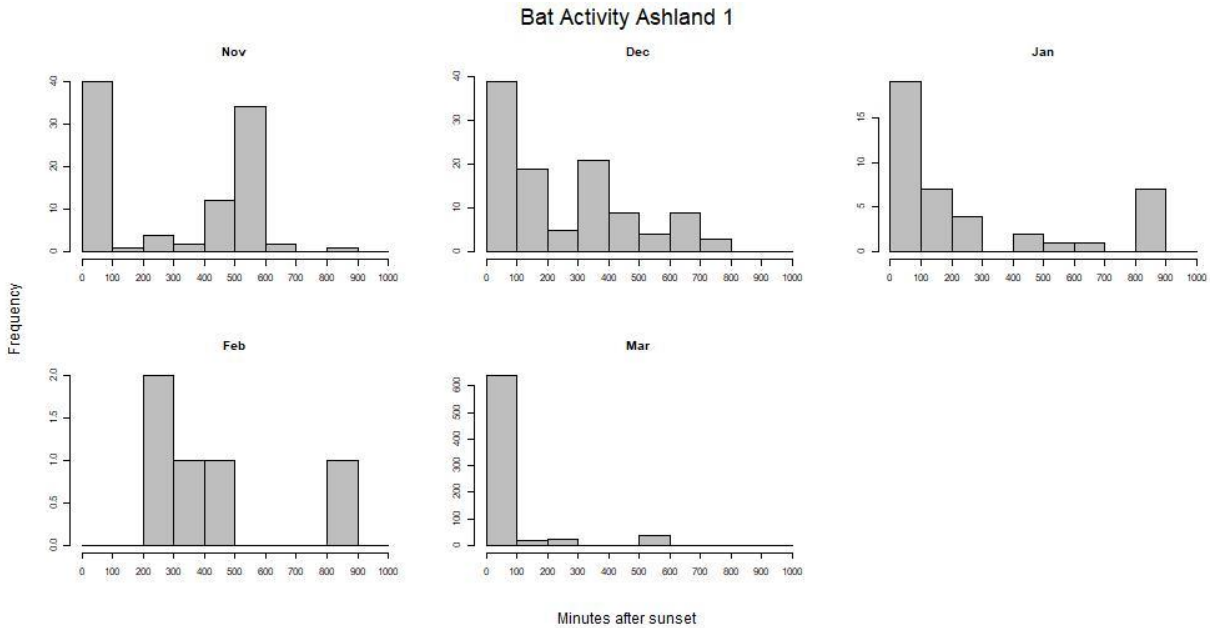


Figure A-11. Hourly activity by month for all bat species at the Ashland 1 Site.

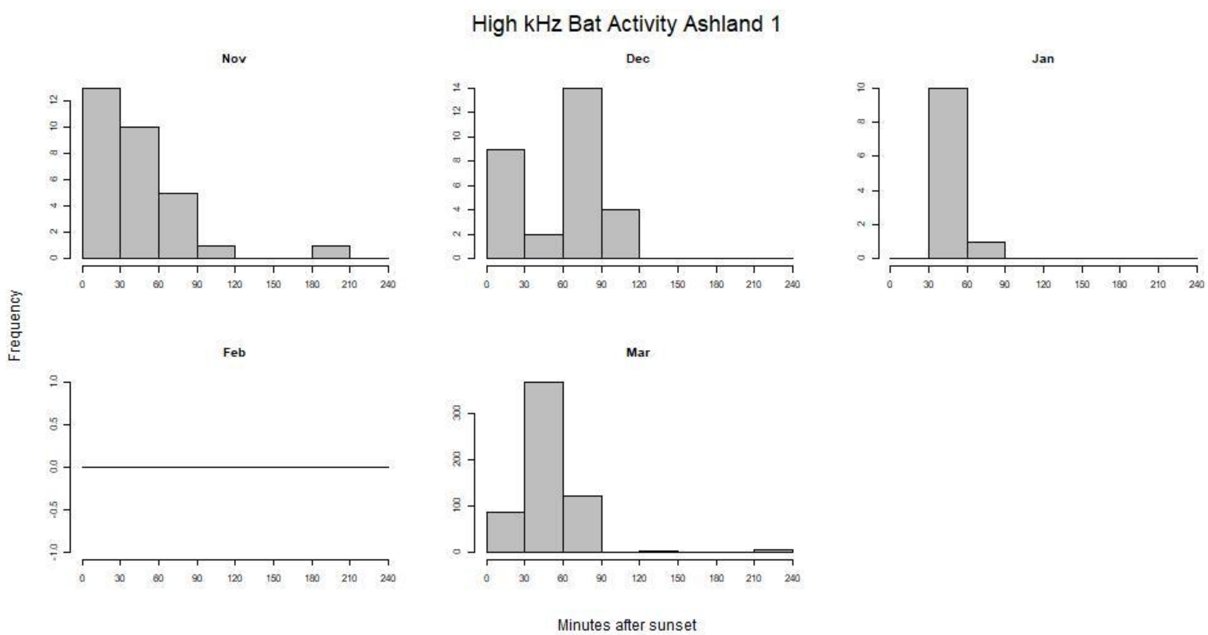


Figure A-12.Hourly activity by month for all high frequency bat species (Myotis bats) at the Ashland 1 Site.

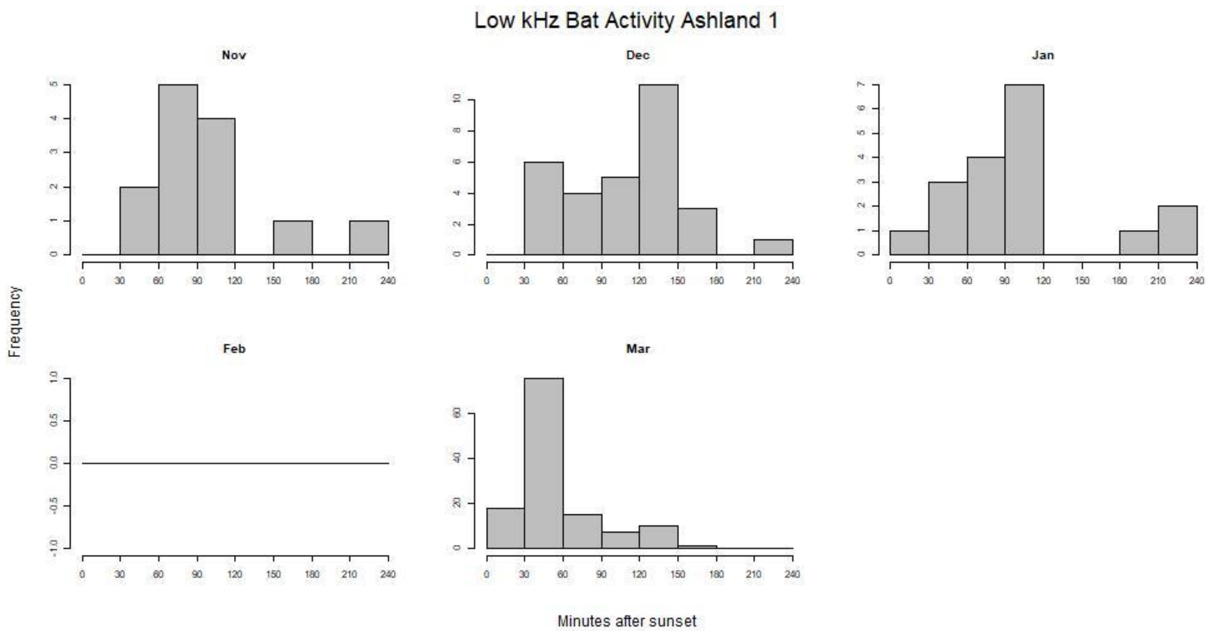


Figure A-13. Hourly activity by month for all low frequency bat species (e.g. Big Brown Bat, Silver-haired bat) at the Ashland 1 Site.

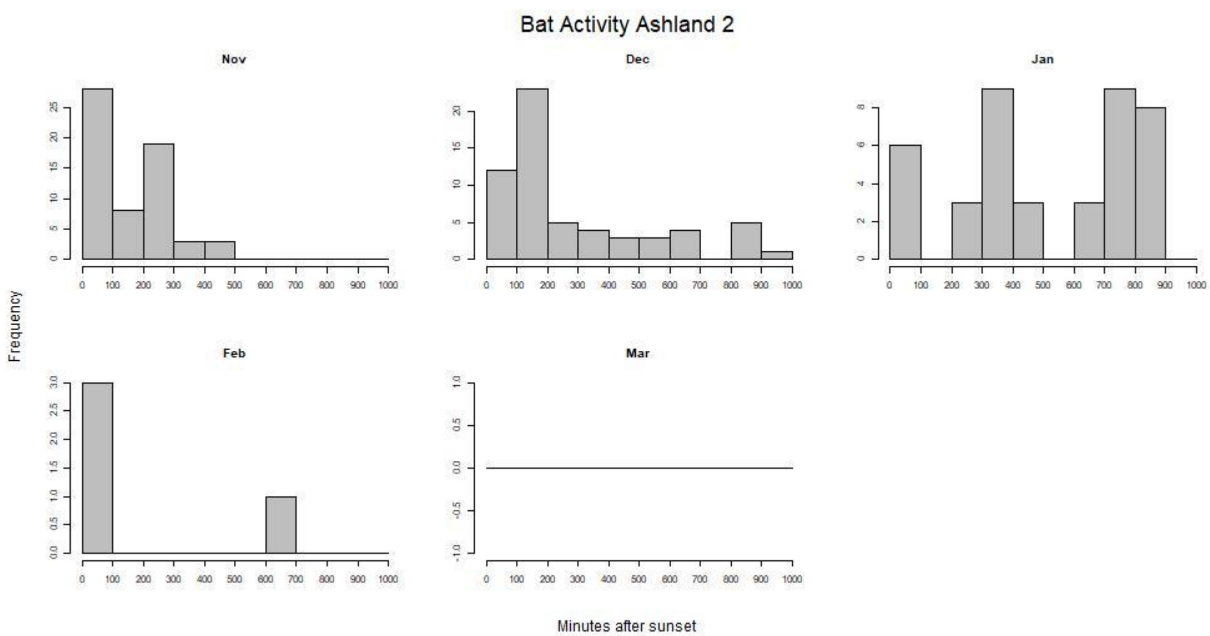
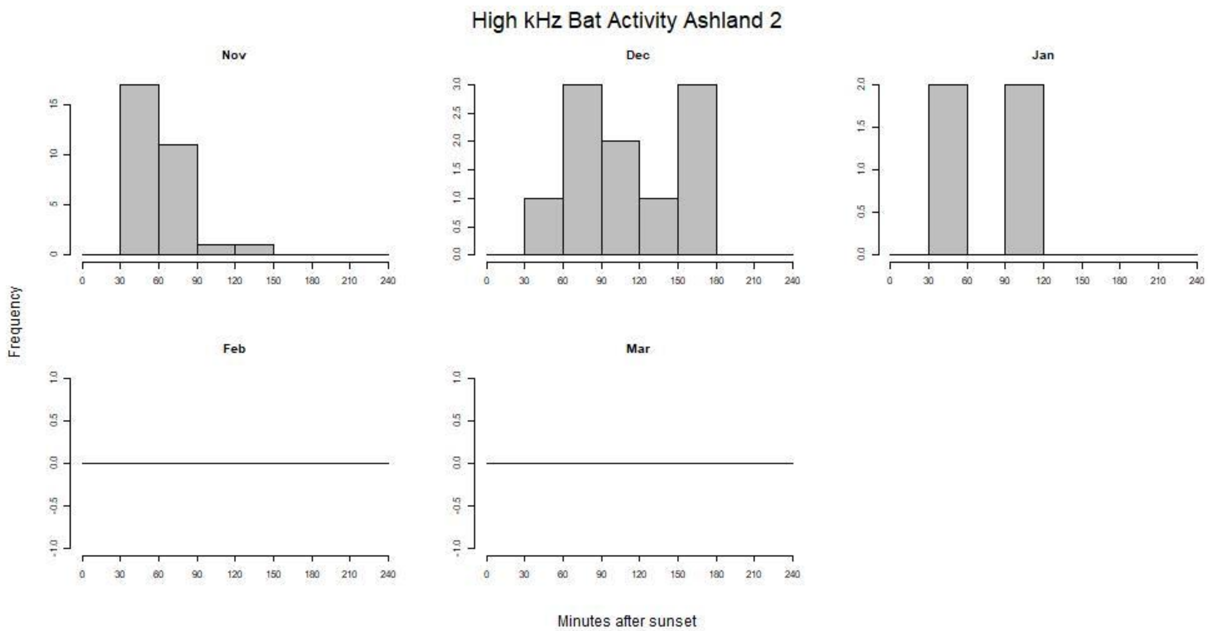


Figure A-14.Hourly activity by month for all bat species at the Ashland 2 Site.



FigureA-15.Hourly activity by month for all high frequency bat species (Myotis bats) at the Ashland 2 Site.

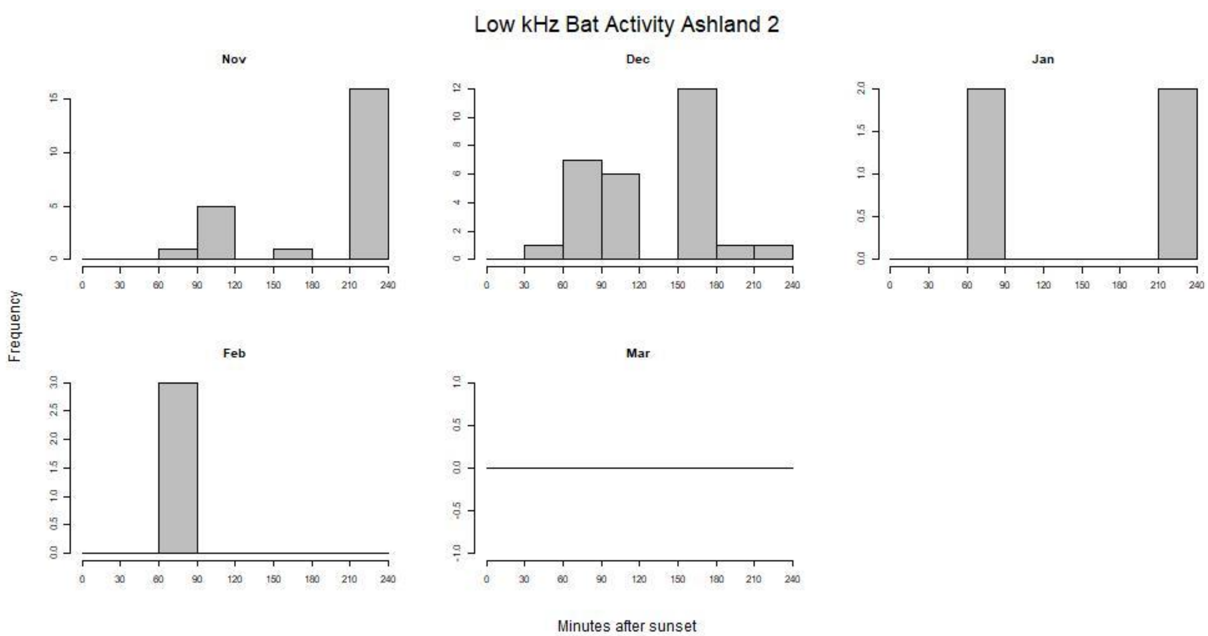


Figure A-16. Hourly activity by month for all low frequency bat species (e.g. Big Brown Bat, Silver-haired bat) at the Ashland 2 Site.

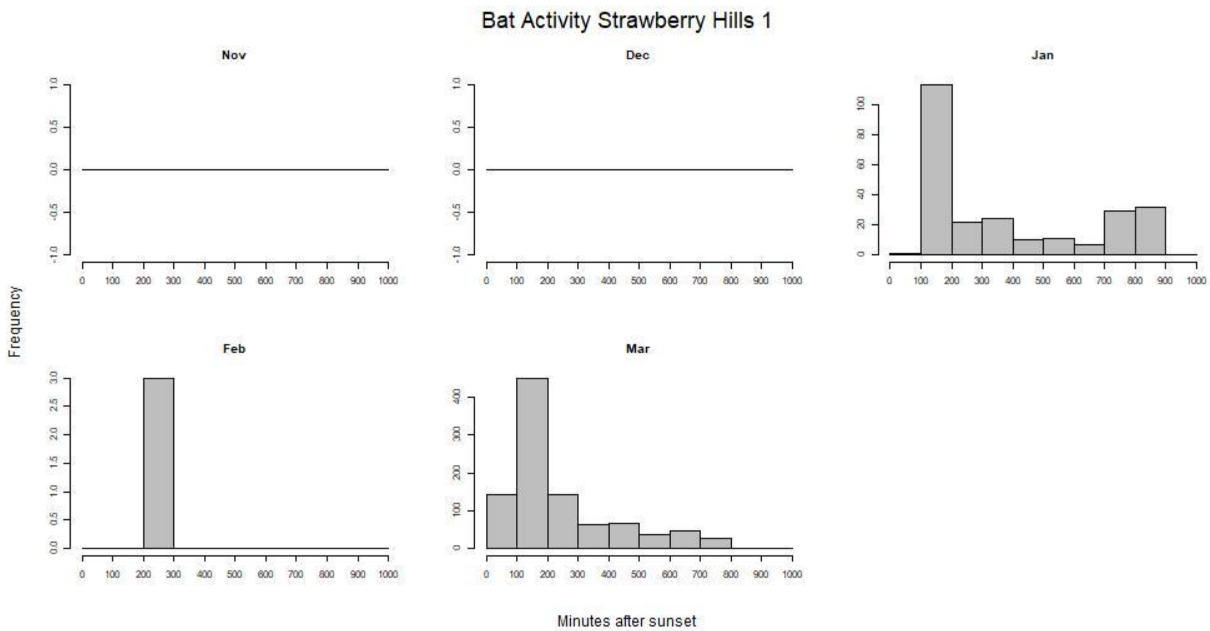


Figure A-17. Hourly activity by month for all bat species at the Strawberry Hills 1 Site.

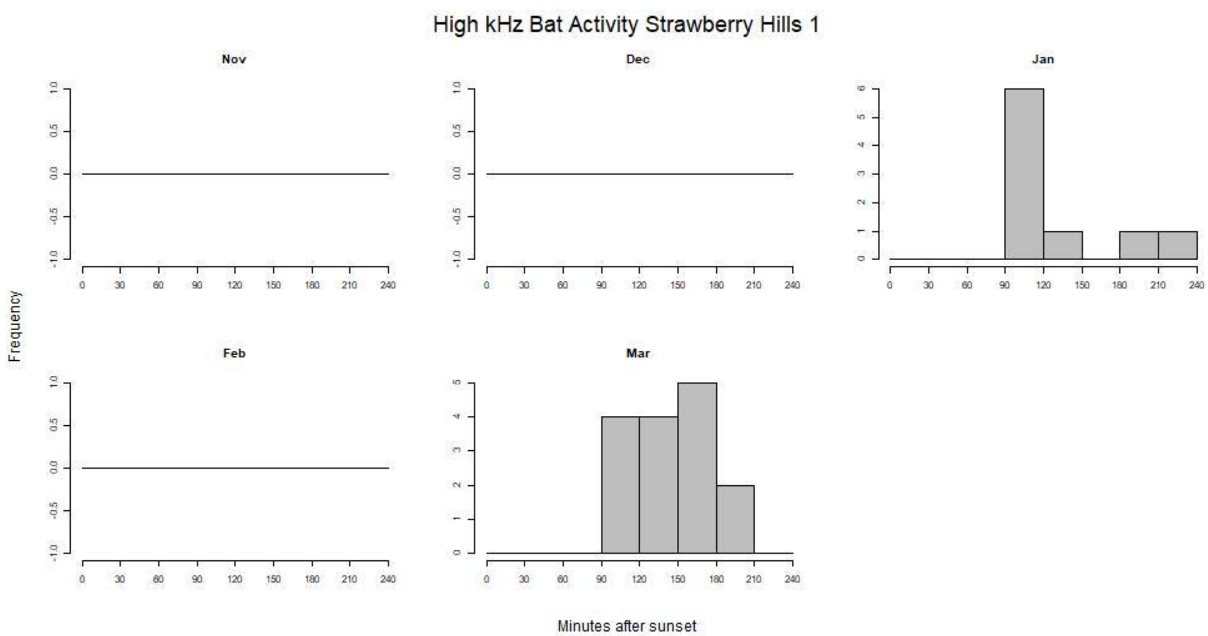


Figure A-18. Hourly activity by month for all high frequency bat species (Myotis bats) at the Strawberry Hills 1 Site.

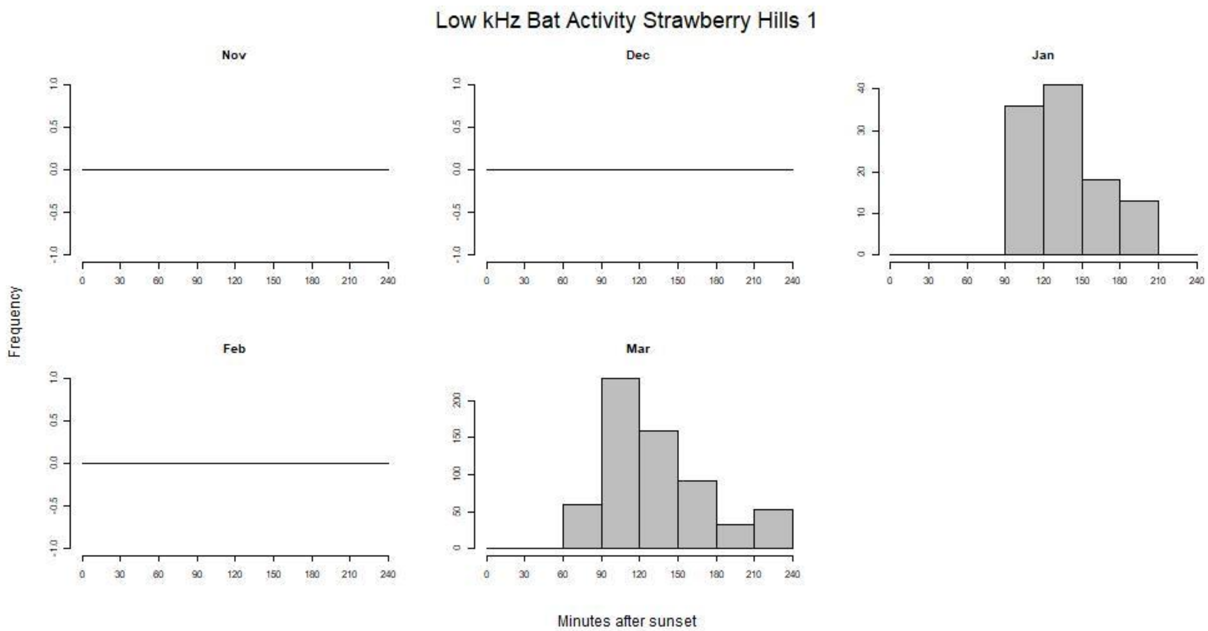


Figure A-19. Hourly activity by month for all low frequency bat species (e.g. Big Brown Bat, Silver-haired bat) at the Strawberry Hills 1 Site.

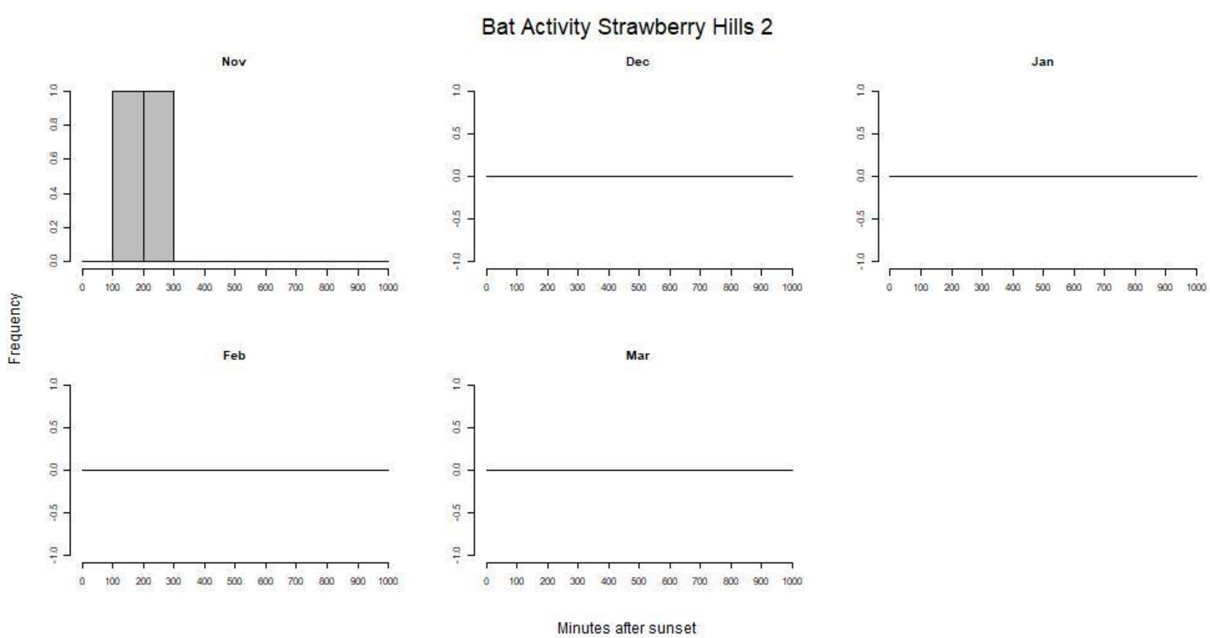


Figure A-20. Hourly activity by month for all bat species at the Strawberry Hills 2 Site.

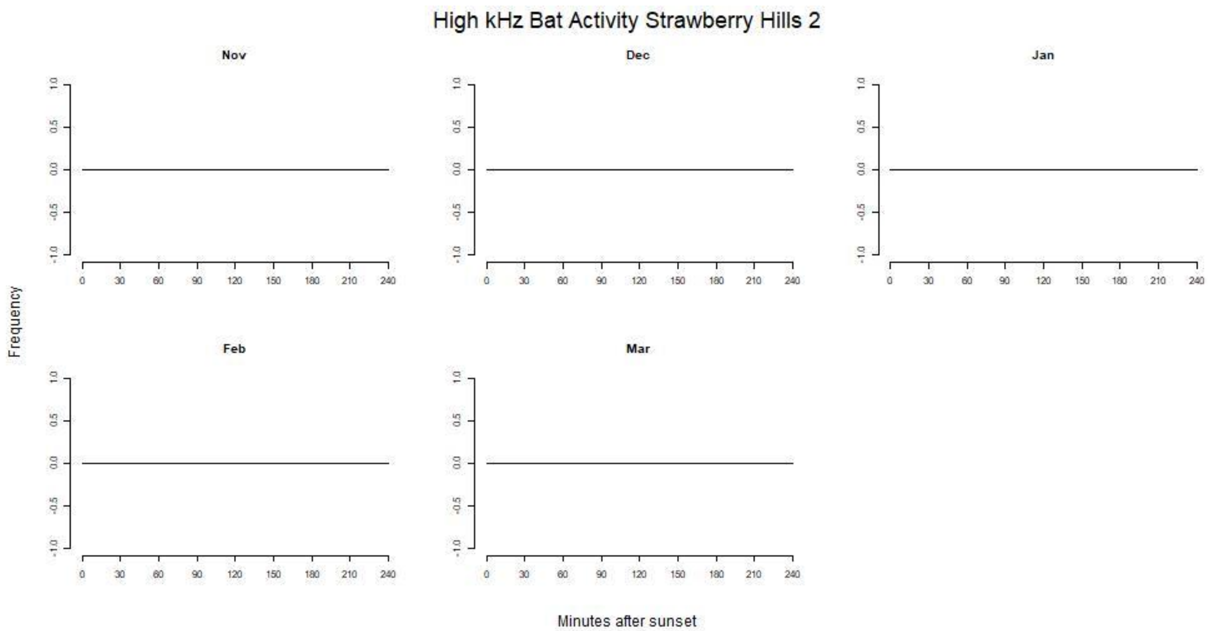


Figure A-21. Hourly activity by month for all high frequency bat species (Myotis bats) at the Strawberry Hills 2 Site.

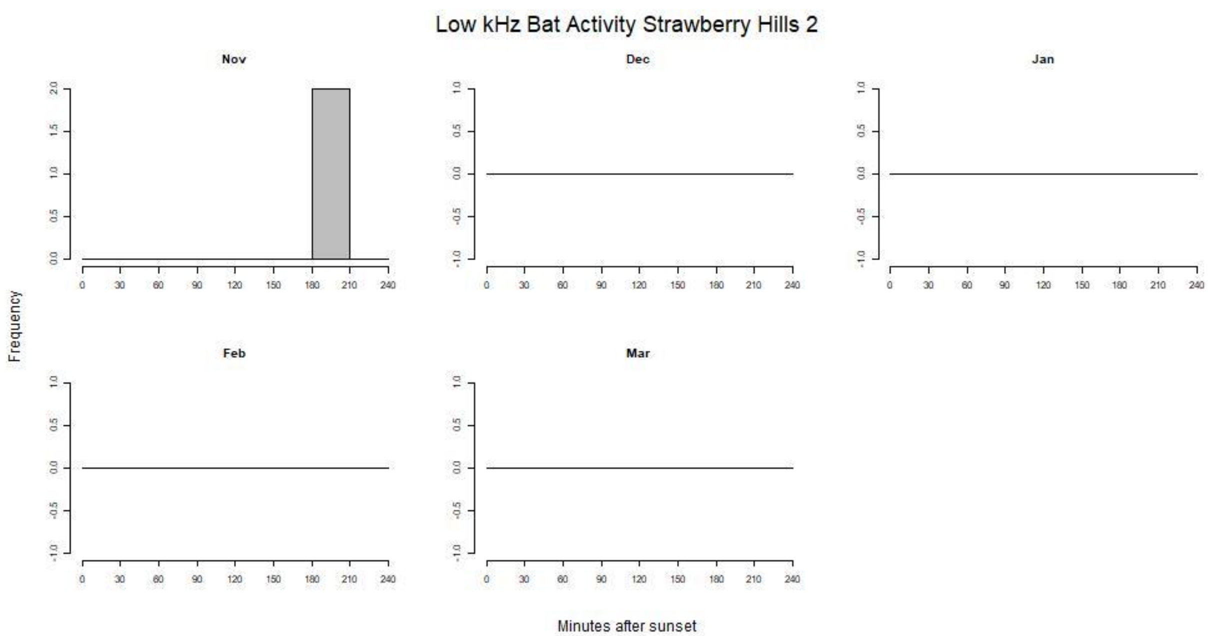


Figure A-22. Hourly activity by month for all low frequency bat species (e.g. Big Brown Bat, Silver-haired bat) at the Strawberry Hills 2 Site.

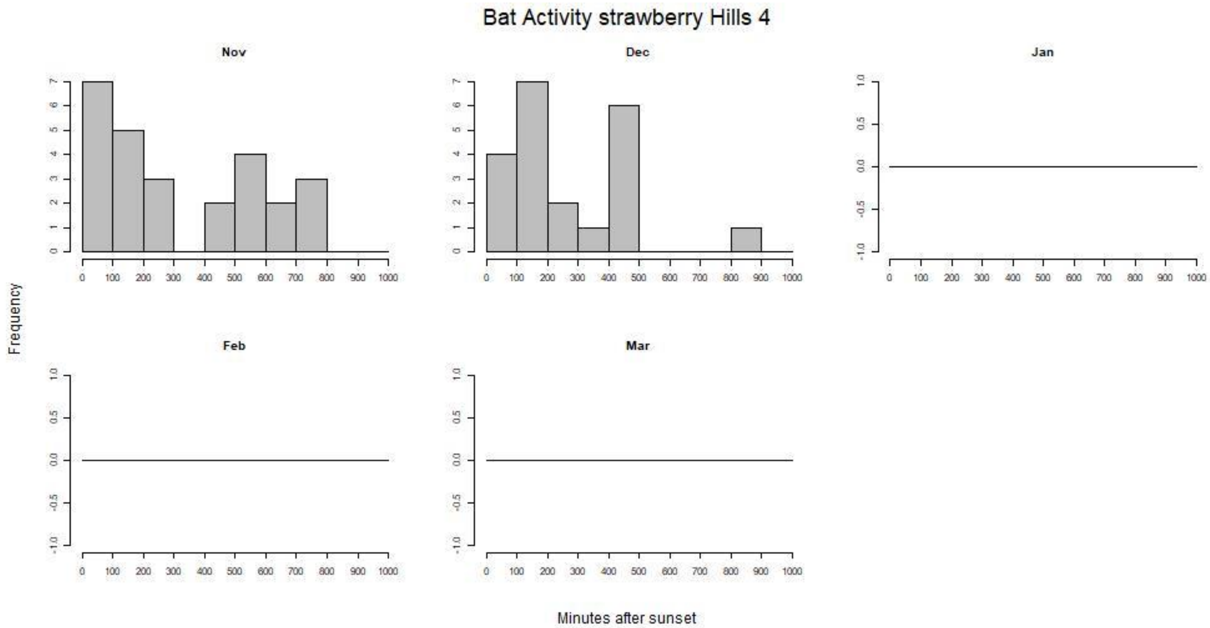


Figure A-23. Hourly activity by month for all bat species at the Strawberry Hills 4 Site.

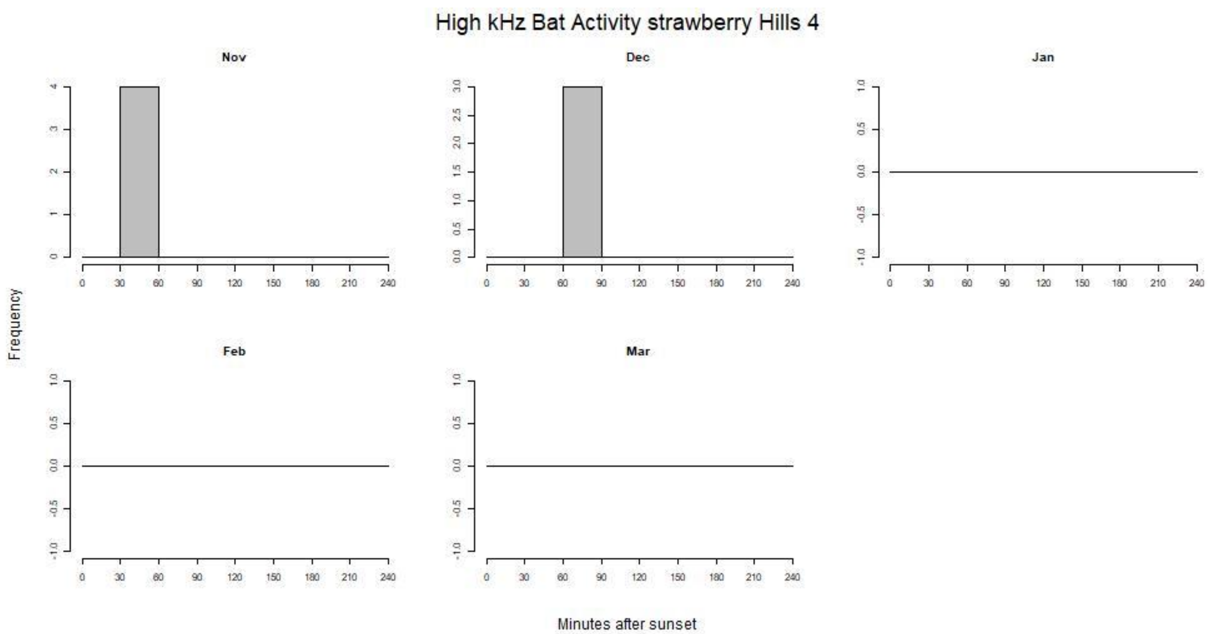


Figure A-24. Hourly activity by month for all high frequency bat species (Myotis bats) at the Strawberry Hills 4 Site.

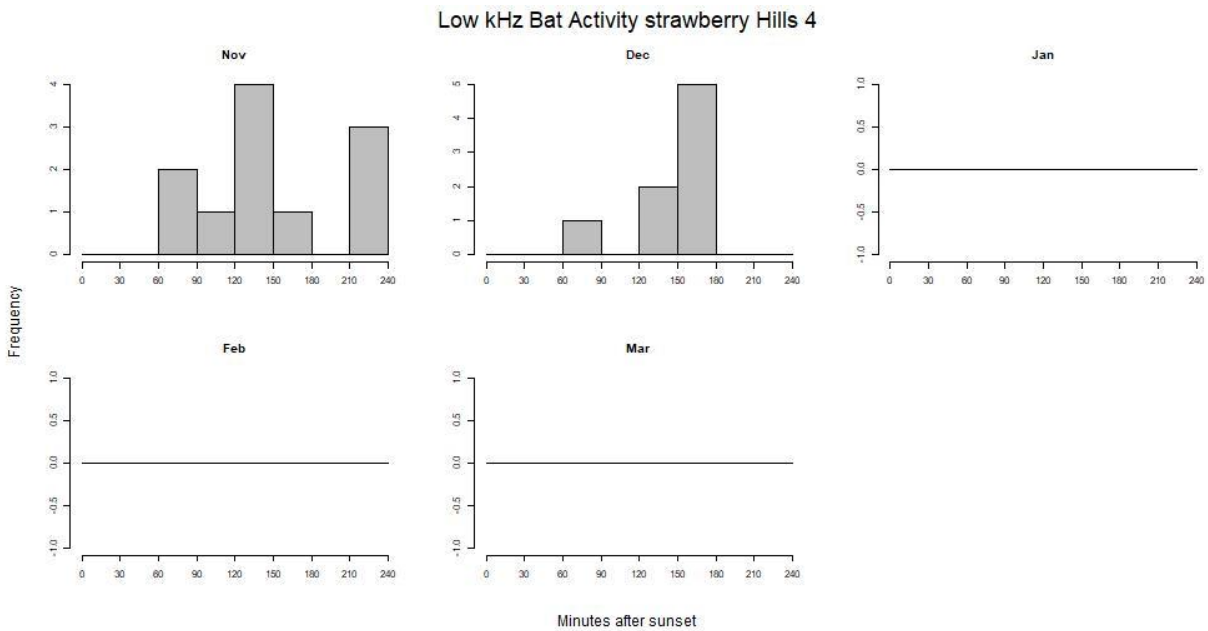


Figure A-25. Hourly activity by month for all low frequency bat species (e.g. Big Brown Bat, Silver-haired bat) at the Strawberry Hills 4 Site.

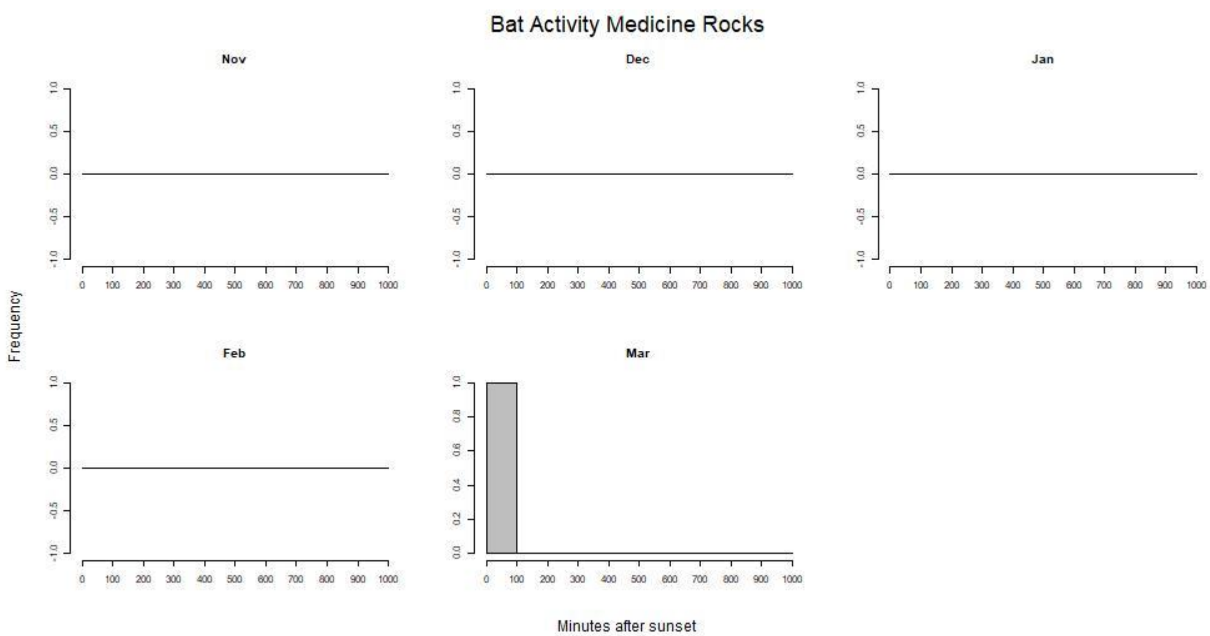


Figure 6. Hourly activity by month for all bat species at the Medicine Rocks Site.

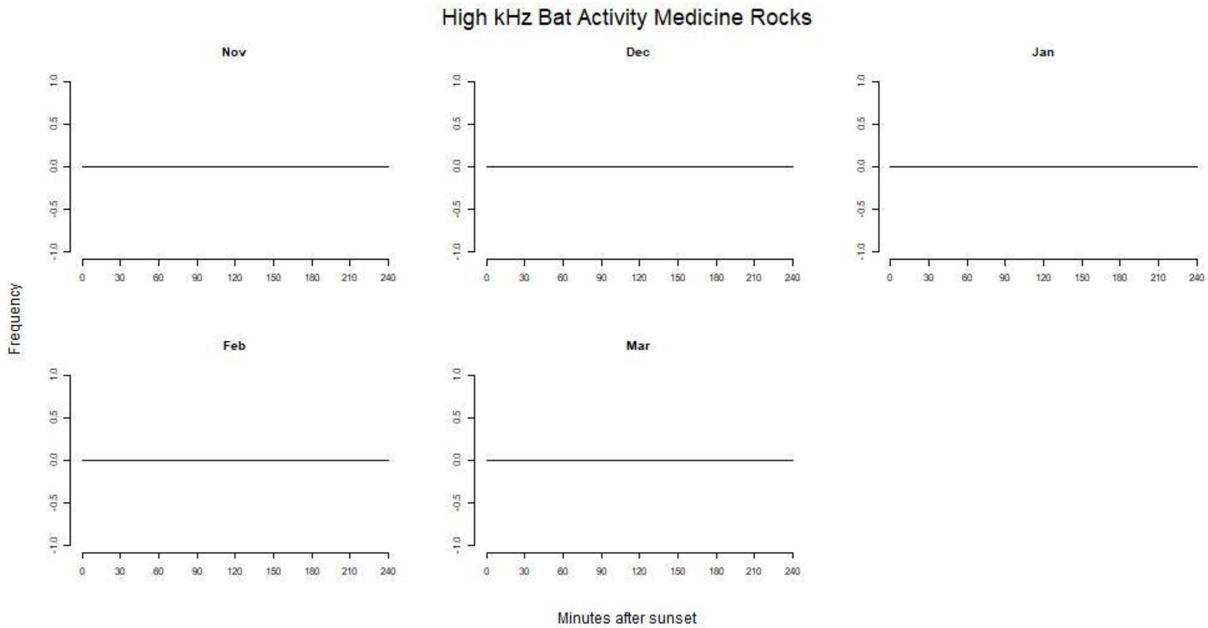


Figure 7. Hourly activity by month for all high frequency bat species (Myotis bats) at the Medicine Rocks Site.

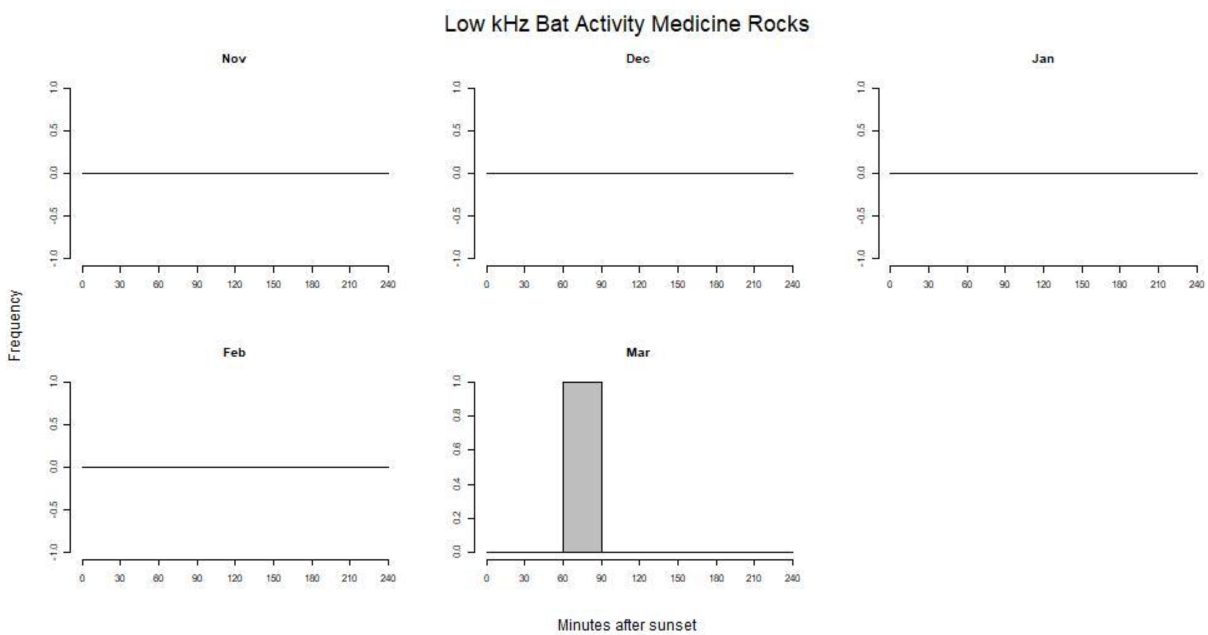


Figure A-28. Hourly activity by month for all low frequency bat species (e.g. Big Brown Bat, Silver-haired bat) at the Medicine Rocks Site.

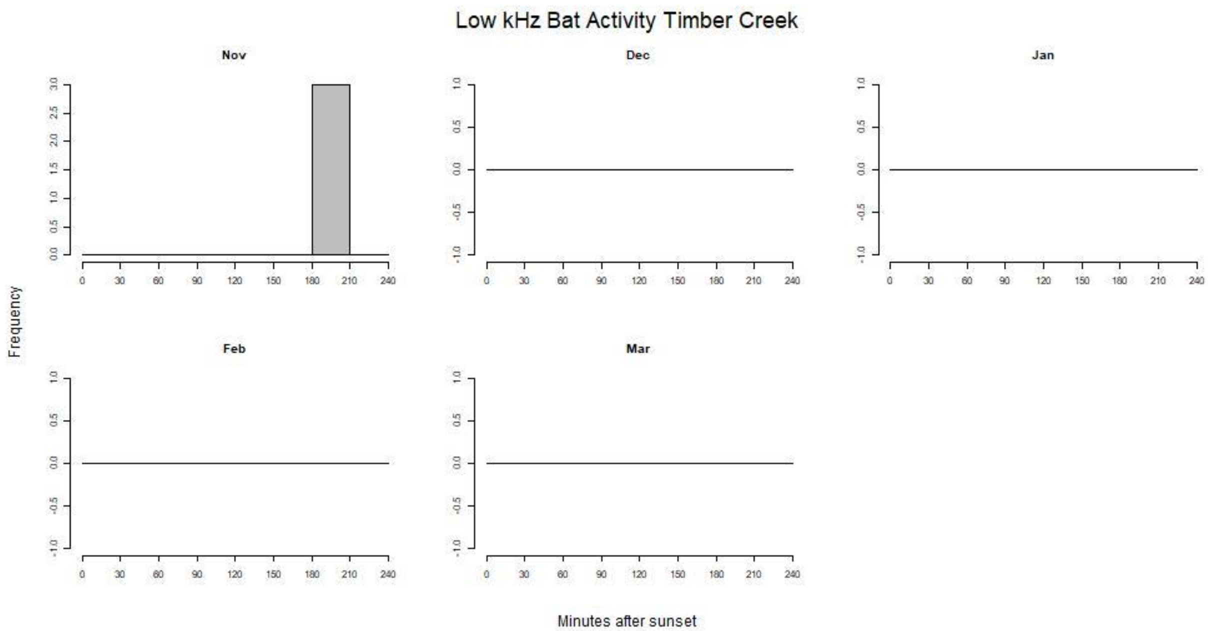


Figure A-29. Hourly activity by month for all bat species at the Timber Creek Site.

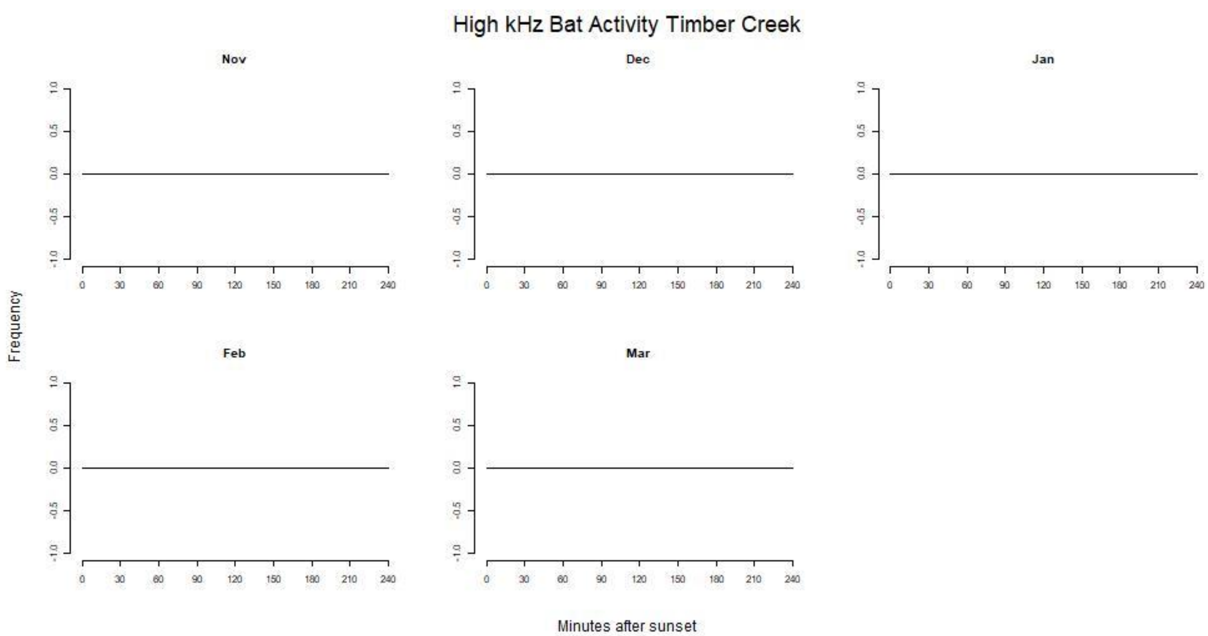


Figure A-30. Hourly activity by month for all high frequency bat species (Myotis bats) at the Timber Creek Site.

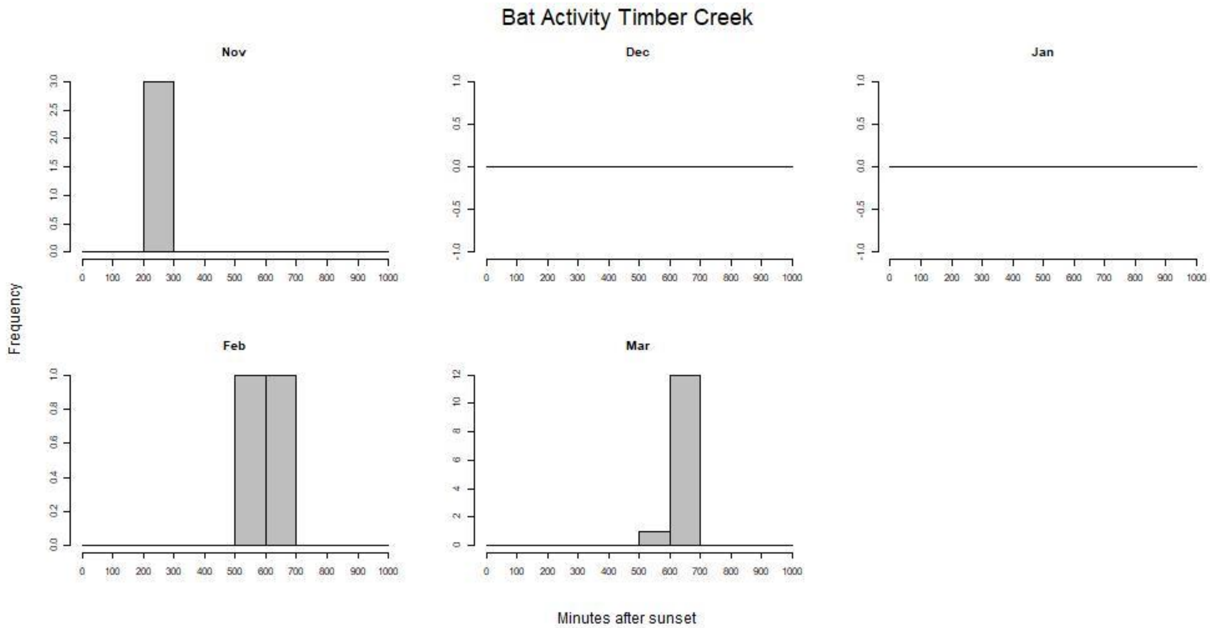
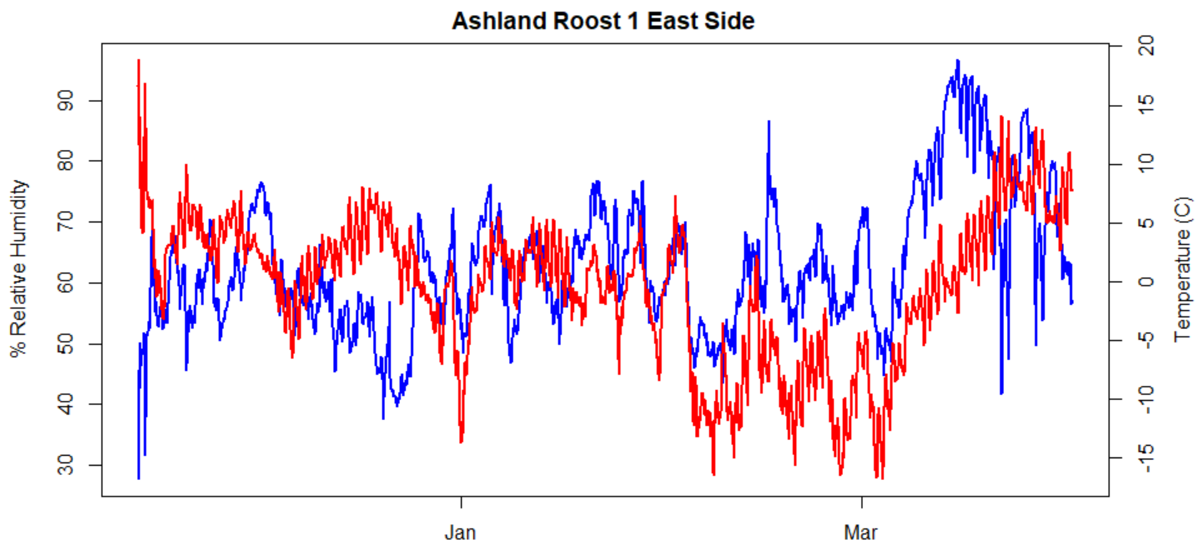


Figure A-31. Hourly activity by month for all low frequency bat species (e.g. Big Brown Bat, Silver-haired bat) at the Timber Creek Site.



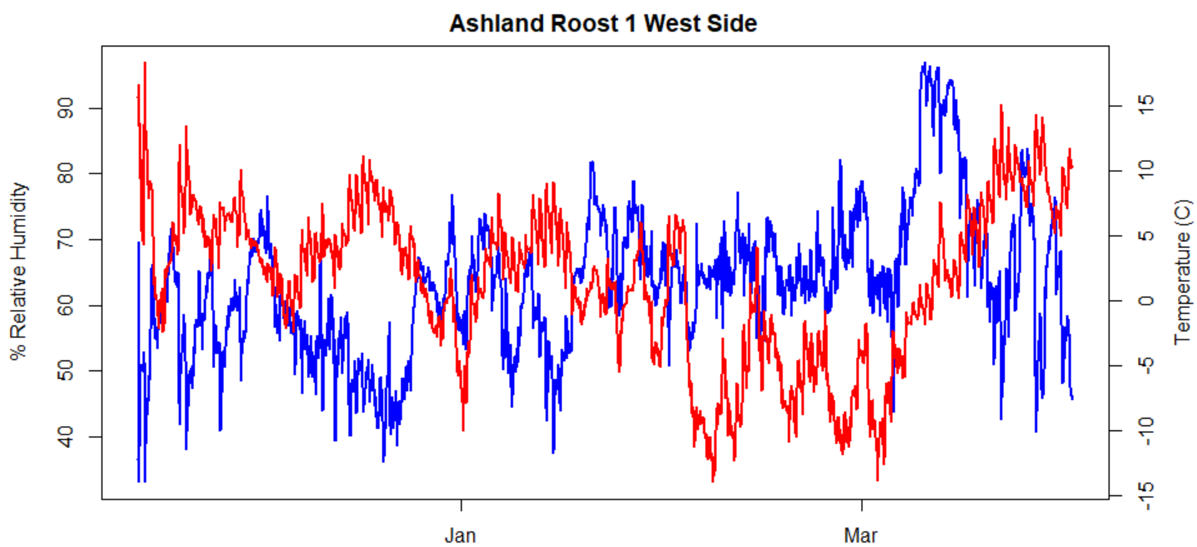


Figure A-32. Temperature (red) and relative humidity (blue) values recorded within the Ashland 1 roost from November 2018 through March 2019. Note two loggers were deployed on the east side and west side of the rock outcrop.

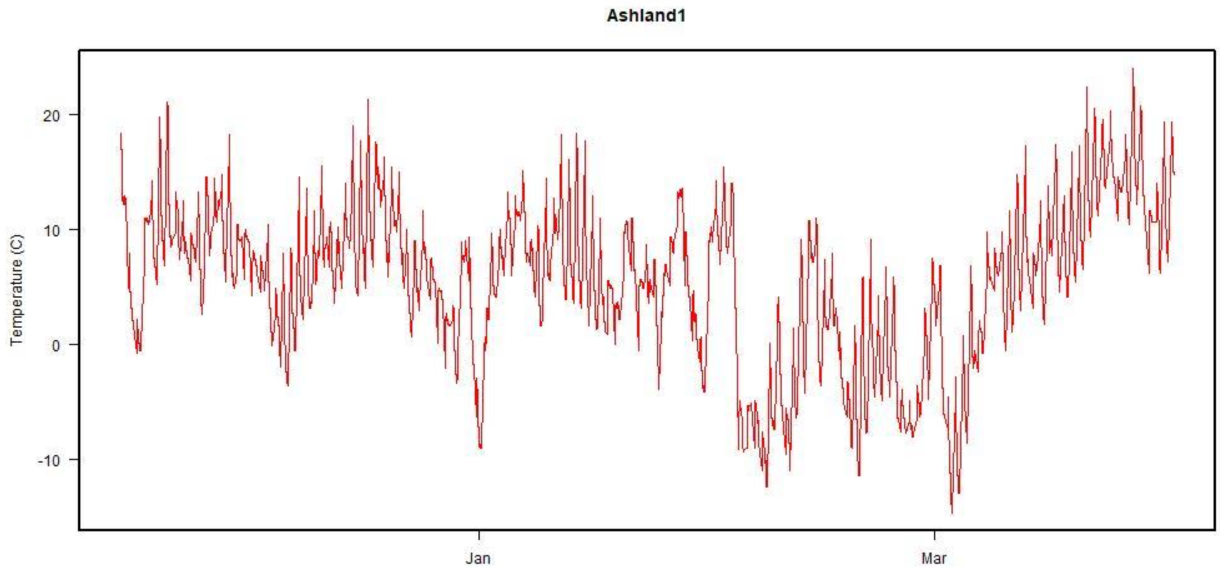


Figure A-33. Temperature recorded by the internal sensor within the Ashland 1 detector from November 2018 through March 2019

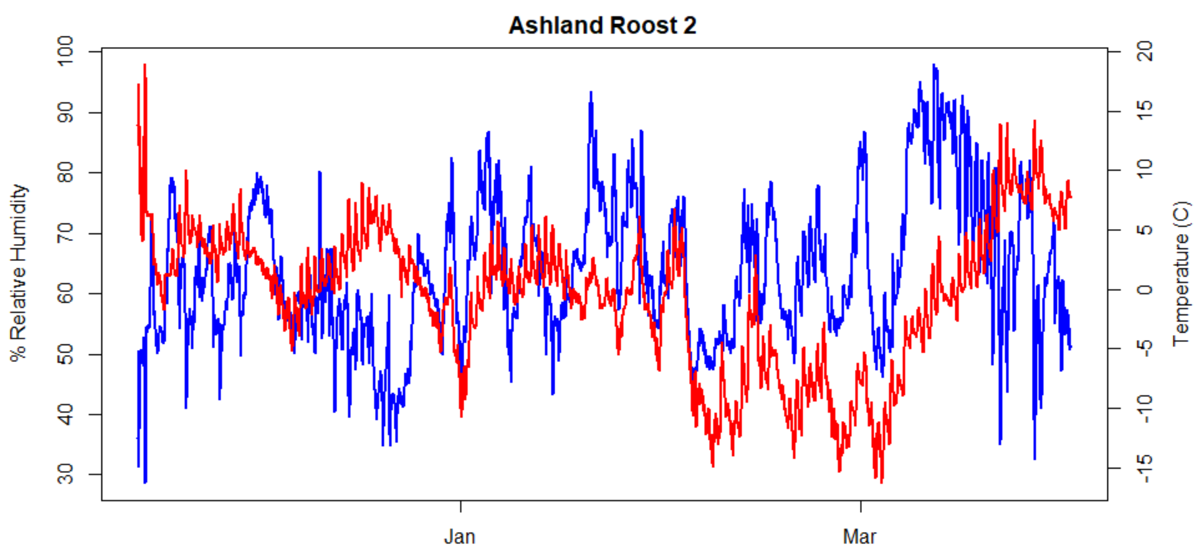


Figure A-34. Temperature (red) and relative humidity (blue) values recorded within the Ashland 2 roost from November 2018 through March 2019. Note this HOBO logger was placed within the East entrance of the feature.

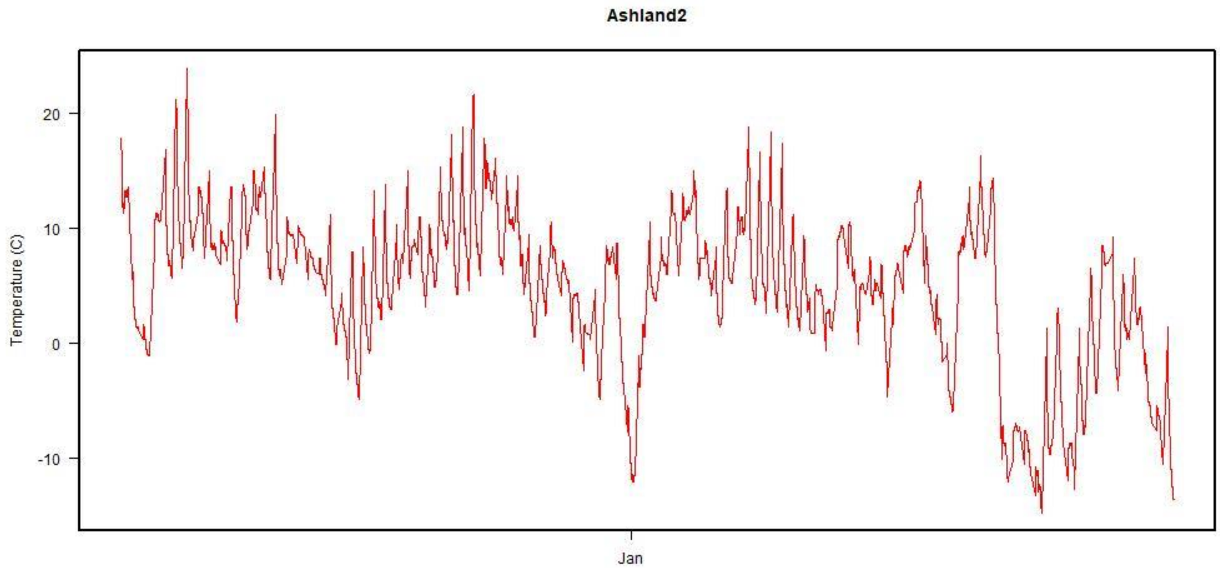


Figure A-35. Temperature recorded by the internal sensor within the Ashland 1 detector from November 2018 through March 2019

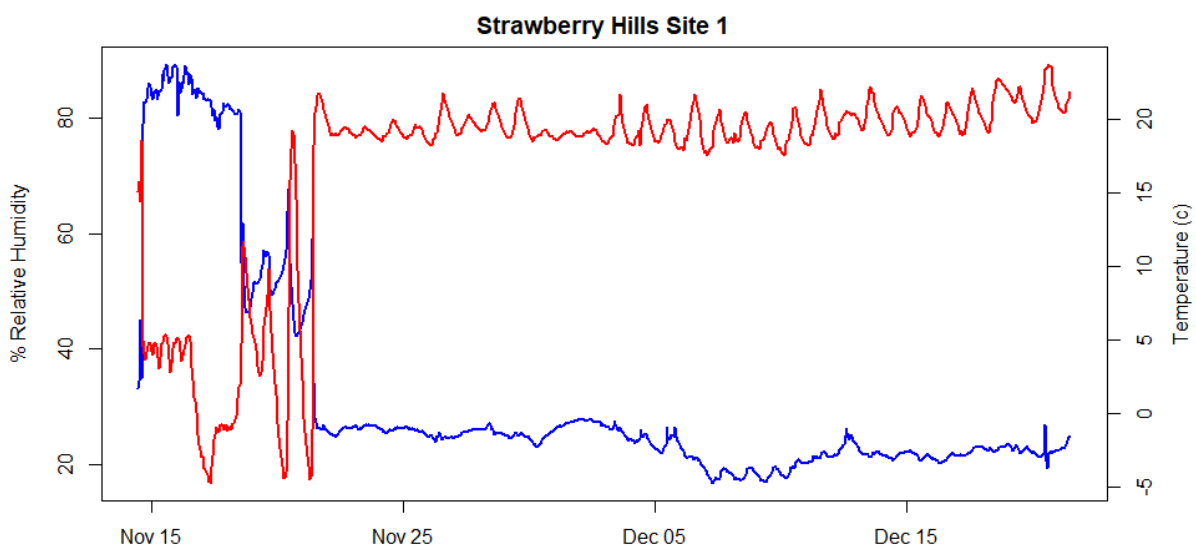


Figure 8. Temperature (red) and relative humidity (blue) values recorded within the Ashland 2 roost from November 2017 through December 2017. Due to equipment failure the device did not record for the full time.

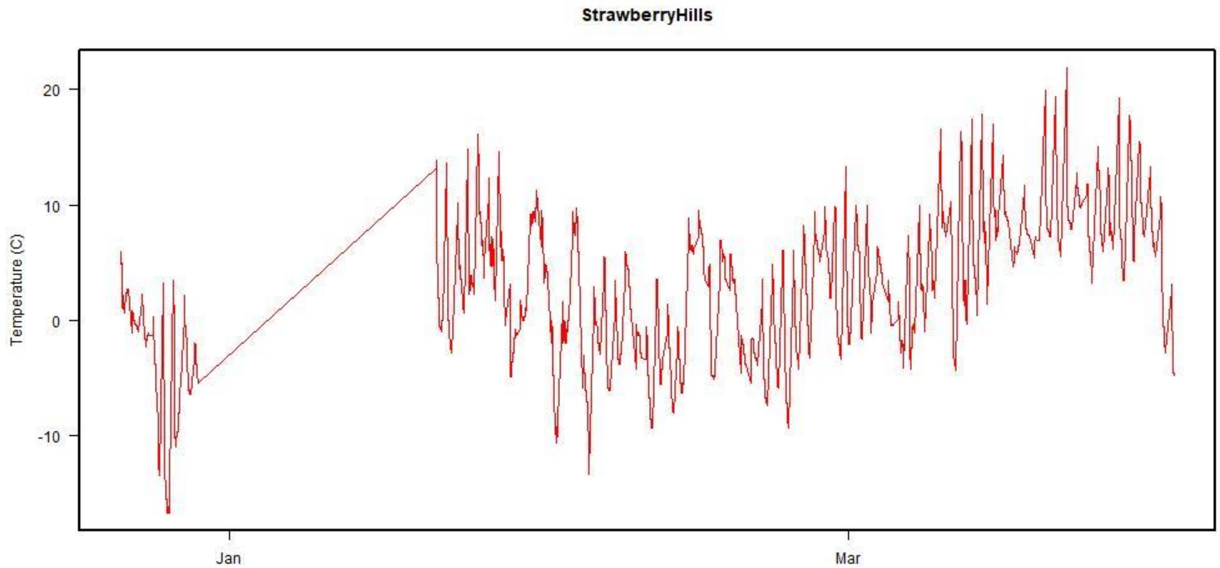


Figure A-37 Temperature recorded by the internal sensor within the Strawberry Hills Site 1 detector from November 2017 through March 2018

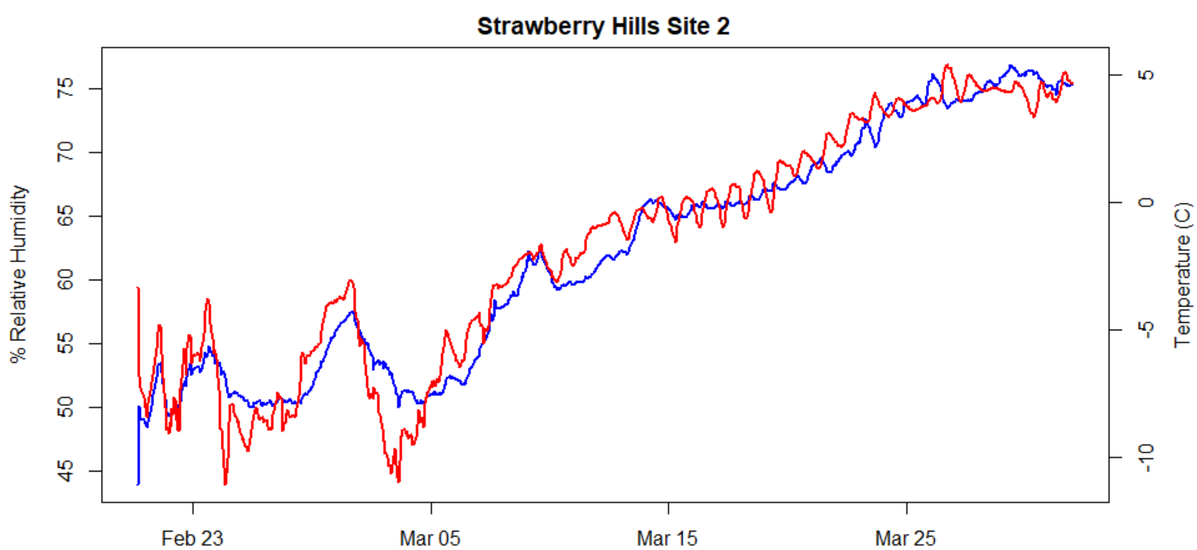


Figure A-38. Temperature (red) and relative humidity (blue) values recorded within the Strawberry Hills Site 2 roost from February 2019 through March 2019.

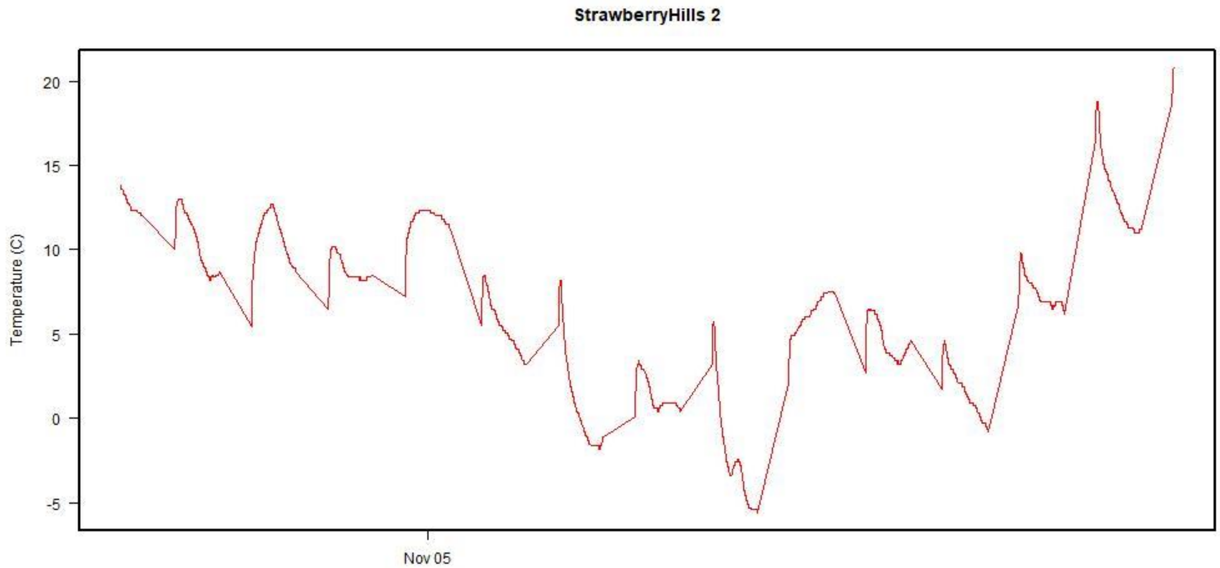


Figure A-399. Temperature recorded by the internal sensor within the Strawberry Hills Site 2 detector in November 2018. Due to equipment failure the detector only recorded for a brief period after deployment.

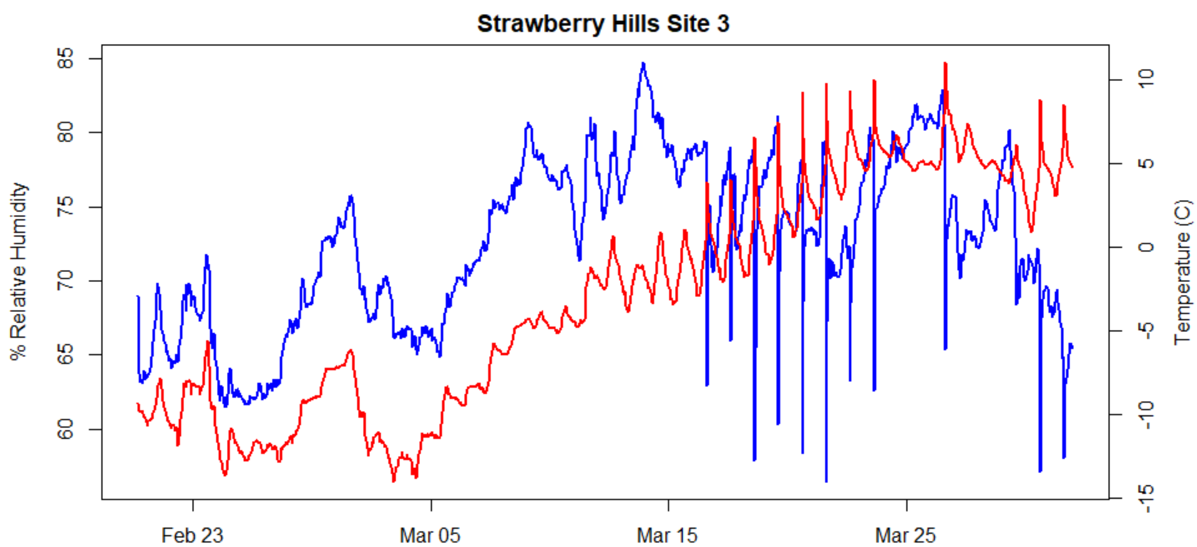


Figure A-40. Temperature (red) and relative humidity (blue) values recorded within the Strawberry Hills Site 3 roost from February 2019 through March 2019.

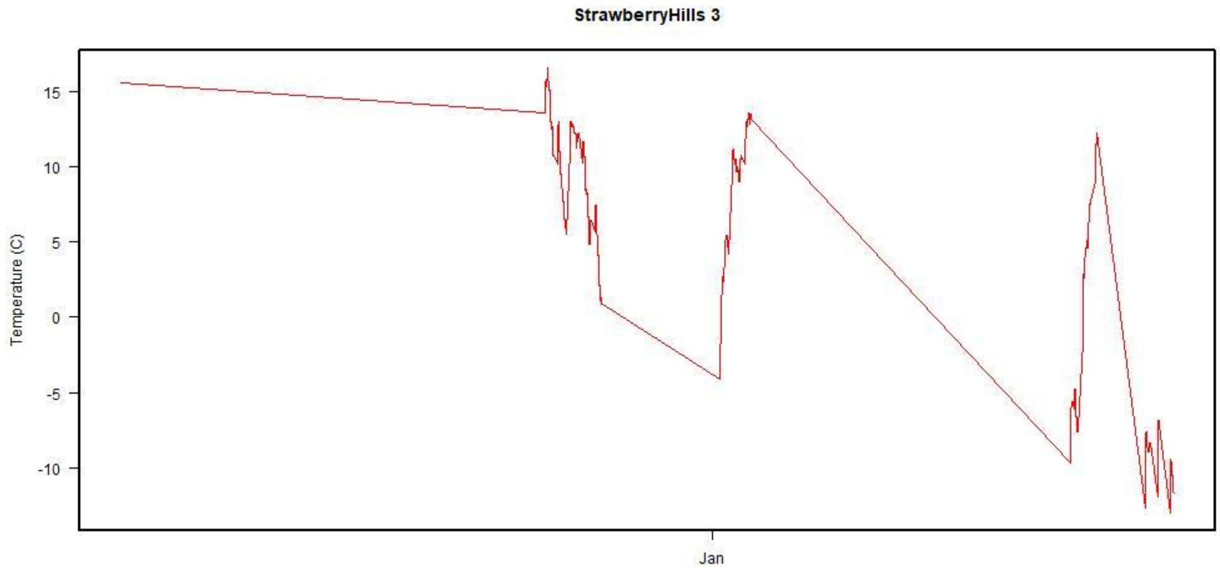


Figure A-41. Temperature recorded by the internal sensor within the Strawberry Hills Site 3 detector from November 2018 through March 2019. Due to equipment failure the detector only recorded intermittently and data across the period are sparse.

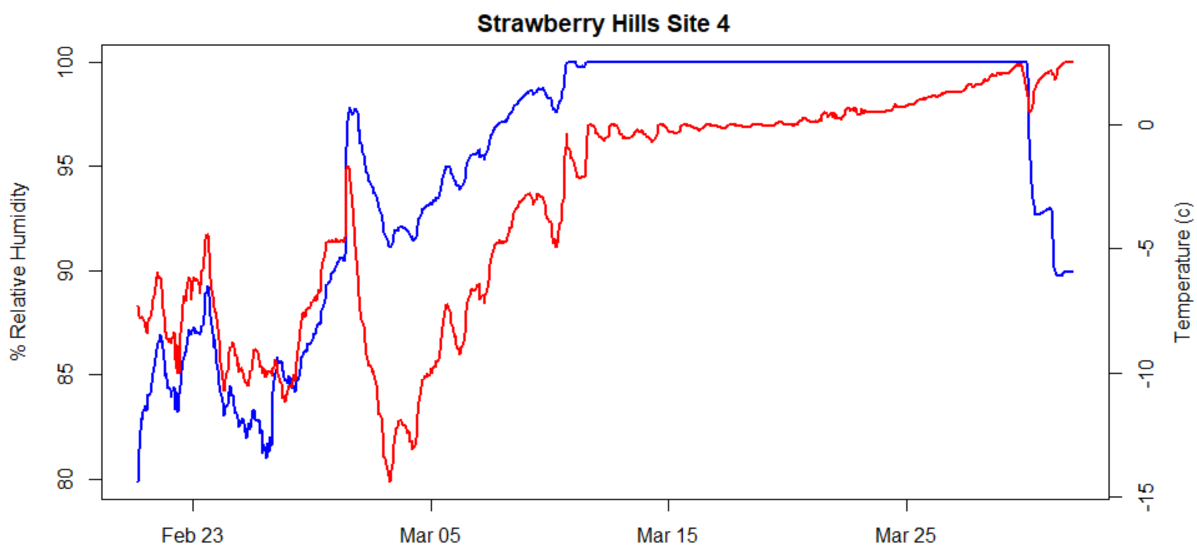


Figure A-42. Temperature (red) and relative humidity (blue) values recorded within the Strawberry Hills Site 4 roost from February 2019 through March 2019.

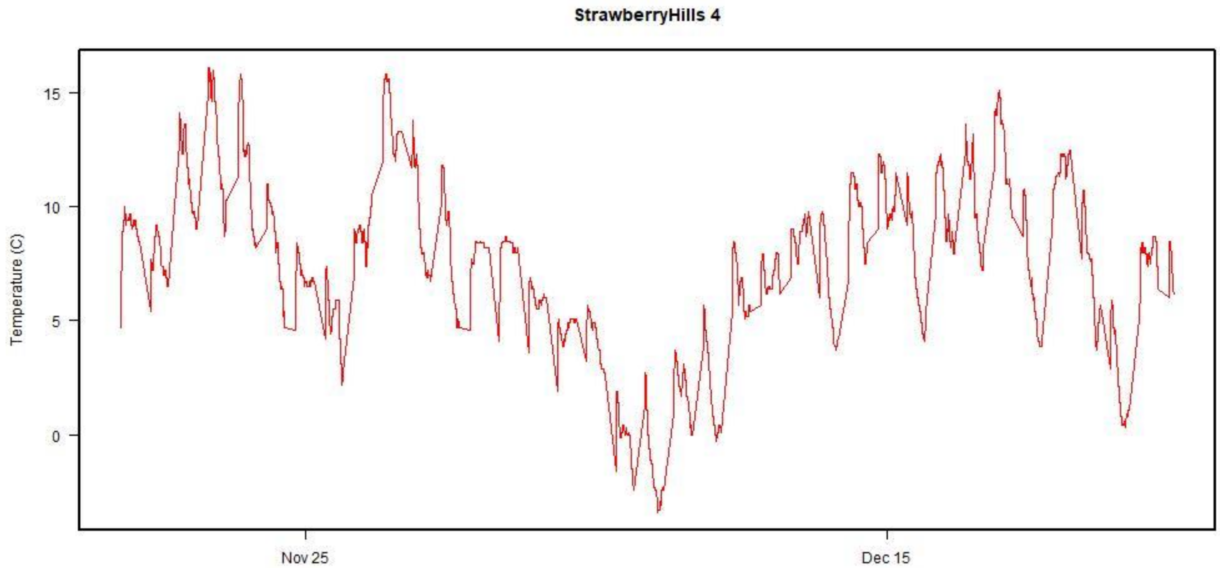


Figure A-43. Temperature recorded by the internal sensor within the Strawberry Hills Site 4 detector in November and December 2018. Due to equipment failure the detector only recorded for a brief period after deployment.