Trends in bat echolocation activity in the Beaverhill Natural Area in relation to bat box occupancy

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Abstract

This report presents the results of an acoustic survey of bats in four habitat types to compare them with those of previous years as an indicator of long-term population trends. It also examines the possible association between levels of foraging activity at different recording stations and their proximity to occupied bat houses. Surveys were conducted between May 25-September 24, 2024 in the Beaverhill Natural Area (BNA) in association with the Beaverhill Bird Observatory's (BBO) long term bat monitoring program following procedures previously established. Seasonally, bat foraging activity (all habitats) followed a unimodal pattern, with most activity between June 16 and July 28 and peaking on July 5 (n=106 recorded call sequences). Among habitats however, the timing of peak activity varied. The forest interior, including the BBO station's location, held the most activity throughout the season, with a peak at the end of July. The edge and riparian habitats reached their peak earlier in the season, with a rapid decline in activity by the end of July. Bat house counts followed similar temporal trends by habitat. The area in the forest interior where the three most active acoustic recording stations were located also included the highest roosting bat counts, suggesting an association between bat roost choice and bat foraging activity. Overall, areas where bat houses had high occupancy also record high foraging activity. Acoustic activity between 2021-2024 fluctuated annually but does not appear to follow a particular directional trend, indicating that overall the bat population may have remained relatively stable.

Introduction

Bats have a long history of acting as nature's pesticide. Each night, they consume copious amounts of insects, therefore interfering with the negative effects of agricultural pests. This relationship aids the agriculture sector each year and saves billions of dollars to farmers (Slough et al., 2023). Regardless of their economic and ecological importance, North American bat populations have been steadily decreasing due to habitat destruction, White Nose Syndrome (WNS), and mortality due to wind energy structures (Boyles et al., 2011).

Human driven impacts, which include converting natural habitats into agricultural lands, forestry, mining operations and other industrial developments, have actively contributed to the loss of habitats for bats (Environment Canada, 2015). In Canada alone, there has been a 70% decrease in wetland area, with the boreal forest receding 0.82% yearly in Alberta (Environment Canada, 2015). A 2008 study found that forest elimination may have negative effects on bats species, limiting their abilities to move through microhabitats to meet reproductive needs and torpor conditions (Henderson and Broders, 2008). Moreover, bats tend to show preference for forested areas for feeding and roosting (Hogberg et al., 2002). The losses of Canada's wetlands and the receding of the Boreal Forest edge in Alberta poses threats to natural bat habitats, effectively causing loss to foraging sites and roosting sites.

Habitat loss in combination with the discovery of WNS in Alberta poses imminent risks to Little Brown Myotis populations (Environment Canada, 2015). White nose syndrome is a fungal infection caused by the fungus *Pseudogymnoascus destructans* (Slough et al., 2023). The fungus is found in roosts of hibernating bats, where the spores can spread between individuals and cause devastating effects (White-nose Syndrome | Alberta.ca 2024 Oct 4). Furthermore, hibernating bats rely exclusively on fat reserves during hibernation. Infected bats arouse from deep torpor during winter, resulting in starvation. The fungal spores were first identified in Alberta in 2022, and two short years later, two Little Brown Myotis were found infected with the illness (White-nose Syndrome | Alberta.ca 2024 Oct 4). The discovery of White Nose Syndrome in combination with loss of vital habitat poses considerable risks to Alberta's bat populations. To better implement plausible conservation strategies for bat populations, understanding their roosting and feeding behaviours, as well as the interactions between those factors is critical.

Bat houses are often implemented as a conservation strategy and understanding what makes a suitable roost is important. Factors that include the age of bat boxes, their distance to the ground, proximity to other bat boxes, and type of bat box affect the occupancy rates of the houses, revealing older boxes higher from the ground tended to result in higher occupancy (Pschonny et al., 2022).

Understanding bats' foraging habitat preferences is a way in which compiling acoustic monitoring data may help researchers better understand behaviours of bat populations. While foraging, bats locate food via echolocation by emitting a call through their mouth and nose (Schnitzler et al., 2003; Russo et al., 2018). Measuring the frequency of various calls, as well as analyzing call types emitted, opens the potential to identify individual species in association with feeding habitats and behaviour (Fenton and Bell, 1981; Holloway and Barclay, 2000; Lear and Torrez, 2010). Studies have shown that some bats located in Alberta preferred foraging in forested riparian habitats as opposed to open spaces (Holloway and Barclay, 2000) while others noticed a strong relationship between bats foraging away from and close to artificial bat houses or roosts (Lear and Torrez, 2010). Better understanding of foraging preferences in bats may help conservationists in better utilizing placements of bat boxes in habitats better suited to foraging preferences in combination with house preference.

In 2022, a study at Beaverhill Bird Observatory found evidence that bat roosts occupancy rates have a strong relationship with proximity to water, suggesting that higher occupancy rates tended to result in closer proximity to water for many houses (Lewicki, 2022). It was also suggested this may be due to foraging behaviours, suggesting bats rely on aquatic insects for food sources. The studies conducted in 2021 and 2022 revealed the treed interior habitat with the highest calls, and in 2021, the edge habitat and water habitats peaked in the early season (June-early July), with a sudden decline in late July (Wagram 2022; Burke and Waldron 2021).

In this study, we conducted acoustic monitoring at the Beaverhill Natural Area as part of their long-term monitoring of local bat populations. Species found here might include *Myotis lucifugus* (little brown bat), *M. septentrionalis* (Northern Myotis), *Eptesicus fuscus* (big brown bat), *Lasionycteris noctivagans* (silver-haired bat), *Lasiurus cinereus* (Hoary bat), and *Lasiurus borealis* (Eastern red bat) (Low, 2024). In this report, I present the results of the acoustic survey in four habitat types and compare them with those of previous years as an indicator of population trends. Additionally, I examine the possible association between levels of foraging activity by *Myotis* at different recording stations and their proximity to occupied bat houses. Higher foraging activity recorded in some habitat types could be explained in part by the number of *Myotis spp*. bats roosting in proximity.

Methods

Study site

Data collection was conducted at the Beaverhill Natural Area (BNA), a 1,013.10 Acre Ecological Reserve located in the Central Parkland Natural Region (Alberta Parks, 2024). This is a protected area, housing a variety of habitats including wetlands and aspen groves, as well as the south side of the Beaverhill Lake. The area is used for recreational hiking as well as maintaining important habitat for 270 migrating bird species, and 145 bird species with local breeding (About BBO | Beaverhill Bird Observatory). Within the BNA is the Beaverhill Bird Observatory (BBO), the nonprofit migration monitoring organization responsible for the deployment and maintenance of the bat boxes used in this study. The bat boxes can be found along various paths within the BBO area, including Harrier Highway, Flicker Freeway, Duck Drive, BBO Boulevard, Weasel Wynd, and Robin's Route leading to the grasslands.

Acoustic survey

Weekly acoustic surveys took place between May 25-September 24, 2024 (except for June 29 and August 11 due to equipment malfunction and poor weather). Monitoring occurred at 16 previously established stations (Low, 2024), including four stations in each of the following habitats: grassland, treed interior, edge (habitat transitionary zone), and riparian (water edge) (Figures 1 and 2). Additionally, we recorded echolocation calls outside the BBO Station building.

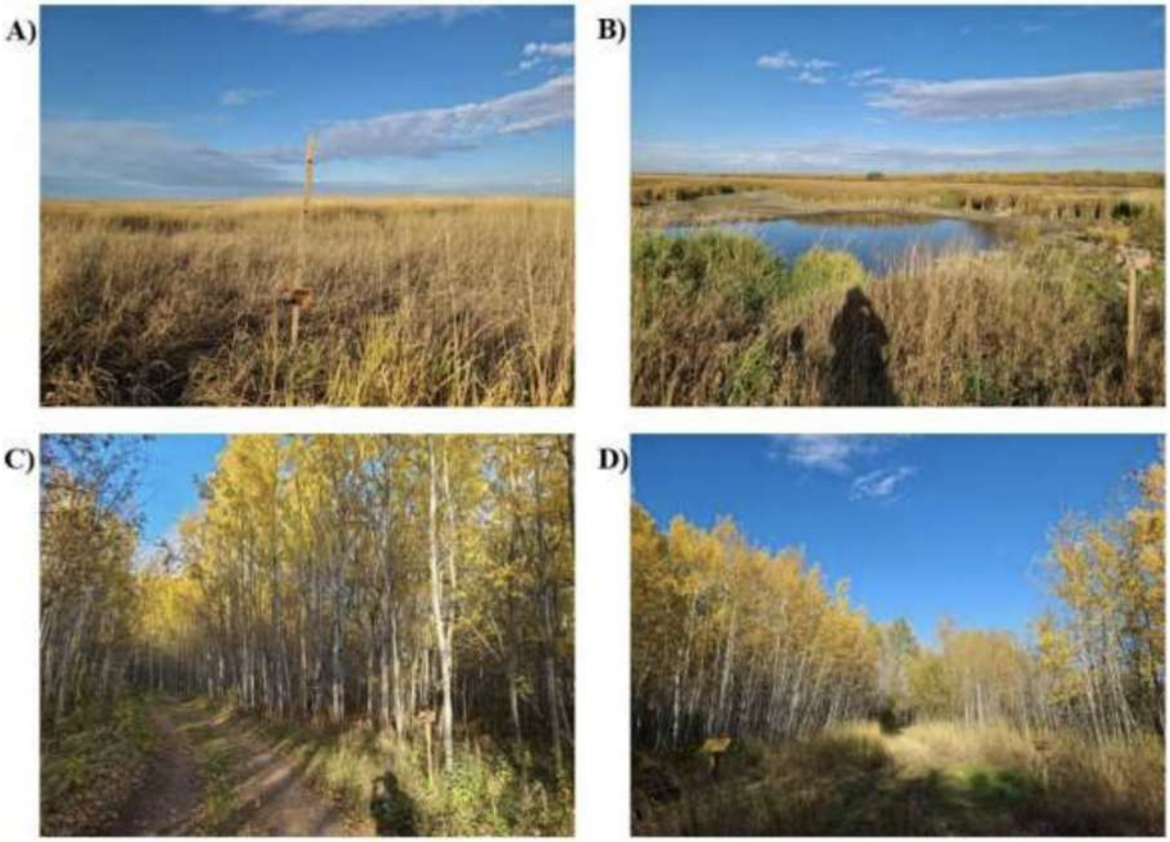


Figure 1. Examples of the habitat types for acoustic stations are as listed: A) Grasslands, B) Water, C) Interior Forest, D) Edge. (Adapted from Figure 4. Burke and Waldron 2021).

Before beginning surveys, environmental variables were collected including temperature, wind speeds (Beaufort wind scale), moon illumination (%), sunset time (24h), cloud coverage (%), and moon phase. Local weather data was collected at the BBO Station using the weather station there. This data was also collected at the end of the survey, along with start and end times. Surveys began at least forty-five minutes after sunset, after bats had left their roosts to forage, following procedures described in Low (2024). Recordings were collected with the EchoMeter Touch 2 (Wildlife Acoustics) UltraSonic Module and saved onto an Amazon Fire HD 8 (8 generation) tablet. Upon arriving at each station, the start time of recording was noted and the Echometer Touch 2 was used to record bat echolocation calls for a total of three minutes. Identification was made live and directly entered on a data sheet. Saved acoustic files were used to verify call identification when necessary. Data collected included bat species (or group), number of calls, number of feeding buzzes, and any noise pollution in the area at the time of recording.

Roost occupancy

Bat boxes were surveyed between May 17 and September 24, 2024, following the procedures described in Uy (2024). When possible, these surveys took place on the same day as the acoustic surveys. To visually analyze the relationship between roost occupancy (roosting bat counts) and echolocation activity, bat boxes and acoustic stations were geolocated using a Garmin GPS and the data transferred to Google Maps. Cumulative roost counts and habitat type of the acoustic monitoring stations were also included in the file and served to create the map. For this analysis, habitat type for each house was assigned according to the habitat type of the nearest acoustic station (Figure 2). The relationship between roost occupancy and foraging activity was also explored descriptively by comparing temporal trends in these two variables across habitat types. The likelihood of spatial overlap between acoustic stations and the proximity of bat boxes from each other precluded statistical analyses for these comparisons.

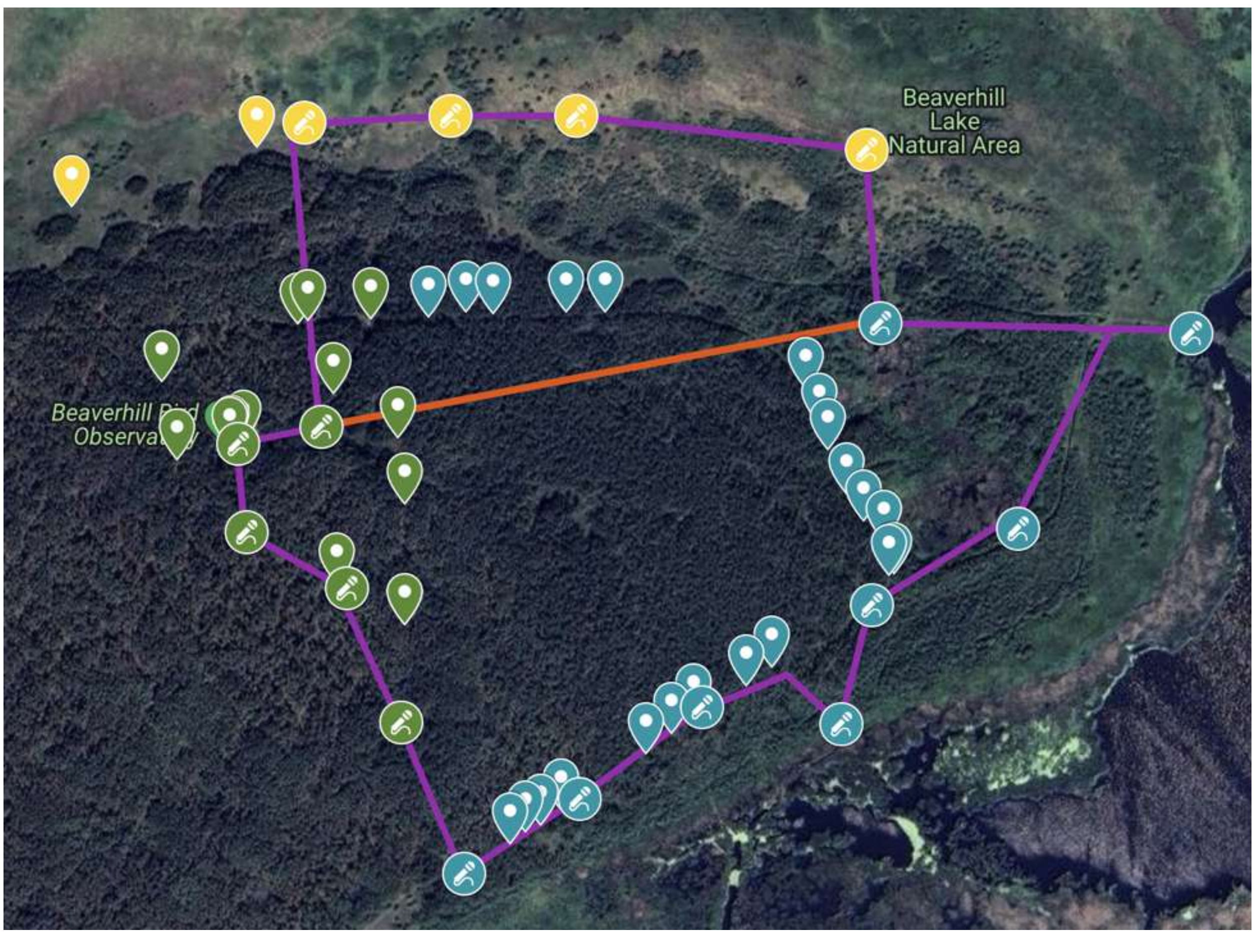


Figure 2. Map of the study area at the BNA including the location of bat boxes bat boxes (pins), acoustic sampling (microphones) stations and survey routes (lines). Habitat type in the analysis is represented by colours: Grassland in yellow, forest interior in green, and the edge+water in blue. The BBO acoustic station is included with the interior forest stations, as it represents the same habitat type. Acoustic stations in edge habitat and those in proximity to water were combined due to strong overlap in habitat. Houses were classified by habitat according to that of their nearest acoustic station.

Inter-annual comparisons in bat acoustic activity

Historic data from the BBO was used to make interannual comparisons of bat populations at BBO between 2021 and 2024. To standardize the results of acoustic activity between years, I calculated an activity index for each year, considering sampling effort. *Sampling effort* per year represents the sum of all sampling units (= *samples*) for that year. Each time a station was monitored represented a sample. The *activity index* (calls per sample) was derived by dividing the total number of calls recorded in a year by the sampling effort. Grassland stations and recordings at the BBO station were excluded from this analysis because they were not always monitored (grassland was not surveyed during weeks around summer solstice and the BBO station was monitored starting only in 2024). Therefore, in the analysis, each weekly session included a possible twelve sampling units, one for each station.

Results

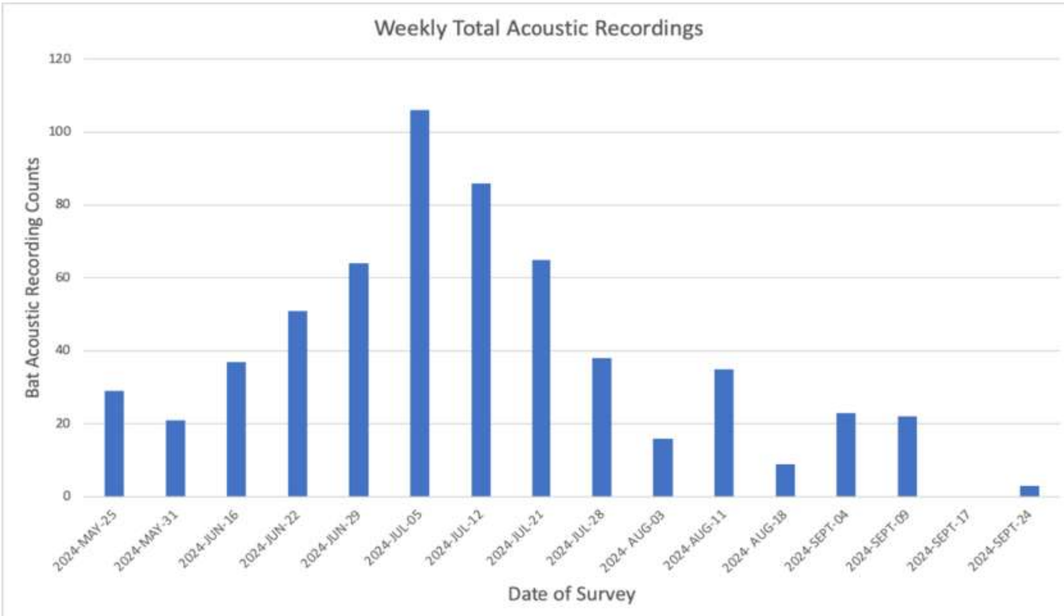
Echolocation activity and bat box occupancy in 2024

We conducted 16 acoustic surveys from May 25-September 24, 2024, for a total of 220 three-minute samples (all habitats). In total 581 bat calls were recorded, of which 547 (94%) were identifiable (Appendix 1). Sampling was conducted through changing weather conditions, including a heat wave in July.

Most identifiable calls (94.5%) were from *Myotis* species, which were detected from the first sampling night until September 9. The *Eptesicus/Lasionycteris* group (big brown bats or silver-haired bats), were detected on 6 nights and represented 2.6% of the identifiable calls. *Lasiurus cinereus* (hoary bat), the only species detected after September 9, was recorded on 4 nights and represented 2.9% of identifiable calls. Seventy-seven call sequences, all from *Myotis* contained a terminal feeding buzz.

Seasonally, bat acoustic activity followed a unimodal pattern (Figure 3a) with the highest number of bat calls recorded in early July (n=106) and declining thereafter, with a sudden drop on August 3, immediately after a heat wave in late July. In contrast, data for the bat house counts was bimodal (Figure 3b), with a peak on June 16 and a second one on July 12. As for the acoustic data, house occupancy declined rapidly in late July.

a)



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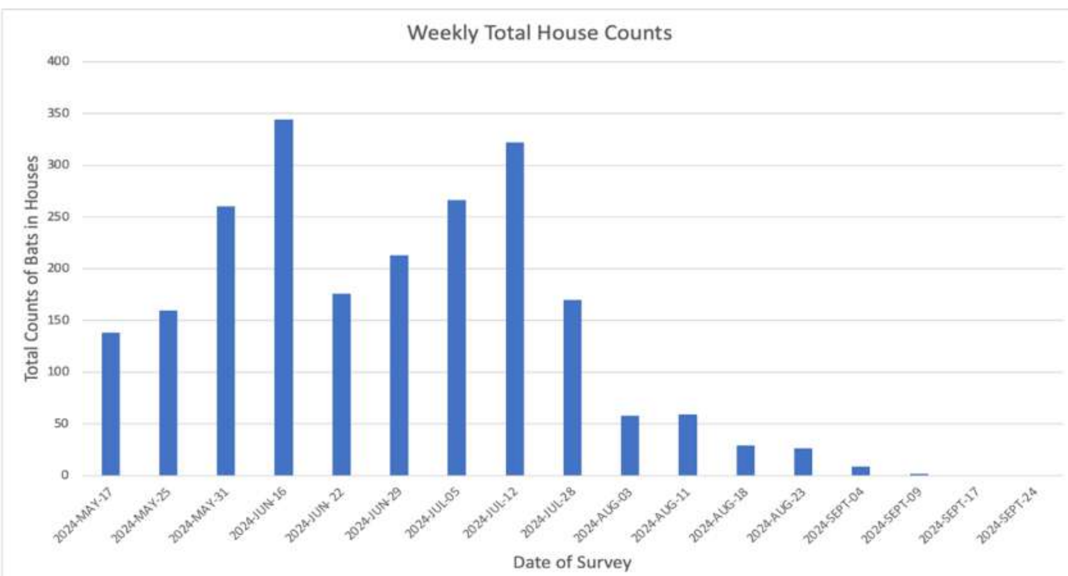


Figure 3. Bat echolocation activity (a) and bat boxes (b) occupancy at BBO through the sampling season.

Bat acoustic activity in relation to bat house counts

Overall, the forest interior acoustic stations, which included the BBO station had the highest levels of acoustic activity (Figure 4, red shaded area). Compared to any other station, the

BBO acoustic sampling station recorded the largest cumulative number of calls (16% of all calls recorded for the season). Bat houses in its surrounding also had the highest counts of roosting bats. This area also includes the three acoustic stations with the highest cumulative recordings, as well as three of the five multi-chamber houses with the highest counts and all six of the single chamber houses with the highest counts.

Additionally, the edge and riparian habitats, indicated by the yellow shaded area on the map (Figure 4), represents another notable area, as it included two acoustic stations with notably high activity (indicated by the red microphones in Figure 4), as well as two of the five multi-chamber houses with the highest counts and three of the five houses with notably elevated house counts.

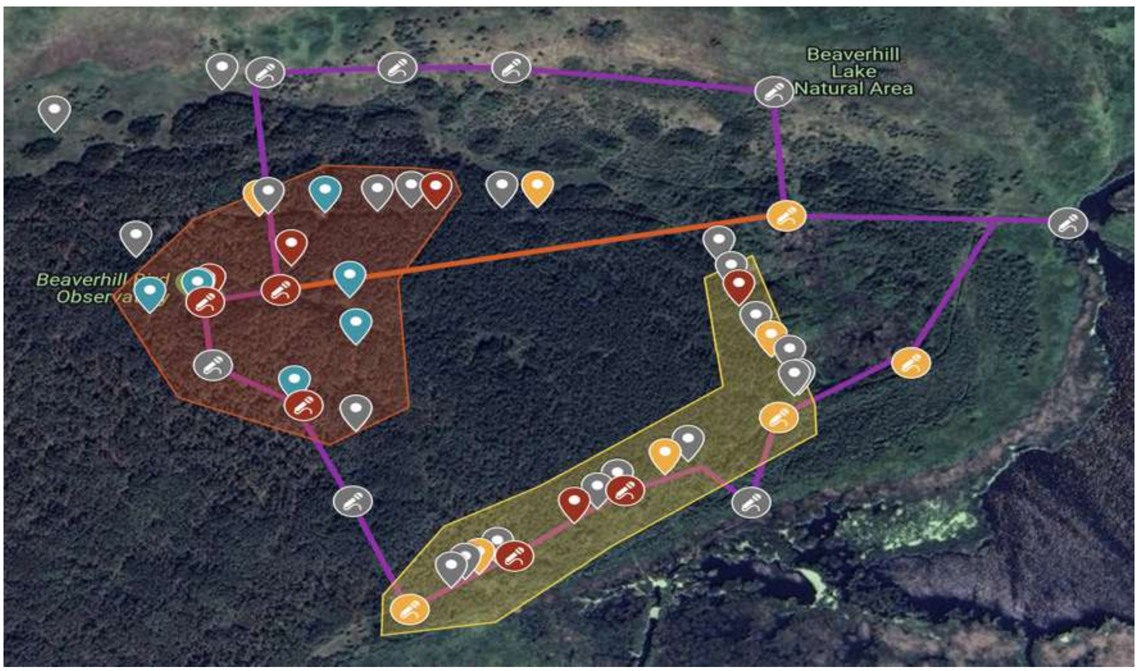
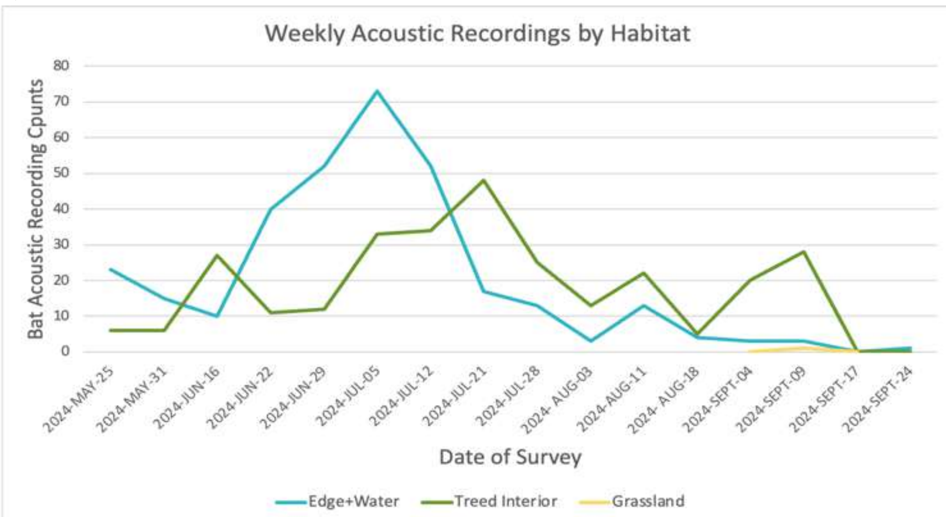


Figure 4. Bat acoustic activity and roost occupancy. Microphones indicate the location of acoustic stations. Red represents acoustic stations and houses with the highest overall counts throughout the entire season (May 17-September 24) and orange reveals the second highest groupings of activity rates for acoustics and house counts. The blue indicates single chamber houses with notably higher counts. The red shaded area reveals a section with higher overall activity and is found in the treed interior habitat. The yellow shaded area represents an area with elevated activity as well and is found in both the edge and water habitats.

To further examine whether acoustic activity and roost occupancy are linked, I explored the temporal trends of those two variables across habitat types. Edge and riparian stations (edge+water) were combined as they are located along a single corridor where Flicker Freeway continues into Harrier Highway and there was a high degree of overlap between these two categories. Most of the acoustic activity occurred in edge+water habitat in the early season (June 22- July12), peaking on July 5 with 73 recordings (Figure 5a), and dropped July 21 during a heat wave. This coincided with increasing acoustic activity in the forest interior on July 21, which peaked in this habitat with 48 recordings (Figure 5a). The forest interior maintained the highest levels of activity for the remainder of the sampling season. In contrast, the edge+water habitat peaked earlier in the season, whilst activity declined sharply after July 21 (Figure 5a).

House counts followed similar trends, with treed interior house counts peaking June 16 at 161 bats (Figure 5b), making it the highest populated habitat. The following week, the counts for the treed interior dropped to 74 (Figure 5b), and did not peak again until July 12. The edge+water habitat remained at its highest counts from June 22- July 12, the highest recorded number being 182 on June 22 (Figure 5b). Following July 28, the edge+water habitat maintained low counts for the remainder of the sampling season.

a)



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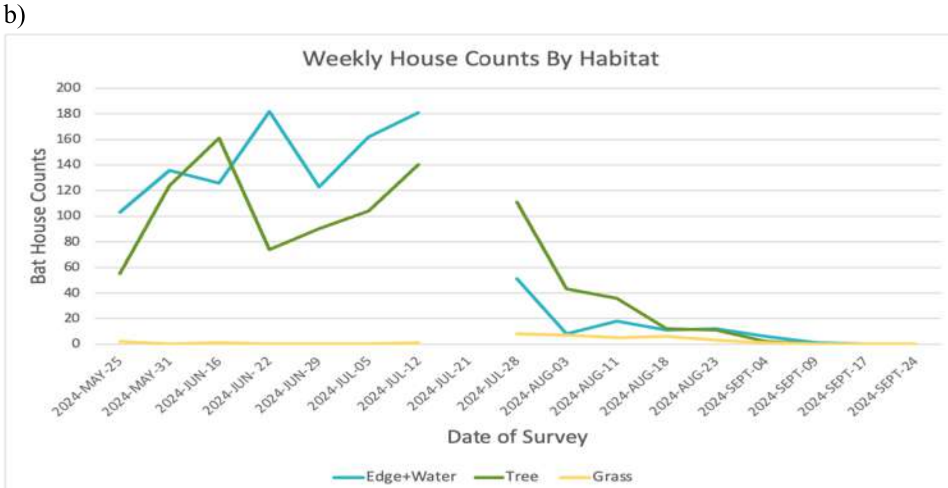

Figure 5. Total weekly counts of bat activity by habitat (a) BBO station included with the forest interior total, equating five stations. Edge + water included 8 stations and grassland 4 stations (b) Houses were divided into habitat types by acoustic stations closest to them. Edge and water habitats have been combined to account for overlap, as they are along the same corridor. Sampling was not conducted on July 21, 2024.

Interannual comparison of bat acoustic activity

From 2021-2024, sampling effort varied between years. After standardizing the bat acoustic counts for comparison, 2022 recorded the highest activity index and 2023 the lowest (Table 1). In contrast, counts of roosting bats recorded the largest number in 2023.

Table 1. Overview of interannual population trends of bats in Beaverhill Natural Area (BNA) from acoustic monitoring and roost counts. Sampling effort was used to calculate the acoustic activity index to make interannual comparisons. For roosting bats, the largest number counted in a weekly survey (highest roosting bat count) was used as estimate of population size.

Year	2021	2022	2023	2024
Surveys Conducted	14	16	11	16
Sampling Effort (n samples)	148	180	127	192
Calls recorded	291	719	237	505
Activity Index (calls/sample)	1.97	3.99	1.87	2.63
Highest roosting bat count	227	241	364	344

Discussion

Overall, in the 2024 season higher roost occupancy coincided with proximity to areas of high foraging activity, as reported in other studies (e.g. Lear and Torrez, 2010). In the early season, both high bat house counts, and high foraging activity were encountered in edge and riparian habitats. Because of the high energy costs of reproduction for adult female bats (Balzer et al. 2023; Wilcox and Willis 2016) it may be advantageous to roost on forest edges and near bodies of water where insects are abundant (Olson and Barclay 2013; Belwood and Fenton 1976; Clare et al. 2011).

In Alberta, high levels of bat foraging activity were observed in treed areas near waterways, as trees offer protection and shelter from weather variables, resulting in larger insect abundance and less disturbance to foraging bats (Holloway and Barclay, 2000). This could account for the consistent levels of foraging within the treed environment of the BNA. In this study area, all houses are within one kilometer of the water edge. Since little brown bats can fly anywhere between 6-34 kilometres per hour (Saunders, 1988), the distance between roosts and foraging sites is a relatively short one for bats.

As the maternity roosts dispersed in late July, there was a sudden influx in bats occupying bat houses in the forest interior that coincided with higher foraging activity in this habitat. A similar pattern was observed in 2021 (Burke and Waldron, 2021) when activity in edge and water habitats peaked in the early season (June-early July) with a sudden drop in late July, followed by an influx in forest interior activity. This shift in the location of foraging activity may reflect the bats' movement to new roosts, consistent with the hypothesis that bats forage near their roosts. As temperatures increased at the end of July, bats may seek forest interiors for thermoregulation.

Several studies reported a negative effect of overheating in bat boxes on bat health with rising temperatures (Griffiths, 2021; Flaquer et al., 2014; Martin Bideguren et al. 2019). On July 21, 2024, during a heat wave, there was a shift in foraging behaviour from edge and water habitats to interior treed habitats. Although data is missing for bat house counts for July 21, from trends in the data we can infer that house occupancy followed foraging behaviour. More importantly, on July 21, according to our collected weather data, the Beaverhill Natural Area was experiencing elevated temperatures during a heat wave. Treed environments are often much cooler than adjacent areas (Kim et al., 2024), making it likely that bats moved for thermoregulatory purposes. Furthermore, studies show that bat houses receiving less sunlight, bat houses with proper insulation, and multi-chambered bat houses experience greater thermoregulatory effects, which can mitigate the effects of heat waves (Crawford et al., 2022).

Overall, bat acoustic activity fluctuated annually and did not appear to follow a particular directional trend. Dates of survey may contribute to the differences observed between years. For instance, in 2024, acoustic sampling started in late May and was carried out until late September. In contrast, surveys in 2022, began earlier and ended in the first week of September, resulting in more surveys during times of higher bat activity, and fewer near the end of the season when activity is lower (Figure 3). Although the activity index is higher for 2022 than that of 2024, the difference is likely due to the timing of sampling in 2022 that coincided more closely with peak activity.

Conclusion and recommendations

This study highlights the importance of considering both roosting and foraging habitat preferences in the placement of artificial bat roosts. With climate change, studies investigating temperature effects on bat behaviour is particularly important. As reproductive females tend to roost on forest edges near water, investigation into bat house criteria necessary to mitigate the effects of rising temperatures should be conducted to determine factors such as insulation needs, bat house aspect, and proper shade needed for the success of reproducing bats. Monitoring temperature in bat houses in upcoming years would be an important next step. Acoustic activity between 2021-2024 fluctuated annually but does not appear to follow a particular directional trend, indicating that overall, the bat population may have remained relatively stable. With the arrival of WNS in Alberta these 4-year results provide an important baseline for long-term assessments of the local population.

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APPENDIX 1-

Summary of acoustic detections at BBO from May 25-September 24, 2024, by sampling date and species. Numbers include the total number of sequences recorded and in parentheses, the number of those sequences that contained a terminal feeding buzz. 'NOID' were echolocation calls that were too faint to be assigned to a species with certainty.

Date	25.05	31.05	16.06	22.06	29.06	05.07	12.07	21.07	28.07	03.08	11.08	18.08	04.09	09.09	17.09	24.09
N. stations	12	12	13	12	12	13	13	13	13	13	13	13	17	17	17	17
MYOTIS	27 (4)	20 (1)	33 (2)	45 (2)	52 (14)	96 (7)	77 (21)	58 (11)	29 (5)	10 (2)	25 (4)	7 (0)	17 (0)	21 (4)	0	0
EPFULANO	2 (0)	1 (0)	2 (0)	0	0	0	0	2 (0)	0	6 (0)	0	0	1 (0)	0	0	0
LACI	0	0	0	0	0	0	3 (0)	0	1 (0)	0	9 (0)	0	0	0	0	3 (0)
NOID	1 (0)	0	0	0	3 (0)	10 (0)	2 (0)	4 (0)	5 (0)	1 (0)	1 (0)	2 (0)	5 (0)	0	0	0