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 1

Reference: CLBMON-11B5

Year 1 and 2 Data Report

Study Period: 2020-21

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FINAL REPORT

CLBMON 11B5- Effectiveness Monitoring of Wildlife Enhancement: 2020 and 2021 Report

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EXECUTIVE SUMMARY

This Work was performed by Nupqu Limited Partnership (Nupqu) under BC Hydro Contract. This Report has been prepared by Nupqu and Ausenco Sustainability (formerly Hemmera Envirochem Inc) based on fieldwork conducted by Nupqu and Ausenco, for the sole benefit and use of BC Hydro. In performing this Work, Nupqu and Ausenco have relied in good faith on information provided by others and have 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.

Under a separate scope of services (CLBWORKS-30A), 5 artificial bat roost structures were installed in the Revelstoke Reach at 2 locations in July 2019, complete with 2 temperature probes in each structure, an ambient temperature logger and solar screen at one monitoring location, and guano traps affixed to each artificial bat structure. Three of the 5 artificial bat roost structures were taken down in October 2019. These 3 structures as well as 1 additional structure were reinstalled in October 2020 at the Hay Field site, a previously approved location near 9 Mile. The 2 artificial bat roost structures that remained in place at the Montana 3 site during the 2020 monitoring season are Branden Bark™ artificial bark pole structures, which represent the first known installation of this type of artificial roost in British Columbia.

The monitoring activities conducted in 2020 for the artificial bat roost structures in the Revelstoke Reach commensurate with the *CLBMON-11B5 Monitoring of Bat Roost Enhancement Structures in the Revelstoke Reach* scope of services were limited due to several external constraints. As such, the 2020 monitoring program was limited to 2 artificial bark pole roost structures during the 2020 monitoring season.

Both Montana 3 artificial bark pole structures monitored in 2020 had confirmed use, through both visual detection during emergence counts, and collection of guano. Little brown myotis was confirmed to be using artificial bark pole structures via guano analysis. Intensity of use by bats of each structure was generally low, and varied by month, with evidence of the highest use (based on quantity of guano) occurring in August and September. However, the low overall quantity of guano observed (i.e., maximum of approximately 15 pellets) suggests intermittent use by a few individuals.

While the internal temperatures in 2020 at both artificial bark poles exceeded 40°C for extended periods at the warmest sensor locations (i.e., south side and high in the structure), temperatures at the coolest sensor (i.e., north side and low in the structure) remained below 40°C, providing an opportunity for movement within the structure for temperature regulation. As such, the internal temperature of the Braden Bark poles was not expected to impede successful utilization by bats due to heat stress.

Following the 2020 monitoring season, we recommended the completion of more frequent (i.e., weekly) guano and occupancy checks at the start and end of the monitoring 2021 season to obtain more detailed occupancy dates. We adopted updated guano collection and storage protocols to align with the BC Community Bat Program and reduce sample degradation and loss. The use of an additional observer during emergence counts in future years was also recommended to improve the efficiency of data collection by allowing simultaneous monitoring of multiple structures.

In addition to the 4 structures installed in October 2020 at the Hayfield site, 3 additional roost structures, consisting of an artificial bark pole, a maternity box, and a rocket box, were installed at Burton Flats in April 2021 under CLBWORKS-30B. These 7 roost structures were available for bat occupancy in 2021 and were included in the 2021 roost monitoring program. A total of 9 artificial roosts were monitored through the 2021 monitoring season.

To date, bat use has been confirmed at all Montana 3 and Hay Field roost structures in 2020 and/or 2021. No bat use has yet been confirmed at the 3 Burton Flats roosts to-date; pellets were observed in 2020 but no bat species were confirmed during genetic analysis. While high temperatures above the heat-stress threshold for temperate bats (40°C) were recorded at all roosts in 2021, temperatures at the cool sensor (lower cavity) within all roosts except the maternity box at Burton (BUR-Mat) remained below the heat threshold throughout the monitoring season indicating that thermal refuge was available within each roost. Evidence of overheating risk was documented at 3 roosts. Extreme high temperatures (>50°C) were recorded at M3-Bark1 and M3-Bark2. Temperatures at the cool sensor within the BUR-Mat roost were above 40°C on 13 days indicating that no thermal refuge was available within this roost for a portion of each day.

A summary of key interim monitoring results that address BC Hydro's management questions are provided in **Table ES.1**.

Recommendations have been provided for consideration for future monitoring seasons. These recommendations are: use of pooled guano sampling to detect additional species that may be using the structures more infrequently, use of thermal imaging for emergence counts, the 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 Braden Bark poles to determine the proportion of roost space below the heat-stress threshold and painting or shading BUR-Mat to reduce overheating.

Table ES.1 Revelstoke Reach Artificial Bat Roost Effectiveness Monitoring Management Questions and Summary of Key Monitoring Results

Management Question		Summary of Key Monitoring Results					
MQ-A	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?	See answers for each sub-question below.					
MQ-Ai	The part of this question that addresses bird nest boxes is not relevant for bats.	N/A					
		Roost	Monitoring Period	Seasonality	Intensity of Use	Bat Species Present	Number of Days Occupied per Year[1]
MQ-Aii	How are the bat maternity structures utilized in terms of seasonality, the intensity of use, species present, and the number of days occupied per year?	M3-Bark1	May 1 to October 31, 2020	Guano was observed in May and July to October 2020 with most guano observed in July and September.	Increasing use over time. Low intensity based on low amounts of guano. A greater quantity of guano was observed in 2021 compared to 2020. No bats were directly observed using M3-Bark1 in 2020. Confirmed occupancy by 2 bats in 2021 based on emergence count.	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 was 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).
		M3-Bark2	May 1 to October 31, 2020	Guano was observed in May and July to October 2020, with most guano observed in July and September.	Low intensity based on low amounts of guano. A greater quantity of guano was observed in 2021 compared to 2020. Confirmed occupancy by 2 bats in 2020 and 4 bats in 2021 based on emergence counts.	Little brown myotis	Intermittent occupancy for at least 116 days in 20.20, 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 was 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).
		HAY-Bark	May 10 to October 16, 2021	Guano was observed in May and July to September 2021, with most guano observed in August. Most guano was observed at late August roost check.	Very low intensity of use in spring and early summer, with slightly higher use in summer through early fall. Confirmed occupancy by 3 bats in 2021 based on emergence count.	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 September 20 roost check).
		HAY-Condo	May 10 to October 16, 2021	Unknown – only one 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. No bats were directly observed occupying HAY-Condo in 2021.	California myotis (probable)	Unknown – only one confirmed bat guano pellet has been collected to date at HAY-Condo (October 8 roost check).
		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.	Very low intensity of use in spring and early summer, with slightly higher use in summer through early fall. Confirmed occupancy by 2 bats in 2021 based on emergence count.	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 August 27 roost check).

Management Question		Summary of Key Monitoring Results

HAY-Rock	May 10 to October 16, 2021	Guano was observed in May, June, July, and August. Most guano observed at late July roost check.	Very low intensity of use based on very low amounts of guano observed. Confirmed occupancy by 2 bats in 2021 based on emergence count.	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).
BUR-Mat	June 15 to October 13, 2021	Use has not been confirmed.	Use has not been confirmed.	None confirmed.	Use has not been confirmed.
BUR-Rock		Use has not been confirmed.	Use has not been confirmed.	None confirmed.	Use has not been confirmed.
BUR-Bark		Use has not been confirmed.	Use has not been confirmed.	None confirmed.	Use has not been confirmed.

Note: [1] Number of days occupied per year is the portion of the active season over which 1 or more bats occupied a roost, at least intermittently, and has been estimated based on the dates of the first and last roost checks at which guano was observed. It does not indicate consistent occupancy over this entire period.

MQ-Aiii	How does the internal temperature of bat maternity structures affect their successful utilization by bats?	• All roosts experienced overheating events where the internal roost temperature at the warm sensor (upper roost) 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. • Very high temperatures were recorded in M3-Bark1 and M3-Bark2 (64.2°C and 55.0°C respectively) during a late June to early July heat wave in 2021. • All roosts have the potential to support maternity roosting. However, 3 structures have the potential to pose risk to non-volant pups: the Montana 3 bark poles (M3-Bark1 and M3-Bark2) due to extremely high temperatures recorded, and the Burton flats maternity box (BUR-Mat) due to lack of thermal refuge recorded on 13 days.
MQ-B	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 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 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 color, 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 complementary 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, 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 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).

The Arrow Lakes Reservoir is unique among reservoirs in that a large proportion of the inundated area is vegetated, providing habitat for wildlife species. The operation of the Hugh Keenleyside Dam results in annual drawdowns and inundation within the reservoir area and these water level fluctuations affect habitats that numerous wildlife species use to meet their life requisites.

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 Black cottonwood *(Populus trichocarpa),* and annually inundated wetlands exist within the reservoir drawdown zone (van Oort et al. 2016).

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.

As part of the Columbia Water Use Plan, BC Hydro has commenced with the development and implementation of the CLBWORKS-30B Arrow Lakes Reservoir Wildlife Enhancement Program. The objective of this program is to improve habitat conditions for wildlife occurring proximate to the Arrow Lakes Reservoir, including a commitment to enhancing summer roosting and maternity roosting opportunities for bats within impacted areas. Within the Revelstoke Reach of the Arrow Lakes Reservoir, habitats near Cartier Bay, Montana, and Airport marshes were identified as foraging habitats for bat species (Utzig and Schmidt 2011).

Roost habitat enhancement is important for bat conservation in the context of anthropogenic land alteration and the spread of white-nose syndrome (Wilcox and Willis 2016). Conservation concern for bats is elevated in Canada with the onset of white-nose syndrome in eastern North America, and the discovery of white-nose syndrome in Washington State and Saskatchewan (Canadian Wildlife Health Cooperative 2021). 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 (SARA).

The implementation of 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 (**Figure 1.1**). BC Hydro commissioned this related scope of work to monitor the artificial bat roosts associated with CLBWORKS-30A: *CLBMON-11B5 Monitoring of Bat Roost Enhancement Structures in the Revelstoke Reach*. Monitoring of these structures will contribute to understanding bat use of artificial roosts in BC and guide future enhancement and compensation work.

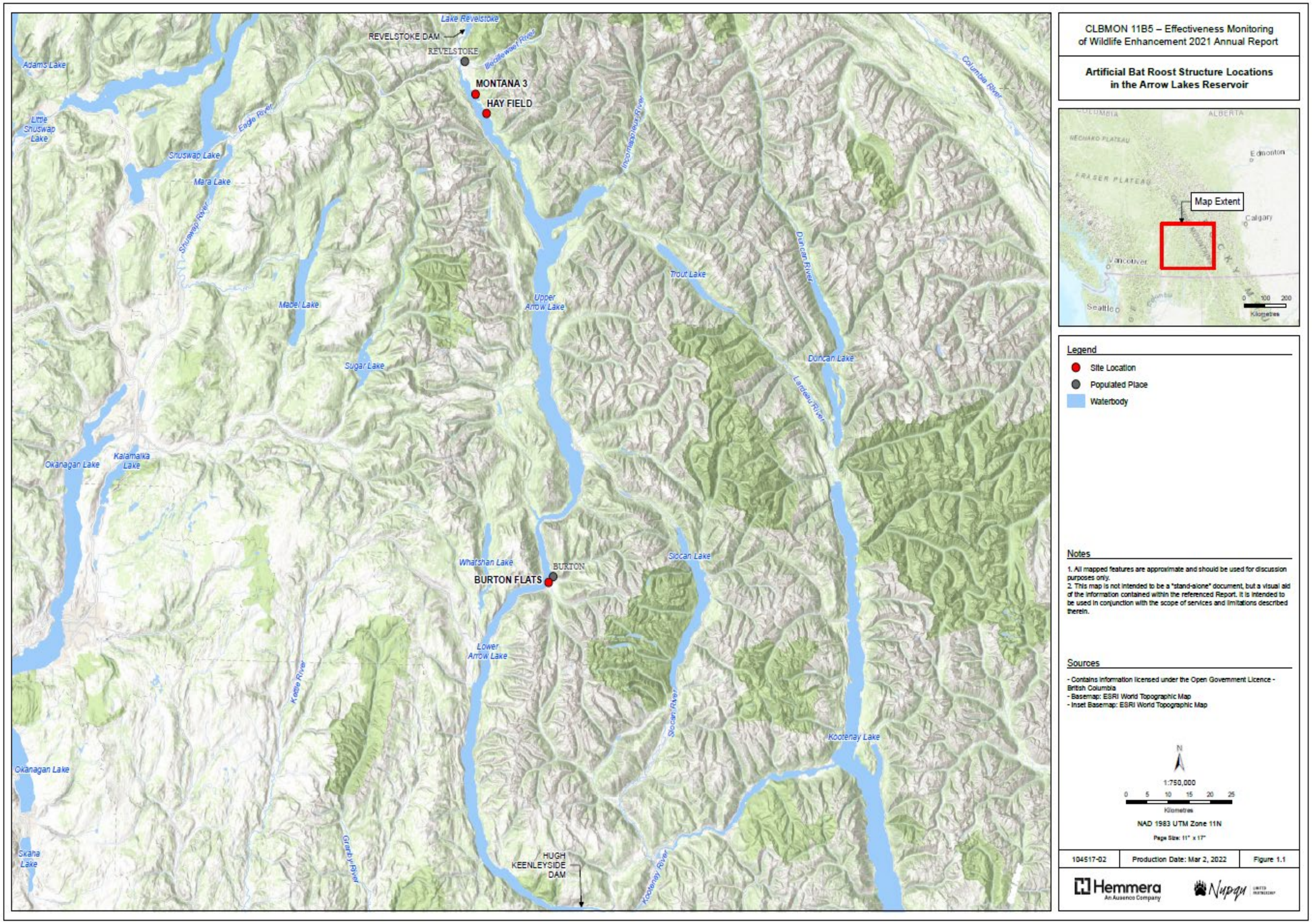

Figure 1.1 Artificial Bat Roost Structure Locations in the Arrow Lakes Reservoir

1.1 Artificial Bat Roosts Installation Summary

In total, 9 artificial roost structures were installed within the Arrow Lakes Reservoir which are the subject of this effectiveness monitoring program (**Figure 1.1, Table 1.1**). There are 6 artificial roost structures installed in the Revelstoke Reach south of Revelstoke: 2 at the Montana 3 site at the north end of Cartier Bay and 4 at the Hay Field site near 9 Mile (**Figure 1.2**). There are 3 artificial roost structures installed at Burton Flats (**Figure 1.3**).

In July 2019, 2 artificial bark poles wrapped with Branden Bark™ (M3-Bark1 and M3-Bark2) were installed at Montana 3 (**Figure 1.4** and **Figure 1.5**). These 2 artificial bark poles were available for bat occupancy throughout the 2020 and 2021 monitoring seasons.

In October 2020, 4 structures were installed at the Hay Field site: a mini condo, a rocket box, a back-to-back maternity box (**Figure 1.6**), and an artificial bark pole wrapped in Branden Bark™ (**Figure 1.7**). The 4 artificial roosts at the Hay Field site were available for bat occupancy throughout the 2021 monitoring season.

In April 2021, one artificial bark pole wrapped with Branden Bark™, one rocket box, and one maternity box were installed at Burton Flats, south of Burton, BC (**Figure 1.8, Figure 1.9, Figure 1.10**). These 3 artificial roost structures were first available for bat occupancy at the start of the 2021 monitoring season.

Details regarding site selection and the installation of the structures are addressed in the *CLBWORKS-30A Bat Box Construction and Installation Report* (Nupqu Development Corporation 2019).

Table 1.1 Arrow Lakes Reservoir Artificial Bat Roosts Summary

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

Note: Artificial roost installations were installed under CLBWORKS 30A

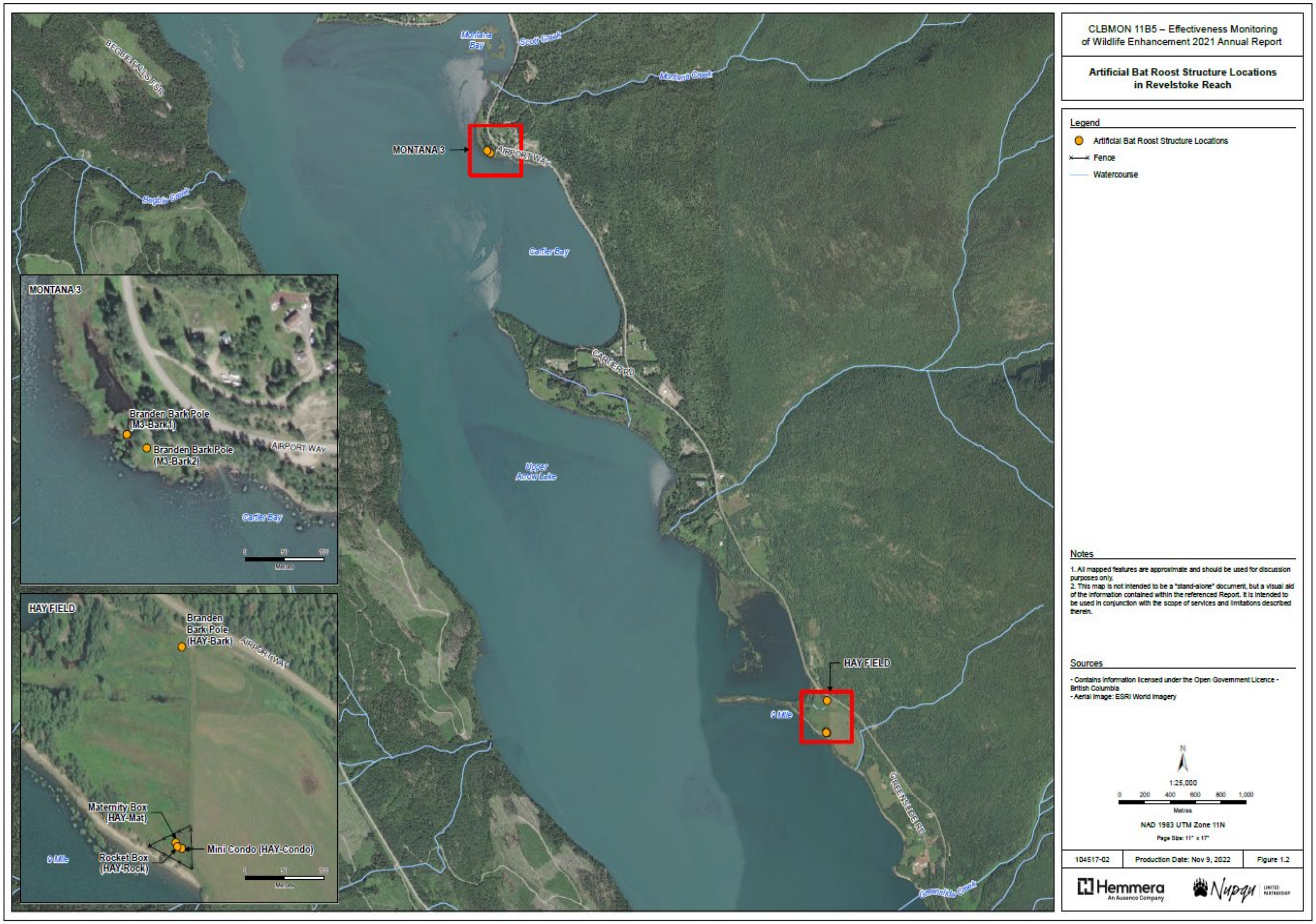

Figure 1.2 Artificial Bat Roost Structure Locations in the Revelstoke Reach.

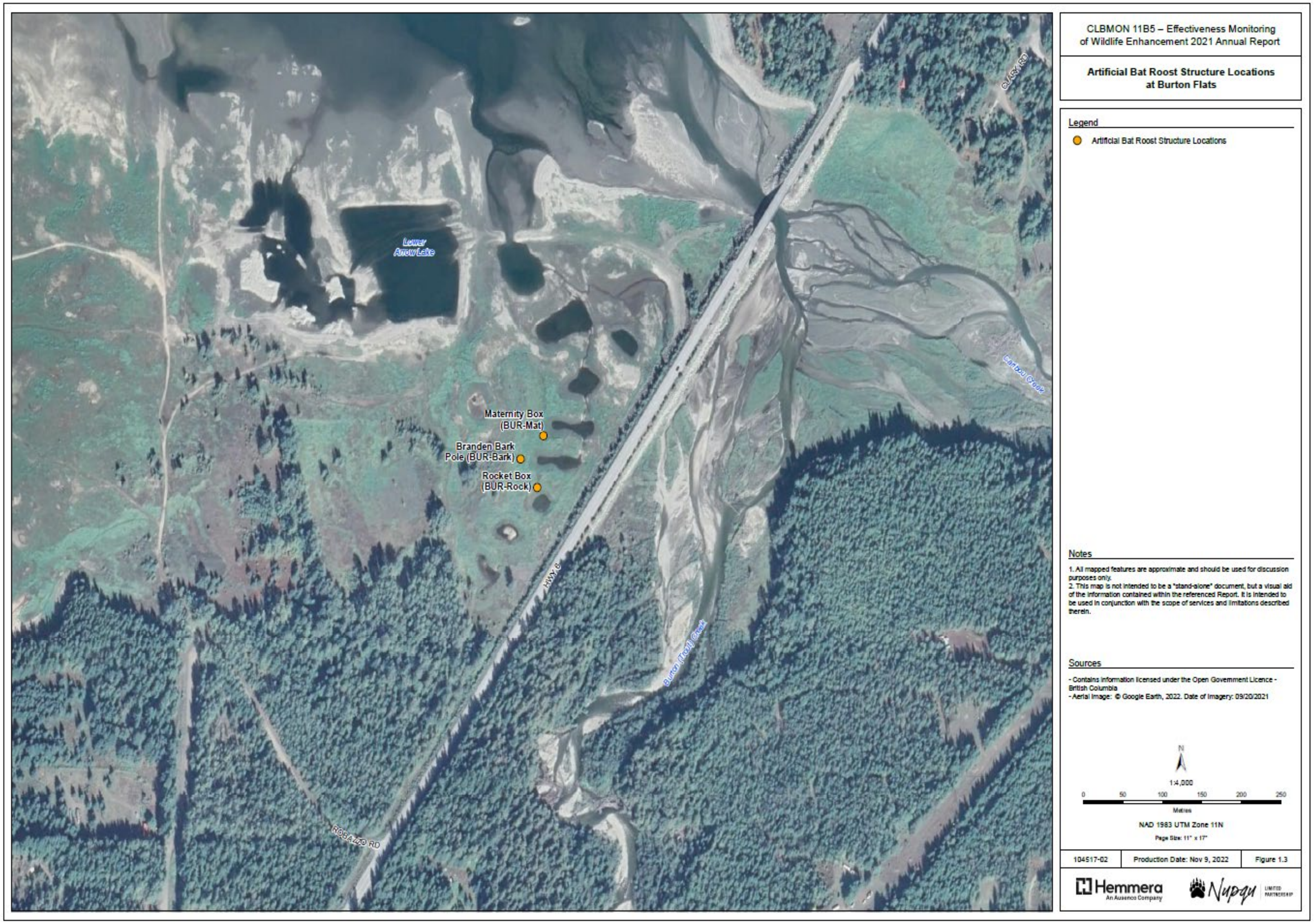

Figure 1.3 **Artificial Bat Roost Structure Locations at Burton Flats south of Burton, BC. Bat roost enhancements at Burton are located within the newly designed wetland features A3-A5.**

Figure 1.4 Branden Bark Artificial Bark Pole M3-Bark1 Installed at the Montana 3 Location.

Figure 1.5 Branden Bark Artificial Bark Pole M3-Bark2 at the Montana 3 Location.

Figure 1.6 From left to right in the photograph, Rocket Box (HAY-Rock), back-to-back Maternity Box (HAY-Mat), and Mini-condo (HAY-Condo) Installed at the Hay Field Location.

Figure 1.7 Branden Bark Artificial Bark Pole HAY-Bark Installed at the Hay Field Location.

Figure 1.8 Branden Bark Artificial Bark Pole BUR-Bark Installed at Burton Flats.

Figure 1.9 Rocket Box BUR-Rock Installed at Burton Flats.

Figure 1.10 Maternity Box BUR-Mat Installed at Burton Flats.

1.1 Background

Artificial bat roost structures have been installed across BC, but comprehensive monitoring of the use of these structures by bats is lacking (BC Hydro 2019). As such, the effectiveness of artificial bat roosts for enhancing roosting habitat is largely unknown. Internal temperature is a critical aspect of artificial roost suitability and is heavily influenced by both bat box design and placement on the landscape (Tillman et al. 2021; Crawford et al. 2022; Fontaine et al. 2021). 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 before bat occupancy.

Reproductive female bats generally require warm maternity roosts due to the high energetic demands of pregnancy and lactation (BC Ministry of Environment 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 for thermoregulation (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 (Crawford et al. 2022; Wilde et al. 1999; Bergeson et al. 2021; Willis and Brigham 2007b). 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 utilize torpor for thermoregulation more regularly (BC Ministry of Environment 2016). Artificial roosts that are suitable as day roosts for non-reproductive bats have internal temperatures lower than 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 a day roost for non-reproductive bats, monitoring internal roost temperature at new roosts is important because concern exists that bats roosting in artificial roosts could be subjected to heat stress and heat-induced mortality (Flaquer et al. 2014; Crawford and O'Keefe 2021; Griffiths et al. 2017). The increasing frequency of extreme weather events associated with climate change, such as the heat dome event experienced across southern BC in the summer of 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 (Tillman et al. 2021; Flaquer et al. 2014; Hoeh et al. 2018; Bideguren et al. 2019). Though it is also noted that thermal tolerance likely varies between species and the thermoregulatory strategy adopted by bats likely varies based on local climatic conditions (Crawford and O'Keefe 2021; Ancillotto et al. 2018; Encarnacao et al. 2012; Czenze et al. 2017).

1.2 Objectives

The objective of monitoring the artificial bat roost structures is to answer the following management questions:

A. Are the wildlife enhancement structures (bat day roosts/maternity structures) effective at enhancing habitat quality and quantity for bats?
    i. 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.
    ii. How are the bat maternity structures utilized in terms of seasonality, intensity of use, species presence, and number of days occupied per year?
    iii. How does the internal temperature of bat maternity structures affect their successful utilization by bats?
B. 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 Years 1 and 2 of the 5 years of planned monitoring. Year 1 (2020) includes monitoring results for 2 artificial bark poles at the Montana 3 site which were available for bat occupancy. Year 2 (2021) includes monitoring results for all 9 artificial roosts across 3 sites (Montana 3, Hay Field, and Burton Flats). Key interim findings that address the management questions are summarized and recommendations for alternations to the monitoring program for subsequent years are also provided.

2.0 METHODS

2.1 Temperature Monitoring

Temperature data collection followed the recommendations of the BC Community Bat Program (Kellner and Sanders 2018). A single HOBO MX2303 Series Data Logger with dual temp sensors was deployed in each artificial bat 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 plastic 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. The intent of arranging the temperature probes in this manner is to determine 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 and year due to structure set-up timing and logistical constraints. Temperature data were downloaded from the data loggers monthly and data were compiled for all downloads 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 in R (R Core Team 2021), using the tidyverse packages (Wickham et al. 2019).

2.2 Occupancy Monitoring

Occupancy of structures was determined using guano traps installed near the base of each structure, via visual roost inspections during roost checks, and through emergence count surveys. Concurrent acoustic monitoring was also conducted during some emergence counts in Revelstoke Reach in 2021.

2.2.1 Guano Traps and Roost Checks

Guano traps were attached to the poles of the artificial roosting structures 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 netting 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 simple guano collection and not interfering with bat flight or flyway path. During monitoring visits, minor maintenance and cleaning of the traps was conducted.

During each monitoring visit, a biologist recorded information including the presence of guano and condition of the roost structures using a standardized data form. A light was shone into each 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 labeled including the structure type, location, and time of collection, and stored for future analysis. After each roost check, all guano was cleaned from the surface of the guano traps. Sample pellets were stored in soft tissue paper (2020), or cotton balls (2021) inside a coin envelope with one envelope per structure. Coin envelopes were stored open, in a dry area to allow the sample pellets to desiccate.

Samples were analyzed by Wildlife Genetics International, in Nelson, BC. Genetic analysis consisted of analyzing individual pellets to determine species. Guano pellet DNA was processed using QIAGEN DNeasy Blood and Tissue Kits, using a 'dip and swish' in digest buffer to remove cells from the surface of pellets. Analysis of species was performed by partial sequencing of the mitochondrial 16S rRNA gene, working with universal mammalian primers for the first round of analysis. Failed samples were reanalyzed using anti-ungulate primers that amplify bats more strongly than the universal primers.

2.2.2 Emergence Counts

Emergence counts were conducted according to protocols outlined in the BC Community Bat Program Annual Bat Count (BC Community Bat Program 2021). On each emergence count survey night, observer effort was focused on artificial roosts with recent or seasonal evidence of use (i.e., presence of guano or bats observed within the roost).

During some emergence counts, acoustic monitoring data were recorded using an Echo Meter Touch 2 from Wildlife Acoustics Inc to provide additional information about which species are 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. Bat calls by species or species group were enumerated using a "bat pass" metric, with one 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 the 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 species 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 Bat Species with the Potential to Occur in the Arrow Lakes Reservoir in Acoustic Groups

Common Name	Scientific Name	Acoustic Groups1						
		Unidentified bat	Low frequency bat	Big brown / silver-haired bat	High frequency bat	Long-eared bats	Myotis	45 kHz Myotis
big brown bat	*Eptesicus fuscus*	■	■	■				
Californian myotis	*Myotis californicus*	■			■		■	■
eastern red bat	*Lasiurus borealis*	■	■		■			
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.

3.0 RESULTS

3.1 Temperature Monitoring

3.1.1 2020 Data

Temperature data were collected from both sensors in each of the 2 artificial roost structures available for monitoring in 2020 (i.e., M3-Bark1 and M3-Bark2), as well as the ambient pendant data logger at Montana 3 (**Table 3.1**). Data are summarized below for April through October, the season during which occupancy of the artificial structures was anticipated (**Table 3.2, Figure 3.1**). However, data was not collected at M3-Bark2 between July 7 and August 18 due to a data logger malfunction, a period that would typically include many warm days.

Table 3.1 Dates of Temperature Monitoring at Revelstoke Reach in 2020

Data Logger ID	Dates Monitored	Number of Days Monitored
Revelstoke Reach		
M3-Bark1	March 15 to November 2	233
M3-Bark2	March 15 to July 7 August 18 to September 3	132
M3-Ambient	March 15 to November 2	233

Table 3.2 Summary of Temperatures and Overheating Events from April to October for each Roost Monitored in 2020

Roost	Probe	Minimum Temperature (°C)	Maximum Temperature (°C)	Average Temperature (°C)	Number of Days Monitored (April to Oct)	Total Number of Overheating Events[1]	Number of Days with an Overheating Event
M3-Bark1	Warm	-10.0	60.6	16.1	215	356	96
	Cool	-8.5	33.3	12.7	215	0	0
M3-Bark2[2]	Warm	-8.1	51.6	16.4	115	130	36
	Cool	-7.3	31.7	12.7	115	0	0

Note: [1] An overheating event is defined as the number of 60 min periods during which the temperature recorded at a logger reached a maximum temperature of at least 40°C during at least one 10-minute interval reading.
[2] Temperature data was not recorded at the M3-Bark2 between July 7 and August 18, 2020.

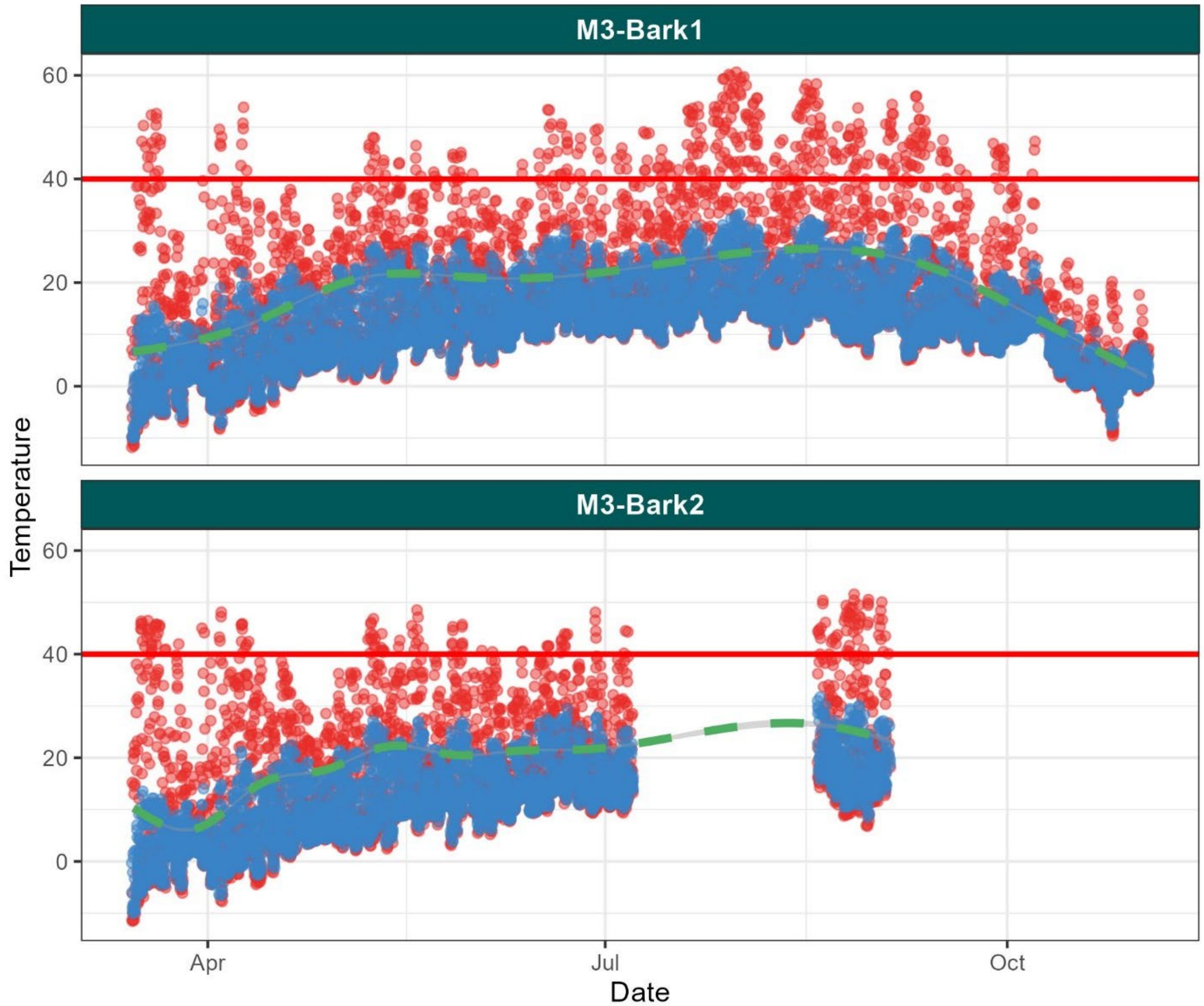

Figure 3.1 Ambient (smoothed daily maximum in green) and Artificial Roost Temperatures (warm sensor = red, cool sensor = blue) Recorded at Montana 3 in 2020.

3.1.2 2021 Data

Temperature data were collected from both sensors in every artificial roost structure with a temperature logger in 2021, as well as at the ambient temperature data loggers at Montana 3 and Burton Flats. No temperature logger was deployed at the Branden Bark™ pole at Hay Field in 2021 so internal temperature data from this roost is not available. The range of dates for which data were collected varied for each data logger (**Table 3.3**). Data are summarized below for April through October, the season during which the occupancy of the artificial structures by bats is anticipated (**Table 3.4**).

Table 3.3 Dates of Temperature Monitoring at Revelstoke Reach and Burton Flats in 2021

Location	Data Logger ID	Dates Monitored	Total Number of Days Monitored
Revelstoke Reach – Montana 3	M3-Bark1	April 5 to August 23	141
	M3-Bark2	April 5 to October 16	195
	M3-Ambient	January 1 to October 16	289
Revelstoke Reach – Hay Field	HAY-Condo	April 5 to October 16	195
	HAY-Mat	April 5 to September 21	170
	HAY-Rock	May 10 to October 16	160
Burton Flats	BUR-Bark	August 5 to October 13	70
	BUR-Rock	July 30 to October 13	76
	BUR-Mat	April 19 to October 13	178
	BUR-Ambient	April 18 to October 13	179

Table 3.4 Summary of Temperatures and Overheating Events from April to October for each Roost Monitored in 2021

Roost	Probe	Minimum Temperature (°C)	Maximum Temperature (°C)	Average Temperature (°C)	Number of Days Monitored (April to Oct)	Total Number of Overheating Events	Number of Days with an Overheating Event
M3-Bark1	Warm	-4.5	64.2	19.4	141	367	82
	Cool	-3.4	37.0	15.7	141	0	0
M3-Bark2	Warm	-4.2	55.0	18.6	195	374	88
	Cool	-2.8	35.6	15.0	195	0	0
HAY-Condo	Warm	-2.0	41.3	16.4	195	2	2
	Cool	-1.7	29.3	14.1	195	0	0
HAY-Mat	Warm	-4.0	41.9	17.5	170	3	2
	Cool	-4.2	39.1	16.2	170	0	0
HAY-Rock	Warm	-1.7	43.2	18.2	160	10	5
	Cool	-2.2	36.1	15.6	160	0	0
BUR-Bark	Warm	-3.1	48.4	18.0	70	69	22
	Cool	-3.0	33.1	13.6	70	0	0
BUR-Rock	Warm	-3.2	49.6	18.6	76	97	31
	Cool	-2.9	33.6	14.8	76	0	0
BUR-Mat	Warm	-3.0	49.6	18.3	178	67	16
	Cool	-3.1	49.0	16.5	178	37	13

3.1.2.1 Montana 3

Temperatures recorded within the 2 roosts from April through October ranged from a low of -4.5°C to a high of 64.2°C (**Table 3.4**, **Figure 3.2**). The coolest portion of the structures never exceeded 40°C but reached 37.0°C in M3-Bark1 and 35.6°C in M3-Bark2 (**Table 3.4**). Ambient temperature from April to October ranged from -3.5°C to 36.4°C.

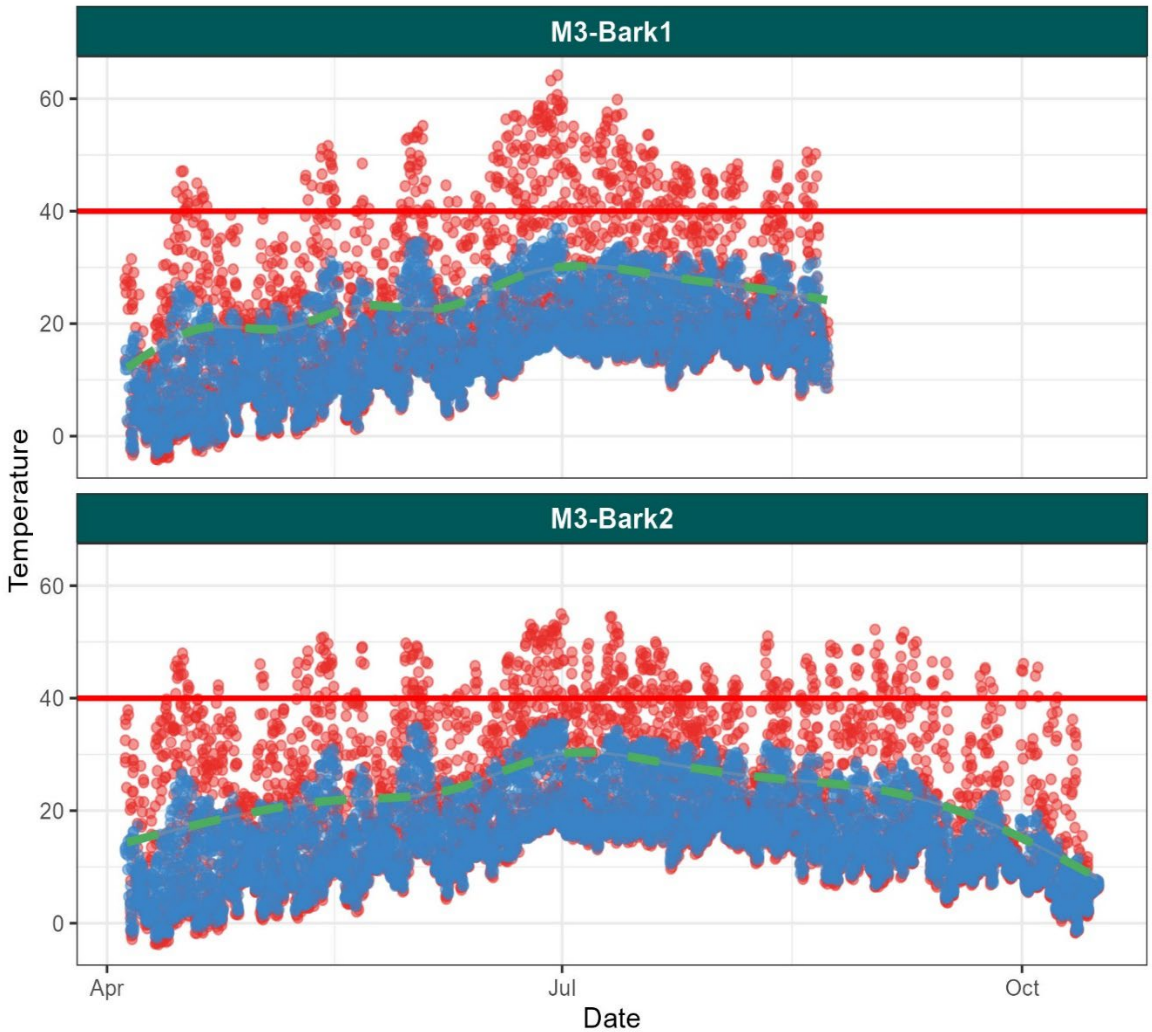

Figure 3.2 **Ambient (smoothed daily maximum in green) and Artificial Roost Temperatures (warm sensor = red, cool sensor = blue) Recorded at Montana 3 in 2021.**

3.1.2.2 Hay Field

Temperatures recorded within the 3 monitored roosts from April through October ranged from a low of -4.2°C to a high of 43.2°C (**Table 3.4, Figure 3.3**). The sensors in the warmest part of the structures occasionally recorded temperatures over 40°C (2 days in HAY-Condo and HAY-Mat, and 5 days in HAY-Rock) (**Table 3.4**). The coolest portion of the structures never exceeded 40°C, but reached 29.3°C in HAY-Condo, 39.1°C int HAY-Mat, and 36.1°C in HAY-Rock.

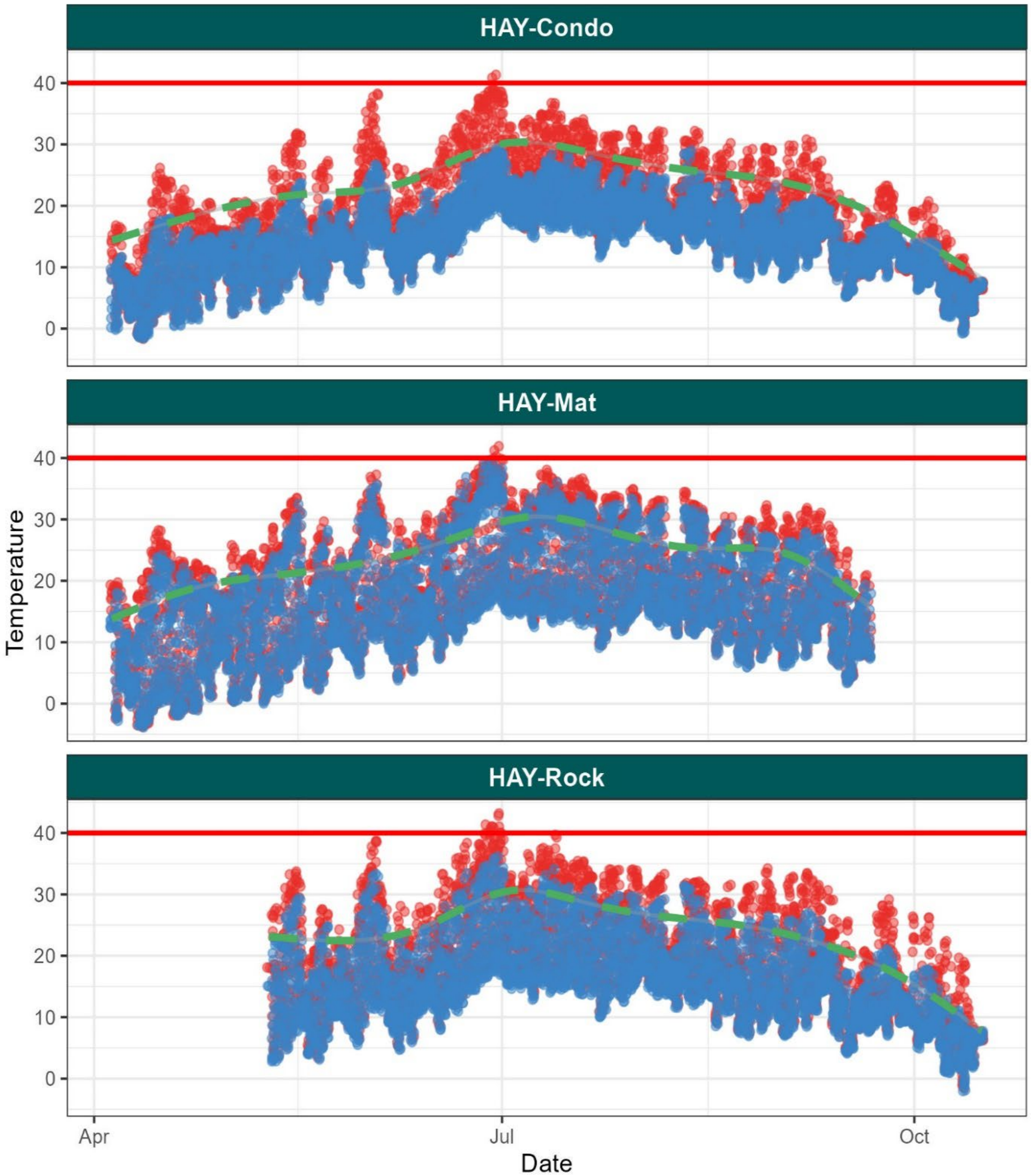

Figure 3.3 **Ambient (smoothed daily maximum in green) and Artificial Roost Temperatures (warm sensor = red, cool sensor = blue) Recorded at Hay Field in 2021.**

3.1.2.3 Burton Flats

Temperature data were collected at all 3 roosts in 2021, however, data was not collected for BUR-Bark and BUR-Rock prior to August 5 and July 30, respectively. This means the minimum and maximum temperature values at those roosts may not be representative of the true range of temperatures within the roosts during the 2021 season.

Temperatures recorded within the roosts from April through October ranged from a low of -3.2°C to a high of 49.6°C (**Table 3.4, Figure 3.4**). Ambient temperature from April to October ranged from -3.7°C to 39.8°C.

The sensors in the warmest part of the structures recorded temperatures over 40°C on 22 days in BUR-Bark, 16 days in BUR-Mat, and 31 days in BUR-Rock (**Table 3.4**). The coolest portion of the BUR-Mat roost exceeded 40°C on 13 days, reaching a maximum of 48.9°C on June 30. Temperatures were not recorded above 40°C in the coolest portions of the BUR-Bark and BUR-Rock roosts, but temperatures were not recorded at these structures prior to July 30.

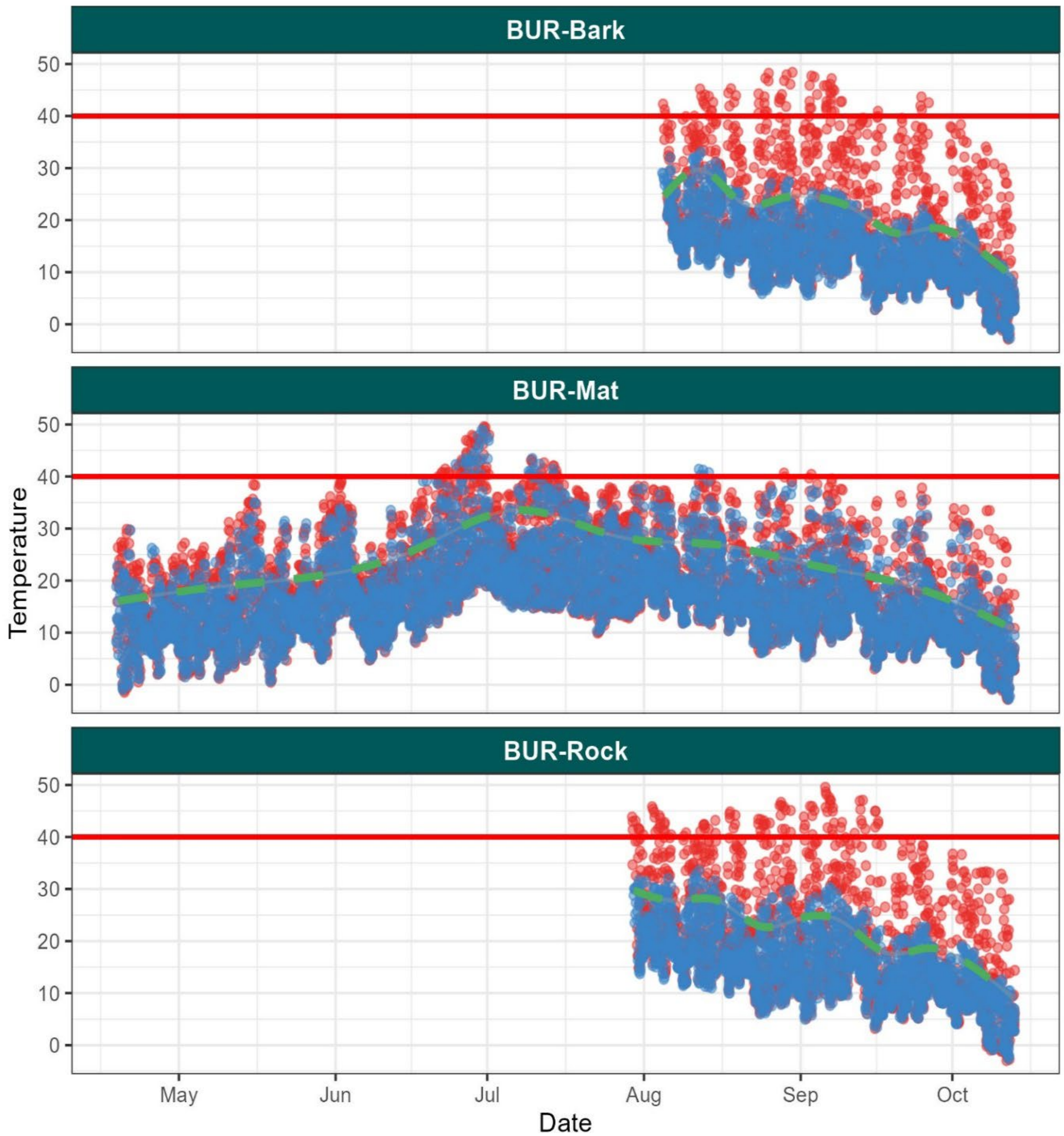

Figure 3.4 **Ambient (smoothed daily maximum in green) and Artificial Roost Temperatures (warm sensor = red, cool sensor = blue) Recorded at Burton Flats in 2021.**

3.2 Occupancy Monitoring

3.2.1 2020 Data

3.2.1.1 Guano Collection and Analysis

Guano was collected monthly from M3-Bark1 and M3-Bark2 between May and October with 10 samples in total being collected, 5 from each structure. Quantities of guano varied across the monitoring period, with the largest quantities observed in July and September. Overall, the amount of guano observed at the Branden Bark™ poles was low, with a maximum of approximately 15 pellets observed at M3-Bark2 during the August monitoring visit. The amount of guano observed differed slightly between the 2 roost structures, with a greater number of pellets recorded at M3-Bark2 than M3-Bark1.

Guano samples were sent to Wildlife Genetics International in December 2020 and analyzed by March 2021 (**Table 3.5**). A total of 17 pellets were analyzed, which represents 10 individual samples, and 7 replicates from each occasion where sufficient pellets of suitable quality were available for sampling. Several pellets were compromised through either storage or shipping, thus some pellets collected could not be analyzed. Some samples failed due to pellet size or composition, so not all pellets produced results. The analysis confirmed use of the artificial bark poles by one species, little brown myotis.

Table 3.5 Guano Samples Collected in 2020 from Branden Bark Poles Installed at Montana 3

Roost Check Date	Number of Pellets Analyzed	Species Detected	Comments
M3-Bark1			
May 1	1	-	Insufficient material
July 7	2	None	2 of 2 pellets failed
August 4	2	*Myotis lucifugus*	1 of 2 pellets failed
September 22	2	*M. lucifugus*	1 of 2 pellets failed
October 31	1	None	1 of 1 pellet failed
M3-Bark2			
May 30	2	*M. lucifugus*	-
July 7	2	*M. lucifugus*	1 of 2 pellets failed
August 4	2	*M. lucifugus*	-
September 22	2	None	2 of 2 pellets failed
October 31	1	None	1 of 1 pellet failed

3.2.1.2 Emergence Counts

In 2020, emergence counts were conducted at the Montana 3 roosts over 4 nights: June 9, June 16, July 27, and August 4. M3-Bark2 consistently had the most guano, thus was the focus of the survey on all 4 nights. Observer effort was not allocated to M3-Bark1 on the first 2 emergence counts because there was no guano at the base, nor was there any sign of bats in the structure.

On June 9 and July 27, single bats were seen flying near M3-Bark2, but were not observed emerging from the structure. A single bat was observed leaving M3-Bark2 on June 16 at 21:44, and a bat was detected with a flashlight inside M3-Bark1 but was not seen leaving the roost.

3.2.2 2021 Data

3.2.2.1 Montana 3

In 2021, both M3-Bark1 and M3-Bark2 were checked 13 times throughout the monitoring season. Both structures had suspected bat occupancy prior to May 20 based on the presence of guano at both structures (**Table 3.6**). No guano was observed again at M3-Bark1 until the June 28 roost check when 70 pellets were counted. Guano was present at each of the subsequent 5 roost checks, the last of which was on September 29. Guano was collected on 5 of 6 roost checks between June 28 and September 29. All guano analyzed was attributed to little brown myotis. No guano was observed at M3-Bark1 after September 29.

Guano was present at all 11 roost checks at M3-Bark2 from May 20 through to October 8 (**Table 3.6**). Guano analysis confirmed the presence of little brown myotis at M3-Bark2 from the May 20 roost check through to the July 26 roost check. Guano was present at the subsequent 4 roost checks; however, no guano was collected on August 3 or September 29, and guano samples collected on August 27 and September 20 failed to produce a species detection. Little brown myotis was again confirmed present at M3-Bark2 in early October based on guano analysis collected on October 8.

Table 3.6 Guano Results for Montana 3 Roosts in 2021

Roost Check Date	Guano Present at Roost Check (Number of Pellets[1])	Number of Pellets Analyzed	Species Detected	Comments
M3-Bark1				
May 10	0	-	-	-
May 20	Yes[2]	0	-	-
May 27	0	-	-	-
June 8	0	-	-	-
June 15	0	-	-	-
June 28	70	3	*Myotis lucifugus*	1 of 3 pellets failed
July 26	42	3	*M. lucifugus*	-
August 3	17	0	-	-
August 27	63	3	*M. lucifugus*	2 of 3 pellets failed
September 20	24	3	*M. lucifugus*	1 of 3 pellets failed
September 29	4	3	*M. lucifugus*	-
October 8	0	-	-	-
October 16	0	-	-	-
M3-Bark2				
May 10	0	-	-	-
May 20	Yes[2]	3	*M. lucifugus*	-
May 27	7	3	*M. lucifugus*	-
June 8	70	3	*M. lucifugus*	-
June 15	82	3	*M. lucifugus*	-
June 28	100	3	*M. lucifugus*	-
July 26	200	3	*M. lucifugus*	1 of 3 pellets failed
August 3	46	0	-	-
August 27	53	3	None	3 of 3 pellets failed

Roost Check Date	Guano Present at Roost Check (Number of Pellets[1])	Number of Pellets Analyzed	Species Detected	Comments
September 20	2	2	None	2 of 2 pellets failed
September 29	3	0	-	-
October 8	6	3	*M. lucifugus*	1 of 3 pellets failed
October 16	0	-	-	-

Note: [1] Pellet counts greater than 100 pellets are approximate.
[2] Guano was present at the time of the roost check, but a count was not completed.

One emergence count was completed at M3-Bark2 on June 15, 2021, during the pre-pup period (June 1 through 21) (BC Community Bat Program 2021). Four bats were observed emerging from M3-Bark2. An emergence count was not completed at M3-Bark1 on this date because no guano was observed at this roost structure.

A second emergence count was conducted at both M3-Bark1 and M3-Bark2 on August 3, 2021. This survey coincided with the period when pups are becoming volant and flying and exiting roosts (July 11 through August 5) (BC Community Bat Program 2021). The surveyors observed 2 bats exit M3-Bark1 and 3 bats exit M3-Bark2. Concurrent acoustic monitoring conducted during the emergence survey captured bat activity in the vicinity of the Montana 3 roost structures at emergence time. A total of 50 bat passes were recorded in the vicinity of M3-Bark2 during the emergence survey, and 21 bat passes were recorded in the vicinity of M3-Bark1 (**Table 3.7**). Bat passes were attributed to 4 species based on acoustic characteristics: big brown bat (2 passes), hoary bat (*Lasiurus cinereus*, 13 passes), little brown myotis (2 passes), and long-eared myotis (*Myotis evotis*, 3 passes). Most bat passes were attributed to the *Myotis* species group (34 bat passes). Several bat passes (6) were also attributed to the 45 kHz *Myotis* group which is comprised of 2 species: California myotis (*Myotis californicus*) and Yuma myotis (*Myotis yumanensis*).

Table 3.7 Bat Activity Recorded in the Vicinity of Montana 3 Roosts During Emergence Counts on August 3, 2021

Bat Species or Group		Number of Bat Passes by Detector Location	
Common Name	Scientific Name	M3-Bark1	M3-Bark2
big brown bat	*Eptesicus fuscus*	-	2
big brown bat / silver-haired bat group	*Eptesicus fuscus / Lasionycteris noctivagans*	3	3
hoary bat	*Lasiurus cinereus*	5	8
little brown myotis	*Myotis lucifugus*	1	1
long-eared myotis	*Myotis evotis*	-	3
low-frequency bat group	-	2	1
Myotis group	*Myotis sp.*	8	26
45 kHz *Myotis* group	*Myotis californicus / Myotis yumanensis*	2	4
unidentified bat	-	-	2
	Totals:	**21**	**50**

3.2.2.2 Hay Field

The Branden Bark™ pole (HAY-Bark) at the Hay Field site was occupied from approximately late July through late September, with guano observed at each of the 5 roost checks completed during this period (**Table 3.8**). Additionally, one guano pellet was observed and collected at this structure on May 20. Guano collected at HAY-Bark on July 26, August 27, September 20, and September 29 was attributed to little brown myotis based on genetic analysis.

Pellets were observed at the mini-condo (HAY-Condo) on the May 10 and May 20 roost checks, and then again in late September through mid-October (**Table 3.8**); however, of all the pellets submitted for genetic analysis from HAY-Condo (10 total), only 1 was attributed to a bat. This pellet was attributed to either California myotis or western small-footed myotis based on the non-diagnostic haplotype 'MYCA' documented in both species. This sample was then analyzed again at the microsatellite locus Mluc21 to resolve the species ambiguity, but this secondary analysis failed. California myotis would be the more likely of the two species based on range. Of the remaining pellets, 8 were attributed to deer mouse (*Peromyscus maniculatus*) and 1 failed to produce a species detection.

Guano was present at the maternity box (HAY-Mat) on 4 of 5 roost checks between late June and late September (**Table 3.8**). A total of 9 pellets collected at HAY-Mat on 3 dates were submitted for genetic analysis. Of these pellets, 5 were attributed to little brown myotis, and 4 failed to produce species detection.

The rocket box was used in mid-May based on the presence of guano on the May 20 roost check (**Table 3.8**). Guano was also observed during 3 roost checks from late July through late August. Of 7 pellets submitted for genetic analysis, 4 were attributed to little brown myotis, and 3 failed to produce a species detection.

Table 3.8 Guano Results for Hay Field Roosts

Roost Check Date	Guano Present at Roost Check (Number of Pellets[1])	Number of Pellets Analyzed	Species Detected	Comments
HAY-Bark				
May 10	0	-	-	-
May 20	Yes[2]	0	-	-
May 27	0	-	-	-
June 8	0	-	-	-
June 15	0	-	-	-
June 28	0	-	-	-
July 26	36	3	*M. lucifugus*	-
August 3	58	0	-	-
August 27	113	3	*M. lucifugus*	-
September 20	92	3	*M. lucifugus*	2 of 3 pellets failed
September 29	42	3	*M. lucifugus*	-
October 8	0	-	-	-
October 15	0	-	-	-

Roost Check Date	Guano Present at Roost Check (Number of Pellets[1])	Number of Pellets Analyzed	Species Detected	Comments
HAY-Condo				
May 10	Yes[2]	1	*Peromyscus maniculatus* (deer mouse)	-
May 20	Yes[2]	0	-	-
May 27	0	-	-	-
June 8	0	-	-	-
June 15	0	-	-	-
June 28	0	-	-	-
July 26	0	-	-	-
August 3	0	-	-	-
August 27	0	-	-	-
September 20	0	-	-	-
September 29	12	3	*P. maniculatus*	1 of 3 pellets failed
October 8	15	3	*M. californicus or M. ciliolabrum – likely M. californicus based on species distributions* *Peromyscus maniculatus*	1 of 3 pellets was bat species 2 of 3 pellets were deer mouse
October 15	6	3	*P. maniculatus*	-
HAY-Mat				
May 10	0	-	-	-
May 20	Yes[2]	0	-	-
May 27	0	-	-	-
June 8	0	-	-	-
June 15	0	-	-	-
June 28	10	3	*M. lucifugus*	-
July 26	0	-	-	-
August 3	52	0	-	-
August 27	168	3	*M. lucifugus*	1 of 3 pellets failed
September 20	106	3	None	3 of 3 pellets failed
September 29	0	-	-	-
October 8	0	-	-	-
October 15	0	-	-	-
HAY-Rock				
May 10	0	-	-	-
May 20	Yes[2]	0	-	-
May 27	0	-	-	-
June 8	0	-	-	-

Roost Check Date	Guano Present at Roost Check (Number of Pellets[1])	Number of Pellets Analyzed	Species Detected	Comments
June 15	0	-	-	-
June 28	1	1	None	1 of 1 pellet failed
July 26	58	3	*M. lucifugus*	-
August 3	23	0	-	-
August 27	19	3	*M. lucifugus*	2 of 3 pellets failed
September 20	0	-	-	-
September 29	0	-	-	-
October 8	0	-	-	-
October 15	0	-	-	-

Note: [1] Pellet counts greater than 100 pellets are approximate.
[2] Guano was present at the time of the roost check, but a count was not completed.

Emergence surveys were completed at the Hay Field roost structures on August 4, 2021. Surveyors observed 3 bats exit HAY-Bark, 2 bats exit HAY-Mat, and 2 bats exit HAY-Rock (**Table 3.9)**. No bats were observed emerging from HAY-Condo during the survey. Concurrent acoustic monitoring conducted during the emergence survey captured bat activity in the vicinity of the Hay Field roost structures at emergence time. A total of 3 bat passes were recorded in the vicinity of HAY-Condo, HAY-Mat, and HAY-Rock during the emergence survey, and 8 bat passes were recorded in the vicinity of HAY-Bark (**Figure 1.2**). Bat passes were attributed to 2 species based on acoustic characteristics: hoary bat (2 passes), and long eared myotis (2 passes). The remaining 7 bat passes could not be identified to species. Three bat passes were attributed to the 45 kHz *Myotis* group, 1 bat pass to the general *Myotis* species group, 2 bat passes to the big brown/silver-haired bat species group, and 1 to the unidentified bat group.

Table 3.9 Bat Activity Recorded in the Vicinity of Hay Field Roosts During Emergence Counts on August 4, 2021

Bat Species or Group		Number of Bat Passes by Detector Location	
Common Name	Scientific Name	HAY-Condo	HAY-Bark
big brown bat / silver-haired bat group	*Eptesicus fuscus / Lasionycteris noctivagans*	-	2
hoary bat	*Lasiurus cinereus*	-	2
long-eared myotis	*Myotis evotis*	-	2
Myotis group	*Myotis sp.*	1	-
45 kHz *Myotis* group	*Myotis californicus / Myotis yumanensis*	2	1
unidentified bat	-	-	1
	Totals:	**3**	**8**

3.2.2.3 Burton Flats

Guano was documented at the rocket box (BUR-Rock) at the Burton Flats site on the July 30 roost check (**Table 3.10**). Guano was also noted at the maternity box (BUR-Mat) on both the July 30 and October 13 roost checks. No guano was observed at the artificial bark pole roost (BUR-Bark) during the 2021 monitoring season.

To-date, presence of bat guano has not been confirmed at the Burton Flats roosts. Potential guano pellets were observed at both the BUR-Rock and BUR-Mat roost structure on July 30; however, of the 6 pellets that were submitted for genetic analysis, 5 pellets failed to produce results. The 1 pellet that produced genetic results was assigned as deer mouse. Pellets were again observed at the BUR-Mat on October 15 at the final roost check of the 2021 monitoring year, but none were submitted for analysis.

No emergence counts were completed at the Burton Flats roosts in 2021.

Table 3.10 Guano Results for Burton Flats Roosts

Roost Check Date	Guano Present at Roost Check (Number of Pellets[1])	Number of Pellets Analyzed	Species Detected	Comments
BUR-Bark				
June 15	0	-	-	-
July 3	0	-	-	Only BUR-Bark was accessible due to high water levels
July 30	0	-	-	-
August 24	0	-	-	-
October 13	0	-	-	-
BUR-Mat				
June 15	0	-	-	-
July 3	-	-	-	Not accessible due to water levels
July 30	3	3	None	3 of 3 pellets failed; lab noted the pellets looked crushed
August 24	0	-	-	-
October 13	5	0	-	-
BUR-Rock				
June 15	0	-	-	-
July 3	-	-	-	Not accessible due to water levels
July 30	8	3	*Peromyscus maniculatus*	2 of 3 pellets failed; lab noted the pellets looked crushed
August 24	0	-	-	-
October 13	0	-	-	-

Note: [1] Guano pellets present during roost check, not equal to total pellets collected.

4.0 DISCUSSION

Since the bat roost enhancement structures in Revelstoke Reach were initially planned, many publications have been released 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 (Bergeson et al. 2021; Bideguren et al. 2019; Brack and Sparks 2021; Crawford et al. 2022; Crawford and O'Keefe 2021; Fontaine et al. 2021; Tillman et al. 2021). 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. The following section addresses each of the management questions identified in the scope of services (BC Hydro 2019) and discusses our interim findings with respect to each question. The interim findings presented here represent the first year of data for the Hay Field and Burton Flats bat roosts and the first and second years of data for the Montana 3 bat roosts.

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:

A. Are the wildlife enhancement structures (bat day roosts/maternity structures) effective at enhancing habitat quality and quantity for bats?
   i. How are the bat maternity structures utilized in terms of seasonality, intensity of use, species present, and number of days occupied per year?

Key interim findings on the utilization of each bat roost to-date are summarized by roost in **Table 4.1**.

Table 4.1 Artificial Bat Roost Utilization 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. Low intensity based on low amounts of guano. A greater quantity of guano was observed in 2021 compared to 2020. No bats were directly observed using M3-Bark1 in 2020. Confirmed occupancy by 2 bats in 2021 based on emergence count.	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 in 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).
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.	Low intensity based on low amounts of guano. A greater quantity of guano was observed in 2021 compared to 2020. Confirmed occupancy by 2 bats in 2020 and 4 bats in 2021 based on emergence counts.	Little brown myotis	Intermittent occupancy for at least 116 days in 20.20, 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 in 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).
HAY-Bark	May 10 to October 16, 2021	Guano observed in May and July to September 2021, with most guano observed in August. Most guano was observed during the late August roost check.	Very low intensity of use in spring and early summer, with slightly higher use in summer through early fall. Confirmed occupancy by 3 bats in 2021 based on emergence count.	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 September 20 roost check).
HAY-Condo	May 10 to October 16, 2021	Unknown – only one 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. No bats were directly observed occupying HAY-Condo in 2021.	California myotis (probable)	Unknown – only one confirmed bat guano pellet has been collected to-date at HAY-Condo (October 8 roost check).

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.	Very low intensity of use in spring and early summer, with slightly higher use in summer through early fall. Confirmed occupancy by 2 bats in 2021 based on emergence count.	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).
HAY-Rock	May 10 to October 16, 2021	Guano was observed in May, June, July, and August. Most guano was observed at late July roost check.	Very low intensity of use based on very low amounts of guano observed. Confirmed occupancy by 2 bats in 2021 based on emergence count.	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 August 3 roost check).
BUR-Mat	June 15 to October 13, 2021	Use has not been confirmed.	Use has not been confirmed.	None confirmed.	Use has not been confirmed.
BUR-Rock		Use has not been confirmed.	Use has not been confirmed.	None confirmed.	Use has not been confirmed.
BUR-Bark		Use has not been confirmed.	Use has not been confirmed.	None confirmed.	Use has not been confirmed.

Note: [1] Days of occupancy are based on the initial observation of guano at each roost, or direct bat observations.

ii. How does the internal temperature of bat maternity structures affect their successful utilization by bats?

In 2020 temperature monitoring was conducted at the Montana 3 bark poles (M3-Bark1 and M3-Bark2) over the period that bats were anticipated to be using the structures. Temperatures in the warmest locations of each artificial bark pole were very high during hot weather in the summer and persisted above 40°C for long periods, presenting a risk of heat stress to bats. However, the coolest portion of each structure never rose above 40°C indicating that there was a location in the structure bats could move to, providing an opportunity for temperature regulation. As such, the internal temperature of the artificial bark poles likely did not impede successful utilization by bats.

M3-Bark2 appeared to have more bat occupancy than M3-Bark1 in 2020 based on the quantity of guano observed. This structure also recorded slightly more consistent temperatures over the 2020 monitoring period, with monthly maximum internal temperatures being lower than those recorded in M3-Bark1. M3-Bark2 is located adjacent to trees to the west and south which provide afternoon shade to the structure, whereas M3-Bark1 is in a more exposed position relative to adjacent vegetation. The finding that internal temperatures in artificial bark pole roosts did not appear to lag behind ambient temperatures indicates that the structures do not provide insulative properties.

In 2021, potential overheating events where internal roost temperature was above the general threshold for heat stress for temperate region bats (40°C) were recorded at all roosts monitored. The exact number of days monitored varied by roost so a direct comparison of number of overheating events cannot be made between roosts. However, the results indicate a much higher frequency of overheating events at the Montana 3 bark poles (M3-Bark1 and M3-Bark2) compared to all other monitored roosts (82 and 88 days with overheating events over 141 and 195 days monitored, respectively). Maximum temperatures recorded at the warm sensor in both Montana 3 bark poles were also very high (64.2 and 55.0°, respectively), well above the threshold for heat-induced mortality (45°C) though no bat mortality was detected. These results are consistent with results reported by Hoeh et al. (2018) from a study in Indiana, in which the maximum temperature at a Braden Bark™ roost was recorded to be 61°C.

While overheating events were recorded at the warm sensor at all roosts in 2021, temperatures at the cool sensor in each roost never surpassed the heat-stress threshold of 40°C except 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 accessible within each roost (i.e., bats could change position to a lower and less sun-exposed aspect within the roost to experience temperatures below 40°C. 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), as was experienced during the 2021 heat dome event from late June to early July. While thermal refuge was present at the cool sensor in all but one roost (BUR-Mat), it is unknown what proportion of space within each roost remained below the heat stress threshold. At least one study has shown that bark pole roosts have a lower proportion of the roost that remains below the heat stress threshold than maternity or rocket box roosts (Hoeh et al. 2018). However, for both maternity boxes (HAY-Mat and BUR-Mat) in this study, the cool sensor temperatures appear to be more similar to the warm sensor than for the other roost types. It should also be noted that no internal temperature information is available for HAY-Bark so thermal profile information for this roost is unknown.

Temperature monitoring at BUR-Mat indicated 13 days with overheating events recorded at the cool sensor and a maximum temperature at the cool sensor of 49.0°C. These results indicate that BUR-Mat poses some risk of overheating, particularly for non-volant pups, due to a lack of thermal refuge within the roost. 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 high temperatures at the cool sensor above ambient temperature (see **Figure 3.3** and **Figure 3.4**). These results may indicate that maternity boxes may provide a narrower range of available temperatures for roosting bats and may be less buffered against hot weather events than other roost types.

The mini-condo at the Hay Field site (HAY-Condo) likely provides the most thermal refuge from hot weather events of all roosts monitored. While the high temperatures recorded at the warm sensor closely mirror those recorded at both the maternity box (HAY-Mat) and rocket box (HAY-Rock) which are both deployed at the Hay Field location, the cool sensor at HAY-Condo was consistently at or below ambient temperature through the monitoring period (**Figure 3.3**). While cooler temperatures are likely protective against overheating, the conditions may be less favorable than warmer roosts for maternity roosting. However, it is possible that if the mini-condo begins to see 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).

The results to-date do not give a clear indication on the suitability of roosts for maternity roosting. No evidence of maternity roosting has been documented. All roosts have the potential to support maternity roosting; however, 3 structures have the potential to pose risk to non-volant pups: the Montana 3 bark poles (M3-Bark1 and M3-Bark2) due to the extremely high temperatures recorded, and the Burton flats maternity box (BUR-Mat) due to lack of thermal refuge recorded over 13 days in 2021.

B. 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 6 of the Montana 3 and Hay Field artificial roosts have a low level of confirmed bat use. The artificial roosts at Burton Flats do not yet have confirmed bat use; however, these roosts were not installed until April 2021, so were new on the landscape at the start of the 2021 monitoring year. In contrast, the Montana 3 and Hay Field roosts were installed the summer and fall respectively, prior to the first season of monitoring. So local bat populations would have had more chance of encountering them prior to the first monitoring year. In addition, the intensity of use of the Montana 3 structures increased between 2020 and 2021. It is anticipated that bat use at all structures will increase over the monitoring program the longer they are available on the landscape.

Preliminary results indicate differences in the thermal profiles of different roost types installed within the same location. Overheating events documented at the Montana 3 bark poles and the Burton Flats maternity box highlights the risk of relying on one bat box design alone, particularly with the frequency of heat wave events predicted to increase under climate change. We suspect that aggregating several roosts of different designs at one location, as was done at Hay Field and Burton Flats, will be a protective measure against overheating risk. Deploying several different structures in combination will allow for roost switching and access to a wider range of thermal conditions at any given time. 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-type roosts include: 1) providing multiple roost structures in close proximity, 2) selecting a lighter roost color with more reflective properties (e.g., for example, a lighter gray artificial bark to mimic a cottonwood tree (*Populus balsamifera*) may be less prone to solar heating); 3) ensuring roosts are tall and well vented to allow for a larger thermal gradient within the roost space, and 4) 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. Artificial roost deployments that are designed to buffer against extreme weather, and therefore can be placed in locations with high solar exposure which are attractive to reproductive bats may be most effective at enhancing productivity (Crawford and O'Keefe 2021).

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 habitats across climate change scenarios and timeframes. Physical works such as the Burton Creek Wetland Enhancement under CLBWORKS 30B support examples of safeguards to focal species like breeding and migratory birds, pond-breeding amphibians, reptiles, and various mammals in the form of habitat enhancements which includes bat species. For example, wetland mounding at Burton Flats provides benefits to bats from the augmentation of emergent and riparian plantings which bolsters feeding potential within the draw-down zone of Arrow Lakes (LGL 2022). Silvicultural practices considerations include including snag retention and creation, as well as retaining a variety of tree age classes to provide future snags, and tree roost creation via modification of live trees should all be considered as options for enhancing productivity and suitability of habitat for bats in the drawdown zone (Crawford and O'Keefe 2021). Wildlife tree enhancement and methodology including stem modifications that provide micro-habitat (i.e., bat slits) can also be utilized in combination with other measures in providing additional bat roost options for bats (Manning 2021).

One study conducted in Australia found that cavities carved into live trees by chainsaw treatment more closely resembled thermal conditions in natural tree hollows, with warmer than ambient temperature recorded at night and cooler than ambient temperature recorded during the day (Griffiths et al. 2018). In comparison, bat boxes monitored in the study showed the opposite pattern, with cooler than ambient conditions at night and much warmer than ambient conditions during the day (Griffiths et al. 2018). Snag retention and creation, as well as stem modification, affect habitat availability in the long term. Whereas installation of artificial bat roosts affects habitat availability in the short term, as evidenced by the uptake of Branden Bark™ pole at Montana 3 in less than one year. Implementing both types of measures in tandem would enhance roosting habitat in the short and long term, and under various climatic regimes.

4.2 Preliminary Findings Summary

- Artificial roost structures in the Revelstoke area showed infrequent use by a small number of bats but had increasing use from 2020 to 2021.
- Little brown myotis was confirmed using the maternity box and rocket box at Hay Field and Branden Bark™ poles at Hay Field and Montana.
- California myotis was confirmed roosting in or on the mini-condo at Hay Field in October 2021.
- Although pellets were observed at Burton structures, these were not confirmed to be from bats - most samples did not produce genetic results and one pellet was confirmed as deer mouse.
- 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

After the completion of the 2020 monitoring year, the following alterations were made for the 2021 monitoring year:

1. Completion of more frequent (i.e., weekly) guano and occupancy checks at the start and end of the monitoring season to obtain more detailed occupancy dates.
2. Adoption of updated guano collection and storage protocols to align with the BC Community Bat Program and reduce sample degradation and loss.
3. Use of an additional observer during emergence counts to improve data collection by allowing simultaneous monitoring of multiple structures.

The study team recommends the following changes be considered for future monitoring seasons:

1. Consideration of the use of the pooled guano sampling and species by feces genetic analysis via Northern Arizona University as an alternative to single pellet analysis to identify bat species that may use the roost structures more infrequently and therefore be missed by a single pellet sampling strategy.
2. Continuation of more frequent (i.e., weekly) roost checks at the start and end of the monitoring season to obtain more detailed occupancy dates, in particular roosts that have not shown occupancy to date.
3. If bat occupancy of artificial roosts continues to increase in future monitoring years, the use of thermal imaging during emergence counts should be considered to assist in the enumeration of bats exiting roosts.
4. Deployment of additional temperature sensors within bark pole roosts shown to experience extreme high temperatures (M3-Bark1 and M3-Bark2) should be considered to better understand what proportion of the roost space remains below the heat-stress threshold and is suitable for bat use.
5. If the BUR-Mat roost continues to experience overheating in 2022, painting this structure in a lighter color, repositioning it to a location with afternoon solar protection, or adding additional venting to reduce temperatures in the lower part of the boxes should be considered.

6.0 CLOSURE

We sincerely appreciate the opportunity to assist you in meeting your research objectives related to bat habitat enhancement in the Columbia River basin. If there are any questions, please do not hesitate to contact the undersigned.

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