# The Effect of Construction-Related Disturbances on the Spatial Distribution of Bats in the Beaverhill Natural Area

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**ABSTRACT** Due to their cryptic nature, the spatial and temporal effects of anthropogenic-related disturbances on the activity of bats in Alberta remain largely unknown. Acoustic monitoring is a less invasive tool that may resolve issues related to the detection of bats by measuring bat activity within a landscape. The short- and long-term effects of land disturbance on acoustic activity were investigated in the Beaverhill Natural Area in Beaver County, Alberta. The occurrence and location of acoustic activity by three bat phonic groups: HighF, LowF, and Myotis, were recorded along a 16-point transect weekly during the five months post-disturbance (2021) and one-year post-disturbance (2022). The HighF phonic group included *Lasiurus borealis*, LowF included *Lasiurus cinereus*, *Eptesicus fuscus* and *Lasionycteris noctivagans*, and Myotis represented *Myotis lucifugus*, *Myotis septentrionalis* and *Myotis volans*. Analysis of results revealed that Myotis bats may disperse to other habitat types to evade human activity and within the Myotis group, *M.lucifugus* may be more tolerant than other species. In addition, *Myotis* activity shifted closer to the disturbance site after one year, indicating that disturbance-induced displacement of *Myotis* bats may be temporary. The responses of LowF and HighF groups remain unclear. Insight into the extent of change in activity by bats in Alberta in response to land modifications will improve the effectiveness of management strategies emplaced to conserve bat species.

## INTRODUCTION

As a keystone species, assessing the ecological needs of insectivorous bats is especially useful in managing conservation efforts (Meramo et al., 2022; Weier et al., 2020). Alberta's bat fauna is comprised of nine bat species. Three of these species are migratory: the eastern red bat (*Lasiurus borealis*), the hoary bat (*Lasiurus cinereus*) and the silver-haired bat (*Lasionycteris noctivagans*) (Reimer et al., 2014). These migratory bats fly south in the fall and return to Alberta as early as May to begin their maternity season (Reimer et al., 2014). Migratory bats tend to be most active in late July and early August when their fall migration begins (Reimer et al., 2014). The remaining six non-migratory bat species are residents of Alberta, they include the little brown Myotis (*Myotis lucifugus*), northern Myotis (*Myotis septentrionalis*), long-legged Myotis (*Myotis volans*), western small-footed Myotis (*Myotis ciliolabrum*), long-eared Myotis (*Myotis evotis*), and the big brown bat (*Eptesicus fuscus*) (Findlay & Barclay, 2019; Reimer et al., 2014; Schowalter, 1980). Resident bats occupy hibernacula in the winter instead of migrating in the fall and emerge around the same time as migratory bats in the spring (Reimer et al., 2014). During the summer, females of some bat species such as *E. fuscus*, *L. noctivagans* and *M. lucifugus* give birth to pups and raise their young in a maternity roost (Gannon & Bovard, 2016; Slough & Jung, 2020). Maternity roosts are usually located within the females' foraging territory and can be found in tree hollows, rock crevices, bat houses and buildings (Gannon & Bovard, 2016; Slough & Jung, 2020). Adult males of the species that form maternity roosts occupy a solitary roost (Gannon & Bovard, 2016; Slough & Jung, 2020).

Bats can function as model organisms to study the impact of anthropic pressures on ecosystems (Azam et al., 2016). When forest edges are eliminated for industrial or agricultural development, the microclimate and community structures located 100 to 300 m into forest interiors are altered (Fonseca, 2008; Gannon & Bovard, 2016). Edge effects are especially impactful on niche breadth (Fonseca, 2008). Species that are sensitive to light and auditory disturbances are more likely to avoid habitats that are threatened by anthropic pressures which affect the overall species abundance within an area (Fraser et al., 2020; Gannon & Bovard, 2016). Reduction of forest habitats for clearing of land purposes may also threaten the availability of maternity roosting habitat (Azam et al., 2016; Fraser et al., 2020; Gannon & Bovard, 2016; Slough & Jung, 2020). Habitat availability is especially concerning for *E. fuscus* and *M. lucifugus* which can occupy tree roosts and have a high annual roost fidelity and natal philopatry (Gannon & Bovard, 2016; Reimer et al., 2014; Slough & Jung, 2020). For example, one female *M. lucifugus* was reported to have occupied a maternity roost for as many as 23 years (Slough & Jung, 2020). Other species such as *L. noctivagans* that form maternity roosts have flexible roost preferences and may switch roost sites (Gannon & Bovard, 2016).

Insectivorous bats emit ultrasonic calls through their mouths or nostrils to navigate their surroundings and locate prey using a technique called echolocation (Findlay & Barclay, 2019; Fraser et al., 2020; Law et al., 2019; Schnitzler et al., 2003). The call bats emit while foraging is called a search call (Findlay &

Barclay, 2019). Echolocation is the process of locating an object of interest by measuring the difference in time between an emitted call and the echo reflected by the object (Runkel et al., 2021; Schnitzler et al., 2003). Ultrasonic bat calls can be used to identify the presence of bats, predict species identity, and capture behavioural data (Findlay & Barclay, 2019; Fraser et al., 2020). The frequency and shape of search calls are relative to a bat's body mass and habitat; this makes search calls particularly useful in species identification (Findlay & Barclay, 2019; Fraser et al., 2020; Schnitzler et al., 2003). Bats that emit high frequency calls (≥ 35 kHz) tend to be smaller and can emit calls that detect smaller insects (Treitler et al., 2016). Whereas, bats that emit low frequency calls (≤ 35 kHz) and inhabit open environments tend to have a larger body mass and emit calls that detect larger insects (Treitler et al., 2016). Mass and wingspan constrains maneuverability during flight; larger bats tend to be fast fliers but less maneuverable and smaller bats tend to be more maneuverable, but slower (Findlay & Barclay, 2019; Runkel et al., 2021).

Myotis bats emit shorter calls with a wider bandwidth/frequency range called frequency modulated (FM) calls (Runkel et al., 2021; Schnitzler et al., 2003). Myotis bats in Alberta are small (approximately 4.5-8 g) and tend to forage in narrow spaces near the ground and vegetation, or over water and surfaces (Findlay & Barclay, 2019; Schnitzler et al., 2003). Myotis emit short, low-pressure calls to orient themselves in high-cluttered environments and contend with interfering echoes by discriminating between prey- and habitat-generated echoes (Findlay & Barclay, 2019; Runkel et al., 2021; Schnitzler et al., 2003). As they approach prey, Myotis continue to emit FM calls, but the duration between calls decreases rapidly as their proximity to prey increases (Schnitzler et al., 2003). In contrast, the solitary bat species *L. cinereus* is the largest bat in Alberta (25-30 g) and typically roosts in the foliage of trees (Gannon & Bovard, 2016). *L. cinereus* emit low constant frequency (CF) calls which, as the name implies, are nearly constant in frequency and aid in navigating low-clutter environments (Barclay, 1999; McBurney & Segers, 2021; Reimer et al., 2010, 2010; Runkel et al., 2021; Schnitzler et al., 2003). While greater in energy, these calls extend farther than FM calls (Reimer et al., 2010; Runkel et al., 2021; Schnitzler et al., 2003). Other members of the *Lasiurus* genus such as *L. borealis* bats can emit FM/quasi-constant frequency (QCF) calls, too (McBurney & Segers, 2021). QCF calls are shallow FM calls that have a narrow frequency range (Schnitzler et al., 2003). *L. borealis* are also solitary by nature (Gannon & Bovard, 2016). These medium sized bats (around 7-13 g) tend to roost in trees and forage in grass and edge habitats (Gannon & Bovard, 2016). Some genera can emit several call types; for example, *Eptesicus* can emit CF and FM calls (Runkel et al., 2021). *E. fuscus* are medium sized (11-16 g) and typically roost in buildings, but can occupy tree hollows (Gannon & Bovard, 2016). *E. fuscus* forage within a short range from their roost and search for insects near the ground and over water (Gannon & Bovard, 2016). The final medium sized bat, *L. noctivagans* (9-12 g), emits broadband FM signals and is known to avoid open habitats, preferring habitats near water instead (Gannon & Bovard, 2016; Reimer et al., 2010). Vocal plasticity varies inter- and intraspecifically relative to geographic location, the ecological characteristics present in a habitat and the context of the activity being performed (Barclay, 1999; Findlay & Barclay, 2019; Schnitzler et al., 2003). When bat species cannot be confidently identified, phonic groups are useful for categorizing groups of bats by a common frequency range/ call type (Barclay, 1999; Fraser et al., 2020).

This study aims to investigate the effect of a land-use change on the spatial distribution of four bat phonic groups: Myotis bats (*M. lucifugus, M.septentrionalis* and *M. volans*), HighF (*L. borealis)* and LowF (*L. cinereus, L. noctivagans* and *E. fuscus)* across four habitats in the Beaverhill Natural Area (BNA) by comparing bat activity before and after a local disturbance in a clearing habitat. Land-use changes refer to the demolition of the original Beaverhill Bird Observatory (BBO) Research Station in October 2020 and the construction of a new research station which was rendered complete in April 2021. Activity is measured by the number of detectable call sequences per survey night and the four habitat types that are characterized are riparian, grass, treed interior and edge. Acoustic recordings collected in the summer that proceeded after the disturbance ceased (2021), and one year after the disturbance (2022) were analyzed to determine the impact of a local disturbance on bat activity in the BNA.

Past studies have suggested that anthropogenic-induced disturbances impact the diversity and activity of several species' populations (Moretto & Francis,

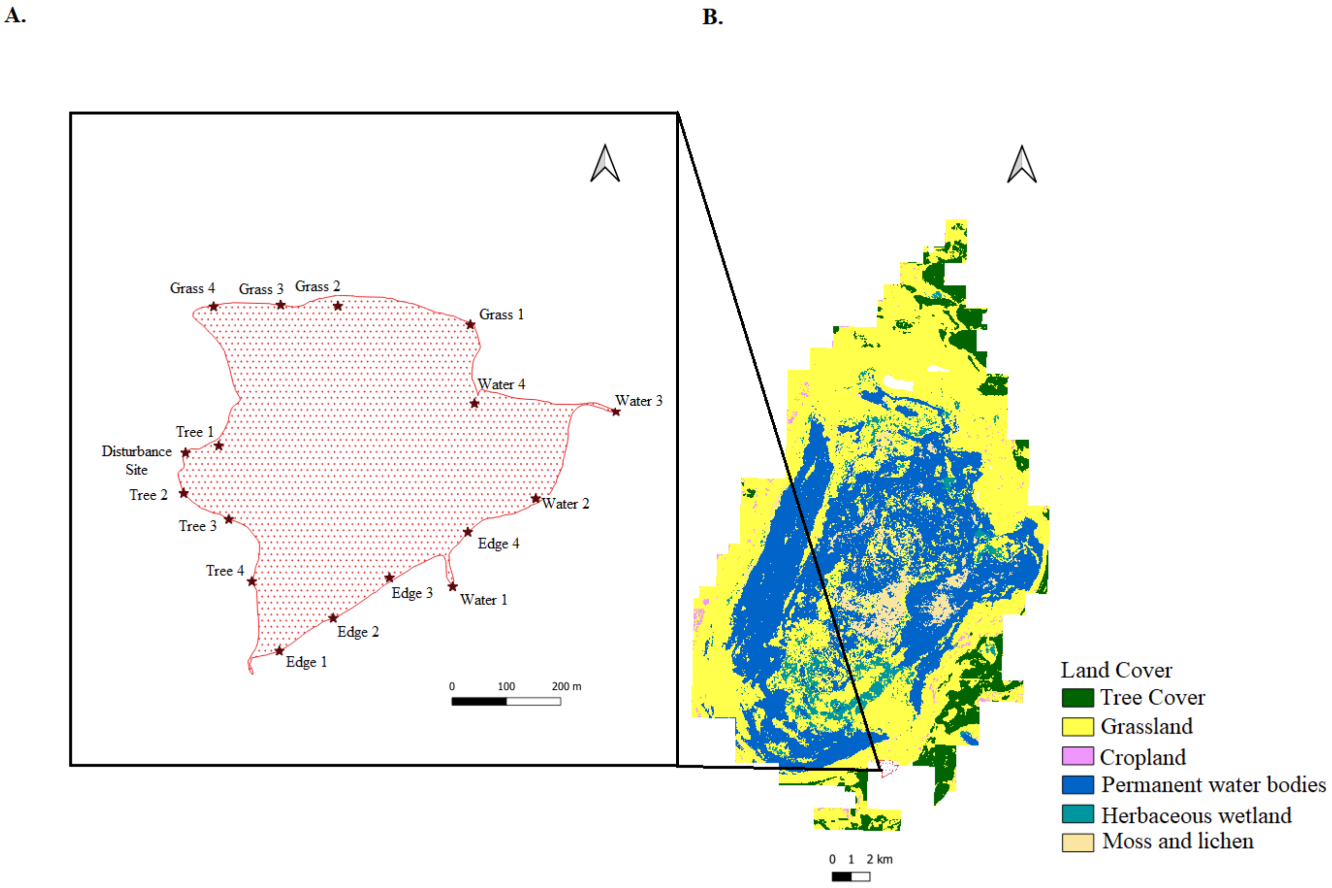

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**Figure 1.** *A)* Enlarged map of the study area located in Beaverhill Natural Area, Alberta. The transect is indicated by the red line. Transect direction changed weekly, in a clockwise (from tree 2 to tree 1, or counter clockwise (tree 1 to tree 2) direction. Stars indicate recording sites along transect. *B)* Map of Beaverhill Lake Heritage Rangeland Natural Area, Alberta located adjacent to the Beaverhill Natural Area. Map was generated using QGIS (QGIS Development Team, %Y), and land cover data were extracted from the World Cover Project (WorldCover 2021 V200, 2021).

2017), including bats (Law et al., 2019; Meramo et al., 2022), as a result of shifts in microclimate and community structure in forest habitats (Fonseca, 2008; Gannon & Bovard, 2016). Therefore, in the year of the disturbance, I predict that bat activity will increase as the distance from the disturbance site increases. Also, I expect that there will be greater bat activity near the disturbance site one-year post-disturbance in 2022 compared to the year of the disturbance event in 2021.

## METHOD

### *Study Area*

Beaverhill Bird Observatory (BBO) is situated within the Beaverhill Natural Area in Beaver County, Alberta (53°22'50.1"N; 112°31'37.4"W), located southeast of Beaverhill Lake (G.R.A., 1984). The study site covers a total area of 290,082.8 m² and has a mean elevation of 668.6 m. Located within the central aspen parkland ecoregion, it has a subarid to semiarid climate with a mean annual temperature of 2℃ and total rainfall of 350-450 mm/year (Shorthouse, 2010). Beaverhill Lake is surrounded by fescue grasslands, willow stands and aspen groves (Shorthouse, 2010).

### *Data Collection*

Acoustic monitoring was performed along a point-stop transect approximately three kms long (Figure 1). The direction of the transect was alternated weekly in a clockwise (from tree 2 to tree 1) or counter clockwise direction (tree 1 to tree 2). The Echo Meter Touch 2 Handheld Detector (Wildlife Acoustics, Concorde, CO, USA) and Amazon Kindle Fire HDX third Generation tablet recorded three minutes of acoustic data using the Wildlife Acoustics app (v.2.8.5). The transect encompassed a total of 16 recording stations that spanned across four habitat types in the BNA: treed interior, riparian, edge, and grassland. Surveys were performed weekly, 45 minutes after sunset for 18 weeks between May 16 to September 2, 2022. The detector was directed towards the least clutter (the direction with the least amount of vegetation canopy) at each station. The detector was set to real time expansion (RTE) and recorded in full spectrum without a headset. The trigger minimum frequency was set to 16 kHz. Before and after the surveys, the temperature (℃), wind speed (Beaufort wind scale) and direction, precipitation (mm), and cloud cover (%) were documented. Surveys were not completed in moderate to heavy precipitation, severe thunderstorms, or when wind velocities were equal to or greater than Beaufort scale 4.

### *Data Analysis*

Recordings were saved to the tablet while field work was conducted and then exported for analysis. Data were processed in the bat analysis mode of Wildlife Acoustics' Kaleidoscope software, version 5.4.8. Full-spectrum .wav files were converted to a zero-cross file for quality assurance. Zero-cross files represented frequencies detected that were greater than ambient noise (McBurney & Segers, 2021). Call sequences containing at least three pulses detected in zero-cross qualified as a bat pass; non-qualifying call sequences were labelled 'NOISE' and excluded from further analyses. Spectrograms were created using a 128 window and a Fast Fourier Transform (FFT) size of 256. Auto-ID was embedded into the wav. files, but manual identification confirmed species designation within a phonic group. To determine the characteristic frequency ($F_c$) value, the entire call sequence was displayed in the viewer window using the x-axis toggle zoom button in the compressed time view, then processed using Kaleidoscope viewer analysis. If more than one species was present in a .wav file, the call sequence for each species was selected and processed independently. Predicted species were grouped by the similarity of their call sequences. Myotis call sequences were identified by a frequency of 40-60 kHz (Kaiser & O'Keefe, 2015; McBurney & Segers, 2021). *L. borealis* were represented by the phonic group HighF and had a frequency of 35-60 kHz (Kaiser & O'Keefe, 2015; McBurney & Segers, 2021). HighF calls were characterized by an undulating minimum frequency, whereby 50% of the total calls in a sequence had a minimum frequency that deviated from the minimum frequency of the call sequence (McBurney & Segers, 2021). In addition, calls were hook-shaped with an upturned tail end. The calls of *L. cinereus*, *E. fuscus* and *L. noctivagans* bats are difficult to differentiate in high-clutter environments and were represented by the phonic group LowF (Kaiser & O'Keefe, 2015; McBurney & Segers, 2021). Calls within the LowF group had a frequency of less than 30 kHz (Kaiser & O'Keefe, 2015; McBurney & Segers, 2021).

In 2021, seven surveys qualified for statistical analysis. The survey on June 1, 2021, was excluded because of datasheet incompleteness, on July 3, 2021 the survey could not proceed due to technical issues, precipitation resulted in an incomplete survey on August 3, 2021, and on August 17, 2021 the Echo Meter Touch 2 Handheld Detector malfunctioned.

Surveys on May 16, July 4, and August 1, 2022 were excluded from statistical analysis because they failed to sample one or more habitats during the survey. On May 16, 2022, the grassland habitat was not surveyed because of lightning, and surveys were not completed on July 4 and August 1, 2022 because of rainstorms. The survey on June 13 was rescheduled to June 15, 2022, due to weather conditions; however, during the rescheduled survey one of the points along the transect in the grassland habitat could not be located and was not recorded. Lastly, 'Tree 1' was not surveyed on July 25, 2022, because the Echo Meter Touch 2 Handheld Detector malfunctioned.

### *Statistical Analysis*

Habitat preference was investigated by plotting the combined mean search calls (SCs) of phonic groups across all habitat types in 2021 and 2022, whereby each habitat had four points within the transect per survey. To resolve concerns of pseudoreplication and account for seasonal variation, observations were pooled at each point in the transect in 2021 and 2022 ($SC_{Pooled}$) and divided by the total number of transect surveys completed within their respective year ($T_{Year}$). Samples were designated by the 16 points in the transect. The mean SCs, $\overline{SC}$, per sample in each year represented the sample observations.

**Equation 1.**

$$\overline{SC} = \frac{SC_{Pooled}}{T_{Year}}$$

The distribution of observations in each habitat was visualized by generating boxplots in R using the *tidyverse* package (R Core Team, 18; Wickham et al., 2019). Medians in the boxplot identified the most frequent occurrences of search calls recorded by a phonic group. Medians were selected to represent recording occurrence, rather than the mean, due to non-normal distributions of SCs within phonic groups. Then, the relationship between the distance from the disturbance site and the mean SCs recorded from phonic groups in 2021 and 2022 was modelled using linear regression. Data were filtered using the *tidyverse* package in R (R Core Team, 18; Wickham et al., 2019), and the $R^2$ output value was used to determine the relative fitness of the model. Lastly, sample means were plotted to visualize the spatial distribution of the SCs by phonic groups within each habitat. The means of the pooled observations in each sample were used to reduce clutter and highlight trends.

## RESULTS

### *Habitat Selection*

Collectively, 568 Myotis SCs were recorded in 2021 and 2022. There were 312 SCs recorded in the treed interior habitat, 184 calls recorded in the edge habitat, 63 calls recorded in the riparian habitat, and nine calls recorded in the grassland habitat. The treed interior habitat had the greatest median SCs from Myotis at 2.91 SCs recorded. A total of 66 LowF SCs were recorded in 2021 and 2022. The treed interior habitat accounted for 28 of the total SCs recorded, edge habitat accounted for nine SCs, riparian habitat had 26 SCs, and the grassland habitat had three SCs. With a median of 0.12, 0.14 and 0.16, LowF search calls were nearly equally likely to be recorded in the grassland, riparian and edge habitats, respectively. However, LowF was rarely recorded in the treed interior habitat. Lastly, 45 SCs were collectively recorded in 2021 and 2022 from the HighF group. Of the total calls recorded, six SCs were recorded in the treed interior habitat, five SCs in the edge habitat, nine SCs in the riparian habitat and 25 SCs in the grassland habitat. The greatest median for the HighF group was 0.45 SCs in the edge habitat, and no SCs were detected from the HighF group in the riparian habitat in 2021 or 2022. HighF was rarely detected in any of the habitats, however, the occurrence of detection was more typical in the edge habitat.

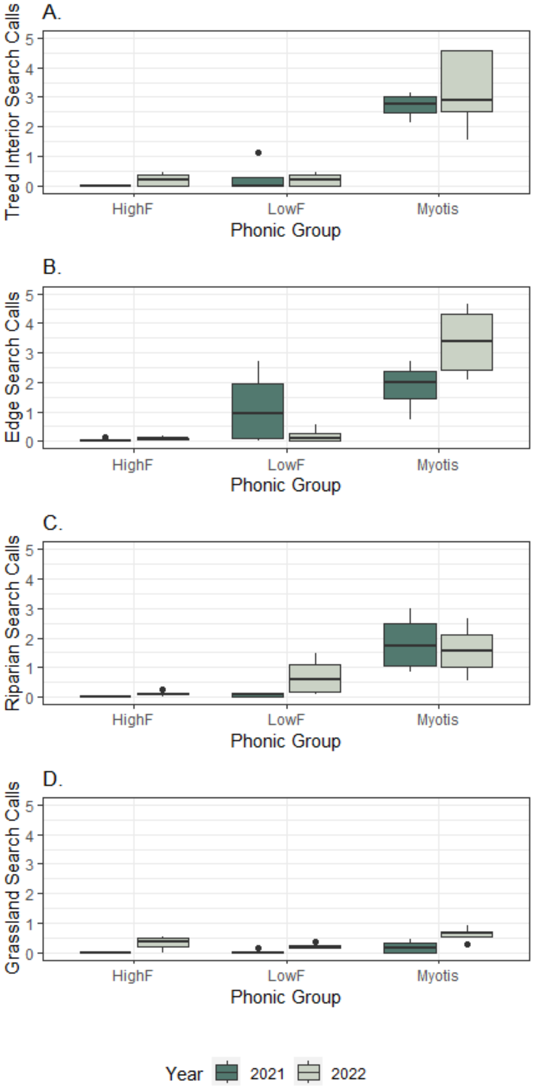

**Figure 2.** Pooled mean search calls were recorded in four habitat types: treed interior *(A)*, edge *(B)*, riparian *(C)* and grassland *(D)*, from three bat phonic groups Myotis, LowF and HighF in 2021 and 2022. Search calls were recorded along a 16-point transect and pooled by point locations. Collectively, 18-point-transect surveys were performed, and each habitat type was recorded at four points. Coloured regions represent the interquartile range, whereby the upper boundary line is the third quartile, and the lower boundary line is the first quartile. The median is indicated by the horizontal line enclosed within each box. Lines extending vertically from the boxes represent the whiskers. Whiskers indicate the minimum and maximum search calls. Values 1.5 times greater than the third quartile were removed. Outliers are presented as points. Search calls were recorded at Beaverhill Natural Area, Alberta, Canada.

### *Disturbance Effects*

To effectively model the spatial distribution of samples per phonic group, phonic groups were plotted relative to the distance from the disturbance within each habitat type to account for covariance by habitat selection. Without the consideration of habitat preferences, residuals were poorly fit to the line of least squares in the linear regression model ($R^2<0.5$, $p> 0.05$). As Figure 3 demonstrates, each phonic group was plotted and fit to a linear regression model in each habitat block, then data points were discriminated by the year they were recorded in R using the *tidyverse* package (R Core Team, 18; Wickham et al., 2019). The spatial distribution of Myotis bats in the treed interior, edge, and riparian habitats changed relative to the recording year. In the treed interior habitat, the slope, which represents the occurrence of search calls as the distance from the disturbance site increased, was much steeper in 2022 than in 2021. Similarly, the slope in the linear regression model in the riparian habitat was also steeper in 2022 compared to 2021. In the model, mean SCs recorded in the riparian habitat increased with distance in 2022, whereas mean Myotis SCs occurred nearly equally across the habitat type in 2021. No significant change was observed in Myotis within the grassland habitat. The phonic group LowF also demonstrated a change in activity relative to the spatial distribution of SCs recorded in the edge and riparian habitats. In 2021, mean SCs in the edge habitat rapidly decreased as distance from the disturbance increased

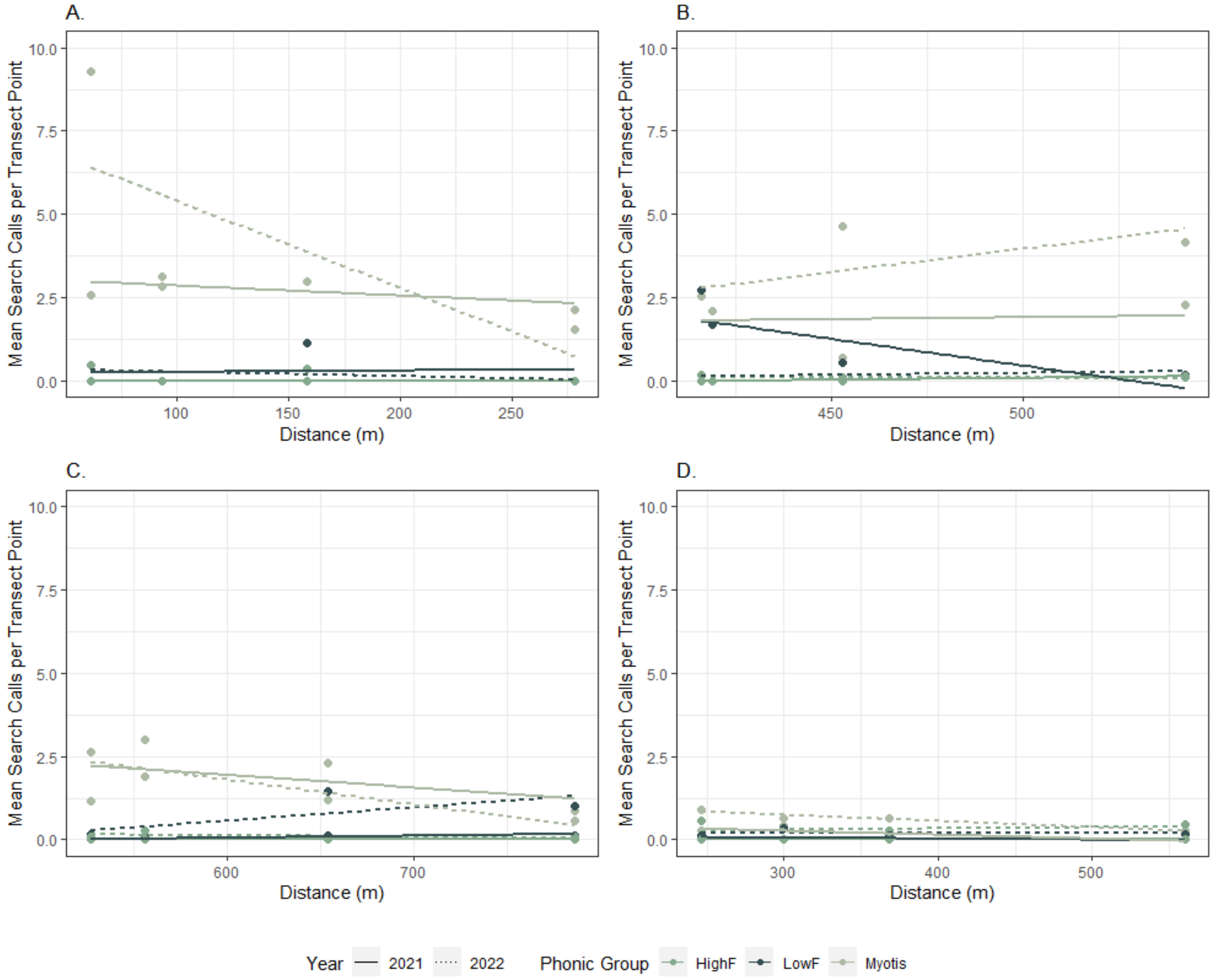

**Figure 3.** Spatial distribution of mean search calls recorded from Myotis, LowF and HighF phonic groups in four habitats: treed interior *(A)*, edge *(B)*, riparian *(C)* and grassland *(D)*. Search calls were measured from the disturbance site immediately after the disturbance event in 2021, and one-year post-disturbance in 2022. Search calls were recorded at Beaverhill Natural Area, Alberta, Canada.

and LowF were rarely recorded in the riparian habitat. Whereas, in 2022 occurrence of recording SCs was rare in the edge habitat and mean SCs in the riparian habitat increased as distance from the disturbance site increased. The phonic group HighF was rarely recorded in both years.

## DISCUSSION

Bat activity increased as distance from disturbance site increased for all phonic groups except LowF. In addition, the disturbance caused by the construction of a new research station in winter 2020/21 failed to shift activity dynamics equally across all phonic groups. Bat activity was greater in some phonic groups near the disturbance site one-year post-disturbance compared to when the disturbance first occurred. These results support the prediction that bat activity undergoes spatial and temporal shifts as a consequence of disturbance events in the Myotis group, but this prediction was not apparent in LowF and HighF phonic groups.

The phonic group representing the genus Myotis had the greatest mean SCs in the treed interior habitat (Figure 2A), which was the habitat nearest to the disturbance site and the habitat Myotis occupied most often. Consequently, SCs recorded less than 100 m from the disturbance site had a lower mean compared to subsequent recordings taken at farther distances from the disturbance site within the treed interior in 2022. Interestingly, Myotis bats had greater mean SCs towards the end of the treed interior habitat in 2021. Thus, Myotis bats appear to increase the distance between where the disturbance event occurred and where they were foraging. Similar observations have been described in previous publications (Treitler et al., 2016), suggesting that a generalist species can abandon the habitat they are occupying more easily and disperse farther than a specialist. Specifically, this behaviour is consistent with the generalist *M. lucifugus* (Findlay & Barclay, 2019). It is assumed that the majority of SCs recorded were from *M. lucifugus* given these findings. *M. lucifugus* activity was greater in the edge habitat in 2022 compared to the nearly equally distributed mean SCs in 2021 (Figure 3B). These observations are reinforced by the assumption that *M. lucifugus* can adapt more easily to other habitats and therefore may have benefited from exploiting their new niche within the edge habitat (Weier et al., 2020). Furthermore, this is consistent with the significant increase in activity observed near the disturbance site in 2022 given that a reduction in interspecific competition would have opened a dietary niche for specialists (Weier et al., 2020). While some Myotis bats may be more sensitive to displacement by a modification within their preferred habitat, *M. lucifugus* may benefit from foraging opportunities that arise from the disturbance in the subsequent of the disturbance (Findlay & Barclay, 2019; Weier et al., 2020).

LowF were infrequently recorded in the treed interior and grassland habitats in 2021 and 2022. However, in 2021 the mean SCs recorded from the LowF group was counteractive to the trend observed in mean SCs recorded in 2022. In 2021, recordings were more frequent near the interface between the edge and treed habitats, whereas LowF were most often recorded near the interface between the riparian and grassland habitats in 2022 (Figure 3). Within the LowF group, *L. noctivagans* are known to have flexible roost preferences and tend to roost near bodies of water, so the observations in the data may be capturing their movement toward the riparian habitat landscape (Gannon & Bovard, 2016). However, there is insufficient evidence to support these ideas.

Given the limited number of SCs detected from the HighF group, there were no apparent trends in their activity across the habitat types (Figure 3). However, SCs were recorded more frequently in 2022 than in 2021 which may indicate that the habitat within the BNA was more favourable for foraging by *L. borealis* in 2022 than 2021 (Figure 2).

## CONCLUSION

The changes in activity by Myotis bats across the BNA in response to a local land disturbance could improve present conservation management strategies for bats in Alberta. High- and low-frequency echolocating bats may benefit from passive acoustic monitoring because of their detection rarity in the BNA to determine the effects of disturbance on their activity and long-term trends in activity. The foraging behaviour of bat phonic groups within the BNA could be represented more completely by increasing the number of point-transects performed or increasing the total passive monitoring devices distributed across the landscape.

## LIMITATIONS

Concerns related to repeated measures associated with the transect and distance could not be accounted for in the statistical analyses. Also, zero-inflation in the data violated the assumptions of comparative parametric tests which limited statistical analysis options. The positive skew in SCs recorded from the Myotis group was resolved using a log transformation, but this strategy was ineffective for resolving the positive skew in the LowF and HighF groups. Consultation with a statistician is recommended to determine the random effects of non-independence and repeated measures in an appropriate mixed effects model. In addition, the observer in 2022 was different from the two observers that collected and analyzed acoustic data in 2021. The potential sampling bias and errors from the different observers could not be accounted for in the statistical analysis performed for the study. Also, data prior to the disturbance event was unavailable, so the effects of the disturbance could not be compared to bat activity prior to the disturbance. Since the construction disturbance occurred in the winter of 2020-2021 when bats were not active, the reported differences in activity could be related to other factors in the BNA that were not been measured.

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