CAMPUS NIGHTLIFE:

Understanding Bat Activity in the Urban Landscape of UBC's Vancouver Campus

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UBC Botanical Garden

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Executive Summary

Understanding the location and distribution of ecologically important features for wildlife on campus has become increasingly important as UBC continues to expand and urbanize. In response, we sought to identify habitat features on the UBC campus with the highest abundance of bat activity and then used this information to recommend ways to support bat populations as campus continues to develop. Our research objectives were as follows:

- Examine the spatial distribution of bats on the UBC Vancouver campus
- Identify hot spots of bat activity
- Understand bat populations' interactions with the surrounding urban landscape
- Guide stakeholders and university policy on co-existing and protecting wildlife

We used a series of acoustic walking transects, mist-netting, guano surveys, emergence counts, and met with stakeholders to meet these objectives. Six hotspots of bat activity were identified, most of which avoid the academic areas on campus (Figure 4). Tree canopy was an important factor for bat activity as recorded calls were on average 4.6 meters from a tree. The endangered Little Brown bat (*Myotis lucifugus)* and blue-listed Yuma myotis (*Myotis yumanensis)* were found at Nitobe Memorial Garden and were later tracked back to the Auditorium Annex roost. Finally, we conclude that UBC's lack of policy or governing body for wildlife co-existence poses challenges for effectively managing threatened and endangered bat species on campus.

Based on our findings, we recommend future research focuses on identifying additional roosts near activity hotspots and that an evaluation of the structural integrity of the Auditorium Annex Offices A be completed. Further recommendations include implementing a policy and governing body for co-existence with wildlife and endangered species, continued monitoring of the campus roost and bat boxes, and protecting vital green spaces for bats on campus.

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List of Abbreviations

BC British Columbia 9

UBC University of British Columbia... 7

IUCN International Union for Conservation of Nature 8

MOA Museum of Anthropology 32

UBC University of British Columbia 8

USA United States of America. 10

WNS White Nose Syndrome 7

1 | Introduction

In an increasingly urbanized world, anthropogenic features have taken on a key role in providing habitats for various wildlife species, including bats (Threlfall et al., 2012; Bergeson et al., 2015). One example of this is the University of British Columbia Vancouver campus, which is home to numerous bat species, including the endangered Little Brown bat (*Myotis lucifugus*) (Bartha et al., 2023). The one known active maternity roost, discovered in 2022 inside the Auditorium Annex Offices A, houses roughly 200-300 endangered Little Brown bats and Yuma myotis (Bartha et al., 2023). Little Brown bats and many other bat species are seeing rapidly declining populations in North America due to numerous interacting pressures, including habitat loss, wind turbines, climate change, and White-Nose Syndrome (WNS) an invasive fungal disease (Hoyt et al., 2020, 2021).

In addition to WNS, logging, pesticide pollution, and urban development are among some of the anthropogenic impacts that are putting bat species at risk (Frick et al., 2020). These threats to bat populations have led to one-third of the world's bat species being classified as either threatened or lacking sufficient data for assessment, according to the International Union for Conservation of Nature (IUCN) (Frick et al., 2020). Infrastructure projects, and specifically wind energy turbines, are one of the leading causes of declining bat populations worldwide, responsible for the deaths of half a million bats annually in North America alone (Hayes, 2013). The numerous threats bats encounter highlights the urgent need to reform conservation policies and implement effective management efforts. Bat research presents both challenges and opportunities, as many bat species gather in concentrated colonies within caves or mines. This clustering makes them vulnerable to threats such as WNS, which can destroy entire colonies in a single season. However, it also allows for more targeted research opportunities in the spaces they are known to inhabit (Furey & Racey, 2016).

Despite the presence of a significant bat roost at UBC in the Auditorium Annex Offices A and widespread bat activity across campus, the spatial distribution of bat species and activity on the UBC campus as well as their foraging behavior, habitat preferences, and interactions with urban spaces across campus remain largely unknown. However, understanding these dynamics is essential for guiding future development of policy and conservation actions. This research project tackles a pressing conservation issue as bat research is still an emerging field at UBC and in the Lower Mainland, it provides valuable insights for managing and conserving urban wildlife. Furthermore, it offers evidence-based research to help UBC align with the university's 2050 Campus Vision for a sustainable future (Campus Vision 2050). Using an acoustic monitoring approach, this study examined the spatial distribution of bat activity across the UBC campus in order to identify hot spots of bat activity and understand these populations' interactions with the surrounding urban landscape. As a way to guide stakeholder and university policy on co-existing and protecting an endangered bat species on campus, we also held meetings with relevant university staff to gather their perspectives and needs with regards to bat presence on campus.

2 | Background

2.1 Ecological and Economic Value of Bats

Bats are vital indicators of ecosystem health and biodiversity since their populations depend on the health of insect populations (quality and quantity), clean water availability, and an abundance of roosting habitats (Boyles et al., 2011). As the top predators of many nocturnal insects, bat populations are indicators of the health of lower trophic levels (Forrest & Craig, 2023). Their high sensitivity to environmental changes reflects overall ecosystem health, with population declines often linked to urbanization or other forms of land-use change (Forrest & Craig, 2023). Bats control insect populations, some of which act as disease vectors and agricultural pests (Frank, 2024; Forrest & Craig, 2023). Therefore, a decrease in bat populations can result in an increased reliance on chemical pesticides which have been linked with environmental and human health issues (Ducummon, 2000). Parts of North America saw an increase in infant mortality and insecticide use following the introduction of white-nose syndrome as well as a loss in crop revenue (Frank, 2024).

In BC, research has shown that bats have species-specific preferences for land use, typically avoiding areas that are brightly lit, heavily urbanized, and far from water sources (Craig, 2022). Instead, they are frequently found in parks with green spaces, tall vegetation, and water features (Craig, 2022). Therefore, preserving mature trees, older forests, and hollow trees that do not present safety hazards to the public can contribute to protecting their habitat on campus (Griebling, 2023). Little Brown bats mate from September to October, and leave their summer roosts during October to March to hibernate; however, their flight activity and the locations of hibernacula are still not well known (Rea & Huxter, 2020). Maternal Little Brown bats return to the same roost each spring to rear their young. Thus, their roosts should not be disturbed between May and September, as they rest there during the day, and forage at night. These months are also when they give birth to and raise their pups. Interfering with the roost could lead to legal consequences; under the B.C. Wildlife Act it is illegal to harm endangered or threatened species or capture wildlife (BC Wildlife Act, 2023).

2.2 White-Nose Syndrome

Pseudogymnoascus destructans is the fungal pathogen responsible for WNS. It was first identified in North America in 2007 during routine bat surveys in a cave in New York, USA (Hoyt et al., 2021). The name given to the disease comes from the fungus, which proliferates as a white film on the muzzles, ears, and wings of bats. While *P. destructans* has existed and co-evolved with bat populations in Eurasia for thousands of years, it has become highly disruptive to bat populations across North America. The fungus thrives in colder conditions (below 20°C) and the earlier onset of bat hibernation in North America leads to faster transmission rates compared to those in Eurasian regions (Hoyt et al., 2020). When bats in the northern hemisphere enter hibernation during mid-to-late autumn, their body temperature lowers, making them ideal hosts for the fungus to colonize their epidermal tissue. This colonization disrupts crucial regulatory functions such as thermoregulation, water balance, and gas exchange, resulting in severe physiological effects including fat depletion, starvation, and often death (Frick et al., 2010). Mortality rates in North America range from 80% to 100%, with over six million bats killed from WNS since the spread of the fungus (Ministry of Forests, 2024). As a disease, WNS has not yet been detected in British Columbia's bats, although the fungus was found in the West Kootenay region of B.C. in April 2023 (CBC Radio Canada, 2023). This finding underscores a critical period for bat conservation efforts in the province, as these endangered populations face increasing threats to their survival (Ministry of Forests, 2024).

2.3 Urbanization and Human-Wildlife Conflict on Campus

The global surge in urbanization has triggered a complete reorganization of landscape components and resource availability (Filgueiras et al., 2021) leading to habitat loss and fragmentation for many native species. Urbanization can be viewed as the alteration of natural environments, where natural areas are developed into buildings, roads, or less diverse parks. These changes pose a serious threat to biodiversity, as these urbanized environments tend to support a limited range of species and often only favor those able to adapt to human disturbance (Apfelbeck et al., 2020; Filgueiras et al., 2021).

While urban environments are often perceived as harmful to wildlife, scientists are recognizing that these areas can also develop into complex and dynamic ecosystems that benefit biodiversity (Dixon, 2012;

Craig, 2022). Functional ecosystems in urban spaces, especially those with abundant green areas like the UBC Vancouver campus, can provide important benefits to both humans and wildlife. These include ecosystem services, such as plant pollination, flood prevention, water filtration, educational opportunities, and chances for humans to reconnect with nature in an urban setting (Chan & Satterfield, 2016).

Prioritizing wildlife corridors while mapping the presence and distribution of wildlife before proceeding with urban development plans can help mitigate the risk to biodiversity and protect vital habitats (Apfelbeck et al., 2020). Thus, understanding bat distribution on campus will be crucial for designing new green spaces and ensuring the effectiveness of ecological mobility corridors as planned for in UBC's Campus Vision 2050 (Campus Vision 2050, 2024). These spaces and corridors, however, can face a high risk of human-wildlife conflict due to their proximity to human used land like residential areas, coupled with the ongoing expansion of the built environment driven by the demand for affordable housing and development of university buildings.

Bats' ability to roost in human spaces paired with their flight capabilities enable some species to thrive in urban ecosystems (Moretto & Francis, 2017). Little Brown bats are adapting to the urban environment by roosting in man-made structures, exemplifying how these spaces can provide habitat for certain species as landscapes change (Border et al., 2017). This is exemplified at UBC after a maternity roost was discovered in the Auditorium Annex Offices A in August 2022, prompting worries from building occupants and managers over bat guano on railings and potential health impacts (Bartha et al., 2023). This conflict was initially addressed by a team of undergraduate students as part of an ENVR 400 course project, in collaboration with UBC’s SEEDS Sustainability Program (Bartha et al., 2023). This project aimed to find an appropriate location for a bat box and recommended measures for protecting the roost on campus. A bat box has been installed between the Auditorium Annex offices and the UBC Old Auditorium (Bartha et al., 2023), since then, there have been few concerns or issues related to the presence of bats near the bat box or inside the Auditorium Annex buildings.

The discovery of the roost and the ongoing presence of guano on the building's railings prompted health and safety concerns from the occupants. When handling bat guano and being in such close proximity to bats, caution is advised especially since bat guano is recognized as a potential source of fungal and bacterial pathogens (Dimkić et al., 2021). Bats can be carriers of histoplasmosis, an infectious virus that presents as a lung infection in humans and animals, although it is more commonly contracted from poultry, pigeon, and starling droppings (BC Bats, 2023). Prevalence of histoplasmosis is typically greater in hotter, more humid regions of the world. In BC, there is minimal risk of histoplasmosis, with no locally-acquired cases documented in humans or animals. Furthermore, concerns about bats often focus on their role as a reservoir species for rabies (i.e., they can carry the disease without showing obvious symptoms), but in BC, only about 0.5% of live bats test positive for rabies, a rate comparable to other species like raccoons (BC Bats, 2023).

Concerns about bat guano on campus are understandable, and they underscore the challenges of cleanup, which would need to be performed weekly during the spring and summer. Custodial staff, responsible only for indoor maintenance, face additional burdens as they lack the appropriate personal protective equipment (PPE) for handling bat guano. This situation has created difficulties in determining who should manage and protect the bats on campus. It also reveals that UBC lacks a comprehensive human-wildlife coexistence policy. According to Bartha et al. (2023), UBC has no wildlife conservation policies, funding, or dedicated team to address wildlife-related issues. Although UBC is a member of the Nature Positive Universities network, pledging to "restore species and ecosystems harmed by the impacts of a university" (Nature Positive Universities, 2023), the daily responsibility for managing the bat roost often falls to building operations and custodial staff, who are not equipped for this task.

Educating the public and engaging in conversations with those directly affected by the bat roost regarding bat presence and guano around buildings is crucial for the conservation of bats on campus. Meeting with relevant stakeholders (i.e., building managers and custodial services) will allow us to understand the challenges posed by the roosts' presence. This is especially important given that bats are more elusive and cryptic than most urban wildlife. Their nocturnal habits and high-frequency calls, which are inaudible to humans, also make them challenging to observe. For centuries, bats have been misunderstood and often feared, due to their association with rabies or blood-consuming vampire bat species in parts of the world outside of BC. The COVID-19 pandemic and the media have also portrayed bats in a negative light resulting in them being overlooked and understudied (Frick et al. 2020; Castilla et al. 2020). Consequently, wildlife coexistence initiatives on campus should aim to protect bat species and preserve their habitat while ensuring that those affected are informed about their presence and how to respond or whom to contact if conflicts arise (Apfelbeck et al., 2020).

2.4 Bat Acoustics and Ecology

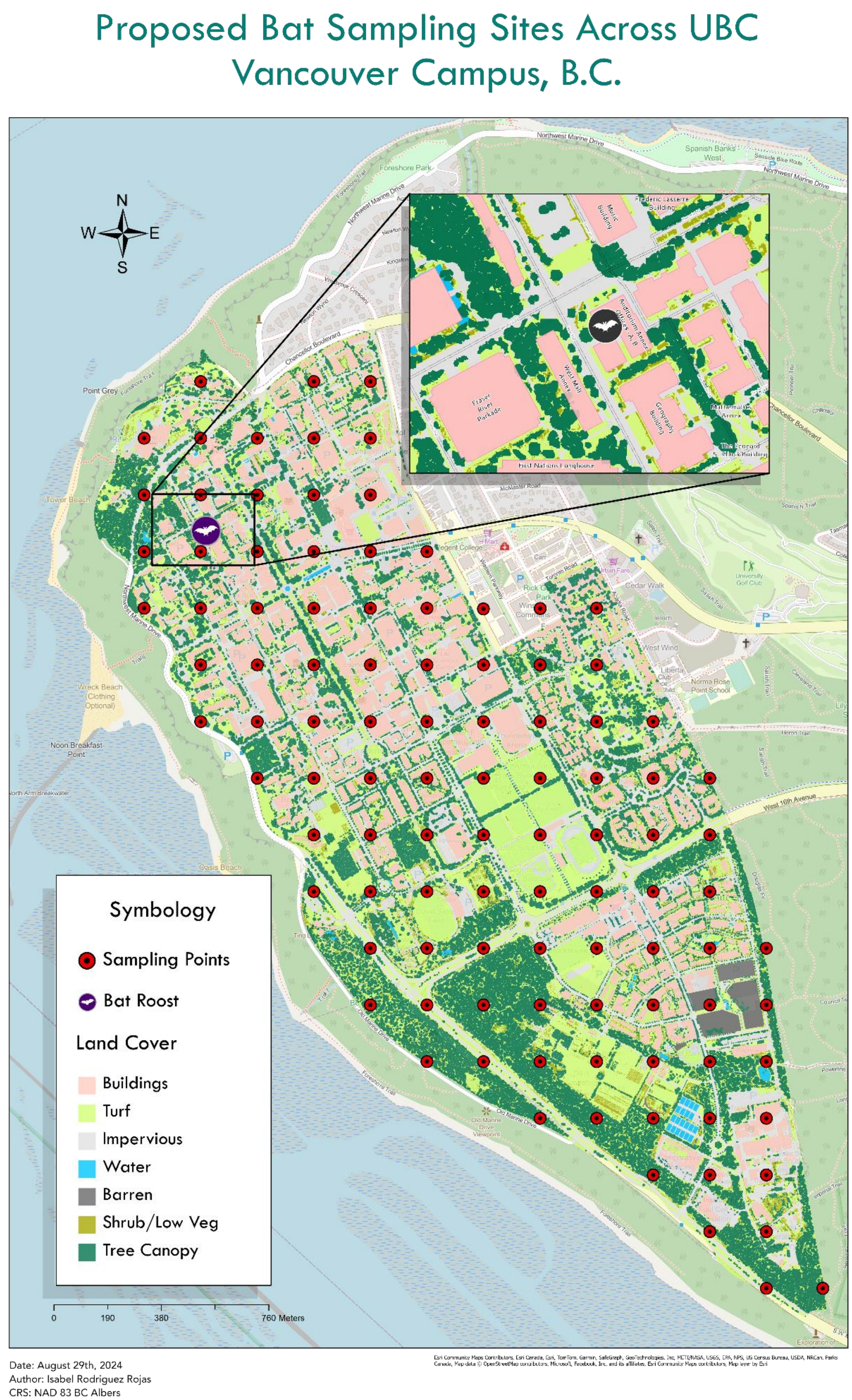
Bats use echolocation to detect obstacles, landscape features, and prey. Most bats produce ultrasonic sounds to echolocate, most of which emit frequencies above 20 kilohertz, falling above the audible range for humans. While foraging, they produce echolocation calls to locate flying insects (aerial hawking) or insects on surfaces like leaves or the ground (gleaning) (Lausen et al., 2022). The way bats use echolocation is influenced by the vegetation and landscape they inhabit. High-frequency calls allow bats to detect small insects with greater detail, but these sounds travel less distance. As a result, bats in open spaces or those that fly quickly, like the Mexican Free-tailed bat (*Tadarida brasiliensis*), use lower-frequency calls that travel longer distances, giving them more time to react to their environment. Bats that echolocate within the range of human hearing are known as audible bats. The only audible bat species in BC is the Spotted bat, which uses low-frequency echolocation to hunt large moths, such as tympanate (eared) moths, that have evolved to evade bats using ultrasonic echolocation (Lausen et al., 2022). Each bat species in BC is classified by the lowest frequency it typically produces. However, identifying bat species by acoustic traits alone can be challenging. For instance, the Canyon bat, Yuma myotis, and California myotis all produce frequencies in the 45-50 kilohertz range, although they can sometimes emit sounds outside of this range (Lausen et al., 2022).

From previous guano surveys, the bat species occupying the Auditorium Annex Offices A were identified as Little Brown bats and Yuma myotis (*Myotis yumanensis)*, both of which emit high-frequency echolocation calls. Little Brown bats' habitat preferences include edge habitats along water bodies and open areas, which allow for drinking and feeding activity (Lausen et al., 2022). In the Okanagan, Little Brown bats were shown to hunt in openings between groups of trees and over lakes, rivers, and bluffs (Lausen et al., 2022). Similarly, Yuma myotis prefer to forage over lakes, rivers, and streams (Lausen et al., 2022). Both species tend to fly on or just above the surface of the water to forage and plunge to drink using their lower jaw (Lausen et al., 2022). Yuma myotis and Little Brown bats have similar appearances and tend to roost together, making it difficult to differentiate the two species with certainty.

3 | Research Methodology

3.1 Study Area

This study was conducted on the University of British Columbia Vancouver campus, which lies on the traditional, ancestral, and unceded territory of the Musqueam people. Bordered by Pacific Spirit Regional Park and the Pacific Ocean, UBC Vancouver comprises more than 400 hectares of urban and dense green spaces as well as various land classes including buildings, impervious surfaces, and multiple water bodies (Figure 1). Within the campus are the UBC Botanical Garden, Nitobe Memorial Garden, and the UBC Farm, all areas of tall dense greenery commonly associated with high bat activity.



F I G U R E 1. Map showing the UBC study site and the 105 points where acoustic recordings were collected (red dots).

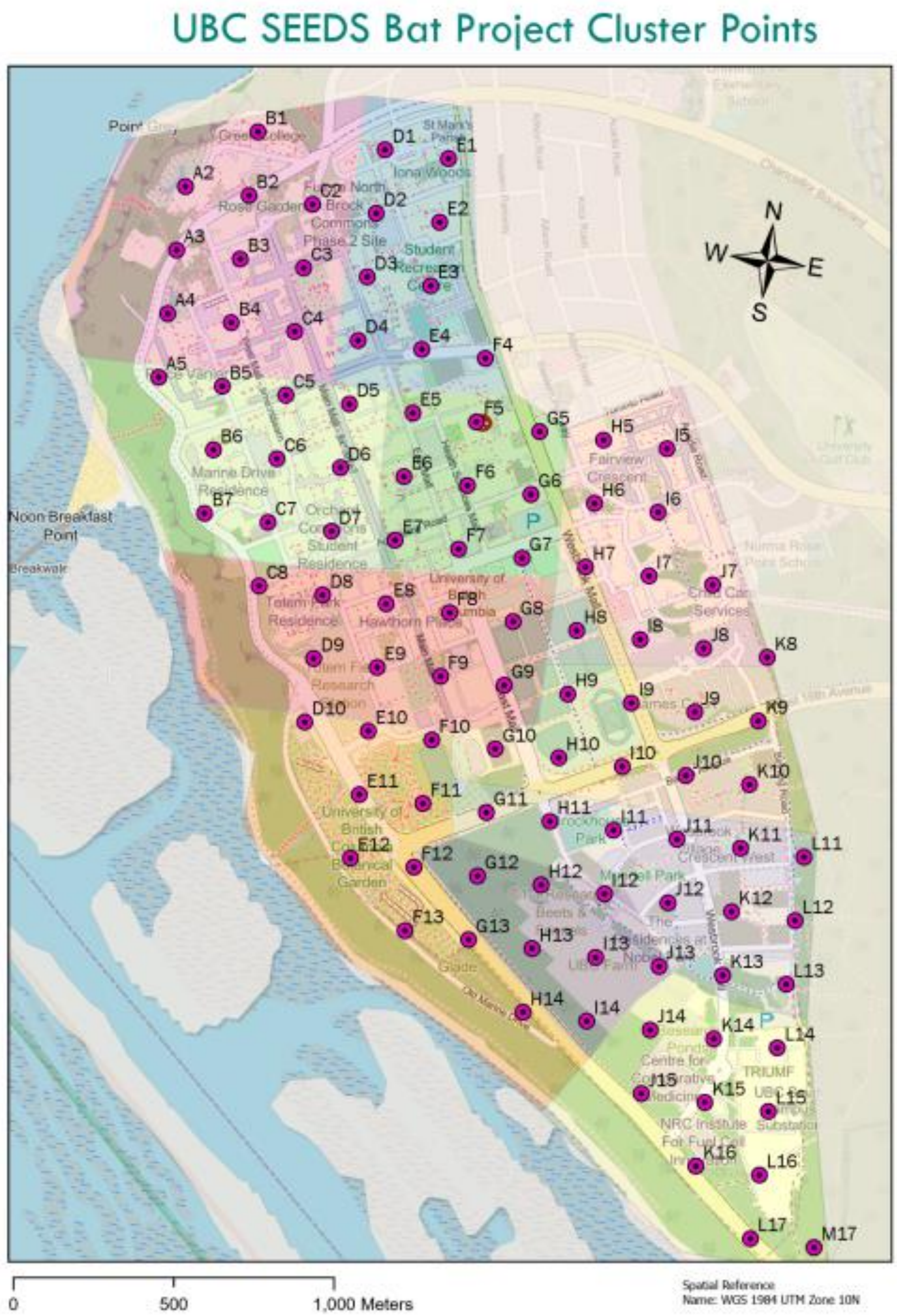
3.2 Data Collection Methods

3.2.1 Acoustic Recordings and Walking Surveys

Bat activity was primarily identified through a combination of fixed-point and walking acoustic surveys. Given our aim to identify bat activity and distribution across the entire UBC Vancouver campus, a systematic sampling approach was used to ensure broad and equal coverage throughout the entire area. The sampling locations were designated using ArcGIS Pro to create a grid of 105 points, each 200 m apart encompassing the total area of the campus. These 105 points were then divided into 11 clusters with 9 to 11 sampling points each (Figure 2). Each cluster was then sampled twice, once in June (round 1) and once in July (round 2) of 2024.

The walking transects (distance between any two adjacent points) were sampled using an Anabat Scout ultrasonic recorder to record bat calls while moving between each adjacent sampling point. Movement between points was mainly restricted to north-south and east-west directions, with only a few diagonal transects between points. To ensure each adjoining transect was sampled, our direction and starting point were reversed during the second round of sampling. Sampling was only conducted during nights without rain, wind speeds below 10 km/hour, and temperatures above 10℃. Acoustic collection began 30 minutes after sunset and had a duration of no longer than 2.5 hours.

In order to detect and record the ultrasonic echolocation calls, we used the Anabat Scout recorder set to capture sounds with frequencies between 16 kHz to 120 kHz in full spectrum files with high trigger sensitivity, a minimum event of 2 milliseconds, and a 3.0-second recording window. At each sampling point we recorded for 5 minutes while recording the average temperature (℃), humidity (%), wind speed (km/h), cloud coverage (%), and wind direction, for the full 5 minutes using a Kestrel 5400FW Fire Weather Pro weather meter. The average light intensity (Lux) was also noted using a Titley WalkAbout bat recorder by taking the average light intensity in each cardinal direction (north, south, east, and west) from the sample point.



F I G U R E 2. Map showing the 11 clusters encompassing the total 105 points sampled across UBC Vancouver Campus in June and July of 2024.

3.2.2 Bat Roost Stationary Acoustic Recorder

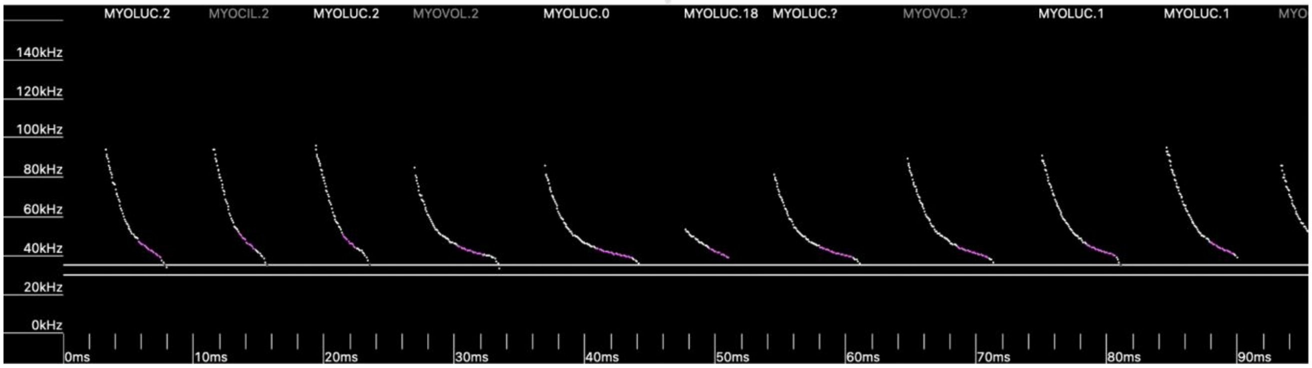
From May 2024 until August 2024, a stationary acoustic recorder was mounted on a light fixture outside the Old Auditorium Annex roost. Recordings were captured on a Wildlife Acoustics Song Meter Mini Bat 2. The song meter was set to record calls 30 minutes before sunset until 30 minutes after sunrise (subject to triggering). The ultrasonic mode was turned on with a full spectrum sample rate of 256 kHz, a minimum trigger frequency of 16 kHz, a maximum recording length of 15 seconds and a trigger window of 2 seconds. Acoustic settings included a sample rate of 24000 Hz, recording mode on the highest quality, 60-minute maximum recording length and right channel gain of 19 dB. The detector's batteries and SD card were changed weekly with recordings being processed after each removal.

3.2.3 Processing and Call Classifications

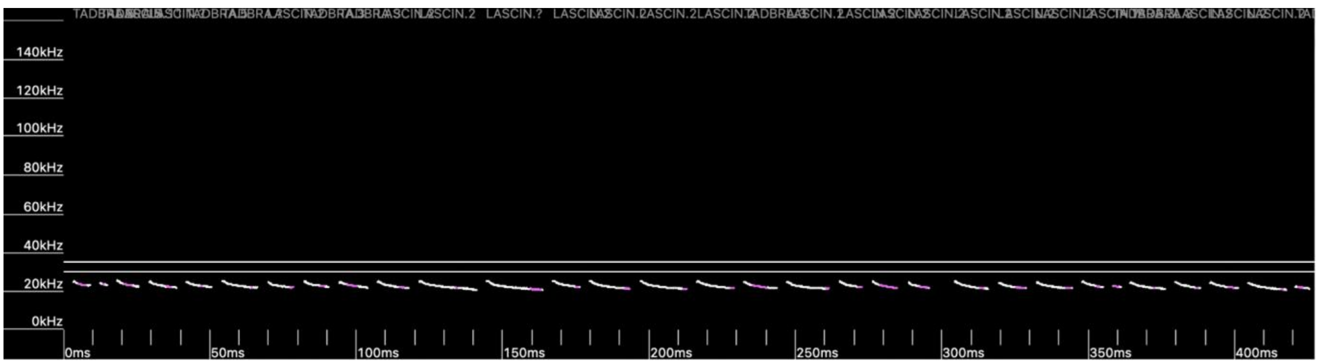
All recordings collected from our stationary points and transects were processed using Kaleidoscope Pro Version 5.4.8 with classifiers set to "Bats of North America" and Auto-ID for species identified in Table 8 of the appendix. Kaleidoscope automatically identifies bat calls and assigns them to species using a reference call library. However, this library isn't fully reliable since it only includes a portion of the calls a species can produce and doesn't account for regional acoustic variations. The software assigns species labels based on statistical probabilities or pattern matching. Instead of basing our conclusions on the auto species ID we manually checked and classified each recording as either *High* (3 or more calls above 30 kHz) (Figure 3.a), *Low* (3 or more calls below 30 kHz) (Figure 3.b), *High Frag* (less than 3 calls above 30 kHz), *Low Frag* (less than 3 calls below 30 kHz), *Bat* (contains calls above and below 30 kHz), or *Noise* (not a bat call).

Classifying bat calls into 'high' or 'low' frequency can help distinguish the species of bat being picked up by the recorder. However, confirmation of species solely from the frequency of the call is extremely difficult due to some species in BC falling into the same frequency range. Thus, acoustic sampling is often paired with mist netting or harp trap capture techniques. Our analysis and methodology do not identify specific species from the acoustic recordings, but may be useful for future researchers who can use this data to try to analyze the species recorded. Bat hotspots were defined as more than 25 calls at the 1 ha spatial scale.

(a) High frequency bat call



(b) Low frequency bat call



F I G U R E 3. (a) High frequency bat call visualized using Kaleidoscope Pro and **(b)** Low frequency bat call visualized using Kaleidoscope Pro.

3.2.4 Data analysis

Data analysis was conducted using R studio version 4.4.1 (R Core Team, 2022 and ArcGIS Pro. All maps were created using ArcGIS Pro.

Bat calls heat map: The total number of calls was aggregated at a 20 m radius to create a layer with a color scheme from high to low.

Grid distribution maps: 1 ha grids were created to encompass the entire area of campus. The total number of calls falling within each grid was calculated. The land cover percentage maps were created by calculating the percentage of pixels of each land cover type within each grid cell.

3.3 Guano Surveys

As a secondary form of data collection used to identify bat presence, we performed guano surveys. Buildings were prioritized based on the year of construction (oldest to newest) and building material (wood preferred). The Old Auditorium bat boxes and Beaty Biodiversity Museum bat boxes were also surveyed for guano as a measure of bat activity. Surveys were conducted by walking the perimeter of the building and looking for droppings on the ground, building railings and underneath the roof slates. If guano was found, it was collected with latex gloves, placed in cotton balls and a coin envelope, labeled, and stored in the lab.

3.4 Emergence Counts

We completed a total of four emergence counts to monitor the population of the maternity roost. Two counts were completed between June 1st and 21st before the pups were born (*BC BATS*, 2024). The last two counts were completed between July 11 and August 5 when pups were active and exiting the roost (*BC BATS*, 2024). Emergence counts were conducted by stationing 7-10 people with counters around the perimeter of the Auditorium Annex Office building, ensuring each facade was accounted for. Observers recorded the number of bats exiting their designated section of the building. If a bat returned to the roost, then the next emerging bat was not counted. The count began at sunset and proceeded for the following hour. The time of the first emerging bat was recorded and a Kestrel 5400FW Fire Weather Pro weather meter was used during the first 10 minutes after sunset to assess the wind speed (km/h) and ambient temperature (℃).

3.5 Mist-Netting

To better understand the species present in our identified hotspots, we captured bats to closely examine their morphology, reproductive status, and identify potential species. Bat trapping was conducted using mist nets, which are fine, handmade nets with shallow pockets designed to catch bats. By strategically placing mist nets in likely bat pathways, we increased the chances of capture, the fineness of the net is thought to not be picked up by their echolocation. We performed mist-netting at Nitobe Memorial Garden since one of our acoustic monitoring data points was located inside and it was determined to be a hotspot of bat activity. Typically, species like Yuma myotis and Little Brown bats fly low, spending extended periods of time foraging over or near water. Therefore, we placed two mist nets on bridges just above the garden's water bodies, one net was a six-meter-long double-high (approximately 5 m high) and the other was a nine-meter-long single-high (approximately 2.5 m high). To identify individuals captured we assessed the slope of their forehead where a steep forehead was Yuma myotis and a shallower forehead was a Little Brown bat. Radio transmitters were glued to bats that weighed more than 6.2 grams, to track them back to their roosting sites.

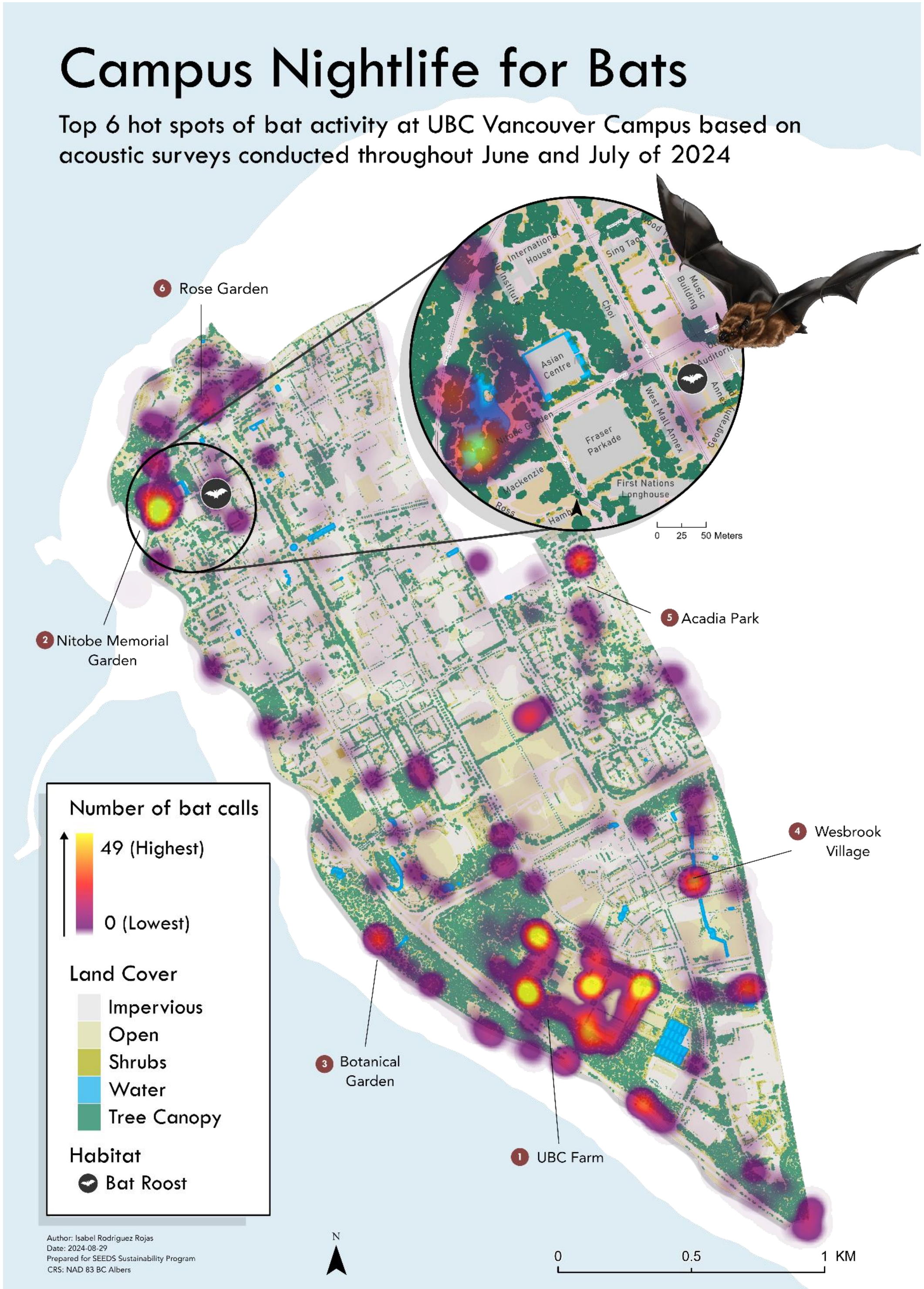
4 | Results

4.1 Mapped distribution of bat activity on campus

Figure 4 shows the distribution of bat activity across the UBC Vancouver campus, based on the acoustic data collected across both rounds of sampling throughout June and July of 2024. The map shows areas where bat calls were recorded, including both high and low-frequency calls; fragmented calls were included in their respective frequencies. Areas with high bat activity (many bat calls) are shown in bright yellow, while areas shown in light purple indicate a lower frequency of bat calls detected in the area. The areas with no color were not sampled.

The UBC Farm was found to have the highest levels of bat activity, with up to 49 calls detected within 1 ha. Nitobe Memorial Garden, located within a 500-meter radius of the roost, is amongst the main hotspots of bat activity (Figure 4). The UBC Botanical Garden, Wesbrook Village, Acadia Park and the Rose garden are identified as areas with moderate levels of bat activity. The heat map shows that most bat activity is concentrated near areas with tree coverage. In contrast, impervious surfaces, such as the central built-up area of the campus, show little to no bat activity.

A total of 686 bat calls were detected across both rounds. Table 1 shows the distribution of these across 5 different types of frequencies; 'high', 'low', 'high-fragmented', 'low-fragmented', and 'bat'. During round 2 of data collection, we recorded 176 more bat calls compared to round one (+69%). In both rounds, 'High' frequency calls made up the largest percentage of calls recorded with 124 (49%) recorded in round 1 and 342 (79%) in round 2. Most notably, the number of 'bat' calls from round 1 to round decreased by 64% and 'high fragmented' calls increased from round 1 to round 2 by 70%. Overall, 'low-fragmented' calls only made up 2.8% of the recorded calls.



F I G U R E 4. Heat map showing the location of all bat calls from both rounds. Areas of hotspots are zoomed in to show the precise location where the call was received.

T A B L E 1. The total number of bat calls (N = 686) recorded per round of sampling, divided by frequency groups: high (> 30 KHz, 3 calls or greater), low (<30 KHz, 3 calls or greater), high-fragmented (> 30 KHz, less than 3 calls), low-fragmented (<30 KHz, less than 3 calls), and bat (both low and high frequency calls present).

	Round 1	Round 2	Total
High	124	342	466
Low	79	32	111
High-Fragmented	12	40	52
Low-Fragmented	12	7	19
Bat	28	10	38
Total	255	431	686

For round 1, the average temperature was 14.37°C, whereas round 2 was 19.73°C, as shown in Table 2. On average, relative humidity and cloud coverage were also lower in round 2 (63.77% and 12.29%, respectively) compared to round 1 (67.25% and 35.41%), with the cloudiest day reaching 98% in round 1 (Table 2). In both rounds, the average wind speed was below 1 km/h, with the highest recorded wind speed being 8.2 km/h in round 2. The lowest light index recorded was 0.00 lux, and the highest was 55.80 lux, both observed in round 1. However, on average, round 2 had a higher mean light level (4.8 lux) than round 1 (3.6 lux).

T A B L E 2. Summary of the weather variables collected at each sampling point (*N* = 105) for each round of sampling across the University of British Columbia Vancouver Campus, B.C.

	Round 1				Round 2			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Temperature (C)	14.37	1.53	10.90	18.20	19.73	2.57	13.90	24.70
Relative humidity (%)	67.25	7.67	46.10	82.90	63.77	12.51	0.65	88.30
Cloud coverage (%)	35.41	41.22	0.00	98.00	12.29	22.60	0.00	90.00
Wind Speed (km/h)	0.77	1.23	0.00	5.20	0.98	1.71	0.00	8.20
Light (lux)	3.63	7.77	0.00	55.80	4.82	10.62	0.01	51.10

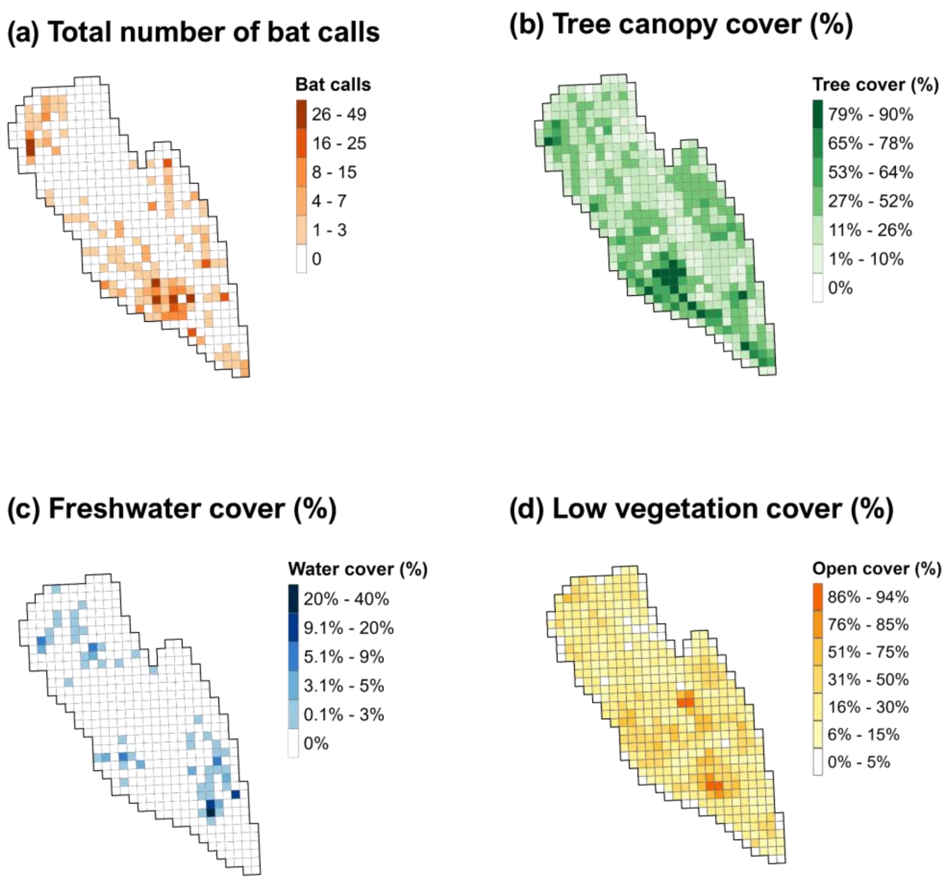
Based on all bat calls recorded during both rounds, the average distance from tree canopy that bat calls were recorded was 4.59 meters, with a maximum distance of 50.16 meters, as shown in Table 3. Among the different call types, 'Bat' calls had the lowest mean distance from the canopy at 3.48 meters, while 'high/high-frag' calls had the highest mean distance at 4.90 meters and the largest sample size (N = 518). The mean distance of all calls to water was 206.76 meters, with a maximum distance of 792.97 meters. The 'low/low-frag' group had the shortest mean distance to water at 175.82 meters, whereas the 'high/high-frag' group had the longest mean distance at 215.64 meters.

T A B L E 3. Proximity of bat calls (N = 686) to tree canopy (m) and water bodies (m) recorded in rounds 1 and 2, categorized by three frequency types (bat, high/high-frag, low/low-frag).

		Distance to Tree Canopy (m)			**Distance to Water (m)**		
	N	**Mean**	**Max**	***SD***	**Mean**	**Max**	***SD***

Bat	38	3.48	21.13	5.33	191.66	463.77	147.11
High/High-Frag	518	4.90	50.16	9.17	215.64	792.97	171.85
Low/Low-Frag	130	3.70	23.57	5.05	175.82	758.28	140.16
All bats	**686**	**4.59**	**50.16**	**8.37**	**206.76**	**792.97**	**165.56**

At the 1 ha spatial scale, bat calls ranged from 0 to 49 (mean = 1.5, SD = 5). Tree canopy cover ranged from 0 to 90% (mean = 25.2, SD = 19.7), with the highest tree canopy cover found near southeast campus, within the UBC Farm and the UBC Botanical Garden (Figure 4). Areas with higher bat activity had overall higher tree canopy cover (Fig 6.b). Freshwater cover ranged from 0 to 40% (mean = 0.4, SD = 2.6). Freshwater was not present in some areas with high levels of bat activity, such as the UBC Farm.



F I G U R E 5. Distribution of (a) total bat calls of any frequency (N = 686) , (b) percentage tree canopy cover, (c) percentage freshwater cover and (d) percentage low/open vegetation cover at 1 ha spatial scale across the University of British Columbia, Vancouver Campus, based on acoustic surveys conducted throughout June and July of 2024.

4.2 Guano Surveys

Both the Annex bat boxes and Beaty Biodiversity bat boxes did not have guano in the trays or underneath at any point throughout the summer, refer to Table 4.

TABLE 4. Results from guano surveys conducted at the Beaty Biodiversity Museum and the Music Building (Annex) Bat Boxes.

Site	Date	Guano Present	Bats Present
Beaty Biodiversity Museum Bat Boxes	6/11/2024	No	No
	7/10/2024	No	No
	7/15/2024	No	No
	7/31/2024	No	No
Annex Bat Boxes	6/11/2024	No	No
	7/10/2024	No	No
	7/15/2024	No	No
	7/31/2024	No	No

4.3 Emergence Counts

Our results from the four emergence counts conducted at the Auditorium Annex Office roost showed a consistent increase in the total number of bats observed each month. From the first to the last count, there was a 112% increase in the total number of bats counted (137 to 291 bats). During the last two emergence counts (July and August) pups were heard and observed flying behind their mothers.

TABLE 5. Data tables from the four emergence counts conducted at the Auditorium Annex Offices roost.

Date	Start Temperature (℃)	Start Time	Time of First Bat	End Time	Total Number of Bats	Pups Seen or Heard
6/12/2024	13.8	9:20 p.m.	9:36 p.m.	10:20 p.m.	137	No
6/19/2024	18.3	9:16 p.m.	9:40 p.m.	10:16 p.m.	183	No
7/17/2024	23.8	9:12 p.m.	9:28 p.m.	10:12 p.m.	253	Yes
8/1/2024	20.9	8:54 p.m.	8:56 p.m.	9:54 p.m.	291	Yes

4.4 Mist Netting

Our trapping results confirmed that the bats flying around Nitobe are Yuma myotis and Little Brown bats. We caught roughly 40 bats but only processed 15 due to time constraints and the need to not hold bats longer than 1 hour. We also were able to attach radio tags to 3 bats. The day after trapping, two out of the three radio tracked bats were located at the Annex roost confirming that the bats roosting at this location are using the Nitobe pond as a foraging and drinking source. Three days after trapping one of the bats was found at the Annex roost, but the other two could not be found. Seven days after trapping telemetry was conducted at night, and only one bat was found at the Annex roost and moved to Nitobe Memorial Garden where it was later found near Wreck beach. The 3rd bat was detected a week after trapping at Nitobe Memorial Garden's Tea Room, although no conclusions can be made to state if this is a roosting site.

TABLE 6. Statistics of Little Brown bats and Yuma myotis trapped at Nitobe Memorial Garden on August 15th, 2024.

Species	Reproduction Status	Male	Female
Myotis lucifugus	Juvenile	1	1
	Reproductive Adult	0	0
	Non-reproductive Adult	1	4

	Total	**2**	**5**
Myotis yumanensis	Juvenile	1	1
	Reproductive Adult	0	1
	Non-reproductive Adult	0	5
	Total	**1**	**7**

5 | Discussion

5.1 Distribution of Bat Activity and Land Cover

Understanding ecologically important features for wildlife has become increasingly important as UBC continues to expand and urbanize. In response, we sought to understand habitat features on the UBC campus which produced the highest abundance of bat activity and used this information to recommend actions to support bat populations throughout the development of the campus. Our primary objective was to assess bat presence on campus, identify hotspots of bat activity, and pinpoint ecologically significant areas that can inform future land use planning at UBC, supporting the UBC Campus 2050 Vision Plan (*Campus vision 2050)*. This vision aims to establish a network of connected green spaces, including wildlife corridors and green roofs, integrated with academic and residential buildings. Our results highlight the impact of urbanization on bat populations with a noticeable absence in the academic areas on campus likely due to a lack of natural spaces, light, and noise pollution. Tree canopy proved to be highly correlated with bat activity as the average distance from the closest tree to a bat call was less than five meters. This finding aligns with previous literature which demonstrates the importance of green spaces for bats (Craig, 2022; (Forrest and Craig, 2023). Green spaces are rich in resources and biodiversity while also providing protection from human impacts subsequently providing ideal habitat for numerous wildlife species (Craig, 2022; Dietz et al. 2020; Nielsen et al. 2014). Despite human efforts to mimic habitat through the implementation of bat boxes, the most effective way to conserve and promote bat populations on campus is through the protection of their vital green spaces.

5.1.1 Forest Cover

Our findings indicate that the central campus, where most academic buildings are located, lacks sufficient tree canopy and freshwater sources. Enhancing bat habitat and supporting species movement by reforesting areas near buildings and extending surrounding forests into the campus, can help create networks between areas of high bat activity. Establishing wildlife corridors has proven effective in connecting bat roosting and foraging sites, thereby supporting bat biodiversity (Gunnel et al., 2012). Forest cover and open grasslands are consistently identified as key elements in supporting bat communities, providing essential roosting and foraging opportunities. Additionally, old-growth forests and hollow trees offer temporary shelters for bats during nighttime foraging when they are distant from their primary roosts (Moretto & Francis, 2017).

5.1.2 Water Coverage

While the academic areas of campus have limited freshwater sources, our findings suggest that tree cover is more crucial for bats than proximity to water. This is evident because some of the key bat hotspots, such as the UBC Farm, lack water sources on site (although the experimental ponds just south of the farm may also be critical to bat activity at the farm). However, the pond at Nitobe Memorial Garden does serve as an important water source for bats roosting in the bat roost. This observation is consistent with our telemetry data and trapping efforts, during which we frequently observed bats flying low and drinking from the pond. Similarly, Craig et al. (2022) found a strong correlation between bat activity and proximity to freshwater sources, further supporting the importance of water availability for bats. Water bodies not only support bat hydration but are also important for bat abundance. Water bodies serve as habitat for a diverse population of insects which bats prey and rely upon for survival (Forrest and Craig, 2023; Mas et al., 2022).

5.1.3 Low Vegetation Cover

Low vegetation (shrubs, grasslands, and natural grass) is readily available on campus and showed no correlation with bat activity. Predictably, the UBC Farm was identified as an area with a large percentage of low vegetation which also serves as a hotspot of bat activity. Although the high bat activity in this area may be due to the large percentage of surrounding forest canopy and not the direct low vegetation cover. One area which challenges these overall results is the sports fields neighboring the Acadia Park Residence (Figure 3). While not considered a hotspot of bat activity, numerous bats were identified foraging and flying above these natural grass fields.

5.1.4 Climatic Conditions and Bat Activity Levels

We recorded a 69% increase in bat calls in July compared to June, likely due to several seasonal factors that influence bat activity. Bat activity tends to increase with warmer temperatures, and during our data collection, July was, on average, 5.36°C warmer than June. This temperature rise may have contributed to the increased bat activity observed in the second round of data collection, possibly due to higher prey availability in warmer conditions (Gorman et al., 2021). Additionally, July had lower average relative humidity and cloud coverage compared to June, which aligns with the literature that suggests bat activity generally declines with increased precipitation, wind speed, and changes in barometric pressure. In coastal areas like the UBC, weather conditions can be more pronounced, as coastal regions typically experience higher wind speeds (Grider et al., 2016; Gorman et al., 2021; Patriquin et al., 2016; Smith and McWilliams, 2016).

Aside from climatic conditions, another reason for the increased bat activity observed in July compared to June could be the presence of bats living in the maternity roost in the Auditorium annex on campus. Throughout June, most reproductive bats are either pregnant, giving birth, or preparing to do so. After giving birth, these bats spend time teaching their young to forage and build adequate fat reserves for the winter (Reynolds, 1999). The heightened presence of bats in July may result from this increased activity of bats teaching their young. The emergence count data also indicate a rise in bat numbers at the roost between June and July, confirming the increased activity level around and near the roost.

5.1.5 Species Specific Differences

High-frequency echolocation calls accounted for 68% of the calls recorded during both rounds of data collection, aligning with our findings. Most bat activity was observed along forest edges or within tall trees, areas where high-frequency calls are particularly useful. These calls, while not traveling far, are highly specific, enabling bats to avoid obstacles like trees and branches and effectively detect small insects while foraging.

Table 7 in the appendix lists all known bat species present in British Columbia and their typical echolocation frequencies. Our mist-netting data confirm that some of the high-frequency calls we recorded are indeed from Little Brown bats and Yuma myotis, both of which prefer edge habitats and typically use high-frequency echolocation calls (Josiah et al., 2017). Little Brown bats generally echolocate at frequencies above 40 kilohertz, while Yuma myotis calls range between 45-50 kilohertz, making Yuma myotis the bat with the highest frequency calls in Canada (Lausen et al., 2022). However, the presence of low-frequency calls suggests there are additional bat species on campus that we have not yet identified through mist-netting (see Table 7). One reason for the lower number of low-frequency calls recorded could be that bats in open areas typically use these calls, which travel farther. However, to conserve energy, bats generally emit fewer pulses per second with low-frequency calls compared to high-frequency calls in forested areas (Lausen et al., 2022).

5.2 Guano Surveys

Guano surveys revealed no activity or occupation of the Old Auditorium or Beaty Biodiversity bat boxes. The Old Auditorium bat boxes were installed in hopes of relocating the maternity roost which has not been the case. While it is difficult to definitely know why the bats have not taken up residence in the boxes, the answer could simply be due to their loyalty to their roost. When bats find suitable habitat, they tend to return year after year, this is applicable to cave, mine, tree, or house roosts (*Living with Bats | Neighbourhood Bat Watch*, n.d.). There is minimal research on how to attract bats to a box, but it appears the most important aspect is the location of the box. Successful relocation of the maternity roost to the bat boxes will likely expand over numerous summers, meaning it could be years before the Auditorium Annex Offices A building can be reconstructed.

5.3 Emergence Counts

With a greater volunteer turnout than in previous years, we were able to place counters in areas of the Auditorium Annex Office A that had not been surveyed before. Bats were observed leaving the Auditorium Annex Offices A from multiple facades with the number of bats leaving each facade varying between counts indicating the roost could expand throughout the entirety of the attic. Although our knowledge regarding their occupancy is limited. The increased number of bats emerging from the roost through the summer is most likely accounted for by the newly born pups. Little Brown bats and Yuma myotis typically give birth at the end of June into early July (Reynolds, 1999; Lausen et al., 2022).

5.4 Mist-Netting

Our mist-netting and telemetry results confirmed that the bats foraging in the Nitobe Memorial Garden and roosting in the Auditorium Annex Offices A are Yuma myotis and Little Brown bats. This finding is crucial as it identifies the Nitobe Memorial Garden as an ecologically significant area for the endangered Little Brown bats, providing valuable insights for UBC policy. The data suggest that the habitat surrounding both the garden and the roost should be carefully considered in any future development plans.

Furthermore, the use of the garden as a primary water source by bats roosting in the Annex aligns with the literature, which indicates that woodland species such as Little Brown bats often commute to water sources after emerging from their roosts. They frequently travel along tree lines and forest edges to avoid predators (Korine et al., 2016). Therefore, protecting the tree canopy between the roost and Nitobe Memorial Garden is essential.

5.5 Limitations

5.5.1 Acoustic Recorders

The Titley Anabat Scout does not have a set radius which it records calls. Recordings will be triggered based on the frequency, volume, and type (i.e., foraging, social, etc.) of the echolocation. Typically, low frequency calls travel further, therefore they can trigger a recording at a farther distance than a high frequency call could. Additionally, infrastructure can block high frequency sound waves. This means some calls will need to be closer to the sensor to trigger a recording, leading to a sampling bias with an uneven representation of calls which can be picked up from a farther radius.

5.5.2 Abiotic Inconsistencies

Lunar phobia is the phenomenon where bat activity decreases during full moons, potentially due to reduced prey activity and predation risk as brighter moonlight makes them more visible (Lang et al., 2006). Studies have shown certain bat species have significantly increased bat activity during dark periods (i.e., crescent moons) (Lang et al., 2006). When completing our transects we did not consider the lunar phase which could result in a sampling bias.

Sampling was not conducted in the event of rain, heavy winds, or low temperatures, but there were discrepancies in these factors. Abiotic factors were recorded as an average across five minutes, and while the average was always within our standards, at certain times during the five minutes' wind speeds and temperatures were not within our set threshold. Acoustic recordings throughout June and July saw varying temperatures with a low of 11.5℃ (June 4, 2024) and a high of 24.7℃ (July 8, 2024). It has been recognized that higher temperatures increase insect activity and reproduction often resulting in increased bat activity (Craig, 2022; Gilbert & Raworth, 1996). Possibly leading to discrepancies in accurate bat activity models.

Guano surveys were conducted to test for bat presence in academic buildings and at the bat boxes. The Beaty Biodiversity Museum bat boxes do not have guano trays leaving us to search through grass for the rice-sized guano which was difficult and could have resulted in us missing guano that was present. However, these results are not abnormal as the boxes near the Old Auditorium contain guano trays and remain unoccupied. A similar limitation was experienced during guano surveys performed outside of academic buildings. Surveys were conducted around the perimeter of buildings most of which had greenery or gravel making it difficult to perform accurate surveys.

5.5.3 Biotic Factors

Acoustic transects were completed in late June through to early July, a period of decreased maternal bat activity, during which they are giving birth to and rearing their pups. Additionally, in mid-July, pups begin to emerge from their roost, learning to forage and fly. While there is only one known maternity roost, it is feasible that others exist in or surrounding the vicinity of the UBC campus. Regardless, completing sampling during a time of varying bat populations may have led to discrepancies in accurate bat activity models. Specifically, for the second round of sampling at the Nitobe cluster, which is near to the maternity roost and was completed on July 31st (when pups are actively leaving the roost). Collection at this location and time may show increased activity which is not represented in other clusters. A future research possibility could study changes in campus bat activity before and after pups are born and leave the roost. This could provide an understanding of how many bats are a part of the maternity roost and which are bachelors or not reproductive females.

6 | Recommendations

6.1 Future Research

While this research provided insights into bat activity and hotspots on campus, it is just the beginning. We still have not identified other roosts on campus nor has UBC implemented a policy for co-existence with wildlife and endangered species. Future research should determine the presence of other roosts in or near the identified hotspots (Figure 4). This could be done through mist netting at hotspots complimented by telemetry, especially in areas on the south side of campus opposite the roost. Other avenues to find campus roosts could include the use of heat detectors or continued guano surveys near hotspots.

Concerns have been raised regarding the structural integrity of the Auditorium Annex Offices A following the roosts' occupation. For the safety of the bats, building occupants, and peace of mind, future research can look into their impact on the building. Knowing bats typically do not chew on or destroy building materials, their effect should be minimal. Although the Auditorium Annex Offices A was constructed in 1925, the need for renovations and concerns are well grounded.

The UBC bat roost serves as the perfect candidate for research regarding bats' attraction to bat boxes. While trying to find literature on this topic there was an obvious knowledge gap. As the climate continues to change species ranges will continue to grow, placing increased pressure on wildlife species, and the use of bat boxes may serve as an avenue to aid bats during this time.

In the eyes of the public, bats are still a conflicting topic with many people fearing bats despite low risk to human health. To help counter negative views of these nocturnal mammals, studies should investigate the ecological and economic benefits of bats. The value of bats is not fully understood especially in British Columbia, let alone the Lower Mainland. By studying the diets of bats, we would gain insight into their pest control capabilities, invasive species management, and consumption of disease vectors (mosquitoes). These findings would not only prove the importance of bats to other fields (i.e., agriculture, medicine, invasive species communities), but can also mitigate fear and misconceptions regarding bats. Understanding what bats consume is also deeply important for their conservation and has not yet been studied in the Lower Mainland.

Future work-learn students can continue to monitor the activity of the roost and bat boxes should be monitored in future years. When a decrease or no activity in the bat roost at the end of each season is identified, custodial services should be notified so a thorough cleaning of the Auditorium Annex Offices A can be completed.

In April of 2023, one bat box was installed near the Auditorium Annex Offices A with the hopes of the roost relocating. Despite consistent monitoring of this bat box throughout the summer of 2024, no guano or bats were detected. Little research has been performed on how to get bats to take to bat boxes but it is thought that guano placed near or inside boxes could make it a more enticing environment. In light of this knowledge, we have collected guano from the pre-existing roost which will be stored for further use including but not limited to placement on the guano trays of the Old Auditorium bat boxes.

The UBC Botanical Garden was recently donated a bat box, with the knowledge that they are a hotspot for bat activity. WorkLearn students should work alongside Botanical Garden staff and BC Bats to decide on the placement and installation process. If granted permission, guano trays and stationary acoustic recordings should be placed on the boxes. After monitoring the Old Auditorium and Beaty Biodiversity bat boxes, we found these two elements to be crucial in providing an effective and accurate measure of the bat boxes activity. Guano trays provide a simple way to monitor the boxes for occupancy while a stationary recorder can potentially identify species or general activity near the box.

6.2 Actions

6.2.1 Custodial Services

UBC Custodial hires EcoPest Inc. for pest management. While bats are not considered pests by either organization, EcoPest Inc. is able to clean guano off of external railings and stairs. Knowing the roost is not used for hibernation, bats should leave the Old Auditorium Annex in October or November. This means that late October or early November is an ideal time to deep clean the exterior portions of the building and contract EcoPest Inc. to clear guano.

Concerns about guano clean-up and power washing buildings were frequently mentioned during interviews. To address these concerns, we created an infographic (Figure 7) specifically for building operations staff, providing educational information about bats and their activity on the UBC campus.

6.2.2 Campus Development

Figure 5 shows the importance of high-quality forest and freshwater sources for bat activity. Incorporating wildlife corridors into the academic parts of campus could serve as a way to promote bat activity and conservation. This can be accomplished through the enhancement of edge habitats such as increasing tree coverage near and around Nitobe Memorial Garden and the UBC Farm. The addition of freshwater bodies, whilst also reducing light and noise around these hotspots of bat activity would also be helpful in aiding conservation efforts. The presence of bats around the Rose Garden and the Museum of Anthropology (MOA) indicates that they may also be using the area for foraging. With the reconstruction of the MOA pond, we anticipate this will greatly benefit the bat population on campus by providing an additional water source for feeding and drinking. Based on our results, adding freshwater features, such as a pond near the Acadia residences, could increase insect densities in the area. This would help expand the ecological habitat and, in turn, enhance the abundance and diversity of bats near Pacific Spirit Park.

UBC Campus Vision 2050 plans to introduce connective corridors which will extend the forest throughout campus. These landscape corridors will run throughout campus, but the West 16th Avenue corridor will connect the UBC Botanical Garden to Pacific Spirit Regional Park using tall trees. With the knowledge that tree canopy positively increases bat activity alongside the high bat activity at the UBC Botanical Garden, this corridor has the potential to greatly support bat populations on campus.

6.2.3 UBC Policy

Currently, there is no specific group on campus dedicated to managing conflicts with bats. Most of the work to mitigate these conflicts falls to building managers and custodial services, who are not responsible for handling wildlife, but often have no other option as the presence of bats in buildings falls into their hands. Based on our research and discussions with key stakeholders regarding the presence of bats on campus, we recognize the urgent need for a dedicated wildlife management body. This would be instrumental in managing human-wildlife conflicts involving bats and supporting conservation efforts for the endangered Little Brown bats. An exemplary organization that addresses human-wildlife conflict is the IUCN SSC Human-Wildlife Conflict & Coexistence Specialist Group (IUCN, 2023). This international advisory group consists of interdisciplinary experts who connect policy, science, and communities, facilitating the integration of knowledge and strengthening the capacity to manage human-wildlife conflicts.

With the extensive research conducted at UBC on biodiversity and wildlife management, collaboration among various groups would be essential in developing guidelines; similar to those of the IUCN SSC which can then be translated into policies for managing different wildlife species on campus (IUCN, 2023). These guidelines should integrate a comprehensive understanding of species-specific differences, specify actionable measures, and highlight the importance of collaborating with communities involved in the conflict. In the case of bats on campus, key stakeholders needed to develop this policy would include those directly affected by the conflict, building managers, individuals responsible for building planning, and researchers specializing in the study of bats' presence and behavior on campus. Effective human-wildlife conflict management requires policies that incorporate suitable and effective instruments to guide the actions of all parties involved (IUCN, 2023).

7 | Conclusions

Understanding bat activity across the UBC campus provides valuable insights into how these species interact with their environment and respond to urbanization. Our study aimed to raise awareness about the endangered Little Brown bat roost on campus and to develop research-based recommendations to inform future policies on wildlife conservation and human-wildlife conflict management at UBC. Key findings identified six hotspots of bat activity on campus, particularly around tree canopies and freshwater sources, and highlighted the importance of the Nitobe Memorial Garden for foraging and water.

We recommend future research focus on locating additional roosts near these hotspots and installing more bat boxes to provide alternative habitats. Additionally, understanding the ecological and economic benefits of bats on campus could inform broader conservation efforts. As urbanization impacts wildlife, it is crucial for UBC to implement policies or establish a governing body to manage these challenges effectively. With the threat of White Nose Syndrome, conserving endangered bat species is vital for ecological balance and species survival. This is a critical time for bat conservation, and continued research and proactive measures are necessary to protect bat populations on campus.

References

1. Affleck, B., Snep, R. P., Hauck, T. E., Ferguson, J., Holy, M., Jakoby, C., ... & Weisser, W. W. (2020). Designing wildlife-inclusive cities that support human-animal co-existence. Landscape and Urban Planning, 200, 103817.

2. Bartha , P., Brehon , R., Wen, M., & Wong , T. (2023). Bats on Campus: Living with an Endangered Species. *Social Ecological Economic*

3. BC BATS. *Bats and human health*. (2023, September 29). https://bcbats.ca/bat-basics/bats-and-human-health/

4. Bergeson, S. M., Cate-Carter, T., & Whitby, M. D. (2015). Adaptive roosting gives little brown bats an advantage over endangered Indiana bats. The American Midland Naturalist, 174(2), 321-330. 10.1674/0003-0031-174.2.321

5. Boyles, J. G., Cryan, P. M., McCracken, G. F., & Kunz, T. H. (2011). Economic importance of bats in agriculture. Science, 332(6025), 41-42. 10.1126/science.1201366

6. BC Wildlife Act. (2023). Retrieved from the Government of British Columbia Website https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/96488_01

7. Border, J.A., S.E. Newson, D.C.J. White, *et al*. 2017. Predicting the likely impact of urbanization on bat populations using citizen science data, a case study for Norfolk, UK. *Landsc. Urban Plan.* 162: 44–55.

8. Castilla, Maria Cecilia, et al. "Perceptions and attitudes of the local people towards bats in the surroundings of the Escaba dam (Tucumán, Argentina)." *Ethnobiology and Conservation* 9 (2020).

9. *Campus vision 2050: Shaping the future of UBC Vancouver*. Campus Vision 2050: Shaping the Future of UBC Vancouver | UBC Campus & Community Planning. (2024, July 25). https://planning.ubc.ca/vision

10. Counting bats | BC BATS. (2024, June 4). BC BATS. https://bcbats.ca/get-involved/counting-bats/

11. Chan, K. M. A., & Satterfield, T. (2016). Managing cultural ecosystem services for sustainability. In Routledge Handbook of Ecosystem Services M. Potschin, R. HainesYoung, R. Fish and R.K. Turner. London and New York, Routledge. (pp. 343-358). http://hdl.handle.net/2429/62188

12. Craig, J. (2022). *Prime real estate: how urban landscape variables influence bat presence in Vancouver, Canada* (T). University of British Columbia. Retrieved from https://open.library.ubc.ca/collections/ubctheses/24/items/1.0417416

13. CBC/Radio Canada. (2023, April 4). *Deadly fungus that has wiped out bat populations detected in B.C. | CBC news*. CBC News. https://www.cbc.ca/news/canada/british-columbia/bc-bats-white-nose-syndrome-1.6800262

14. *Development Studies (SEEDS) Sustainability Program Student Research Report,* 1–50.

15. Dixon, M. D. (2012). Relationship between land cover and insectivorous bat activity in an urban landscape. Urban Ecosystems, 15(3), 683-695

16. Dimkić, I., Fira, D., Janakiev, T., Kabić, J., Stupar, M., Nenadić, M., ... & Grbić, M. L. (2021). The microbiome of bat guano: for what is this knowledge important?. *Applied microbiology and biotechnology*, *105*, 1407-1419.

17. Ducummon, S. L. (2000). Ecological and economic importance of bats. *Bat Conservation International, Austin, TX*.

18. Filgueiras, B. K. C., Peres, C. A., Melo, F. P. L., Leal, I. R., & Tabarelli, M. (2021). Winner–Loser Species Replacements in Human-Modified Landscapes. Trends in Ecology & Evolution, 36(6), 545–555. https://doi.org/10.1016/j.tree.2021.02.006

19. Frank, E. G. (2024). The economic impacts of ecosystem disruptions: Costs from substituting biological pest control. *Science*, *385*(6713). https://doi.org/10.1126/science.adg0344

20. Frick, W. F., Kingston, T., & Flanders, J. (2020). A review of the major threats and challenges to global bat conservation. Annals of the New York Academy of Sciences, 1469(1), 5-25.

21. Frick, W. F., Pollock, J. F., Hicks, A. C., Langwig, K. E., Reynolds, D. S., Turner, G. G., ... & Kunz, T. H. (2010). An emerging disease causes regional population collapse of a common North American bat species. *Science*, *329*(5992), 679-682.

22. Forrest, D. Craig, J. (2023). Bats in Vancouver, BC. Who, where, why, and how can we help? City of Vancouver. https://ires2015.sites.olt.ubc.ca/files/2023/10/Forrest_Craig_Bat_Report_Compressed-202 3.pdf

23. Furey, N.M. & P.A. Racey. 2016. Conservation ecology of cave bats. In *Bats in the Anthropocene: Conservation of Bats in a Changing World*. C. Voigt & T. Kingston, Eds.: 463–500. Springer International Publishing.

24. Grider, J.F., Larsen, A.L., Homyack, J.A., Kalcounis-Rueppell, M.C., 2016. Winter activity of Coastal Plain populations of bat species affected by white-nose syndrome and wind energy facilities. PLoS ONE 11 (11), 0166512.

25. Griebling , H. (2023). Human-Wildlife Conflict Management at UBC. A case study using bats. *Social Ecological Economic Development Studies (SEEDS) Sustainability Program* , 1–12.

26. Gunnel, K.,Grant, G. and WIlliams, C. (2012) Landscape and urban design for bats and biodiversity. Bats Conservation Trust. Landscape_and_urban_design_for_bats_and_biodiversityweb.pdf

27. IUCN (2023). IUCN SSC guidelines on human-wildlife conflict and coexistence. First edition. Gland, Switzerland: IUCN

28. Lang, A.B., Kalko, .E.K, Römer, H., Bockholdt, C., Dechmann, D.K. Activity levels of bats and katydids in relation to the lunar cycle. Oecologia. 2006 Jan;146(4):659-66. doi: 10.1007/s00442-005-0131-3. Epub 2005 Nov 5. PMID: 16273422.

29. Lausen, C., Nagorsen, D., Brigham, M., & Hobbs, J. (2022). *Bats of British Columbia*. Independent Publishers Group : The Royal British Columbia Museum.

30. *Living with bats | Neighbourhood Bat Watch*. (n.d.). https://batwatch.ca/living-bats

31. Mas, M. T., Flaquer, C., Puig-Montserrat, X., Porres, X., Rebelo, H., & López-Baucells, A. (2022). Winter bat activity: The role of wetlands as food and drinking reservoirs under climate change. Science of the Total Environment, 828, 154403. https://doi.org/10.1016/j.scitotenv.2022.154403

32. Moretto, L., & Francis, C. M. (2017). What factors limit bat abundance and diversity in temperate, North American urban environments? *Journal of Urban Ecology*, *3*(1). https://doi.org/10.1093/jue/jux016

33. Hayes, M.A. 2013. Bats killed in large numbers at United States wind energy facilities. *Bioscience* 63: 975–979.

34. Hoyt, J. R., Langwig, K. E., Sun, K., Parise, K. L., Li, A., Wang, Y., ... & Kilpatrick, A. M. (2020). Environmental reservoir dynamics predict global infection patterns and population impacts for the fungal disease white-nose syndrome. *Proceedings of the National Academy of Sciences*, *117*(13), 7255-7262..

35. Hoyt, J. R., Kilpatrick, A. M., & Langwig, K. E. (2021). Ecology and impacts of white-nose syndrome on bats. *Nature Reviews Microbiology*, *19*(3), 196-210.

36. Josiah J. Nelson, Erin H. Gillam, Selection of foraging habitat by female little brown bats (*Myotis lucifugus*), *Journal of Mammalogy*, Volume 98, Issue 1, 8 February 2017, Pages 222–231, https://doi.org/10.1093/jmammal/gyw181

37. Korine, C., Adams, R., Russo, D., Fisher-Phelps, M., & Jacobs, D. (2016). Bats and water: anthropogenic alterations threaten global bat populations. *Bats in the Anthropocene: Conservation of bats in a changing world*, 215-241.

38. Patriquin, K. J., Leonard, M. L., Broders, H. G., Ford, W. M., Britzke, E. R., & Silvis, A. (2016). Weather as a proximate explanation for fission–fusion dynamics in female northern long-eared bats. *Animal Behaviour*, *122*, 47-57.

39. Rea, R. V., & Huxter, C. E. (2020). Late-autumn record of Little Brown Myotis (Myotis lucifugus) in north-central British Columbia. *The Canadian Field-Naturalist*, *134*(3), 248-251.

40. Reynolds, D.S. (1999) Variation in life-history traits in the little brown bat, *Myotis lucifugus* (Chiroptera: Vespertilionidae). PhD thesis, (ed T.H. Kunz), pp. 337. Boston University, Boston, MA, USA.

41. Smith, A.D., McWilliams, S.R., 2016. Bat activity during autumn relates to atmospheric conditions: implications for coastal wind energy development. J. Mammal. 97 (6), 1565–1577. https://doi.org/10.1093/jmammal/gyw116.

42. Threlfall, C. G., Law, B., & Banks, P. B. (2012). Sensitivity of insectivorous bats to urbanization: Implications for suburban conservation planning. *Biological Conservation*, *146*(1), 41-52.

43. *Vancouver - UBC Campuses | The University of British Columbia*. (n.d.). https://www.ubc.ca/our-campuses/vancouver/

44. Ministry of Forests. (2024, June 11). *White-Nose Syndrome (WNS) - Province of British Columbia*. https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-conservation/wildlife-health/white-nose-syndrome-wns#batcolonies

45. *Walkabout*. Titley Scientific. (2024, May 16). https://www.titley-scientific.com/product/anabat-walkabout/

46. *What is Nature Positive - Nature Positive Universities*. (2024, March 21). Nature Positive Universities. https://www.naturepositiveuniversities.net/what-is-nature-positive/

Appendices

Table 7. Table showing dates of acoustic sampling and the accompanying moon phase for that evening.

Sampling Date	Moon Phase
06/04/24	Waning Crescent
06/06/24	New Moon
06/10/24	Waxing Crescent
06/13/24	Waxing Crescent
06/17/24	Waxing Gibbous
06/18/24	Waxing Gibbous
06/24/24	Waning Gibbous
06/25/24	Waning Gibbous
07/08/24	Waxing Crescent
07/09/24	Waxing Crescent
07/15/24	Waxing Gibbous
07/16/24	Waxing Gibbous
07/22/24	Waxing Gibbous
07/23/24	Waxing Gibbous
07/31/24	Waning Crescent

Table 8. Table identifying species on Kaleidoscope for AutoID

AutoID	**Scientific Name**	**Common Name**
CORTOW	Corynorhinus townsendii	Townsend's big-eared bat
EPTFUS	*Eptesicus fuscus*	Big brown bat
LASCIN	*Lasiurus cinereus*	Hoary Bat
LASNOC	*Lasionycteris noctivagans*	Silver-haired bat
MYOCAL	*Myotis californicus*	California myotis
MYOCIL	*Myotis ciliolabrum*	Western Small-footed myotis
MYOEVO	*Myotis evotis*	Long-eared myotis
MYOLUC	*Myotis lucifugus*	Little Brown bat
MYOTHY	*Myotis thysanodes*	Fringed myotis
MYOVOL	*Myotis volans*	Long-legged myotis
MYOYUM	*Myotis yumanensis*	Yuma myotis
NYCMAC	*Nyctinomops macrotis*	Big free-tailed bat
TADBRA	*Tadarida brasiliensis*	Mexican free-tailed bat

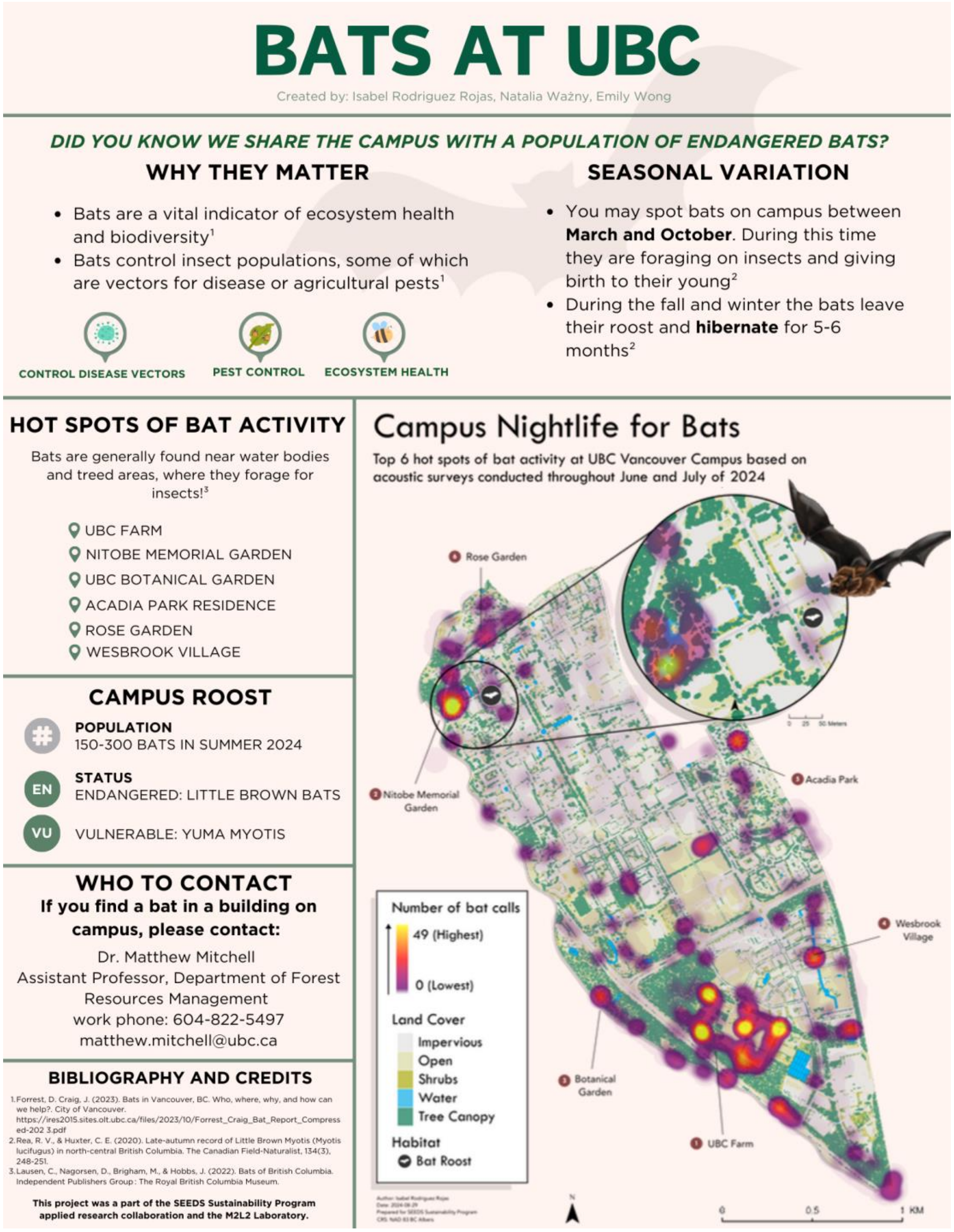


Figure 6. Infographic for building operations staff

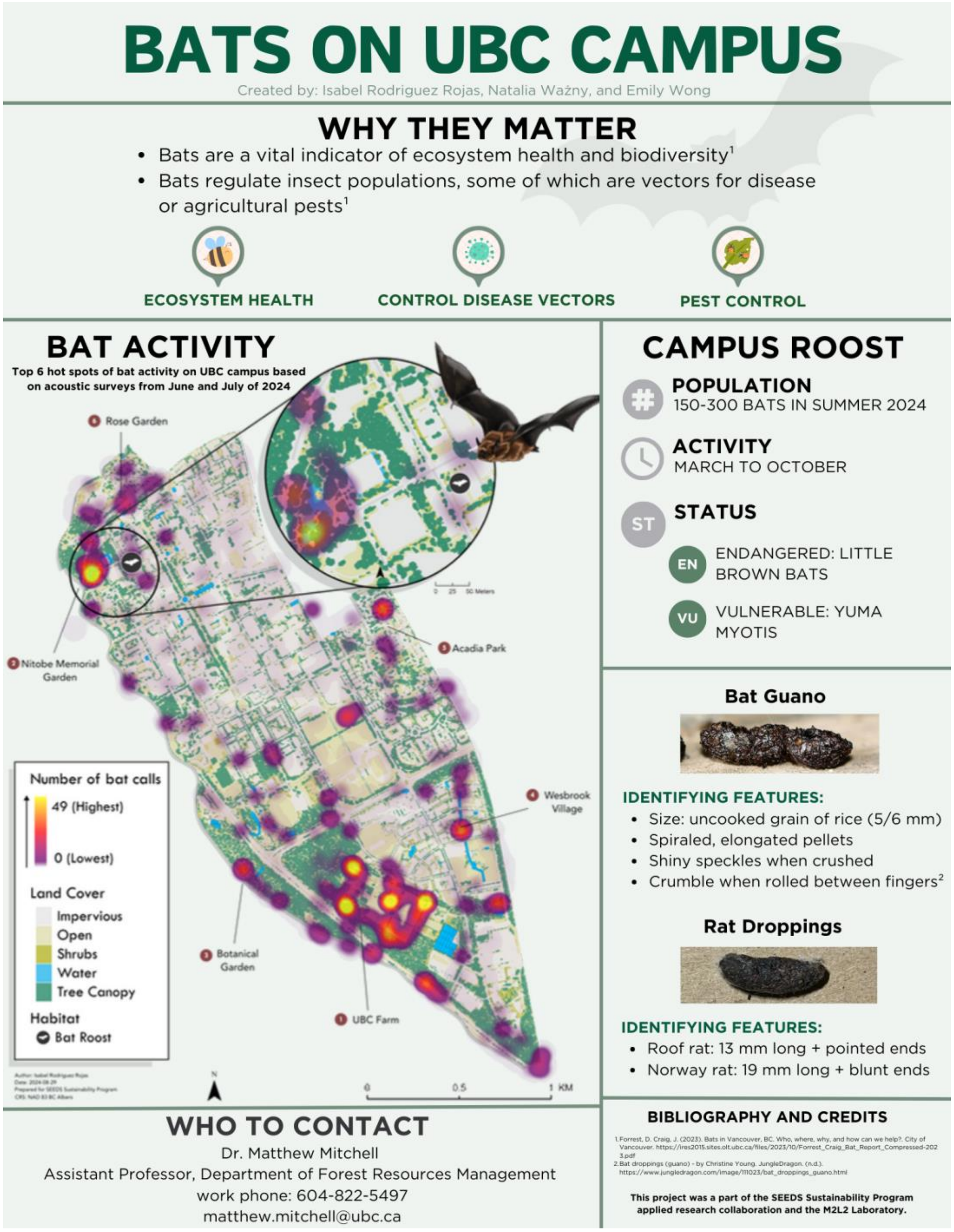


Figure 7. Infographic for custodial services

Table 9. Known bat species in Vancouver. Data from Craig (2022).

Common Name	**Scientific Name**	**Echolocation Frequency**
Big Brown bat	Eptesicus fuscus	Low
California myotis	Myotis californicus	High
Dark-Nosed Small-Footed myotis	Myotis melanorhinus	High
Hoary bat	Lasiurus cinereus	Low
Little Brown bat	Myotis lucifugus	High
Long-Eared myotis	Myotis evotis	Low
Long-Legged myotis	Myotis volans	High
Mexican Free-Tailed bat	Tadarida brasiliensis	Low
Silver Haired bat	Lasionycteris noctivagans	Low
Yuma myotis	Myotis yumanensis	High