Columbia River Project Water Use Plan

Kinbasket and Arrow Reservoirs Revegetation Management Plan

Effectiveness Monitoring of Wildlife Enhancement Structures in Arrow Lakes Reservoir (Bat Roost Structures)

Implementation Year 3

Reference: CLBMON-11B5

Year 3 Data Report

Study Period: 2022

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Final Report

CLBMON 11B5 – Effectiveness Monitoring of Wildlife Enhancement: 2022 Annual Report

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Disclaimer

This work was conducted by Nupqu Limited Partnership (Nupqu) and Ausenco Sustainability ULC (Ausenco), under the BC Hydro Contract Order #00107818. This report has been prepared by Nupqu and Ausenco, based on fieldwork conducted by Nupqu and Ausenco for the sole benefit and use of BC Hydro. In performing this work, Nupqu and Ausenco has relied in good faith on information provided by others and has assumed that the information provided by those individuals is both complete and accurate. This work was performed to current industry standard practice for similar environmental work, within the relevant jurisdiction and same locale. The findings presented herein should be considered within the context of the scope of work and project terms of reference; further, the findings are time-sensitive and are considered valid only at the time the report was produced. The conclusions and recommendations contained in this report are based upon the applicable guidelines, regulations, and legislation existing at the time the report was produced; any changes in the regulatory regime may alter the conclusions and/or recommendations.

This Executive Summary is not intended to be a stand-alone document, but a summary of findings as described in the following Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Executive Summary

The CLBWORKS-30A Bat Box Construction and Installation program resulted in the installation of 9 artificial bat roost structures at 3 locations within the Arrow Lakes Reservoir in 2019 and 2020. The objective of the program was to improve habitat conditions for wildlife occurring proximate to the Arrow Lakes Reservoir, including a commitment to enhance summer roosting and maternity roosting opportunities for bats. BC Hydro commissioned this related scope of work, *CLBMON-11B5: Monitoring of Bat Roost Enhancement Structures in the Revelstoke Reach,* to monitor the use of the artificial bat roosts.

In July 2019, 2 artificial bark (BrandenBark™) poles were installed at Montana 3 and these poles (M3-Bark1 and M3-Bark2) were monitored throughout the 2020, 2021, and 2022 seasons. In October 2020, 4 roost structures (bark pole [HAY-Bark], mini-condo [HAY-Condo], rocket box [HAY-Rock], and maternity box [HAY-Mat]) were installed at Hay Field, and, in April 2021, 3 roost structures (bark pole [BUR-Bark], rocket box [BUR-Rock], and maternity box [BUR-Mat]) were installed at Burton Flats. The roost structures at Hay Field and Burton Flats were monitored throughout the 2021 and 2022 monitoring seasons.

Effectiveness monitoring consisted of periodic artificial bat roost checks throughout the effective migratory and breeding season. The internal roost temperature was monitored using HOBO MX2303 Series data loggers. A temperature of 40°C or greater was used as a threshold for heat stress for temperate region bats. Guano monitoring was completed during scheduled roost checks and analyzed by Wildlife Genetics International (WGI) in Nelson, British Columbia

The bark poles at Montana 3 have seen increasing use each year of the study and use by little brown myotis (*Myotis lucifugus*) and Yuma myotis (*M. yumanensis*) confirmed by genetic analysis of guano collected at these roosts. Temperature monitoring at these roost structures has shown that although the warmest part of the structures reached temperatures over 60°C, the cooler part of the structures remained below 40°C, providing an opportunity for bats to move within the structure to regulate temperature.

There has been some use at each of the roost structures at Hay Field, with increasing use over the last 2 seasons at HAY-Mat. Little brown myotis was confirmed at all the structures at Hay Field, and Californian myotis (*M. californicus*) was confirmed at the HAY-Condo. HAY-Mat and HAY-Rock appear to have less of a thermal gradient (difference between the cool and warm sensors) than HAY-Bark and HAY-Condo, but the roost structures at Hay Field have relatively few documented overheating events. However, temperature monitoring did not occur consistently throughout the monitoring season in 2022.

Very little guano has been observed at the Burton Flats roost structures, but the use of BUR-Mat by little brown myotis was confirmed by guano genetic analysis in 2022. Temperatures at the warm and cool sensors at BUR-Mat have been documented to exceed 40°C, suggesting a potential lack of thermal refuge within the roost. Temperatures within BUR-Bark and BUR-Rock had a larger thermal gradient and did not exceed 40°C at the cool sensor. Temperature data were not collected over the full monitoring season at these roosts in 2021 and 2022, thus future data collection will improve our understanding of their thermal conditions.

A summary of key interim monitoring results that address BC Hydro's management questions is provided below (Table ES.1). Recommendations for future monitoring seasons include: use of pooled guano sampling to detect additional species that may be using the roost structures less frequently, use of thermal imaging for emergence counts, continuation of frequent roost checks at the beginning and end of the monitoring season to document first and last dates of occupancy, deployment of additional temperature sensors within the BrandenBark™ poles to determine the proportion of roost space below the heat-stress threshold, ensuring consistent temperature data collection to improve our understanding of thermal conditions within the roosts, and painting or shading BUR-Mat to reduce overheating.

Table ES.1 Summary of Effectiveness Monitoring Results

Management Questions		Summary of Key Monitoring Results
MQ-1	Are the wildlife enhancement structures (waterfowl nest boxes and bat day roosts/maternity structures) effective at enhancing habitat quality and quantity for birds and bats?	The artificial bat roosts have been effective at enhancing habitat for bats as shown by the increasing use of the roosts since installation.
MQ-1a	How are the waterfowl nest boxes utilized by waterfowl in terms of species present and apparent nesting success?	Not applicable to this project.
MQ-1b	How are the bat maternity structures utilized in terms of seasonality, intensity of use, species present, and number of days occupied per year?	• Seasonality - Based on the presence of guano, the roost structures are used between May and October. • Intensity of Use - Guano counts indicated that the highest intensity of use is between July to September. • Species Present - Three species were confirmed at the Revelstoke Reach roosts: little brown myotis, Californian myotis (probable), Yuma myotis - One species was confirmed at the Burton roosts: little brown myotis • Days occupied per year - Based on guano presence, structures at Revelstoke Reach, except HAY-Condo, had intermittent occupancy over a minimum of 73 to 150 days. - BUR-Mat was occupied for at least 45 days in 2022 but use was not confirmed at the structures in Burton.

Management Questions		Summary of Key Monitoring Results
MQ-1c	How does the internal temperature of bat maternity structures affect their successful utilization by bats?	• All roosts have experienced overheating events where the internal roost temperature at the warm sensor was above the general threshold for heat stress for temperate region bats (40°C). • Temperatures at the paired cool sensor, however, did not exceed this threshold in any roosts except for BUR-Mat. This indicates that thermal refuge was consistently available in every roost but one throughout the monitoring period. The proportion of roosting space below the heat stress threshold is unknown. • All roost structures have the potential to support maternity roosting. However, some structures have the potential to pose risk to non-volant pups due to extreme high temperatures recorded and lack of thermal refuge.
MQ-2	Which wildlife enhancement structure methods or techniques (including those not yet implemented) are likely to be most effective at enhancing the productivity and suitability of wildlife habitat in the drawdown zone at Revelstoke Reach?	• Artificial roost structures require more time on the landscape to be encountered by bats before their utility to bats can be determined. • Aggregating several types of artificial roost structure designs together in one location is likely to be protective against overheating risk and may also enhance roost uptake. • Measures to mitigate overheating risk at the bark pole and maternity box-type roosts should be considered, such as selecting a lighter roost colour, designs that are tall and well vented, and landscape positions with some late afternoon shade. • Consideration of snag retention and creation, and live tree modification, alongside artificial roost installation as a complimentary approach to habitat enhancement, may be beneficial for safeguarding the availability of suitable habitat across climate change scenarios and timescales.

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1.0 Introduction

The Columbia River Treaty between Canada and the United States of America ratified in 1964, dictated that "treaty dams" were to be built in Canada to provide downstream flood control and water storage for hydroelectric power generation (BC Hydro 2007). The second of these treaty dams, the Hugh Keenleyside Dam near Castlegar, British Columbia (BC) completed in 1968, impounded the Columbia River and Arrow Lakes, creating the Arrow Lakes Reservoir (Figure 1.1). The Arrow Lakes Reservoir extends from the Hugh Keenleyside Dam near Castlegar north to Revelstoke, over approximately 230 kilometers (km).

During European settlement, and later construction of the reservoir, land-clearing and forestry operations removed virtually all forested habitat from within the inundation area. Estimates of the footprint impact of Columbia River basin reservoirs indicate a loss of 26% of wetlands, 21% of riparian cottonwood, and 31% of shallow water and ponds in the BC portion of the basin relative to baseline (Utzig and Schmidt 2011). Currently only small patches of mature riparian cottonwood and annually inundated wetlands exist within the reservoir drawdown zone (van Oort et al. 2016).

The Arrow Lakes Reservoir is unique among reservoirs in that a large proportion of the seasonally inundated terrestrial land is vegetated, providing habitat for wildlife; however, the suitability of drawdown zone available vegetation is heavily modified by the operation of the Hugh Keenleyside Dam. Water storage cycles in the Arrow Lakes Reservoir cause annual drawdown and inundation within the reservoir area. The degree to which habitat is modified by reservoir operations depends on the elevation of the site within the reservoir drawdown zone, and the associated period of inundation. Higher elevation sites have shorter periods of inundation, and a greater diversity of terrestrial plant species and habitat structure.

The creation of the Arrow Lakes Reservoir and the ongoing operations of the Hugh Keenleyside Dam have likely reduced the availability of regional bat foraging and roosting habitat due to the loss of valley-bottom forests and wetlands. The regional availability of large trees, snags, and wetlands has also been reduced due to other land uses, such as agriculture and forestry. The modified ecology in the drawdown zone of the reservoir likely poses habitat limitations for bats; in particular, the availability of suitable roosting structures may be more limiting than food abundance.

The Columbia River Water Use Plan (WUP) was developed by a multi-stakeholder consultative process to inform how reservoir operations could achieve better balance among various values, including wildlife. The Consultative Committee supported the implementation of wildlife physical works (i.e. the CLBWORKS-30A and CLBWORKS-30B projects) to help mitigate the effect of Arrow Lakes Reservoir operations on wildlife and wildlife habitat (Consultative Committee for the Columbia River Water Use Plan 2005). Within the scope of CLBWORKS-30A and CLBWORKS-30B is a commitment to enhance summer roosting and maternity roosting opportunities for bats within affected areas.

In addition to mitigating operational impacts on ecosystem function, roost habitat enhancement is important for bat conservation in the context of limiting stressors to bats affected by the spread of the fungal disease known as white-nose syndrome (Wilcox and Willis 2016). Conservation concern for bats is elevated in western Canada with the discovery of white-nose syndrome in Washington State and Saskatchewan, and the detection of the fungus that causes the syndrome in Alberta and BC (Canadian Wildlife Health Cooperative 2021, 2023; Government of BC 2023). White-nose syndrome has resulted in the death of millions of bats in eastern North America and spurred the federal emergency listing of northern myotis (*Myotis septentrionalis*) and little brown myotis (*M. lucifugus*) as Endangered under the *Species at Risk Act* S.C. 2002, c. 29. Both species are also provincially Blue-listed, as are several other species that could occur in the region: Townsend's big eared bat (*Corynorhinus townsendii*), Yuma myotis (M. *yumanensis*), western small-footed myotis (*M. ciliolabrum*}, and fringed myotis (*M. thysanodes*).

Nine roost structures were installed around the Arrow Lakes Reservoir between 2019 and 2021 and are the subjects of this effectiveness monitoring program (Table 1.1, Figure 1.1, Figure 1.2, Figure 1.3, Photos 1-7). Details regarding site selection and the installation of the roost structures are addressed in the *CLBWORKS-30A Bat Box Construction and Installation Report* (Nupqu Development Corporation 2019).

Table 1.1 Summary of Arrow Lakes Reservoir Artificial Bat Roosts

Site	Roost Structure ID	Roost Type	Location	Install Date
Montana 3	M3-Bark1	BrandenBark™ artificial bark pole	11U 418658, 5643214	July 2019
	M3-Bark2	BrandenBark™ artificial bark pole	11U 418619, 5643237	
Hay Field	HAY-Bark	BrandenBark™ artificial bark pole	11U 421292, 5639227	October 2020
	HAY-Condo	Mini-condo	11U 421292, 5638992	
	HAY-Mat	Maternity box	11U 421284, 5638999	
	HAY-Rock	Rocket box	11U 421286, 5638994	
Burton Flats	BUR-Bark	BrandenBark™ artificial bark pole	11U 435942, 5536649	April 2021
	BUR-Mat	Maternity box	11U 435971, 5536676	
	BUR-Rock	Rocket box	11U 435963, 5536616	

Figure 1.1 Artificial Bat Roost Structure Locations Around the Arrow Lakes Reservoir

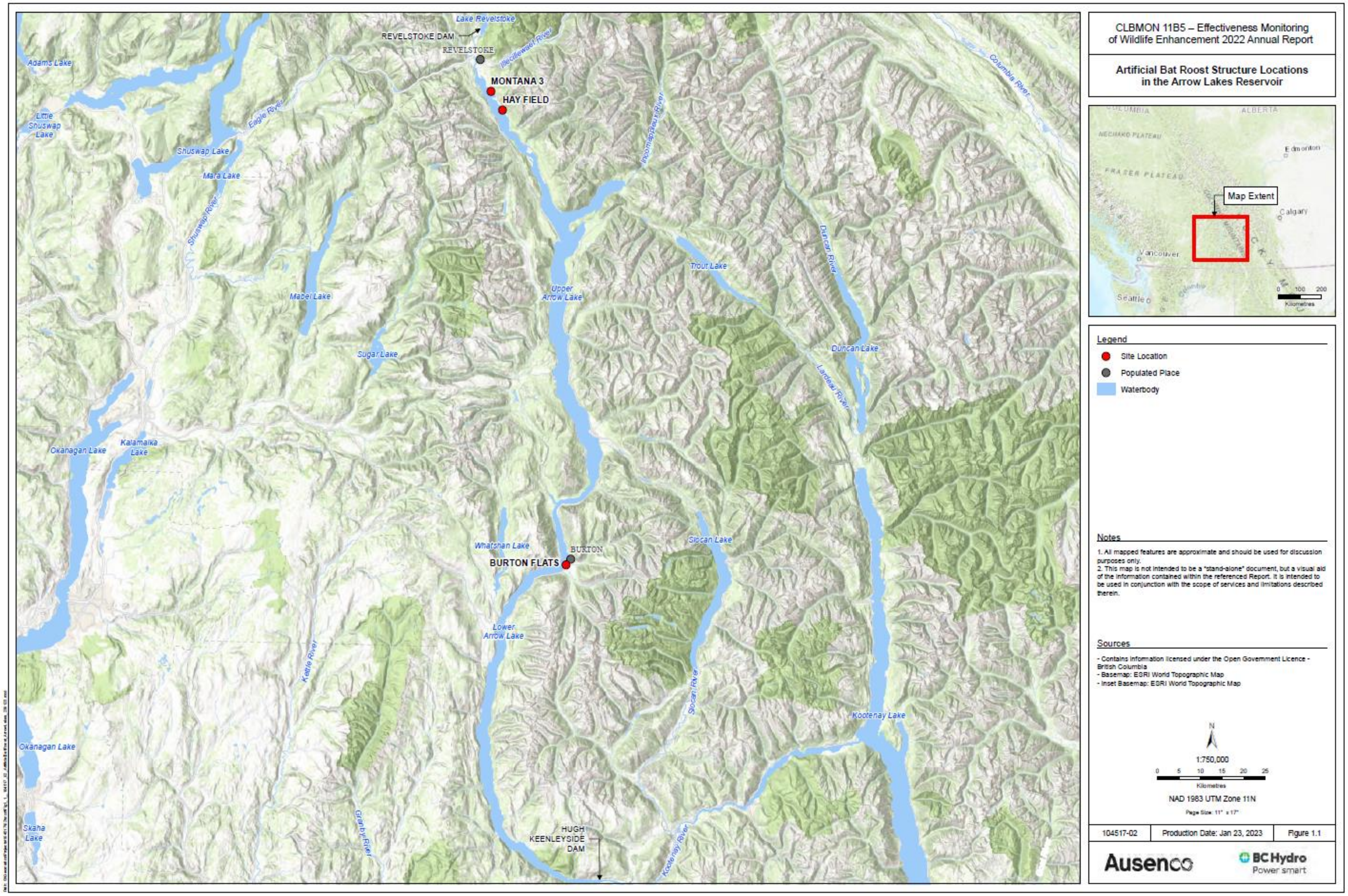

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Figure 1.2 Artificial Bat Roost Structure Locations Around the Revelstoke Reach

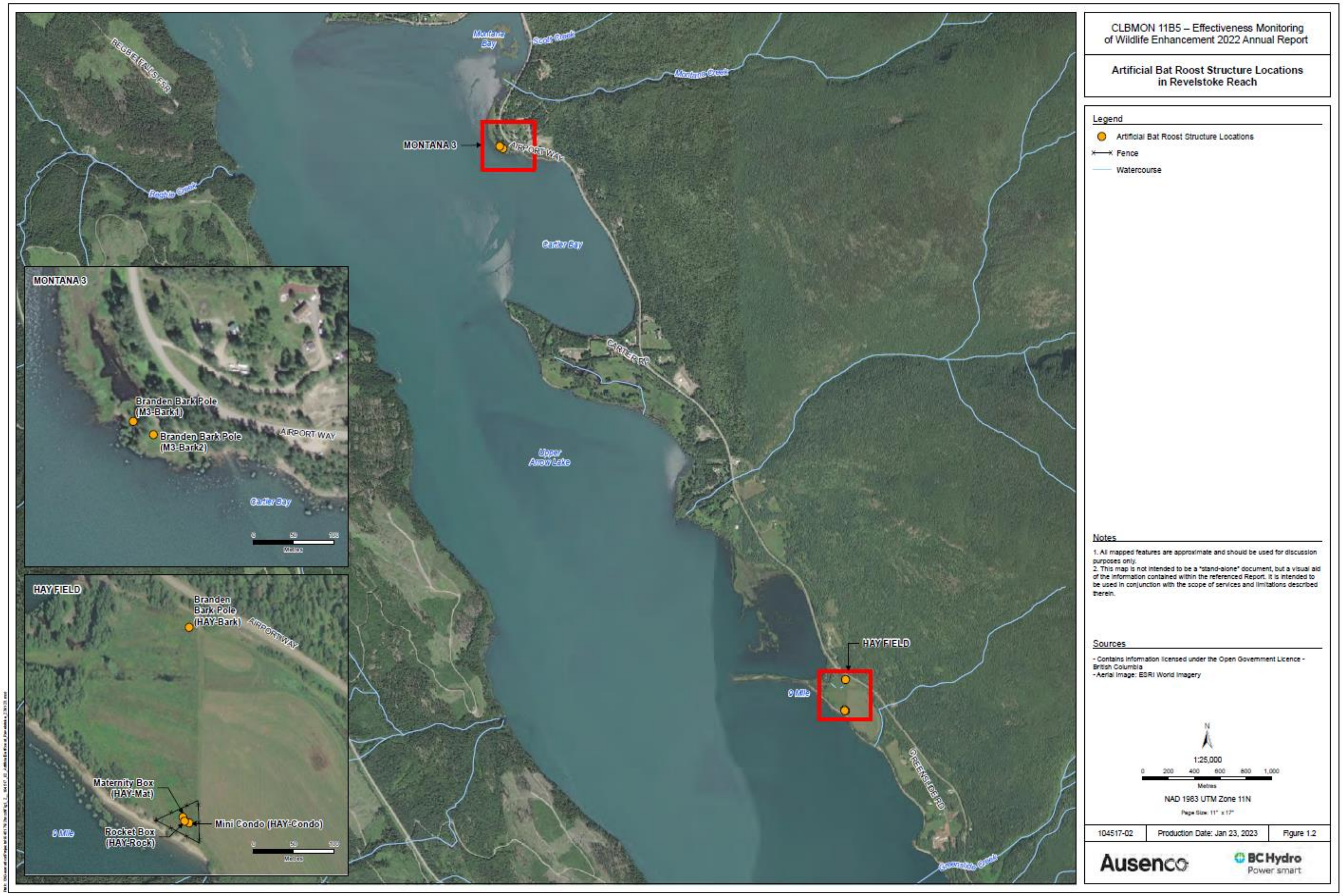

Figure 1.3 Artificial Bat Roost Structure Locations at Burton Flats

Photo 1 BrandenBark™ Artificial Bark Pole Installed at Montana 3 (M3-Bark1)

Photo 2 BrandenBark™ Artificial Bark Pole Installed at Montana 3 (M3-Bark2)

Photo 3 Rocket box (HAY-Rock, left), Maternity Box (HAY-Mat, Centre), and Mini-condo (HAY-Condo, Right) Installed at Hay Field

Photo 4 BrandenBark™ Artificial Bark Pole Installed at Hay Field (HAY-Bark)

Photo 5 BrandenBark™ Artificial Bark Pole Installed at Burton Flats (BUR-Bark)

Photo 6 Rocket Box Installed at Burton Flats (BUR-Rock)

Photo 7 Maternity Box Installed at Burton Flats (BUR-Mat)

Bat box installation is a common technique to enhance roosting habitat across North America and many, but not all, bat species have been documented using them. In BC, they are commonly used by little brown myotis, Yuma myotis, and big brown bat (*Eptesicus fuscus*) and occasionally used by Californian myotis (*Myotis californicus*), long-legged myotis (*M. volans*), and long-eared myotis (*M. evotis*) (BC Community Bat Program 2019). Artificial bat roost structures have been installed across BC, but comprehensive monitoring of the use of these roost structures by bats is lacking. As such, the effectiveness of artificial bat roosts for enhancing roosting habitat is largely unknown.

Internal temperature is an important aspect of roost suitability and is heavily influenced by both bat box design and placement on the landscape (Tillman et al. 2021; Fontaine et al. 2021; Crawford et al. 2022). Monitoring the internal temperature of a newly installed artificial roost provides an indication of whether a roost will be suitable for bats, and whether it could be suitable as a maternity roost, even prior to bat occupancy.

Reproductive female bats generally require warm maternity roosts due to the high energetic demands of pregnancy and lactation (MOE 2016; Wilde et al. 1999). Nursery roosts, a type of maternity roost where females congregate to give birth and rear pups, can be very warm with temperatures reaching 35 to 40°C (Lausen et al. 2022). During the maternity period and particularly during lactation, reproductive female bats limit their use of torpor (i.e. their body temperature and metabolic rate are temporarily lowered to conserve energy), because torpor comes at a reproductive cost of slower fetal and pup development and reduced milk production (Wilde et al. 1999; Willis and Brigham 2007; Bergeson et al. 2021; Crawford et al. 2022). An approximate internal roost temperature of 30°C, up to as high as 40°C, would be suitable for a maternity roost for temperate bats (Tillman et al. 2021; Lausen et al. 2022). Roost temperatures from 30 to 40°C are within what has been referred to as the “permissive” or “prescriptive” temperature range (Mitchell et al. 2018; Tillman et al., 2021). In this temperature range core body temperature is not strongly influenced by ambient temperature (i.e. homeothermy is maintained) and energy is conserved for milk production and pup development. Conversely, males and non- or post-lactating females select cooler day roosts and use torpor for thermoregulation more regularly (MOE 2016). Artificial roosts that are suitable as day roosts for non-reproductive bats have internal temperatures lower than those of maternity roosts, likely remaining lower than approximately 30°C (Tillman et al. 2021).

In addition to helping us understand the potential for a new artificial roost to function as a maternity roost versus as a day roost for non-reproductive bats, monitoring internal roost temperature at new roosts is important because bats roosting in artificial roosts could be subjected to heat stress and heat-induced mortality (Flaquer et al. 2014; Griffiths et al. 2017; Crawford and O'Keefe 2021). The increasing frequency of extreme weather events associated with climate change, such as the heat dome event experienced across southern BC in the summer 2021, compounds this risk (Bideguren et al. 2019). Non-volant pups present in maternity roosts are particularly sensitive to overheating risk because they are less able to thermoregulate early in development, have smaller body sizes that heat up faster and are less able to exit hot roosts (Crawford and O'Keefe 2021). In general, 40°C internal roost temperature is considered the threshold above which there is a risk of heat stress to temperate bats (Crawford and O'Keefe 2021). The lethal heat threshold for temperate region bats is thought to be approximately 45°C (Flaquer et al. 2014; Hoeh et al. 2018; Bideguren et al. 2019; Tillman et al. 2021), though thermal tolerance likely varies between species and the thermoregulatory strategy adopted by bats likely varies based on local climatic conditions (Encarnacao et al. 2012; Czenze et al. 2017; Ancillotto et al. 2018; Crawford and O'Keefe 2021).

The implementation of the CLBWORKS-30A Bat Box Construction and Installation program resulted in the installation of 9 artificial bat roost structures (hereafter referred to as 'roost structures') at 3 locations within the Arrow Lakes Reservoir (**Figure 1.1**). Bat roost structures were built within the Revelstoke Reach near Cartier Bay, Montana Slough, and the Airport Marsh, and further south on Burton Flats. These locations were identified to have existing suitable foraging habitats for bats (Utzig and Schmidt 2011); additionally, foraging habitat was created via wetland enhancements at Burton Flats under CLBWORKS-30A.

BC Hydro commissioned this related scope of work to monitor the effectiveness of the CLBWORKS-30A artificial bat roosts installations: *CLBMON-11B5 Monitoring of Bat Roost Enhancement Structures in the Revelstoke Reach*. Monitoring of these roost structures will contribute to understanding bat use of artificial roosts in BC and guide future enhancement and compensation work.

1.1 Objectives

The objectives for CLBMON-11B5 as per the Terms of Reference (BC Hydro 2017) are to:

1. Assess the effectiveness of wildlife enhancement structures at enhancing wildlife habitat in the drawdown zone of Arrow Reservoir.
2. Provide recommendations about which wildlife enhancement structure methods or techniques are most likely to be effective at enhancing wildlife habitat in the drawdown zone of Arrow Reservoir.

To achieve the above objectives the following Management Questions will be addressed by the monitoring program:

1. Are the wildlife enhancement structures (bat day roosts/maternity structures) effective at enhancing habitat quality and quantity for bats?

a. Not applicable – the part of this question that addresses bird nest-boxes is not relevant for bats and therefore is not addressed in this report.
b. How are the bat maternity structures utilized in terms of seasonality, intensity of use, species presence, and number of days occupied per year?
c. How does the internal temperature of bat maternity structures affect their successful utilization by bats?

2. Which wildlife enhancement structure methods or techniques (including those not yet implemented) are likely to be most effective at enhancing the productivity and suitability of wildlife habitat in the drawdown zone at Revelstoke Reach?

This report summarizes the findings of the artificial roost monitoring efforts in 2022, Year 3 of 5 years of planned monitoring. Key interim findings that address the management questions are summarized and recommendations for alterations to the monitoring program for subsequent years are provided.

2.0 Methods

2.1 Occupancy Monitoring

Occupancy of roost structures was determined using guano traps installed near the base of each structure, via visual roost inspections during roost visits, and by conducting emergence count surveys. Concurrent acoustic monitoring was also conducted during some emergence counts in Revelstoke Reach in 2022.

2.1.1 Guano Traps and Roost Checks

Guano traps were attached to the poles of all the roost structures except HAY-Condo in early spring when the risk of damage from heavy snowfalls had passed. Guano traps were constructed of 2 x 4 lumber with metal mesh forming a flat surface to catch falling guano. Guano traps were approximately 60 cm x 60 cm and positioned as close to the internal roosting space as was feasible, while still allowing easy collection and not interfering with bat flight. Minor maintenance and cleaning of the traps was conducted during monitoring visits.

During each monitoring visit, a biologist using a digital data form recorded information including whether guano was present and an approximate count of the pellets. A light was shone into each roost structure to look for roosting bats and signs of bat occupancy were noted. Guano traps were checked at a minimum frequency of once per month, and, if guano was present, guano samples were collected and samples were labeled and stored for future analysis. Sampled pellets were stored in cotton balls inside a coin envelope with 1 envelope per structure. The envelopes were stored open, in a dry area, to allow the sample pellets to desiccate. After each roost visit, all guano was cleaned from the surface of the guano traps.

Samples were analyzed by Wildlife Genetics International, in Nelson, BC. Genetic analysis consisted of analyzing individual pellets to determine species. Guano pellet DNA was purified using QIAGEN DNeasy Blood and Tissue Kits, with the tissue protocol. Pellets were dipped and swished in digest buffer to remove cells from the surface without disturbing the pellets. Analysis of species was performed by partial sequencing of the mitochondrial *16S rRNA* gene, working with 'anti-ungulate' primers for all rounds of analysis. Up to 3 rounds of analysis were completed for the samples.

2.1.2 Emergence Counts

Observer effort for emergence count surveys was focused on artificial roosts with recent evidence of use (i.e. the presence of guano or a bat observed within the roost). Emergence counts were conducted according to protocols outlined by the BC Community Bat Program (BC Community Bat Program 2022).

During some emergence counts, acoustic monitoring data were recorded using an Echo Meter Touch 2 (Wildlife Acoustics Inc.) to provide additional information about the species present in the vicinity of the artificial roost sites at emergence time. The acoustic data were processed in Kaleidoscope Pro (Wildlife Acoustics 2022) and species or species group labels were assigned to files containing bat calls while viewing the data in AnalookW (Titley Scientific 2022). Bat calls were identified to species or species groups based on call characteristics compared to a reference library of confirmed call signatures for the species potentially present in the region (Table 2.1). Bat calls by species or species group were enumerated using a "bat pass" metric, with 1 pass being attributed to a bat flying through the detection radius of the microphone. Since multiple passes may be made by the same bat, the bat pass results provide a relative index of activity (bat passes per survey effort) and are not an estimate of bat numbers within the sampling area.

Some calls with distinguishing characteristics were identified to a species level. However, calls from some species and lower-quality call recordings have characteristics shared by several species. Calls with overlapping acoustic characteristics make species identification difficult. Bat passes with insufficient detail to identify to the species level were classified into discernable acoustic groups based on their broad call characteristics. Each acoustic group represents several bat species, one of which is the species that made the call. The level of activity for any one species is represented by the bat passes attributable to the species, plus a portion of the species group(s) that also contain that species. Bat species with the potential to occur in the Arrow Lakes Reservoir and the relevant acoustic groupings used in the analysis are provided in Table 2.1.

Table 2.1 Acoustic Groups of Bat Species with the Potential to Occur in the Vicinity of Arrow Lakes Reservoir

Common Name	Scientific Name	Acoustic Groups[1]							
		Unidentified bat	Low -frequency bat	Big brown / silver-haired bat	Eastern red bat / little brown myotis	High-frequency bat	Long-eared bats	Myotis	45 kHz Myotis
big brown bat	*Eptesicus fuscus*								
Californian myotis	*Myotis californicus*								
western small-footed myotis	*Myotis ciliolabrum*								
eastern red bat*	*Lasiurus borealis*								
fringed myotis	*Myotis thysanodes*								
hoary bat*	*Lasiurus cinereus*								
little brown myotis	*Myotis lucifugus*								
long-eared myotis	*Myotis evotis*								
long-legged myotis	*Myotis volans*								
northern myotis*	*Myotis septentrionalis*								
silver-haired bat	*Lasionycteris noctivagans*								
Townsend's big-eared bat*	*Corynorhinus townsendii*								
Yuma myotis	*Myotis yumanensis*								

Note: [1] Gray shading indicates potential species included in an acoustic grouping.
[*] Species is unlikely to use bat boxes.

2.2 Temperature Monitoring

Temperature data collection followed the recommendations of the BC Community Bat Program (Kellner and Sanders 2018). HOBO MX2303 Series Data Loggers with dual temp sensors were deployed in each roost structure. Two temperature probes were arranged to capture the range of temperatures within the structures. Externally mounted electrical conduit boxes house the MX2303 data logger units, and each of the 2 probes are housed inside a white PVC tube. The PVC tube covers the anterior portion of the sensor to ensure that guano does not touch or interfere with the probe. The tubes were mounted inside each structure at 2 different heights: 1) near the top of the structure on the south side, representing the highest internal temperature, and 2) in the lower portion of the structure on the north side, representing the lowest internal temperature. This arrangement of the temperature probes will allow for the determination of the temperature range available to bats within each structure.

Ambient temperature was recorded with HOBO Pendant MX Temp-MX2201 devices that were deployed in conjunction with a solar radiation shield (RS1 by Onset). One device to record ambient temperature was deployed at Montana 3 in Revelstoke in 2019 and another was deployed at Burton Flats in 2021.

Temperatures were recorded at 10-minute intervals. The dates for which temperature data were collected varied by location due to roost structure set-up timing and logistical constraints. Temperature data were downloaded from the data loggers on at least a monthly basis and data from all downloads were compiled at the end of the season.

These data were used to determine the maximum, mean, and minimum temperatures at each sensor within each structure and plot figures showing the change in temperature throughout the potential occupancy period. Data were compiled, formatted, and plotted with R (R Core Team 2023), using the tidyverse packages (Wickham et al. 2019).

3.0 Results

3.1 Occupancy Monitoring

The roost structures were visited regularly during the monitoring season for guano counts and collection, as well as emergence counts. The following sections describe the results of these occupancy monitoring visits.

3.1.1 Montana 3

In 2022, M3-Bark1 was visited 23 times from April 8 to November 2 and guano was collected on 10 days (Table 3.1). Twelve pellets from 4 days were submitted for analysis (Table 3.1). All guano successfully analyzed was attributed to little brown myotis and 5 pellets failed to produce results. Guano was first observed at M3-Bark1 on May 14 and last observed on October 15. Guano was present on all visits between May 27 and September 13, indicating the structure was consistently used from at least mid-May through mid-September.

M3-Bark2 was visited 23 times between April 8 and November 2 and guano was collected on 12 days (Table 3.1). Twelve pellets from 5 days were submitted for analysis and all except 1 were successfully analyzed (Table 3.1). Ten pellets were attributed to little brown myotis and 1 pellet from October 23 was attributed to Yuma myotis. Guano was first observed at M3-Bark2 on May 20 and last observed on October 23. Guano was present on all visits between May 20 and September 1, indicating the structure was used consistently between mid-May and August.

Emergence counts were completed on June 1, June 29, and August 4 at M3-Bark1 and M3-Bark2. Acoustic monitoring was conducted during the June 1 and June 29 counts.

On June 1, 3 bats were counted emerging from M3-Bark1, and no bats were observed emerging from M3-Bark2. Concurrent acoustic monitoring recorded 9 bat passes in the vicinity of the roosts during the emergence count (Table 3.2). Most of these passes (8) were classified as *Myotis* sp. and 1 was attributed to the eastern red bat / little brown myotis (*Lasiurus borealis* / *Myotis lucifugus*) species group.

On June 29, 11 bats were counted emerging from M3-Bark1 and 1 bat was counted emerging from M3-Bark2. Concurrent acoustic monitoring recorded 65 bat passes in the vicinity of the roosts during the emergence count (Table 3.2). Most bat passes were attributed to the *Myotis* species group (52). Some bat passes were also attributed to the high-frequency bat species group (6) and the big brown bat / silver-haired bat group (*Eptesicus fuscus* / *Lasionycteris noctivagans*, 2). The remaining bat passes were attributed to the following species: little brown myotis (2), long-eared myotis (*Myotis evotis*, 1), western small-footed myotis (*Myotis ciliolabrum*, 1), and northern myotis (1).

On August 4, 3 bats were counted emerging from M3-Bark1 and 4 bats were counted emerging from M3-Bark2. No acoustic monitoring was conducted during the August counts.

Table 3.1 Occupancy Monitoring Results for Montana 3 Roosts in 2022

Date of Roost Check	Number of Guano Pellets Present[1]	Guano Collected?	Number of Pellets Analyzed	Guano Genetic Analysis Results	Emergence Count Results
M3-Bark1					
April 8	0	No			
April 26	0	No			
May 4	0	No			
May 14	2	Yes			
May 20	0	No			
May 27	8	Yes	3	little brown myotis	
June 1	-	No			3 bats observed
June 10	3	Yes			
June 22	12	Yes			
June 29	250	No			11 bats observed
July 7	1	Yes			
July 20	200	Yes			
July 22	80	Yes	3	little brown myotis	
August 4	195	No			3 bats observed
August 5	350	Yes			
August 16	215	Yes	3	little brown myotis, 2 pellets failed	
September 1	110	Yes			
September 16	13	No			
September 23	0	No			
September 29	0	No			
October 15	4	Yes	3	All pellets failed	
October 23	0	No			
November 2	0	No			
M3-Bark2					
April 8	0	No			
April 26	0	No			
May 4	0	No			
May 14	0	No			
May 20	8	Yes	3	little brown myotis	
May 27	27	Yes			
June 1	-	No			No bats observed

Date of Roost Check	Number of Guano Pellets Present[1]	Guano Collected?	Number of Pellets Analyzed	Guano Genetic Analysis Results	Emergence Count Results
June 10	125	Yes			
June 22	312	Yes			
June 29	5	No			1 bat observed
July 7	400	Yes			
July 20	80	Yes			
July 22	350	Yes	3	little brown myotis	
August 4	-	No			4 bats observed
August 5	72	Yes			
August 16	52	Yes	3	little brown myotis	
September 1	8	Yes			
September 16	0	No			
September 23	0	No			
September 29	0	No			
October 15	2	Yes	2	little brown myotis, 1 pellet failed	
October 23	1	Yes	1	Yuma myotis	
November 2	0	No			

Note: [1] Pellet counts greater than 100 pellets are approximate.

Table 3.2 Bat Activity Recorded Near the M3-Bark2 Artificial Roost During Emergence Counts in 2022

Bat Species or Group		Number of Bat Passes by Date	
Common Name	Scientific Name	June 1	June 29
big brown bat / silver-haired bat group	*Eptesicus fuscus / Lasionycteris noctivagans*	0	2
eastern red bat / little brown myotis	*Lasiurus borealis / Myotis lucifugus*	1	0
little brown myotis	*Myotis lucifugus*	0	2
long-eared myotis	*Myotis evotis*	0	1
western small-footed myotis	*Myotis ciliolabrum*	0	1
northern myotis	*Myotis septentrionalis*	0	1
Myotis group	*Myotis* sp.	8	52
High-frequency bat group	*Myotis* sp. / *Lasiurus borealis*		6
	Total	9	65

3.1.2 Hay Field

HAY-Bark was visited 20 times between April 8 and November 2 and guano was collected on 8 days (Table 3.3). Ten guano pellets from 3 days were submitted for analysis, but only 2 were successfully analyzed (Table 3.3). These 2 pellets were attributed to little brown myotis. Guano was first observed on July 20 and last observed on October 15. Guano was present on most visits between those dates, indicating consistent use of the structure and potential for its use as a maternity roost.

HAY-Condo was visited 21 times between April 8 and November 2 and guano was collected on 12 days (Table 3.3). Twelve guano pellets from 4 days were submitted for analysis and 9 were successfully analyzed (Table 3.3). One pellet was attributed to little brown myotis, and the rest were determined to be from deermice. Guano was first observed on May 4 and last observed on September 29. Guano was present on most visits between those dates; however, it was also noted that some of the pellets may have been mouse droppings. This roost does not have a guano trap, so many pellets were collected from the ground below the structure.

HAY-Mat was visited 23 times between April 8 and November 2 and guano was collected on 13 days (Table 3.3). Sixteen guano pellets from 5 days were submitted for analysis and 14 were successfully analyzed (Table 3.3). All pellets were attributed to little brown myotis. Guano was first observed on June 10 and last observed on October 23. Guano was present on most visits between those dates, indicating consistent use of the structure and potential for its use as a maternity roost.

HAY-Rocket was visited 21 times between April 8 and November 2 and guano was collected on 5 days (Table 3.3). Twelve guano pellets from 4 days were submitted for analysis and 10 were successfully analyzed (Table 3.3). All 10 pellets were attributed to little brown myotis. Guano was first observed on May 14 and last observed on October 15, but was only present sporadically throughout the monitoring season, indicating it is unlikely to have been used as a maternity roost.

No emergence counts were completed at HAY-Bark in 2022.Emergence counts were completed on July 19 at HAY-Mat and HAY-Rocket, and August 10 at HAY-Condo, HAY-Rock, and HAY-Mat. On July 19, 2 bats were counted emerging from HAY-Mat and 1 bat was counted emerging from HAY-Rock. Bats were also heard within both of these structures. Concurrent acoustic monitoring recorded 12 bat passes in the vicinity of the roost during the emergence count (Table 3.4). These passes were attributed to the following species and species groups: big brown bat / silver-haired bat group (4), hoary bat (*Lasiurus cinereus*, 2), little brown myotis (1), long-eared myotis (3), Californian myotis (1), and fringed myotis (*Myotis thysanodes*, 1).

On August 10, observers counted 1 bat emerging from each of HAY-Mat and HAY-Condo, but no bats were observed at HAY-Rock. Acoustic monitoring was not conducted during this count.

Table 3.3 Occupancy Monitoring Results for Hay Field Roosts in 2022

Date of Roost Check	Number of Guano Pellets Present[1]	Guano Collected?	Number of Pellets Analyzed	Guano Genetic Analysis Results	Emergence Count Results
HAY-Bark					
April 8	0	No			
April 26	0	No			
May 4	0	No			
May 14	0	No			
May 20	0	No			
May 27	0	No			
June 10	0	No			
June 22	0	No			
July 7	0	No			
July 20	15	Yes			
July 22	0	No			
August 5	45	Yes			
August 16	42	Yes	3	little brown myotis, 2 pellets failed	
September 1	75	Yes			
September 16	47	Yes	4	little brown myotis, 3 pellets failed	
September 23	8	Yes			
September 29	23	Yes			
October 15	3	Yes	3	All pellets failed	
October 23	0	No			
November 2	0	No			
HAY-Condo					
April 8	0	No			
April 26	0	No			
May 4	10	Yes	3	deermouse	
May 14	12	No			
May 20	7	Yes			
May 27	1	Yes			
June 10	11	Yes			
June 22	120 – on ground, may have been mice	Yes	3	All pellets failed.	
July 7	4	Yes			

Date of Roost Check	Number of Guano Pellets Present[1]	Guano Collected?	Number of Pellets Analyzed	Guano Genetic Analysis Results	Emergence Count Results
July 20	1	Yes			
July 22	2	Yes			
August 5	1	Yes			
August 10	-	No			1 bat observed
August 16	4	Yes	3	little brown myotis (2), deermouse (1)	
September 1	0	No			
September 16	0	No			
September 23	1	Yes			
September 29	3	Yes	3	deermouse	
October 15	0	No			
October 23	0	No			
November 2	0	No			
HAY-Mat					
April 8	0	No			
April 26	0	No			
May 4	0	No			
May 14	0	No			
May 20	0	No			
May 27	0	No			
June 10	7	Yes	3	little brown myotis, 2 pellets failed	
June 22	52	Yes			
June 29	42	Yes			
July 7	52	Yes			
July 19	-	No			2 bats observed
July 20	150	Yes			
July 22	200	Yes	3	little brown myotis	
August 5	170	Yes			
August 10	-	No			1 bat observed
August 16	200	Yes	4	little brown myotis	
September 1	180	Yes			
September 16	41	Yes			
September 23	29	Yes	3	little brown myotis	
September 29	13	Yes			

Date of Roost Check	Number of Guano Pellets Present[1]	Guano Collected?	Number of Pellets Analyzed	Guano Genetic Analysis Results	Emergence Count Results
October 15	3	Yes	3	little brown myotis	
October 23	1	No			
November 2	0	No			
HAY-Rock					
April 8	0	No			
April 26	0	No			
May 4	0	No			
May 14	1	No			
May 20	0	No			
May 27	0	No			
June 10	0	No			
June 22	0	No			
July 7	0	No			
July 19	-	No			1 bat observed
July 20	2	No			
July 22	4	Yes	3	little brown myotis	
August 5	25	Yes	3	little brown myotis, 1 pellet failed	
August 10	-	No			No bats observed
August 16	12	Yes	3	little brown myotis	
September 1	0	No			
September 16	7	Yes			
September 23	0	No			
September 29	8	Yes			
October 15	3	Yes	3	little brown myotis, 1 pellet failed	
October 23	0	No			
November 2	0	No			

Note: [1] Pellet counts greater than 100 pellets are approximate.

Table 3.4 Bat Activity Recorded near Hay Field Roosts During Emergence Counts on July 19, 2022

Bat Species or Group		Number of Bat Passes at HAY-Condo/Rocket/Maternity
Common Name	Scientific Name	
big brown bat / silver-haired bat group	*Eptesicus fuscus / Lasionycteris noctivagans*	4
hoary bat	*Lasiurus cinereus*	2
little brown myotis	*Myotis lucifugus*	1
long-eared myotis	*Myotis evotis*	3
Californian myotis	*Myotis californicus*	1
fringed myotis	*Myotis thysanodes*	1
	Total	12

3.1.3 Burton Flats

In 2022, the 3 roost structures at Burton Flats were visited 4 times: May 14, June 29, August 11, and September 27 (Table 3.5). No emergence counts were conducted at Burton Flats in 2022.

BUR-Bark only had guano present on August 11, indicating limited use of the structure. Two pellets were collected on August 11, but unfortunately the genetic analysis was not successful.

At BUR-Mat, guano was present and collected on the 3 latter dates, confirming some use of the structure between at least late June through August. Sixteen pellets from 2 days were submitted for genetic analysis, but only 6 were successfully analyzed. All these pellets were attributed to little brown myotis.

BUR-Rock had guano present on August 11 and September 27, indicating some use of the structure in early August and September. Nine pellets were collected on August 11, but the genetic analysis failed for all pellets.

Table 3.5 Occupancy Monitoring Results for Burton Flats Roosts in 2022

Date of Roost Check	Number of Guano Pellets Present	Guano Collected?	Number of Pellets Analyzed	Guano Genetic Analysis Results
BUR-Bark				
May 14	0	No		
June 29	-	No		
August 11	2	Yes	2	Both pellets failed
September 27	0	No		
BUR-Mat				
May 14	0	No		
June 29	8	Yes	4	little brown myotis, 1 pellet failed
August 11	21	Yes	12	little brown myotis, 9 pellets failed
September 27	14	Yes		
BUR-Rock				
May 14	0	No		
June 29	-	No		
August 11	9	Yes	9	All pellets failed
September 27	3	Yes		

3.2 Temperature Monitoring

Temperature data were collected from 2 sensors in each roost structure as well as from an ambient temperature data logger at Montana 3. In August, a new data logger was installed at the Hay Field BrandenBark™ pole, where temperature data have not previously been collected (Table 3.6).

Unfortunately, there were technical issues with multiple data loggers in 2022. The data logger at M3-Bark1 was not functioning and was replaced, so data were collected only from June 13 onward (Table 3.6). The data loggers installed at HAY-Condo, HAY-Mat, and HAY-Rock also only recorded data for part of the monitoring period (Table 3.6). The data loggers at Burton Flats did not begin collecting data until after a maintenance visit in June, but they operated consistently for the remainder of the season (Table 3.6). The ambient logger at Burton Flats was non-functional throughout the monitoring season.

Data are summarized below for April through October, the season during which use of the roost structures by bats is anticipated (Table 3.7). Overheating events were recorded on the warm sensor at both Montana 3 bark poles, HAY-Bark, and all Burton Flats roost structures (Table 3.7). BUR-Mat was the only structure where overheating events were recorded on both the warm and cool sensors within the roost (Table 3.7). However, due to the technical issues described above, data were not collected at the Hay Field roosts in July and August, months that typically would include many warm days (Table 3.6).

Table 3.6 Dates of Temperature Monitoring at Revelstoke Reach and Burton Flats in 2022

Location	Data Logger ID	Dates Monitored	Total Number of Days Monitored
Revelstoke Reach – Montana 3	M3-Bark1	June 13 to November 2	143
	M3-Bark2	April 7 to November 2	210
	M3-Ambient	April 7 to November 2	210
Revelstoke Reach – Hay Field	HAY- Bark	August 10 to November 2	85
	HAY-Condo-N	July 20 to August 5 August 16 to August 24	26
	HAY-Condo-S	April 7 to August 29	145
	HAY-Mat	July 20 to July 22 August 15 to November 2	82
	HAY-Rock	July 20 to July 24 August 16 to September 17	38
Burton Flats	BUR-Bark	June 29 to September 27	91
	BUR-Rock	June 29 to September 27	91
	BUR-Mat	June 29 to September 27	91
	BUR-Ambient	-	0

Table 3.7 Summary of Temperatures and Overheating Events from April to October for Each Artificial Roost Structure Monitored in 2022

Data Logger ID	Probe	Minimum Temperature (°C)	Maximum Temperature (°C)	Average Temperature (°C)	Number of Days Monitored (April to Oct) [1]	Total Number of Overheating Events[2]	Number of Days with an Overheating Event
M3-Bark1	Warm	0.3	59.5	19.6	141	334	**86**
	Cool	-0.4	35.0	15.7	141	0	0
M3-Bark2	Warm	-5.6	59.6	18.4	208	505	**100**
	Cool	-4.1	36.9	14.6	208	0	0
HAY-Bark	Warm	-0.3	57.8	16.4	83	100	**37**
	Cool	0.3	36.8	14.1	83	0	0
HAY-Condo-N	Warm	11.8	37.3	24.1	26	0	0
	Cool	11.8	28.4	20.7	26	0	0
HAY-Condo-S	Warm	-2.6	38.5	16.6	145	0	0
	Cool	-3.0	29.3	14.6	145	0	0
HAY-Mat	Warm	0.5	39.0	15.8	80	0	0
	Cool	0.1	33.9	14.0	80	0	0
HAY-Rock	Warm	6.9	37.4	20.3	38	0	0

Data Logger ID	Probe	Minimum Temperature (°C)	Maximum Temperature (°C)	Average Temperature (°C)	Number of Days Monitored (April to Oct) [1]	Total Number of Overheating Events[2]	Number of Days with an Overheating Event
	Cool	6.4	33.2	18.4	38	0	0
BUR-Bark	Warm	3.7	51.9	24.9	91	346	**55**
	Cool	3.2	36.6	18.5	91	0	0
BUR-Mat	Warm	3.1	46.3	22.0	91	93	**25**
	Cool	3.0	45.3	19.8	91	34	**19**
BUR-Rock	Warm	3.1	54.1	25.1	91	342	**64**
	Cool	3.1	36.5	19.3	91	0	0

Notes: [1] Temperature data were not recorded for the full monitoring period at all roosts. See **Table 3.6** for details.
[2] An overheating event is defined as a 60-minute period during which the temperature recorded reached a maximum of at least 40°C during at least one 10-minute interval reading.

3.2.1 Montana 3

Temperatures recorded within the 2 roosts from April through October ranged from a low of -5.6°C to a high of 59.6°C (Table 3.7, Figure 3.1). The coolest portion of the structures never exceeded 40°C but reached 35.0°C in M3-Bark1 and 36.9°C in M3-Bark2 (Table 3.7). Ambient temperature from April to October ranged from -5.0°C to 33.6°C.

Temperature was not monitored at M3-Bark1 prior to June 13 due to technical issues with the data logger; potentially decreasing the number of overheating events recorded within this roost. However, the data logger was operational during the hottest part of the monitoring period (July and August).

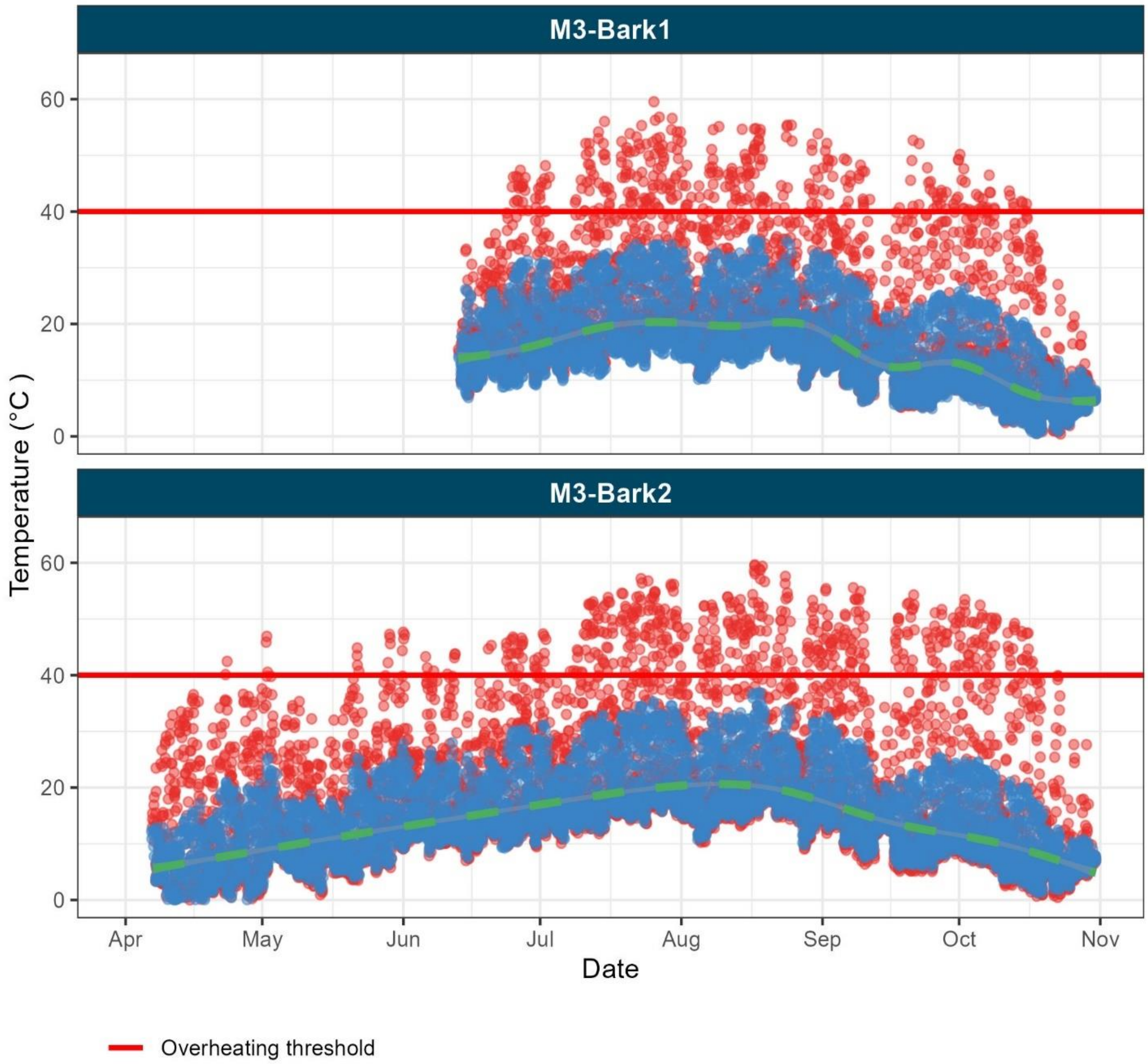

Figure 3.1 Ambient (Smoothed Hourly Maximum in Green) and Artificial Roost Temperatures (Warm Sensor = Red, Cool Sensor = Blue) Recorded at Montana 3 in 2022

3.2.2 Hay Field

No overheating events were recorded at HAY-Condo, HAY-Mat, or HAY-Rock and temperatures recorded within these roosts ranged from -3.0°C to 39.0°C (Table 3.7). However, technical issues with the data loggers at these roosts meant that we did not collect data for the full monitoring season, including gaps during the warmest period of July and August (Figure 3.2, Figure 3.3).

A temperature logger was installed at HAY-Bark on August 10, 2022, and recorded data for the rest of the season. Temperatures within the roost ranged from -0.3°C to 57.8°C, with overheating events recorded on 37 days (Table 3.7, Figure 3.2). The coolest part of the structure never exceeded 40°C, but reached a maximum of 36.8°C.

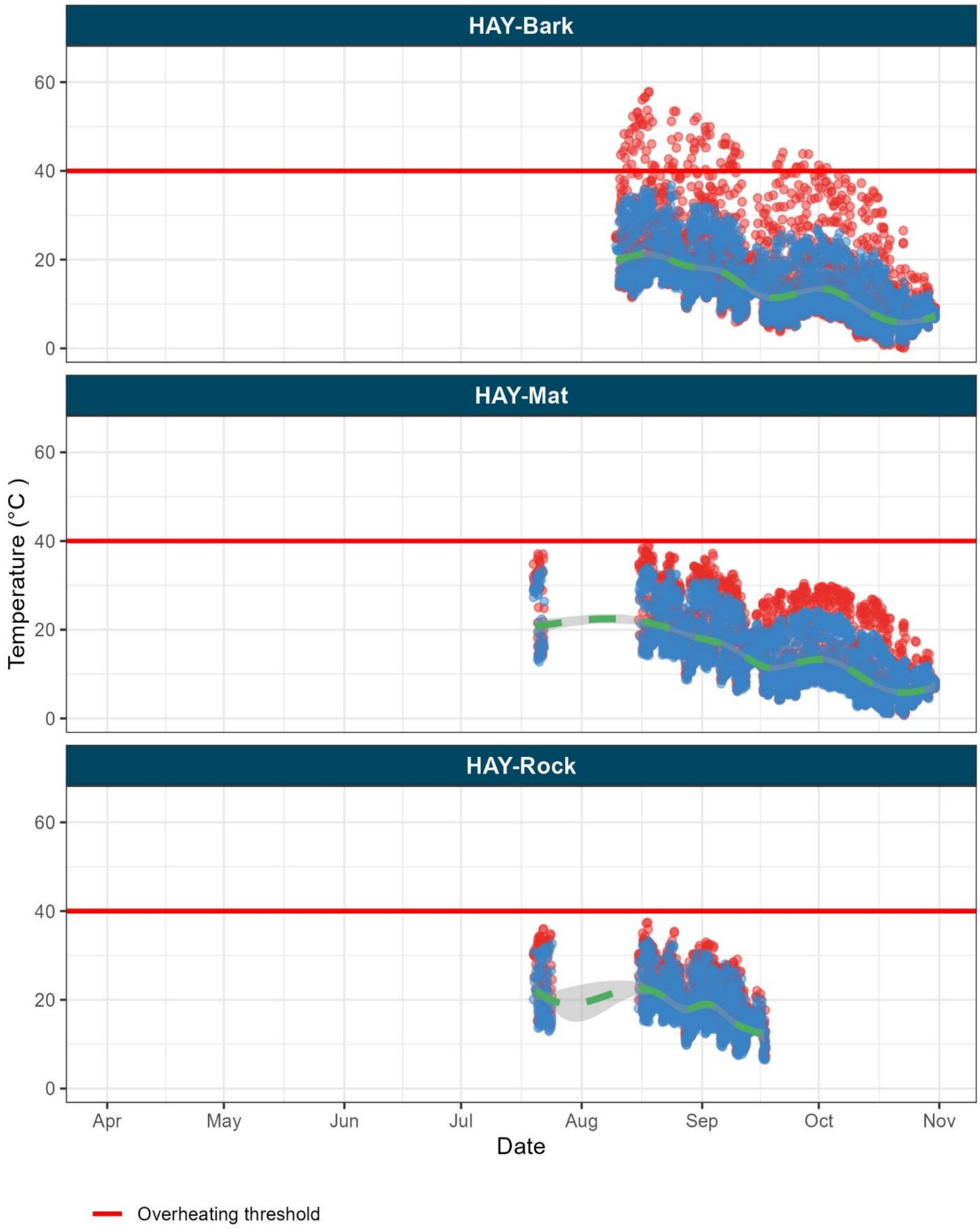

Figure 3.2 Ambient (Smoothed Daily Maximum in Green) and Artificial Roost Temperature (Warm Sensor = Red, Cool Sensor = Blue) Recorded at HAY-Bark, HAY-Mat, and HAY-Rock in 2022

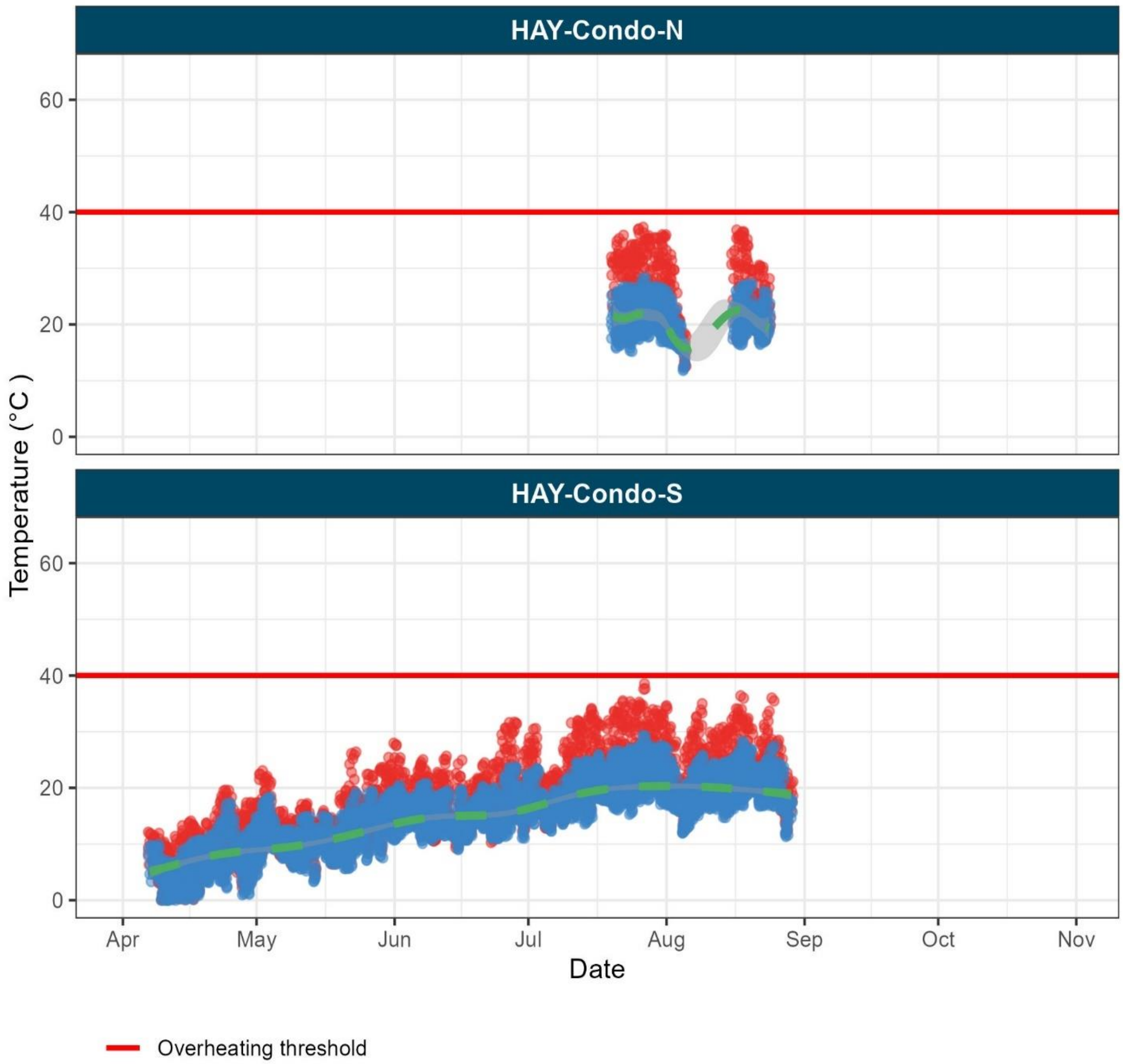

Figure 3.3 Ambient (Smoothed Daily Maximum in Green) and Artificial Roost Temperatures (Warm Sensor = Red, Cool Sensor = Blue) recorded at HAY-Condo in 2022

3.2.3 Burton Flats

In 2022, temperature data were collected within all 3 Burton Flats roost structures from June 29 through September 27 (Table 3.6). Ambient temperature data were not collected in 2022.

Temperatures recorded within the roosts ranged from 3.0°C to 54.1°C (Table 3.7, Figure 3.4). Overheating events were recorded on the sensors in the warmest parts of the structures on 55 days in BUR-Bark, 25 days in BUR-Mat, and 64 days in BUR-Rock (Table 3.7). The coolest portion of the BUR-Mat roost exceeded 40°C on 19 days (Table 3.7). Temperatures above 40°C were not recorded in the cooler portions of BUR-Bark and BUR-Rock (Figure 3.4).

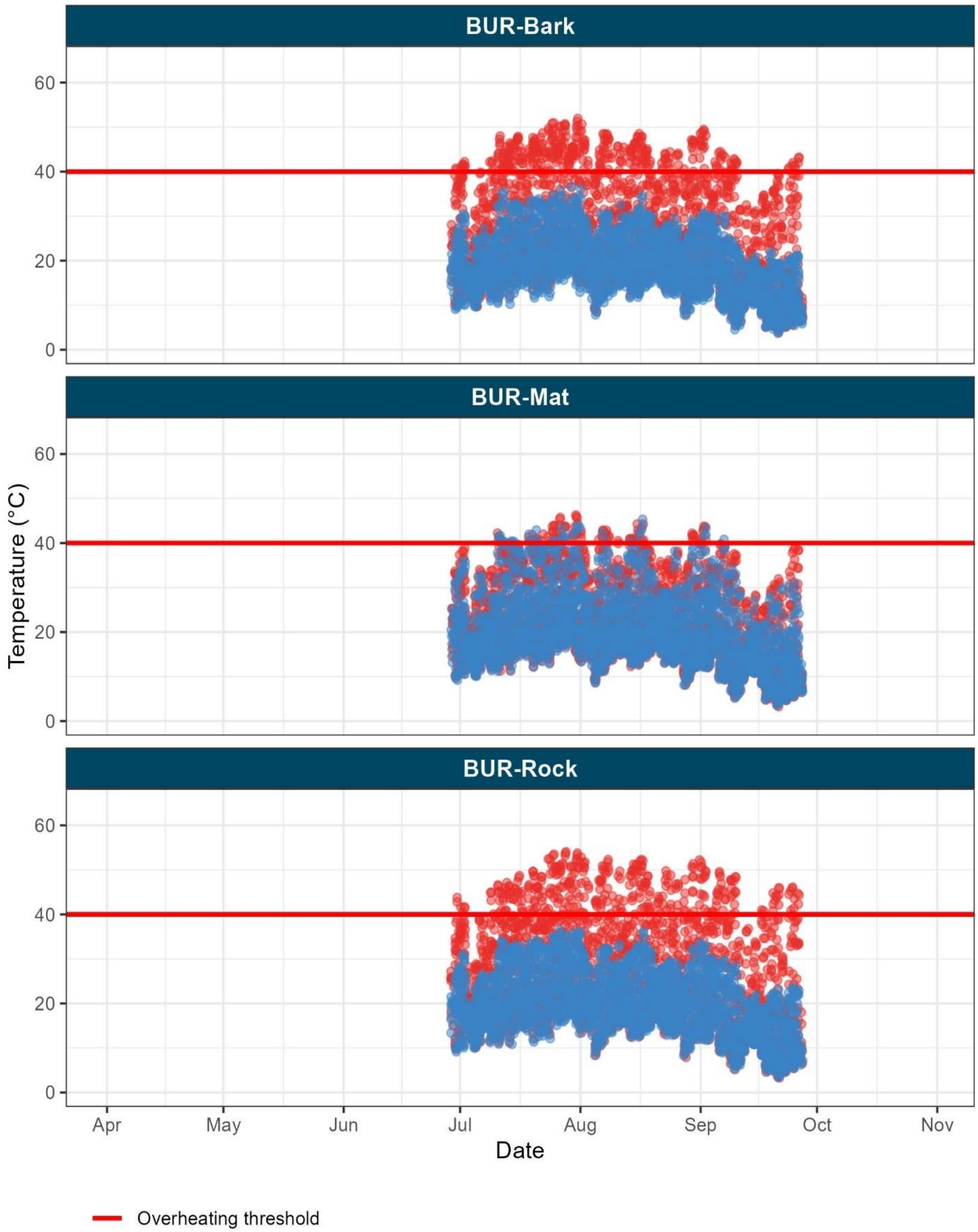

Figure 3.4 Artificial Roost Temperatures (Warm Sensor = Red, Cool Sensor = Blue) Recorded at Burton Flats in 2022

4.0 Discussion

The following section addresses each of the management questions identified in the Terms of Reference (BC Hydro 2017) and discusses our interim findings with respect to each question. In recent years, there have been many publications on the topic of artificial bat boxes, suitable bat box design, and thermodynamics as it relates to artificial roosts and overheating risk from climate change (Bideguren et al. 2019; Bergeson et al. 2021; Brack and Sparks 2021; Crawford and O'Keefe 2021; Fontaine et al. 2021; Tillman et al. 2021; Crawford et al. 2022). A review of the emerging research puts the monitoring results from this program in context and will guide recommendations for work in future monitoring years.

4.1 Management Questions

The monitoring program to date has resulted in the following interim findings with respect to each of the program research objectives.

1. **Are the wildlife enhancement structures (bat day roosts/maternity structures) effective at enhancing habitat quality and quantity for bats?**
    a. **How are the waterfowl nest boxes utilized by waterfowl in terms of species present and apparent nesting success? (not addressed in this report)**
    b. **How are the bat maternity structures utilized in terms of seasonality, intensity of use, species present, and number of days occupied per year?**
    c. **How does the internal temperature of bat maternity structures affect their successful utilization by bats?**

Management Question 1a is not relevant to this report.

Regarding Management Question 1b, bat use was confirmed for all roosts except for BUR-Bark and BUR-Rock. A small amount of guano was collected at both roosts, but genetic analysis failed. Little brown myotis was detected at 7 roosts. Bat use appears to be increasing in nearly all roosts based on the quantities of guano observed, and bat use for most roosts appears to occur from spring through fall. Roost use was confirmed to vary from 0 days up to at least 146 days. Up to 11 bats have been observed emerging from a single roost. Most of the roosts appear to be of value as roosting structures, thus enhancing habitat quality and quantity for bats.

Details regarding interim findings on the specifics of use of each bat roost to date are available in Appendix A and are summarized by roost as:

- Use of the BrandenBark™ poles at Montana 3 (M3-Bark1 and M3-Bark2) has increased in each year of the study (2020 to 2022). Up to 11 bats were observed at M3-Bark 1 and use by little brown myotis was confirmed. Guano was observed from May to September or October each year, with roost use characterized as intermittent and the roost used at least 146 days. Up to 4 bats were observed in M3-Bark2, with use by little brown myotis and Yuma myotis confirmed. Guano was present from May to October with roost use characterized as intermittent over at least 144 days (Appendix A).
- At Hay Field, the use at HAY-Mat increased from 2021 to 2022. There was a low intensity of use in spring with higher intensity use in summer, with intermittent occupancy for at least 129 days. A maximum of 2 bats were observed and use by little brown myotis was confirmed (Appendix A).

- HAY-Condo had low use in both 2021 and 2022, with only a single bat observed. Little brown myotis use was confirmed (Appendix A). This structure does not have a guano catcher below it, but very little guano has been found within the structure and limited activity has been observed during emergence counts.
- In both 2021 and 2022, the use of HAY-Bark increased in the later summer and fall compared to the early spring and summer, based on guano counts. Guano was observed from spring (low use) to September in 2021 and summer through September in 2022. Use was characterized as intermittent over at least 73 days (Appendix A).
- Use of HAY-Rock was low intensity in both years and guano was primarily observed in August, outside of the maternity period. Use was characterized over 2021 and 2022 as intermittent for at least 77 days, and use by little brown myotis was confirmed (Appendix A).
- At BUR-Mat, there was a slight increase in use in 2022 based on guano counts and use by little brown myotis was confirmed during the maternity period (although evidence of use as a maternity roost was not documented). There was no use in 2021 and a minimum intermittent occupancy period of 45 days in 2022 (Appendix A).
- Bat use of BUR-Rock could not be confirmed (Appendix A).

Regarding Management Question 1c, although overheating events (temperatures > 40°C) have been recorded by the warm sensors at many of the roosts monitored in 2021 and 2022, temperatures at the cool sensors only surpassed the heat-stress threshold of 40°C at the maternity box at Burton Flats (BUR-Mat). These results indicate that in all roosts, except for BUR-Mat, thermal refuge below the heat stress threshold was consistently available within each roost (i.e. bats could change position within the roost to experience temperatures below 40°C). However, it is unknown what proportion of space within each roost remained below the heat stress threshold. A large thermal gradient provides a wider range of available temperatures at a given time and may be protective against extreme hot weather events (Crawford and O'Keefe 2021). At least one study has shown that a lower proportion of bark pole roosts remain below the heat stress threshold than maternity or rocket box roosts (Hoeh et al. 2018). However, for the maternity boxes (HAY-Mat and BUR-Mat) in this study, the cool sensor temperatures are more similar to the warm sensor than for the other roost types.

All roosts have the potential to support maternity roosting; however, some structures have the potential to pose risk to non-volant pups: the 4 bark poles (M3 Bark1, M3-Bark2, HAY-Bark, BUR-Bark) and 1 rocket box (BUR-Rock) due to extreme high temperatures recorded (>45°C), and the Burton Flats maternity box (BUR-Mat) due to lack of thermal refuge. Several roosts had inconsistent collection of temperature data during the monitoring season, so additional data on both temperature and use over the next 2 years will improve our understanding of whether temperature may be affecting the use of the roost structures. The temperature profiles of the artificial bark poles at M3 are relatively similar and, given their increasing use, it appears that the internal temperatures in these roosts are suitable for bats, despite some high temperatures (> 60°C) occurring at the warm sensor.

HAY-MAT had few overheating events in 2021 and had none in 2022, but temperature data were not recorded prior to mid-August in 2022. This roost has a narrow thermal gradient, meaning that the cool and warm sensor temperatures are relatively similar. This could be a concern if overheating did occur because there would be no refuge from the heat within the roost.

In 2021, temperatures at HAY-Condo averaged lower than the other roosts at Hayfield and the maximum temperatures on the cool sensors were below 30°C in each year. While the high temperatures recorded at the warm sensor were similar to those recorded at HAY-Mat and HAY-Rock, the cool sensor at HAY-Condo was consistently at or below ambient temperature through the monitoring period. Temperature monitoring at the Hay Field roosts was inconsistent in 2022, so we can not make the same comparisons for that year. While the cooler temperatures recorded in 2021 are likely protective against overheating, the conditions may be less favourable than in warmer roosts for maternity roosting. However, it is possible that if HAY-Condo begins to have higher levels of occupancy in the future, roosting bats may compensate for lower roost temperature through social thermoregulation (i.e. congregating to generate heat and conserve energy) (Willis and Brigham 2007a).

Temperature monitoring at HAY-Bark was not initiated until August of 2022, so we do not know if there was a difference in the internal temperature at this roost between the 2021 and 2022 monitoring seasons.

In 2021, HAY-Rock had only 10 overheating events and there was a thermal gradient between the warm and cool sensors. Very few temperature data were collected at this roost in 2022.

BUR-Mat is the only roost monitored for this study at which the temperature at the cool sensor exceeded 40°C. This indicates that BUR-Mat could pose some risk of overheating, particularly for non-volant pups, due to a lack of thermal refuge within the roost. BUR-Bark and BUR-Rock have had very little guano observed, no bat use confirmed, and temperature profiles more similar to the bark pole and rocket box roosts at other sites (such as the Montana 3 bark poles where use is much higher).

Both maternity boxes (BUR-Mat and HAY-Mat) exhibited more overlap in temperature at the warm and cool sensors than the other roost types installed at the same locations, and more temperatures at the cool sensor above ambient temperature. However, the maximum and average temperatures recorded on the warm sensors in these roosts were lower than at some other roosts (e.g. BrandenBark™ poles). These results may indicate that maternity boxes may provide a narrower range of available temperatures for roosting bats.

2. Which wildlife enhancement structure methods or techniques (including those not yet implemented) are likely to be most effective at enhancing the productivity and suitability of wildlife habitat in the drawdown zone at Revelstoke Reach?

All roosts at Montana 3 and Hay Field and 1 roost at Burton Flats have confirmed bat use (7 of 9 roosts, 78%). Use at Montana 3 appears to have increased each year since the roosts were installed in 2020 based on guano and emergence counts. The Hay Field and Burton Flats roosts were installed later, and it is expected that bat use at roost structures will increase the longer they are available on the landscape as local bat populations encounter them.

The roosts continue to have slightly different temperature profiles and we suspect that aggregating several roosts of different designs or placements at one area, such as was done at Hay Field and Burton Flats, will be protective against overheating risk. This will provide a wider range of thermal conditions and allow for roost switching. It has been hypothesized that this approach may also enhance roost uptake (Crawford and O'Keefe 2021).

Measures that could be considered for future artificial bat roost deployments to mitigate overheating risk at bark pole and maternity box roosts include:

- Providing multiple roost structures in proximity to each other and monitoring temperatures after installation.
- Selecting (or painting) a lighter roost colour with more reflective properties (for example, a lighter gray artificial bark to mimic a cottonwood tree (*Populus balsamifera*) that may be less prone to solar heating).
- Adding a shade to decrease the time of exposure to direct sunlight if a box is found to be overheating.
- Ensuring roosts are tall and well vented to allow for a larger thermal gradient within the roost space.
- Selecting landscape positions that will be shaded or partially shaded in the late afternoon and early evening during summer to reduce solar exposure at the hottest part of the season and day.

Given the uncertainty of future climatic conditions, advancing more than one approach to habitat enhancement for bats will likely be beneficial for safeguarding the availability of suitable habitat across climate change scenarios and timeframes. Snag retention and creation, tree roost creation via modification of live trees, or planting additional trees could be considered as options for enhancing productivity and suitability of habitat for bats in the drawdown zone over the long term (Crawford and O'Keefe 2021). Installation of artificial bat roosts can affect habitat availability in the short term, as evidenced by the uptake of BrandenBark™ pole at Montana 3 in less than 1 year. Implementing both types of measures in tandem would enhance roosting habitat in the short and long term, and under various climatic regimes. A summary of management questions and responses is presented as Appendix B.

4.2 Preliminary Findings Summary

- Roost structures at Montana 3 have had increasing use each year from 2020 to 2022 (Appendix A). Little brown myotis has been confirmed using M3-Bark1 and M3-Bark2; Yuma myotis has been confirmed using M3-Bark2.
- There has been some use of the structures at Hay Field, with increasing use at HAY-Mat. Little brown myotis has been confirmed using all the structures at Hay Field, and Californian myotis was confirmed roosting in or on HAY-Condo at in October 2021.
- Very little guano has been observed at the Burton Flats structures. The use of BUR-Mat by little brown myotis was confirmed by guano genetic analysis in 2022. Genetic analysis of pellets from the other structures was unsuccessful.
- Preliminary temperature results suggest that almost all structures provide thermal conditions that are below the general threshold for heat stress for temperate-region bats (40°C).

5.0 Recommendations

We recommend the following for future monitoring seasons:

- Consider using the pooled guano sampling and '*species from feces'* genetic analysis via Northern Arizona University as an alternative to single-pellet analysis to identify bat species that may use the roost structures less frequently and therefore be missed by a single-pellet sampling strategy.
- Continue more frequent (i.e. weekly) roost checks at the start and end of the monitoring season (April, May, September, and October) to obtain more detailed occupancy dates.
- Consider using thermal imaging to assist with enumeration during emergence counts if bat occupancy of artificial roosts continues to increase in future monitoring years.
- Consider deploying additional temperature sensors within bark pole roosts shown to experience extremely high temperatures (M3-Bark1 and M3-Bark2) to better understand what proportion of the roost space remains below the heat-stress threshold and is suitable for bat use.
- Work to eliminate technical difficulties with the temperature loggers to ensure more continuous data collection throughout the monitoring season.
- If the BUR-Mat roost continues to experience overheating in 2022, consider painting this structure in a lighter colour, repositioning to a location with afternoon solar protection, or adding additional venting or a shade to reduce temperatures in the lower part of the boxes.

6.0 Closure

We sincerely appreciate the opportunity to have assisted you with this project and if there are any questions, please do not hesitate to contact the undersigned by phone at 250.919.6856.

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Appendix A
Artificial Bat Roost Use Summary

Roost	Monitoring Period	Seasonality	Intensity of Use	Bat Species Present	Number of Days Occupied per Year[1]
M3-Bark1	May 1 to October 31, 2020	Guano observed in May and July to October 2020 with most guano observed in July and September.	Increasing use over time. Greater quantity of guano observed in each year from 2020 to 2022. No bats directly observed in 2020. Confirmed occupancy by 2 bats in 2021 and 11 bats in 2022 based on emergence counts.	Little brown myotis	Intermittent occupancy for at least 146 days in 2020, April 30 to September 22 (i.e. guano deposited prior to May 1 roost check and after September 22 roost check).
	May 10 to October 16, 2021	Guano observed May through September 2021 with most guano in June and August.			Intermittent occupancy for at least 125 days in 2021, May 19 to September 20 (i.e. guano deposited prior to May 20 roost check and after September 20 roost check).
	April 8 to November 2, 2022	Guano observed May through October 2022 with most guano in June through August.			Intermittent occupancy for at least 123 days in 2022, May 14 to September 16 (i.e. guano deposited prior to May 27 roost check and after September 16 roost check.
M3-Bark2	May 1 to October 31, 2020	Guano observed in May and July to October 2020, with most guano observed in July and September.	Increasing use over time. Greater quantity of guano observed in each year from 2020 to 2022. Confirmed occupancy by 2 bats in 2020, 4 bats in 2021, and 4 bats in 2022 based on emergence counts.	Little brown myotis, Yuma myotis	Intermittent occupancy for at least 116 days in 2020, May 29 to September 22 (i.e. guano deposited prior to May 20 roost check and after September 22 roost check).
	May 10 to October 16, 2021	Guano observed May through early October 2021, with most guano observed in June and July.			Intermittent occupancy for at least 134 days in 2021, May 19 to September 29 (i.e. guano deposited prior to May 20 roost check and after October 8 roost check).
	April 8 to November 2, 2022	Guano observed May through October 2022 with most guano observed in June and July.			Intermittent occupancy for at least 144 days in 2022, May 20 to October 15 (i.e. guano deposited prior to May 20 roost check and after October 15 roost check.
HAY-Bark	May 10 to October 16, 2021	Guano was observed in May and July to September 2021, with most guano observed in August, particularly at the late August roost check.	Very low intensity of use in spring and early summer, with slightly higher use in summer through early fall.	Little brown myotis	Intermittent occupancy for at least 125 days in 2021, May 19 to September 19 (i.e. guano deposited prior to May 20 roost check and after the September 20 roost check).
	April 8 to November 2, 2022	Guano observed in July through September, with the most guano observed in August and September.			Intermittent occupancy for at least 73 days in 2022, July 19 to September 29 (i.e. guano deposited prior to July 20 roost check and after September 29 roost check).
HAY-Condo	May 10 to October 16, 2021	Unknown – only 1 confirmed bat guano pellet has been collected to date at HAY-Condo (October 8 roost check).	Very low intensity of use of HAY-Condo in 2021 and 2022. No bats were directly observed occupying HAY-Condo in 2021, but 1 bat was confirmed occupying the condo in 2022 (based on emergence counts).	Little brown myotis, Californian myotis (probable)	Unknown – only 1 confirmed bat guano pellet has been collected to date at HAY-Condo (October 8 roost check).
	April 8 to November 2, 2022	Unknown – the only confirmed bat pellet in 2022 was collected on the August 16 roost check. Additional pellets observed/collected may have all been deermice.			Guano was documented over at least 143 days in 2022, May 3 to September 23 (i.e. guano deposited prior to May 4 roost check and after the September 23 roost check). However, genetic analysis of guano indicated that the guano present earlier in the season was likely deermice.
HAY-Mat	May 10 to October 16, 2021	Guano was observed in May, June, August, and September. Most guano was observed at late August and mid-September roost checks.	Lower intensity of use in spring and early summer, with higher intensity use in summer. Use increased in 2022 compared to 2021. Confirmed occupancy by 2 bats in 2021, and 2 bats in 2022 based on emergence counts.	Little brown myotis	Intermittent occupancy for at least 101 days in 2021, May 19 to August 27 (i.e. guano deposited prior to May 20 roost check and after the August 27 roost check).
	April 8 to November 2, 2022	Guano was observed from June through October, with the most guano observed in July and August.			Intermittent occupancy for 129 days in 2022, June 9 to October 15 (i.e. guano deposited prior to June 10 roost check and after the October 15 roost check).
HAY-Rock	May 10 to October 16, 2021	Guano was observed in May, June, July, and August. Most guano was observed during the late July roost check.	The low intensity of use based on very low amounts of guano observed. Confirmed occupancy by 2 bats in 2021, and 1 bat in 2022 based on emergence counts.	Little brown myotis	Intermittent occupancy for at least 77 days in 2021, May 19 to August 3 (i.e. guano deposited prior to May 20 roost check and after the August 3 roost check).
	April 8 to November 2, 2022	Guano was observed in May, July, August, and September, with most guano being observed in August.			Intermittent occupancy for 140 days in 2022, May 13 to September 29 (i.e. guano deposited prior to May 14 roost check and after the September 29 roost check).
BUR-Bark	June 15 to October 13, 2021	Guano was not observed.	Use was not confirmed.	None confirmed	Use was not confirmed.
	May 14 to September 27, 2022	Guano was observed in August (2 pellets), but genetic analysis failed.	Use was not confirmed.		Use was not confirmed.
BUR-Mat	June 15 to October 13, 2021	Guano was observed in July, but genetic analysis failed.	Use was not confirmed.	Little brown myotis	Use was not confirmed.
	May 14 to September 27, 2022	Guano was observed in June, August, and September.	The low intensity of use is based on low amounts of guano observed.		Intermittent occupancy for at least 45 days in 2022, June 28 to August 11 (i.e. guano deposited prior to June 29 roost check and after August 11 roost check).
BUR-Rock	June 15 to October 13, 2021	Guano was observed in July, but genetic results indicated it was from deermice.	Use was not confirmed.	None confirmed	Use was not confirmed.
	May 14 to September 27, 2022	Guano was observed in August and September, but genetics analysis of all pellets failed.	Use was not confirmed.		Use was not confirmed.