AN EXAMINATION OF WINTER BAT AND FLYING SQUIRREL ACTIVITY, STANLEY PARK, BRITISH COLUMBIA, 2018/2019

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ABSTRACT

Stanley Park is home to several species of bats and may be home to two species of flying squirrel. The goals of this project were to determine which areas of Stanley Park are occupied and/or receive use by bats, record activity of wintering bats using acoustic recording devices, confirm the presence of the flying squirrels in the park using remote cameras, and provide location recommendations for the installation of bat boxes. Flying squirrels, a nocturnal *sciurid*, have not been recorded in the park since 2008.

200 meter transects were established at four previously identified areas of high feeding activity for bats. Each site was monitored once per month for the duration of the study by walking these transects with an acoustic recorder. Ideal locations for the installation and construction of bat boxes within the park were identified and recommended. Considerations for the placement of these bat boxes included reducing predation, adequate temperature range, as well distance to-and-from feeding areas and access to these areas for bats. During the study, bats were found to be active on two separate occasions during the winter season.

Flying squirrels were detected using a combination of camera traps and bait stations. Remote wildlife cameras were set up opposite a platform baited with peanut butter and sunflower seeds on two adjacent trees. Trees were selected based on assumed favourability for flying squirrels. Flying squirrels prefer hemlock and cedar trees with significant heart rot. A total of seven rotating bait stations were set up during the duration of the study. Flying squirrels were confirmed to be using the park at two separate locations based on images and video footage retrieved from the camera traps. It could not be confirmed which of the two species of flying squirrel was using the camera traps and bait stations, as up until 2017 only one species (the Northern Flying Squirrel) was known to be in the area. However, recent research has shown that a second species looking almost identical (The Humboldt's Flying Squirrel) also inhabits nearby areas. DNA sampling research has yet to be done to see if only one or both species inhabit the area.

KEY WORDS

Echo meter; wildlife camera; camera trapping; bat box; spectrogram; pulse; echolocation; bait station;

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1.0 INTRODUCTION

1.1 BATS IN STANLEY PARK

Bats (Order *Chiroptera*) represent the second largest order of mammals, ranging from 900 - 1100 species worldwide (Nagorsen and Brigham 1993). Very diverse, and spreading across Canada, some bats reach their northern limits in British Columbia (Nagorsen et al. 1993). Of the 19 species that inhabit Canada, 16 live in BC, and 10 of which reside in the lower mainland (BC Conservation Data Centre 2018). Two BC dwelling bats, Townsend's Big-eared Bat (*Corynorhinus townsendii*) and Keen's Myotis (*Myotis keenii*) are designated as red and blue-listed under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Ministry of Environment Lands and Parks 2010, Rutherford and Sinclair 2010).

Many bats live in close company with humans, one being the Little Brown Myotis (*Myotis lucifugus*), which relies heavily on human infrastructure for roosting and raising of their pups (ACBP 2018). Despite their proximity to humans, there is very little research done on bat species in the lower mainland, with only six species confirmed to be in Stanley Park (Rutherford and Sinclair 2010). Species documented within Stanley Park include *M. lucifigus*, Yuma Bat (*Myotis yumanensis*), Big Brown Bat (*Eptesicus fuscus*), Hoary Bat (*Lasiurus cinereus*), Silver-haired Bat (*Lasionycteris noctivagans*), and California Myotis (*Myotis californicus*) (SPES 2010). Records indicate that *C. townsendii* are present in the lower Fraser Valley (Ministry of Environment Land's and Parks 2010); however, the species has not been recorded in Stanley Park in recent years.

Throughout the year, bats typically occupy three types of enclosures: day roosts, night roosts, and hibernation dens (ACBP 2018). Bats spend most of their time in day roosts, coming out up to 30 minutes before sunset to feed (Saremba pers. comm.). In between periods of feeding, bats will rest in night roosts (e.g. crevices and loose bark) to digest their food before a second outing (ACBP 2018). Roosting sites can be characterized as one of the most important sites in the environment for bats. Roosts include caves, cavities, and loose bark in wildlife trees which provide cover and protection from predators during resting periods (SPES 2010; Evelyn et al. 2003).

Both structure and habitat are important for not only roosting locations, but also for setting up bat boxes to add extra roosting sites (SPES 2010). These structures are "man-made and designed to provide bats with a warm, dry, and safe roost site" (KCBP 2013). A previous study suggests that bats prefer mature and old growth stands, as they provide corridors and foraging areas (Humes et al. 1999). Preferred stands typically consist of *T. plicata*, a prime material for climbing and insulation in colder months (Saremba pers. comm.).

During most winters, bats survive by either migrating or hibernating, also known as torpor (ACBP 2018). In the coastal Pacific Northwest, evidence shows that species occasionally stir from torpor to be active for a short period, with records for seven out of the 16 species in BC (Nagorsen et al. 1993) displaying this behaviour. Studies in the Kootenays have found that these winter-active species are not restricted to, but include *E. fuscus*, *L. noctivagans*, *M. yumanensis* and *M. californicus* (KCBP 2013). *L. lucifugus* however, one of the more common species found in Stanley Park (SPES 2010), seem to be inactive in the winter months (November – March) (Duifhuis and Yaniw 2013). Winter strategies of many bats in the Pacific Northwest are still poorly understood (Barbour and Davis 1969), but a suggested reason for winter arousal may be to feed, drink, change location, or to mate (Boyles et al. 2006).

1.2 FLYING SQUIRRELS IN STANLEY PARK

Another nocturnal species thought to inhabit Stanley Park are flying squirrels. Prior to 2017, all species of flying squirrel in Western Canada were thought to be the Northern Flying Squirrel (*G. sabrinus*) (Arbogast et al. 2017). However, recent literature shows that there is a cryptic species known as the Humboldt's Flying Squirrel (*G. oregonensis*) resembling *G. sabrinus,* but does not hybridize with them, and also inhabits the Pacific Northwest (Figure 1) (Arbogast et al. 2017). *G. oregonensis* is only known to be along the coastal areas of the Pacific Northwest. There is also a thought that coastal flying squirrels are *G. oregonensis*, but there is no evidence yet to make this claim. (Ransome pers. comm.). They do occur sympatrically in the Pacific Northwest, but the only way to tell the difference between *G. oregonensis* and *G. sabrinus* is to sequence their mitochondrial DNA. (Arbogast et al. 2017) Therefore for the purpose of this study we will refer to squirrels as *Glaucomys ssp. (G. ssp.*) since the species cannot be accurately identified in the absence of DNA analysis.

G. ssp. are nocturnal, non-hibernating species which "inhabit boreal, coniferous, and mixed stands in the United States and Canada." Such areas consist of cool and moist winters, a well-developed canopy, and promote an abundance of cavities and snags (Weigl 2007). These characteristics show a positive association with the density of flying squirrels (Holloway and Smith 2011; Carrey 1995).

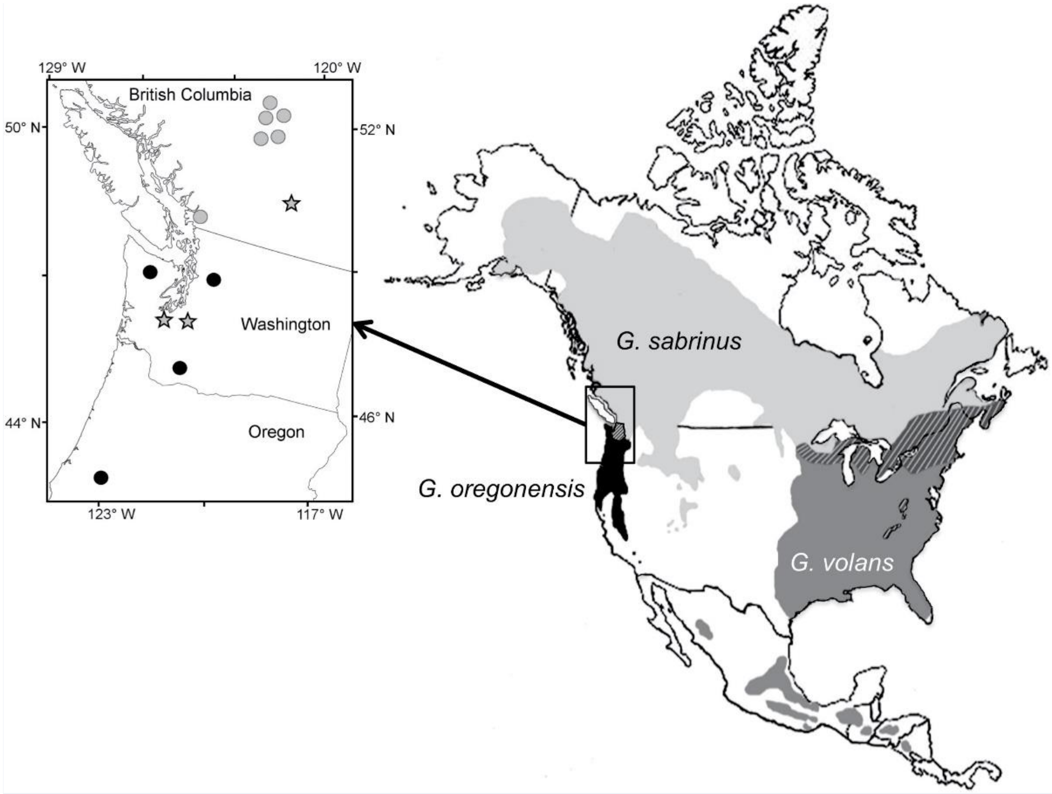

Figure 1. Range of *G. sabrinus* vs. *G oregonensis*, black circles represent *G. oregonensis*, light gray represent *G. sabrinus*, and stars represent where the species occur in sympatry (Arbogast et al. 2017).

Previous studies done on *G. sabrinus* in other fragmented landscapes have shown that their dens in old growth stands consist of live and dead trees, with visible conks or boles, or snags, where decay is substantial (Carey 1995, Pyare 2010). Another study shows *G. sabrinus* populations were not significantly different between second-growth and old-growth stands, suggesting that their presence was not cavity-dependent (Ransome 1994).

In Stanley Park, these squirrels are found in high volume stands of the park, where they nest in cavities (SPES 2010). Squirrels that did inhabit live and dead trees denned mainly in *T. heterophylla*, with *T. plicata* being the second-most frequently used. Denning sites of western hemlock (*Tsuga heterophylla)* were typically characterised by large diameters, high tree densities, and heart rot infection (Pyare 2010). Sites where squirrels were found also contained a slightly higher percent cover of water, less barren/rock coverage, and less herbaceous coverage (Mahan et al. 2010).

Considered to be common in uninterrupted populations, the most recent sighting of *G. ssp.* within Stanley Park was in 2008. It was found exiting a large old-growth cedar near the

Seven Sisters site (SPES 2010). Such an elusive species poses an issue to the Stanley Park Ecology Society (SPES) as lack of information prevents the development of an effective conservation strategy (Weigl 2007).

1.3 PURPOSE AND OBJECTIVES OF THE STUDIES

The significance of the bat study is to provide data for SPES on the wintering activity of bats within Stanley Park. Data can be used for the creation of educational programming, used for engaging the public in the conservation of bats. In addition, data gathered contributes to knowledge of bat winter activity. As previously stated, some bat species are active during the winter months, so by monitoring these species in Stanley Park, we contribute data to a relatively unknown subject.

The significance of a squirrel study is to aid SPES in creating management plans and educational content. By confirming the presence of *G. ssp.* within Stanley Park, SPES can strengthen their management plans by accounting for these species. Confirming the presence of *G. ssp.* can also lead to the creation of educational programming and materials.

The goals of the Stanley Park bat and flying squirrel project are:

Table 1. Goals and objectives of 'An Examination of Winter Bat and Flying Squirrel Activity. Stanley Park, British Columbia, 2018/2019.

Goals	Objectives
Monitor wintering bat activity in Stanley Park and document species present	• Use echo-meters to conduct presence/not detected surveys to determine the wintering bat activity • Use Wildlife Acoustic Software to analyze bat species by call
Conduct a presence/not detected survey for *G. ssp.*	• Conduct presence/not detected survey of *G. ssp.* within Stanley Park using camera traps and bait stations
Provide a list of suitable locations for the creation of alternative bat roosting habitat	• Find suitable trees and areas for bat box installations based on known suitable habitat attributes and/or via previous/current study findings.
Recommend interpretative signage locations for *G. ssp.*, and bats.	• Mark suitable areas near trails for the installation of interpretive signage using Garmin GPS units.

2.0 STUDY SITE

2.1 STANLEY PARK

This study is being conducted in Stanley Park, a municipal park located between the Lions Gate Bridge and downtown Vancouver (Figure 2). Originally home to Burrard, Musqueam, and Squamish First Nations, Stanley Park is now a 400-hectare public park (City of Vancouver 2018). This park is primarily comprised of second and third-growth forests, consisting of western hemlock *T. heterophylla*, *T. plicata*, Douglas- fir (*Pseudotsuga menziesii*), and Sitka spruce (*Picea sitchensis*) (Green & Klinka 1994).

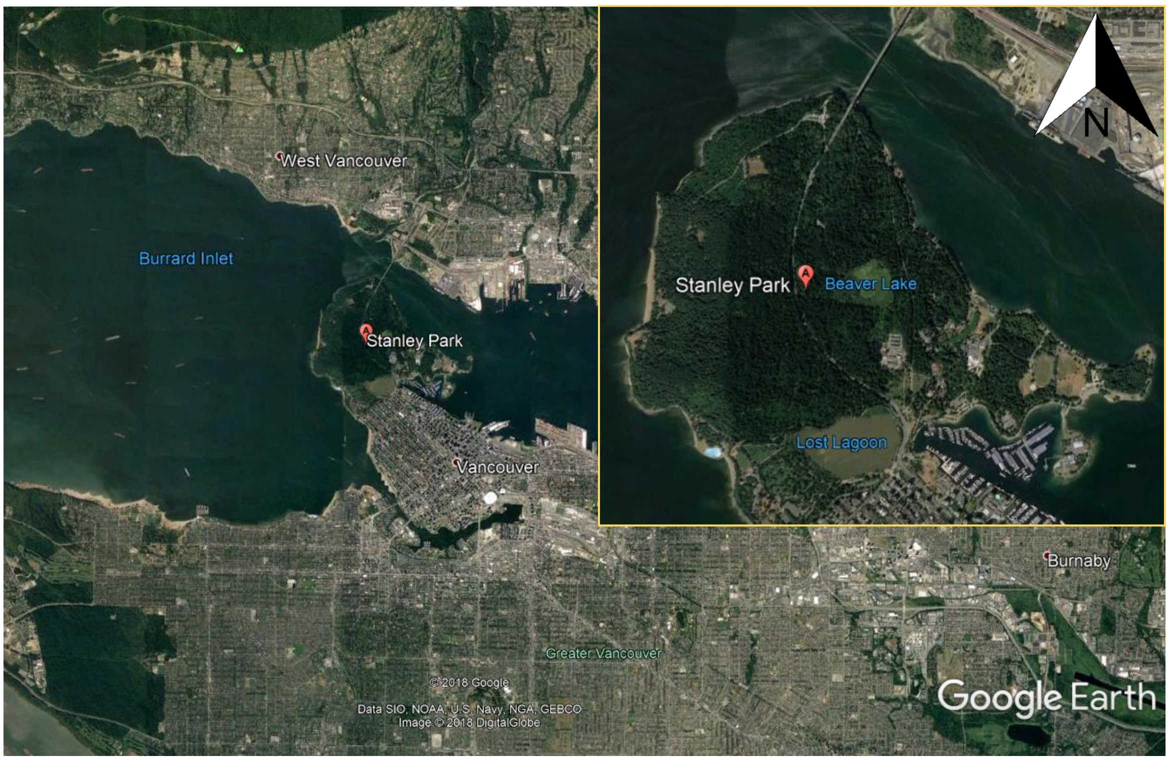

Figure 2. Stanley Park study site located next to Vancouver, British Columbia. (Source: Google Earth).

Stanley Park consists of a mix of dense forests, riparian areas, and the built environment. The Park is in the Coastal Western Hemlock dry maritime subzone (CWHdm) (ImapsBC 2018). Defining characteristics of the CWHdm are "dry summers and moist, mild winters with little snowfall" (Green and Klinka 1994). Dominant vegetation includes species such as *P. menziesii*, *T. plicata*, and *T. heterophylla* (Green and Klinka 1994). Forest stand age ranges across various seral stages with approximately 79% being conifer forest (SPES 2010). Older forest stands were affected by a windstorm in 2006 which knocked down many trees, opening room for newer seral stages to progress (SPES 2010).

2.2 HISTORICAL USES OF STANLEY PARK

Historically, Stanley Park was used by the local First Nations, who would modify the forest environment (SPES 2010). First Nations would use the bark from trees, as well as employ the use of fire to modify the environment; however, the forest remained mostly intact until the arrival of European settlers in the 1800's (SPES 2010). Logging began in the 1850's through to the 1880's, permanently changing the landscape (SPES 2010). Logging has not occurred in the park since that time, but various forms of pathogen and insect control took place during the early 1900's resulting in the removal of trees within selected areas of the park (SPES 2010).

2.2 CURRENT USES OF STANLEY PARK

2.2.1 Modern Stanley Park

Today, Stanley Park attracts approximately 8 million visitors annually (City of Vancouver 2019). The park provides entertainment including several playgrounds, the Vancouver Aquarium, the Stanley Park Train, restaurants, a pub, and the seawall. Sports such as tennis, golf, bowling, and rowing are regularly played within the park. In addition, there is much to see as there is a wide variety of wildlife that reside in the park, many monuments, First Nations art, and totem poles.

2.2.2 The Stanley Park Ecology Society

Managed by the Vancouver Park Board (VPB), in 1988 the park joined in agreement with the Stanley Park Ecology Society (Duifhuis and Yaniw 2013). This organization is a leader in stewardship at Stanley Park that promotes awareness, education, and conservation to the park users. In this study, British Columbia Institute of Technology (BCIT) students have entered a sponsorship with SPES to study the bats and flying squirrels that inhabit Stanley Park. This is intended to promote awareness and education on how these species inhabit local habitats(i.e.,parks) and to provide insight into their ecology.

3.0 METHODS

3.1 BAT ACOUSTIC SURVEY

3.1.1 Acoustic Surveys

Acoustic surveys began on October 24, 2018 and continued until March 27, 2019. These surveys were based on the Resource Inventories Standards Committee (RISC) for Inventory Methods for Bats and modified for winter surveys (Ministry of Environment 1998). A trial acoustic survey took place on September 23, 2018, but the data collected was not deemed standardized and therefore not included.

Four points were selected for surveying, based on sites that SPES had previously identified as having a high abundance of bat feeding activity (Figure 3). Feeding areas were chosen over roosting areas as there was a higher chance of detecting feeding bats (via emitted pulses) as the bats would be searching for prey, rather than remaining relatively silent in their roosts. These areas were characterized as points on the park trails facing an open body of water, including the marine environment, potentially supporting insect populations.

Selected study locations were labelled as Hot Spots (HS). HS1 (UTM 10U, 489953 E, 5461365 N) is located at Beaver Lake in Stanley Park (Figure 4). HS2 (UTM 10U, 489791 E, 5460492N) and HS3 (UTM 10U, 489374 E, 5460343N) are both located along the shore of Lost Lagoon. During previous studies, Lost Lagoon and Beaver Lake were the only two study sites monitored during winter (Duifhus and Yaniw 2013). Finally, site HS4 (UTM 10U 488456 E, 5460940 N), near Third Beach, was added to account for bats that might be using the interface between the marine and terrestrial environment. Studies were conducted on Wednesdays of each week, or the next possible day as required to address sporadic scheduling conflicts.

Figure 3. Previously recorded areas of bat call abundance of feeding bats in Stanley Park, BC, provided by Dr. Cori Lausen from South Coast Bat Conservation Society for SPES (Google Earth, March 28, 2019).

Figure 4. Bat acoustic survey sites HS1, HS2, HS3 HS4 located within Stanley Park, British Columbia (Source: Google Earth Oct 24, 2019).

Each transect was surveyed once per month, alternating weekly. Surveying began 30 minutes prior to sunset and extended an hour past sunset for a total time of one hour and 30 minutes. Beginning 30 minutes before sunset ensured surveyors would catch any bats that might emerge early to feed. Bats are known to forage for 30 to 45 minutes at a time (Saremba pers. Comm.). To account for this feeding, surveys ended one hour after sunset.

During these surveys, surveyors walked a 200 m line transect, pacing 100m from the hot spot midpoint in each direction along the nearest trail (Figure 5).

The weather was also assessed at the beginning and end of each survey; this included weather condition, temperature (°C), wind speed (km/hr), and relative humidity (%). Acoustics and weather were then transcribed for further processing and analysis. The average temperature from the beginning and end of the survey was calculated.

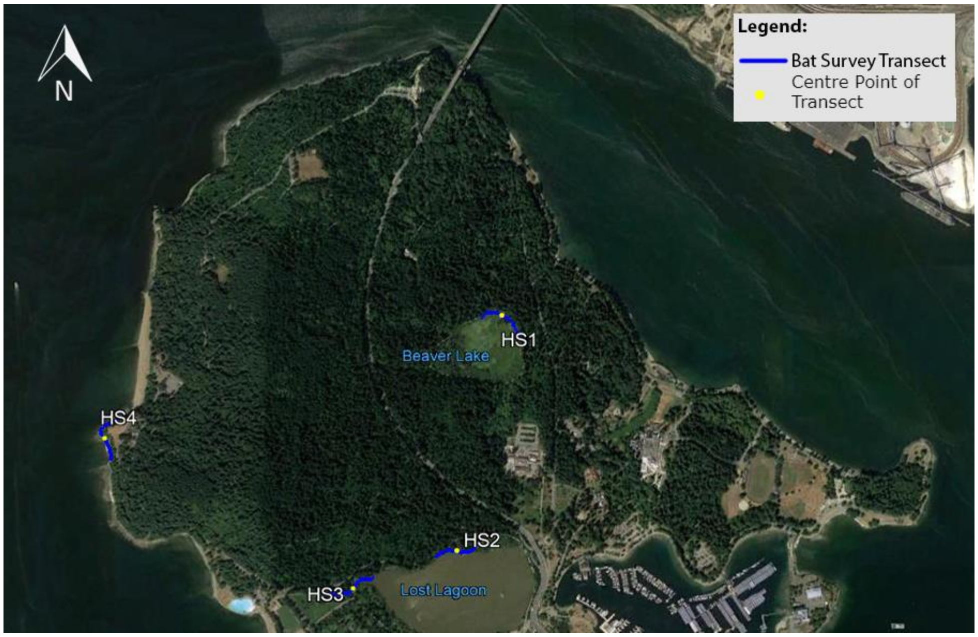

Figure 5: Transects for bat acoustic monitoring. Lines represent the path walked. The dot represents the centre point. (Google Earth April 15, 2019)

3.1.2 Technology

An Echo Meter Touch 2 Pro handheld bat detector and associated computer applications by Wildlife Acoustics were used for acoustic monitoring. This device allows the user to record the supersonic bat echolocation sound at multiple frequencies and play it back to the user at subsonic levels (Wildlife Acoustics 2018). The echo meter also analyzes the frequencies of the calls and identifies the potential species. The meter is only compatible with an Apple device with a lightning port and was used on either an iPhone 8+ or an iPad 9.7 in conjunction with the Wildlife Acoustics App during acoustic surveys.

Temperature, wind speed, and relative humidity were recorded using a Kestrel 3000. At the beginning and end of the surveys, the Kestrel would be placed hanging for 10 minutes to ensure an accurate recording of the ambient temperature, wind speed, and relative humidity.

Further acoustic survey processing was done using the Kaleidoscope Pro 5 Analysis Software by Wildlife Acoustics. This software system allows the user to better visualize any recordings, analyze any sounds that may have been picked up, and contains a more complex system for identifying bats (Wildlife Acoustics 2018). Imputing data into the Auto ID software would generate a species identification for bat calls.

3.2 FLYING SQUIRREL PRESENCE SURVEY

Presence detected/not detected surveys for *G. spp.* began on January 9, 2019 and continued to April 3, 2019 using bait stations and camera traps. Prior to setting up bait stations, GIS data from a forest composition atlas (provided by SPES) was analyzed and used for the placement of potential bait stations around the park. Using this GIS data, bait stations were placed in these forest composition sites in a random stratified fashion; this placement of these bait stations gave a better representation of the park. A total of seven stations were established (Figure 6).

Within the representative forest composition types, the site-specific bait station setups were based on previous studies' habitat preferences of *G. ssp.* According to previous studies on *G. sabrinus,* it was found that areas with more overstory trees, high volume, mixed coniferous forests, either old growth or second growth stands, and large *T. heterophylla* with extensive heart rot were sites of preference (Mahan et al 2010; Weigl 2007; Ransome 1994; Pyrare 2010). Bait stations in this study were placed in Wet Conifer type, the Alder zone, the Mixed Maple/Conifer type, and the Dry Conifer (Appendix III) (SPES 2009). No cameras were placed in the 'Dry, exposed ridge' forest type as the steep slopes would breach safety practices.

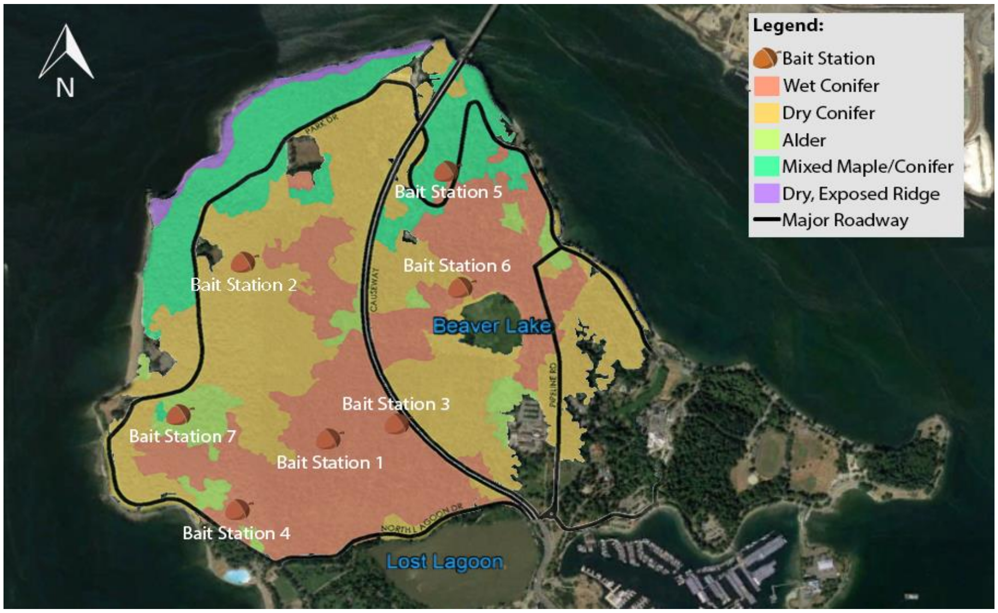

Figure 6: Location of all squirrel bait stations established within Stanley Park overlaid with the Forest Composition types, Vancouver, BC (Google Earth April 29, 2019)

Once suitable habitat preferences were found, camera traps and bait stations were set up on two adjacent trees that could hold both the squirrel bait station platform and the wildlife camera, both of which were placed adjacent to each other, often near *T. plicat*a or *T. heterophylla* with signs of heart rot. The bait platform was strapped onto the trees using two ratchet straps, while the camera was strapped onto the trees using the straps provided with the camera unit. Cameras used for this study were the Stealth Cam STC – P12SCTC. Cameras were set to record both photo and video, alternating between weeks (Appendix III).

These stations were set at least 1.0 - 1.5 m above the ground, up to 2.0 m when able to do so safely, and cached with bait composed of sunflower seeds and peanut butter, as done in previous studies on *G. ssp* (Karmacharya et al. 2013; Mark and Anthony 1989) (Figure 7). Bait stations were checked weekly for tampering, vandalism, theft, SD card exchange, and stocked with bait prior to commencing weekly bat surveys.

Due to high recreational use in Stanley Park, camera traps and bait stations were hidden as much as possible to prevent any tampering or theft. This affected the setup of camera traps and bait stations as much of the park consisted of an extensive network of trails, causing camera placements to be in hidden areas. Bait Stations 1 and 2 were trial runs and were set up for one month. After the trials a third camera was obtained, and all subsequent stations were rotated through the park on a bi-weekly basis. (Appendix III).

Figure 7. Bait station set up example with bait platform and camera trap in Stanley Park, Vancouver, British Columbia.

3.3 BAT BOX SURVEY

Bats tend to prefer some distance between their roosting and foraging sites (Brittingham and Williams 2019; Saremba pers. comm.). To account for this, a 500 m buffer was established from known feeding sites using Google Earth. A polygon showing preferable areas for bat box installation based on distance from feeding sights was established (Figure 8). The existing park trails within this polygon were walked, searching for *T. plicata* with south facing aspects exposed to sunlight. Bats require bat boxes installed in southeast to southwestern aspects with greater than seven hours of direct sunlight (Brittingham and Williams 2000; Flaquer et al. 2014). A variety of aspects offer high daily temperatures and wide temperature gradients, giving the bats many options and providing a greater chance of survival (Brittingham and Williams 2019).

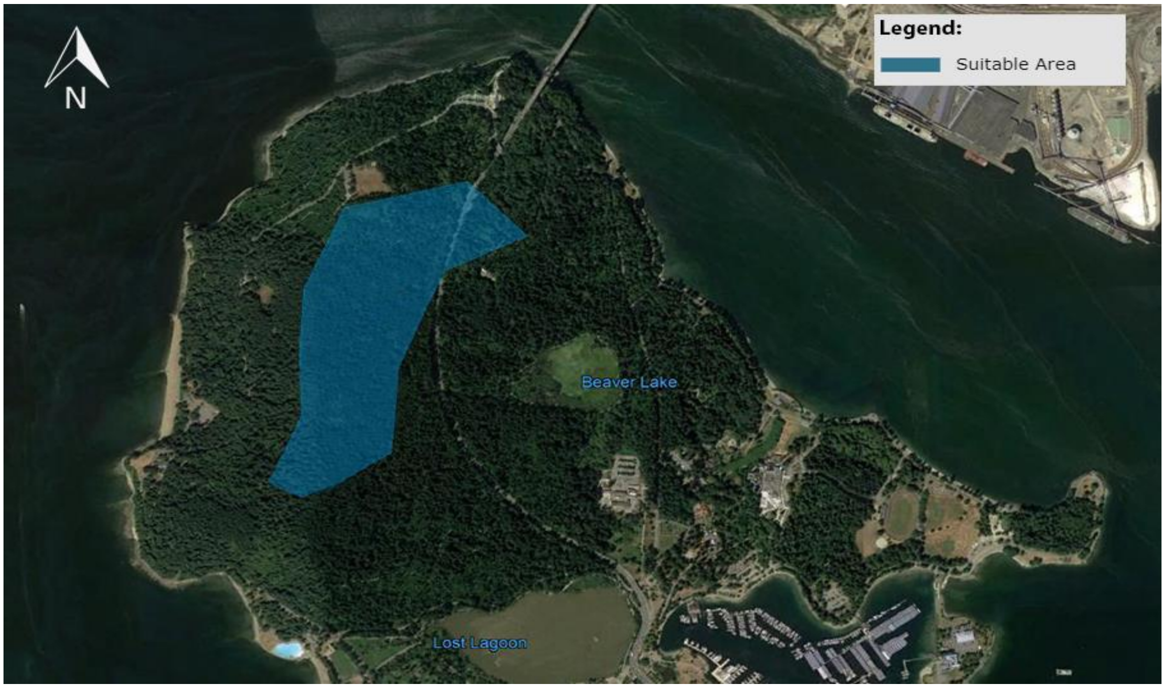

Figure 8. Polygon of suitable areas for potential bat box installation within Stanley Park, Vancouver, British Columbia, April 2019.

4.0 RESULTS

4.1 BAT ACOUSTIC SURVEY

Acoustic surveying began on October 3, 2018. All data collected on October 3 was lost due to the recording device running out of power due to cold weather. No research was conducted on October 10 and October 17 as team members were unable to attend. Continuous monitoring began on October 24, 2018.

From October 24, 2018 to March 20, 2019, a total of 248 bat acoustic calls were recorded. However, after inspection of the recordings and their related spectrograms, only 128 of these calls can be reliably identified as a bat. The other 120 were most likely ambient noise being picked up and identified by the software as having the same frequency of the listed bat calls. Of the 128 bat calls recorded, seven of the possible 14 bat species were identified by the auto ID software (Table 1) (Appendix I).

The species with the highest number of calls recorded was *L. noctivagans*, 99 recorded calls, followed by *M. californicus*, 4 recorded calls (Table 2). *L. noctivagans* was recorded as being present on December 14, 2018 during the winter months, and *M. californicus* was recorded on February 20, 2019 (Appendix II). The location with the most bat activity detected during the winter months was HS2, the shore of Lost Lagoon, with 20 recordings.

Bat call detections followed a trend of high numbers in mid-fall that quickly dropped to zero or near-zero until mid-March (Figure 9). Most surveys had zero detections that were actual bats. The least used site was HS4 with no detections made during the study. An average temperature of 10.6 ^{0}C was recorded on December 14, 2018, which was the highest temperature recorded for bat activity during the winter months. An average temperature of 6.0 ^{0}C was recorded on February 20, 2019.

Table 2. Number of recorded bat calls per species from the echo meter between Oct 24th and March 20th in Stanley Park, Vancouver, BC.

Species	Scientific Name	Detections
Silver-haired Bat	*Lasionycteris noctivagans*	99
California Myotis	*Myotis californicus*	4
Hoary Bat	*Aeorestes cinereus*	3
Big Brown Bat	*Eptesicus fuscus*	2
Yuma Myotis	*Myotis yumanensis*	2
Little Brown Myotis	*Myotis lucifugus*	1
Long-legged Myotis	*Myotis volans*	1
Unidentified		16
Total		128

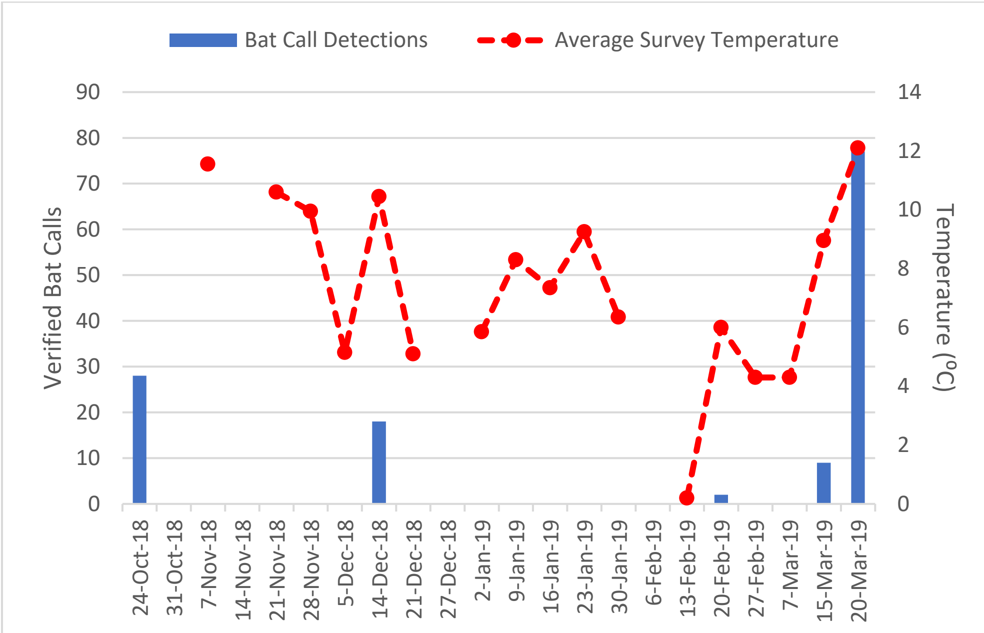

Figure 9. Number of bat calls recorded and average ambient temperature per acoustic bat survey for all surveys and survey sites in Stanley Park, Vancouver, BC.

4.2 FLYING SQUIRREL PRESENCE SURVEY

Throughout the survey, 12 successful recordings of *G. ssp.* were documented in Stanley Park (Figure 10). The first recording was captured on February 20, 2019, followed by the last sighting on March 10, 2019 (Appendix III). All sightings of *G. ssp.* were recorded at Bait Station 3 and Bait Station 4, both of which were located in the Wet Conifer site of Stanley Park and were relatively close to the major causeways in the park. The other stations may not have been visited by *G. ssp.*, but were visited by other inhabitants of the park including the Eastern Grey Squirrel *(Sciurus carolinus),* Racoons (*Procyon lotor*), and an unidentified mouse species.

Figure 10. Flying squirrel detected on February 20, 2019 at Bait Station 3, Stanley Park, Vancouver, BC.

The camera component of the camera traps from Bait Stations 1 and 4 were unfortunately stolen sometime between January 9 and January 23, 2019, and February 27, 2019 and March 20, 2019 respectively. The theft of these cameras prevented any further potential *G. ssp.* detections from being collected at Bait Stations 1 and 4.

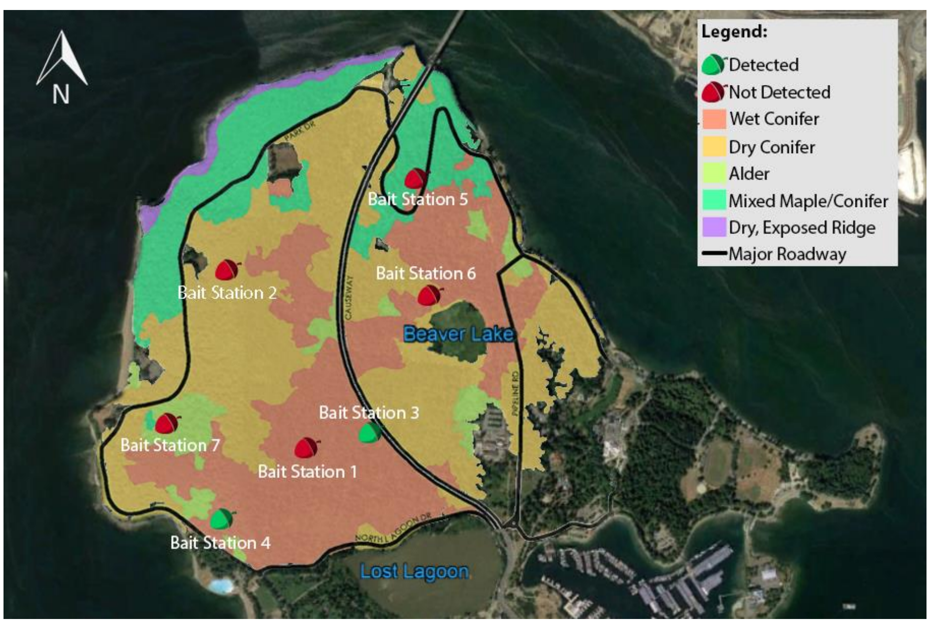

Figure 11. Location of bait stations that detected and did not detect *G.ssp* activity within Stanley Park overlaid with the Forest Composition types, Vancouver, BC (Google Earth April 29, 2019)

5.0 DISCUSSION

5.1 BAT ACOUSTIC SURVEY

5.1.1. Bat activity in winter conditions

The previous BCIT study of bats in Stanley Park reduced their winter monitoring to one visit a month. This year's study did regular weekly surveys visiting each of the four survey sites in succession. The benefit of this was the increased likelihood of recording winter bat activity. The phone-attachable Echo Meter Touch 2 Pro and easily traversable survey locations made weekly sessions feasible.

As expected from previous studies, bat activity significantly dropped in the second half of November (Rutherford and Sinclair 2010). From a previous recorded number of recorded bat calls, 24, on October 24, 2018, to zero calls being recorded per session. This change is indicative of bat activity decreasing through the fall and winter periods; as temperatures decrease, bats will either survive by migrating or hibernating to escape the winter (ACBP 2018). This cooler weather and unfavourable conditions also yield lower insect populations, providing too much of a bioenergetic cost to be active in these conditions (Rutherford and Sinclair 2010).

However, on December 14, 2018, 18 calls were recorded, with two bats being visually counted. This recording diverged from Rutherford and Sinclair's study of fall-winter acoustic monitoring, but it was not an unexpected outcome (Rutherford and Sinclair 2010). Re-emergence in midwinter is characteristic Pacific Northwestern bats, which occasionally wake from torpor in warmer winter temperatures to stretch, drink, or feed (Nagorsen et al. 1993). Temperatures recorded on December 14, 2018 were an average of 10.4 °C. Another day of confirmed bat activity, February 20, 2019, also had relatively low temperatures, far lower than what was expected for bats to be active. Other days with higher temperatures (10 - 12 °C) yielded different results as no bats were recorded again until March 15, 2019.

In previous studies, emergence and return of bats were observed in February (Rutherford and Sinclair 2010); this year the bats returned on March 15, 2019. Temperatures recorded for the increase in bat numbers were averaged at 8.95 °C during the study, and a high of 12 °C for the day. However, without enough data, correlations between temperature, prey density, and activity during the winter could not be assessed, but instead is recommended for future studies.

5.1.3. Bat Species in the Park

Bats normally documented within Stanley Park include, *L. lucifigus*, *M. yumanensis*, *E. fuscus, L. cinereus, L. noctivagans*, and *M. californicus* (SPES 2010). Despite being present, some species, like *M. lucifugus*, are known to hibernate during the winter months, while others migrate outside of the park (Duifhuis and Yaniw 2013). During winter acoustic surveys, *M. californicus* and *L. noctivagans* were detected. These results were expected as these species were known to display winter activity in other regions of British Columbia (e.g. Kootenay) (KCBP 2013).

The presence of *L. cinereus* was also detected on November 7, 2018. The presence of this species was unexpected as *L. cinereus* is strictly a migratory species that moves south during the winter periods to either stay active or to hibernate (KCBP 2013; Nagorsen and Brigham 1993). Close inspection of the spectrogram revealed the detection of *L. cinereus* to be a false positive. Every *L. cinereus* detected after October 24, 2018 was confirmed to be a false positive through visual inspection of the spectrograms.

Another infrequent species, The Long-legged Myotis (*Myotis Volans*), had also been identified by the software on October 24th, 2018. However, the software did provide *M. lucifugus* as an alternative match, leaving the match inconclusive.

Auto ID makes it hard to give an exact species identification for bats, due to its limitations. Anytime a sound with a frequency would be picked up by the software it would potentially identify it as a bat. Thus, it was important for the auto ID data to be verified by visually looking at the spectrograms. In visually confirming the spectrograms, it was possible to identify whether bats were present as bat calls look like distinct lines in comparison to random noise when portrayed on a spectrogram (Figure 12). However, identification to actual species was still difficult without formal training, as certain bat species calls are similar in appearance. This means that certain bat species may have been misidentified, leading to potential under representation or over representation of the detected species.

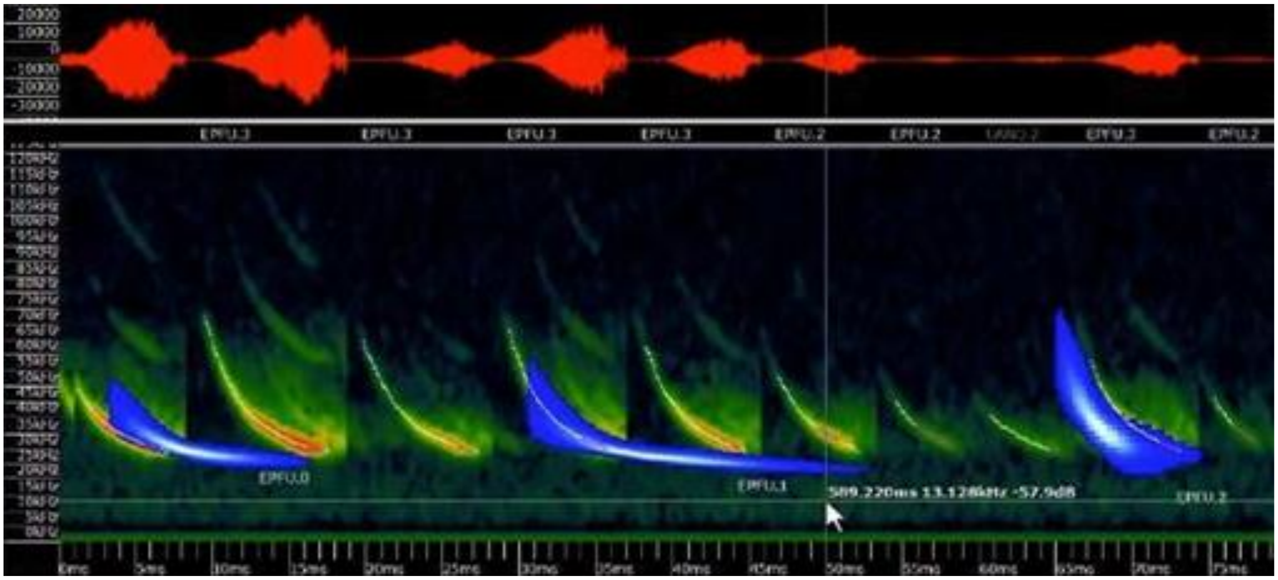

Figure 12: *E. fuscus* calls represented as distinct lines or curves on a spectrogram display in Kaleidoscope Pro 5 (Kaleidoscope 2019)

5.2 FLYING SQUIRREL PRESENCE SURVEY

As an interest to SPES, presence/not-detected surveys were conducted to determine if *G. ssp.* were present in the park. These surveys were conducted by setting up seven separate bait stations and attempting to catch their presence with camera traps. Throughout the survey, 12 recordings of *G. ssp.* were captured on camera. Other wildlife that visited the bait stations included *S. carolinensis*, *P. lotor*, and an unidentified mouse species.

Comparing the results from the seven bait stations (besides Bait Station 1), the Wet conifer sites forest type gained the only visitations from *G. ssp.* in the study, at Bait Station 3 and Bait Station 4. At these stations, it was noted that the forest structure in the area was different from other bait stations. These sites were noted to be typically composed of high-volume densities of *T. heterophylla* and *T. plicata* with varying decrease of decay (e.g. fungi, many broken branches, and signs of foraging) and less herbaceous cover as the sites were well-traversed and used. These parameters are characteristic of potential denning habitats for flying squirrels (Mahan et al. 2010, Pyare 2010). Unfortunately, due to the time constraints and the objectives of the survey, quantifiable habitat/vegetation assessments were unable to be conducted, preventing any definitive habitat associations from being made. However, it is highly recommended for future studies related to this species that quantitative vegetation data be collected so that it may be compared and contrasted with the bait station and camera trap locations. These comparisons/contrasts will give a stronger inference into *G. ssp.*'s habitat preferences and associations.

Bait Station 1 was placed in the Wet Conifer zone as well. Unfortunately, between January 9, 2019 and January 23, 2019, the camera was stolen, preventing any further detections from being made for the Wet Conifer forest type. Bait Stations 3 and 4 were also noted to be close to the major causeways in Stanley Park. This was surprising as it was assumed that *G. ssp.*, a prey species affected by fragmentation, would be found further inside the park rather than proximate to edge habitat. By being further inside the park, *G. ssp*. wouldn't be subjected to weather, predation, and human disturbance (e.g. roads and foot traffic). However, it has been shown that even in fragmented habitats such as Stanley Park, the distances from edges does seem to factor into flying squirrel's preference for microhabitat. It has even been demonstrated that flying squirrels have denned in edge habitat when other options are available (Pyare 2010).

The other Bait Stations, 2, 5, 6, and 7 were placed in the Alder, Dry conifer and Mixed Maple/Conifer forest types (Figure 11). These sites differ from the Wet Conifer sites as they had differing forest stand composition (aside from the Dry Conifer sites) with trees spaced farther apart from each other with less structural diversity in-between.

Initially better representative sites were intended to be used, but due to Stanley Park's extensive trail network, it was difficult to locate a secure place to conduct the presence/not-detected survey. Ultimately, the decisions for placement came down to security so that data could be collected without constant interference (e.g. camera theft). A more in-depth approach at examining habitat associations and genetic identification of the flying squirrels would be a recommended step for future studies of the species within Stanley Park.

5.3 LIMITATIONS

During this study, four sites were chosen for acoustic monitoring surveys of bats. One site was visited per week (accumulating to each site being surveyed once per month), which was monitored before and after the sunset. Despite this time being the most active time for bats, it still only represents a small portion of a total day period that could've been monitored. There was also a likelihood of missing possible encounters if bats were to rise from torpor on any other day of the week or were visiting a different feeding site than the one being surveyed. Therefore, by being able to only conduct research on the same day of the week (e.g. Wednesdays), surveys were subjected to highly variable weather conditions, and thus not giving a representative view of winter bat activity. Field deployable acoustic recorders throughout the park, able to passively record bats 24 hrs per day, would do much to alleviate this issue.

Another limitation was the identification of individual bat species. The identification of species relied on the Wildlife Acoustics' software Echo Meter and Kaleidoscope. Echo Meter suggests the bat species and Kaleidoscope later either confirms or denies the suggestion. After Kaleidoscope processes the data, it reports a match ratio, which displays the percentage of the bat call that matches their reference. The match ratio ranges from 0.0 to 1.0, indicating 100%. Many ratios were not 100%, calling into question the validity of the identification process. The auto-identification process itself may not be reliable, even with a 100% match.

This error can be attributed to passing bikes and jiggling keys as they would trigger a species identification in the Echo Meter iOS app. It is reasonable that a bat could have called nearby, and it could be observer bias linking bikes and false identifications. However, later visual observation of the spectrogram patterns recorded from the Echo Meter proved these types of identifications were not representative of bat calls. One example was the *M. volans* that was recorded was not on SPES' list of regularly observed species, thus demonstrating that the identification program is not a completely reliable method of discerning different species of bat calls.

Flying squirrel bait stations and camera trap setup also provided the study with its own sets of limitations. Stanley Park is a very popular park, covered with an extensive trail network. With many trails and lots of foot traffic, finding a proper location for the bait stations was difficult as there were many security risks to the project (e.g. theft, tampering with the equipment). Instead of trying to find areas with an optimal potential habitat (i.e. using LiDAR data), researchers located areas obscured by the foliage, making the camera's less visible from nearby trails.

Once a suitable area was located, the setup further relied on finding two trees that were relatively close together to attach the bait station and camera trap an appropriate distance away from each other. Finding two suitable trees limited the areas that could be established as a station and the areas were further limited as there was a high potential of camera theft. Two of the cameras were stolen during the duration of the study.

Safety was also a large limitation. Because bat surveys were conducted from sunset to an hour after sunset, personal safety at night was an issue within an urban city park. Without this constraint, surveyors would have been able to survey transects as individuals rather than in groups, and thus being able to survey multiple sites simultaneously. This could therefore increase the amount of possible survey sites substantially around the park.

6.0 RECOMMENDATIONS

6.1 BAT BOXES

6.1.1 Bat Box Locations

As bats prefer to roost a distance from their feeding grounds, a recommended distance of 500 m from bat box locations and any feeding site will benefit the bats (Saremba pers. comm.) (Figure 13). Adult female bats are known to fly directly to their foraging sites after emergence at dusk (Rainho and Palmeirim 2011); therefore, a direct route from roosting site to foraging site could be the ideal choice.

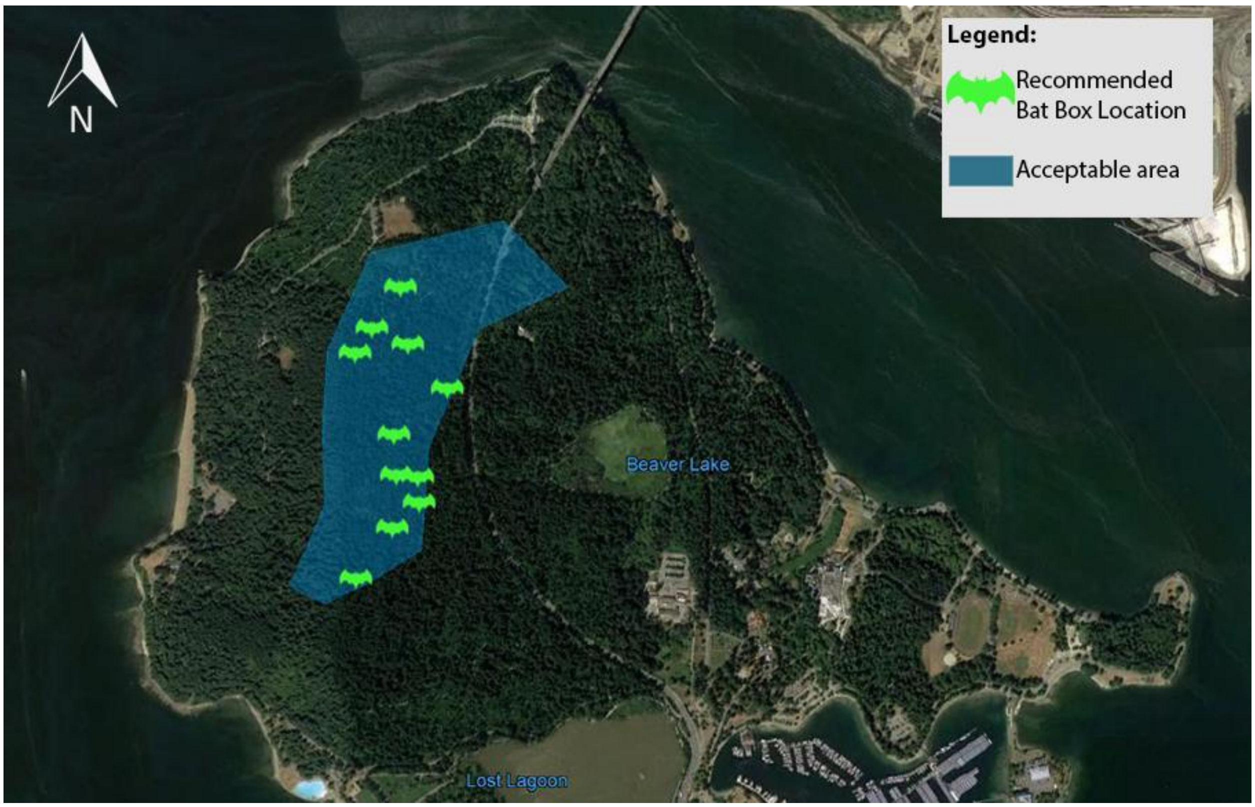

Figure 13. Recommended bat box/bat condo location, with recommended distance from feedings sites, in Stanley Park, British Columbia. (Google Maps 2019).

It is important to consider that this bat box survey was done in the spring. Spring is an undesirable time of year as the sun will be in a different position during the summer when maternity colonies will be using the boxes. It is recommended that the survey be done again, during the summer with similar methods, to determine the optimal location for bat boxes.

6.1.2 Bat Box Construction

Building bat boxes would be preferable to commercial options as those products lack many of the benefits and features outlined below. Bats prefer *T. plicata* to other trees as a roosting material (Saremba pers. comm.); therefore, it is the best material to build bat boxes with. Boxes should be placed at least 10 feet above the ground to give the bats space to safely take flight (Saremba pers. comm.). Sealing the roof and sides of the box is important to keep the inside dry and temperature regulated (Figure 14).

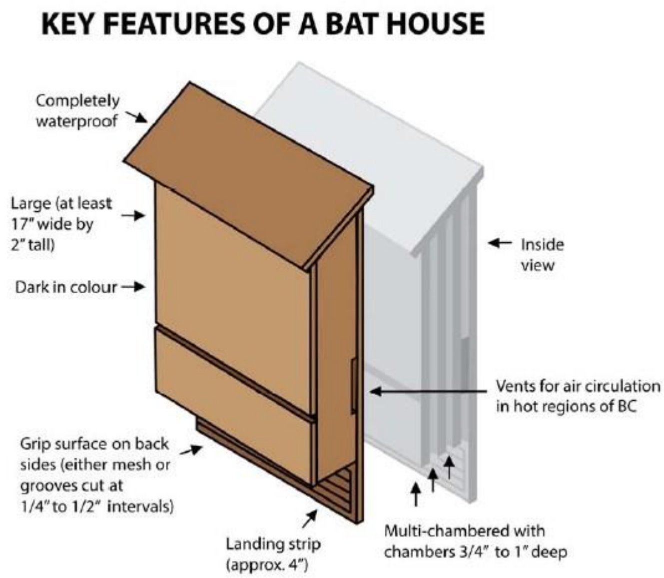

Figure 14. A diagram for a bat box. (Building Homes for Bats: A Guide for Bat Houses in British Columbia 2016)

Multiple, layered one-inch chambers that are at least 24” tall allow for more bats to roost, move to chambers with preferred temperatures, and exercise for juveniles by moving from chamber to chamber (Craig and Keller 2017; Saremba pers. comm.). The width should be at least 17” as some studies have suggested bats prefer wide boxes which allow for more bats and better temperature regulation (Craig and Keller 2017; Brittingham and Williams 2000). Bats avoid over-heating by roost switching, therefore installing extra boxes at different aspects will provide the bats with further options for temperature regulation (Flaquer et al. 2014).

Below the chambers, a grooved landing strip of at least four inches is important to allow space for the bats to land and crawl up into the box (Craig and Keller 2017). The grooves should extend up into the entire inside of the chambers to allow the bats to take hold with their feet and roost (Craig and Keller 2017). A mesh is not recommended to be used, as bats have been known to get their claws stuck leading to mortality (Saremba pers. comm.).

Painting the boxes black can retain too much heat leading to bats abandoning the box or perishing from heat stroke (Saremba pers. comm.). The risk of overheating and perishing increases above 40 ^{0}C, or roost abandonment as *E. fuscus* are known to leave bat boxes when temperatures exceed 35 ^{0}C (Flaquer et al.2014; Brittingham and Williams 2000).

6.2 FLYING SQUIRREL SURVEY

During this study, habitat associations and genetic identification between *G. oregonensis* and *G. sabrinus* were not focused on due to the scope of the project. Further studies in habitat associations for flying squirrels is recommended to provide a better image on their locations inside the park. Genetic studies are also recommended as the both ranges of *G. oregonensis* and *G. sabrinus* overlap in the southern portion of British Columbia and knowing which species is present will help with further management of *G. ssp.* in the park. Hair traps could be added to the bait stations that were set up in the park, to snag squirrel hair for DNA analysis.

Reliance on using natural structures to physically set up the bait stations proved difficult because it limited the trees, we could use to trees that were close in proximity, even if there was a more suitable tree nearby. Future studies should consider using a post that can be placed into the ground; the camera can then be attached to the post, allowing researchers to pick a more representative tree for *G. ssp.* habitat.

Future recommendations for security include securing the trail cameras by installing further protection and implement a maintenance system with the workers at SPES. Further protection could include installing a locking mechanism to prevent the public from easily stealing the trail camera. To increase the protection from data loss (via theft), purchasing camera traps with the ability to upload wirelessly would also be beneficial.

A maintenance system with SPES can also be useful for protection; as surveyors were only able frequent the area once a week, there is a lot of time in between where damage or theft can occur. But by communicating with SPES, regular check ins could be negotiated where SPES workers check the bait station locations once a day, increasing the security around the station.

6.3 BAT ACOUSTIC SURVEY

6.3.1. Additional Equipment and Crew

In order to collect as much data as possible, it is recommended that future surveyors use field-deployable acoustic recorders at areas of high bat activity such as the Lost Lagoon. This will ensure that researchers will obtain more representative data on the winter activity of bats in Stanley Park. It is not advised to rely solely on these field acoustic readers, as they are an additional tool to gather data when researchers are not present.

A fourth member to the future studies is highly recommended as well. Most of the surveys and setup in the study can be done with two people, and since safety requires crews of at least two people, it squanders the use of the third-party member. By having a fourth member, multiple surveys and bait station visits can be done simultaneously in one day, vastly improving the efficiency and range of the study within the park.

6.3.2. Time and Day

To keep a consistent study, times and the days when surveys began were standardized. However, because of this standardization, a large portion of data regarding the winter activity of bats was potentially lost. Future recommendations for this project suggest going on the warmest days (8 - 12 °C) of the week, where bat activity has shown to be its highest, rather than the same weekday consistantly.

Time is also a factor that one should consider when designing a winter study for bats. It has been shown that bats are typically most active 30 minutes before sunset and one hour after sunset. This time is allocated for feeding, breeding, stretching, and drinking, but there is little information regarding if the same can be said during the winter months. Possibly these shifts in weather conditions may affect the time of activity during the day,

6.3.3. Weather and Other Variables

Due to the lack of data, a correlation between the temperature, humidity, and weather conditions to the amount of winter activity of bats cannot be made via this study. But it is still recommended that these variables are considered and incorporated while planning another survey. Being able to correlate short-term emergence from torpor to weather conditions can allow wildlife managers predict and plan for the return of bats to mitigate them into new nest boxes or out of infrastructure.

Insect density is another variable that should be considered when planning future surveys or forms of research. Prey density was not touched upon in this study but is recommended as it was assumed that a large majority of winter bat activity was to forage.

6.3.4. Bat Acoustics

Dedicating time to learning how to identify bat calls or contracting out bat call identification could be beneficial. This way the validity of the auto ID software can be either confirmed or denied.

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8.0 APPENDICES

APPENDIX I – BAT SPECIES AND CODES

Below is a table listing several species of bats in BC, their scientific names, and their species code according to Wildlife Acoustics Echo Meter App.

Scientific Name	Common Name	Species Code
Antrozous pallidus	Pallid Bat	ANTPAL
Corynorhinus townsendii	Townsend's Big-eared Bat	CORTOW
Eptesicus fuscus	Big Brown Bat	EPTFUS
Euderma maculatum	Spotted Bat	EUDMAC
Lasionycteris noctivagans	Silver-haired Bat	LASNOC
Lasiurus cinereus	Hoary Bat	LASCIN
Myotis californicus	California Myotis	MYOCAL
Myotis ciliolabrum	Western Small-footed Myotis	MYOCIL
Myotis evotis	Long-eared Myotis	MYOEVO
Myotis lucifugus	Little Brown Myotis	MYOLUC
Myotis septentrionalis	Nothern Myotis	MYOSEP
Myotis thysanodes	Fringed Myotis	MYOTHY
Myotis volans	Long-legged Myotis	MYOVOL
Myotis yumanensis	Yuma Myotis	MYOYUM

APPENDIX II – BAT IDENTIFICATION RAW RESULTS

Data table showing bat species identification generated by Wildlife Acoustic's Kaleidoscope Software. Data includes date recorded, species ID generated, number of pulses of bat call recorded, number of bat call pulses matching ID, the ratio of matching pulses to pulses recorded and location recording took place.

Date	Auto ID	Pulses	Matching	Match Ratio	Alternate	Bat	Location
2018-10-24	LASCIN	4	4	1	N/A	No	HS3
2018-10-24	LASCIN	3	3	1	N/A	No	HS3
2018-10-24	LASCIN	2	2	1	N/A	No	HS3
2018-10-24	LASCIN	2	2	1	N/A	No	HS3
2018-10-24	LASCIN	2	1	0.5	N/A	No	HS3
2018-10-24	LASCIN	3	1	0.333	N/A	No	HS3
2018-10-24	LASNOC	67	57	0.851	EPTFUS	Yes	HS3
2018-10-24	LASNOC	70	54	0.771	EPTFUS	Yes	HS3
2018-10-24	LASNOC	48	45	0.938	EPTFUS	Yes	HS3
2018-10-24	LASNOC	52	45	0.865	EPTFUS	Yes	HS3
2018-10-24	LASNOC	39	39	1	EPTFUS	Yes	HS3
2018-10-24	LASNOC	55	34	0.618	EPTFUS	Yes	HS3
2018-10-24	LASNOC	36	32	0.889	EPTFUS	Yes	HS3
2018-10-24	LASNOC	35	31	0.886	LASCIN	Yes	HS3
2018-10-24	LASNOC	29	29	1	EPTFUS	Yes	HS3
2018-10-24	LASNOC	29	28	0.966	LASCIN	Yes	HS3
2018-10-24	LASNOC	28	27	0.964	EPTFUS	Yes	HS3
2018-10-24	LASNOC	25	24	0.96	EPTFUS	Yes	HS3
2018-10-24	LASNOC	23	23	1	LASCIN	Yes	HS3
2018-10-24	LASNOC	21	21	1	LASCIN	Yes	HS3
2018-10-24	LASNOC	21	21	1	LASCIN	Yes	HS3
2018-10-24	LASNOC	21	18	0.857	EPTFUS	Yes	HS3
2018-10-24	LASNOC	15	15	1	LASCIN	Yes	HS3
2018-10-24	LASNOC	16	15	0.938	LASCIN	Yes	HS3
2018-10-24	LASNOC	16	15	0.938	EPTFUS	Yes	HS3
2018-10-24	LASNOC	12	12	1	EPTFUS	Yes	HS3
2018-10-24	LASNOC	12	9	0.75	LASCIN	Yes	HS3
2018-10-24	LASNOC	8	8	1	EPTFUS	Yes	HS3
2018-10-24	LASNOC	7	7	1	LASCIN	Yes	HS3
2018-10-24	LASNOC	4	4	1	LASCIN	Yes	HS3
2018-10-24	MYOCAL	12	10	0.833	MYOYUM	Yes	HS3
2018-10-24	MYOCAL	11	6	0.545	MYOYUM	Yes	HS3
2018-10-24	MYOLUC	3	1	0.333	MYOCIL	Yes	HS3

Date	Auto ID	Pulses	Matching	Match Ratio	Alternate	Bat	Location
2018-10-24	MYOVOL	35	19	0.543	MYOLUC	Yes	HS3
2018-10-31	LASCIN	3	3	0.397766	N/A	No	HS1
2018-10-31	NoID	2	0	0	N/A	No	HS1
2018-11-07	LASCIN	32	21	0.262739	N/A	No	HS4
2018-11-07	LASCIN	5	3	0.254831	LASNOC	No	HS4
2018-11-07	LASCIN	5	2	0.32282	LASNOC	No	HS4
2018-11-07	MYOCAL	3	2	0.524307	N/A	No	HS4
2018-11-07	MYOYUM	9	6	0.320479	MYOCAL	No	HS4
2018-11-07	LASCIN	-3.6	-2.5	0.452522	N/A	No	HS4
2018-11-14	NoID	13	0	0	N/A	No	HS2
2018-11-14	NoID	20	0	0	N/A	No	HS2
2018-11-14	NoID	5	0	0	N/A	No	HS2
2018-11-21	NoID	3	0	0	N/A	No	HS3
2018-11-21	NoID	3	0	0	N/A	No	HS3
2018-11-28	NoID	2	0	0	N/A	No	HS1
2018-11-28	NoID	2	0	0	N/A	No	HS1
2018-11-28	NoID	2	0	0	N/A	No	HS1
2018-12-05	MYOLUC	8	6	0.75	MYOVOL	No	HS4
2018-12-05	MYOLUC	2	2	1	MYOVOL	No	HS4
2018-12-05	MYOYUM	3	2	0.667	N/A	No	HS4
2018-12-05	NoID	10	0	0	N/A	No	HS4
2018-12-05	NoID	3	0	0	N/A	No	HS4
2018-12-14	LASCIN	2	2	1	LASNOC	No	HS2
2018-12-14	LASNOC	65	44	0.677	EPTFUS	Yes	HS2
2018-12-14	LASNOC	48	32	0.667	EPTFUS	Yes	HS2
2018-12-14	LASNOC	63	32	0.508	EPTFUS	Yes	HS2
2018-12-14	LASNOC	56	28	0.5	EPTFUS	Yes	HS2
2018-12-14	LASNOC	25	24	0.96	EPTFUS	Yes	HS2
2018-12-14	LASNOC	48	23	0.479	EPTFUS	Yes	HS2
2018-12-14	LASNOC	25	22	0.88	EPTFUS	Yes	HS2
2018-12-14	LASNOC	19	19	1	EPTFUS	Yes	HS2
2018-12-14	LASNOC	18	18	1	EPTFUS	Yes	HS2
2018-12-14	LASNOC	23	17	0.739	EPTFUS	Yes	HS2
2018-12-14	LASNOC	19	16	0.842	EPTFUS	Yes	HS2
2018-12-14	LASNOC	35	14	0.4	EPTFUS	Yes	HS2
2018-12-14	LASNOC	31	13	0.419	EPTFUS	Yes	HS2
2018-12-14	LASNOC	11	10	0.909	EPTFUS	Yes	HS2
2018-12-14	LASNOC	8	8	1	EPTFUS	Yes	HS2
2018-12-14	LASNOC	9	6	0.667	EPTFUS	Yes	HS2
2018-12-14	MYOLUC	6	6	1	MYOVOL	No	HS2
2018-12-14	MYOLUC	2	1	0.5	N/A	No	HS2
2018-12-14	NoID	3	0	0	N/A	No	HS2
2018-12-14	NoID	10	0	0	N/A	Yes	HS2

Date	Auto ID	Pulses	Matching	Match Ratio	Alternate	Bat	Location
2018-12-14	NoID	62	0	0	N/A	Yes	HS2
2018-12-14	NoID	2	0	0	N/A	No	HS2
2018-12-21	NoID	2	0	0	N/A	No	HS2
2018-12-21	EPTFUS	10	7	0.7	N/A	No	HS3
2018-12-21	LASCIN	8	4	0.5	N/A	No	HS3
2018-12-21	LASCIN	3	2	0.667	EPTFUS	No	HS3
2018-12-21	LASCIN	3	2	0.667	N/A	No	HS3
2018-12-21	LASNOC	2	1	0.5	LASCIN	No	HS3
2018-12-21	NoID	2	0	0	N/A	No	HS3
2018-12-21	NoID	3	0	0	N/A	No	HS3
2018-12-21	NoID	2	0	0	N/A	No	HS3
2018-12-21	NoID	2	0	0	N/A	No	HS3
2018-12-21	NoID	2	0	0	N/A	No	HS3
2018-12-21	NoID	2	0	0	N/A	No	HS3
2018-12-21	NoID	8	0	0	N/A	No	HS3
2018-12-21	NoID	9	0	0	N/A	No	HS3
2018-12-21	NoID	5	0	0	N/A	No	HS3
2019-01-02	NoID	4	0	0	N/A	No	HS3
2019-01-02	EPTFUS	2	1	0.5	N/A	No	HS4
2019-01-02	LASNOC	21	13	0.619	LASCIN	No	HS4
2019-01-02	NoID	2	0	0	N/A	No	HS4
2019-01-02	NoID	2	0	0	N/A	No	HS4
2019-01-02	NoID	2	0	0	N/A	No	HS4
2019-01-02	NoID	2	0	0	N/A	No	HS4
2019-01-09	NoID	3	0	0	N/A	No	HS4
2019-01-09	LASNOC	2	2	1	EPTFUS	No	HS1
2019-01-09	MYOYUM	3	1	0.333	N/A	No	HS1
2019-01-16	NoID	2	0	0	N/A	No	HS1
2019-01-16	EPTFUS	2	1	0.5	N/A	No	HS2
2019-01-16	NoID	2	0	0	N/A	No	HS2
2019-01-16	NoID	4	0	0	N/A	No	HS2
2019-01-16	NoID	2	0	0	N/A	No	HS2
2019-01-16	NoID	9	0	0	N/A	No	HS2
2019-01-23	NoID	8	0	0	N/A	No	HS2
2019-01-23	MYOCAL	8	7	0.875	N/A	No	HS3
2019-01-30	NoID	2	0	0	N/A	No	HS3
2019-01-30	LASCIN	3	2	0.667	N/A	No	HS4
2019-01-30	NoID	2	0	0	N/A	No	HS4
2019-01-30	NoID	3	0	0	N/A	No	HS4
2019-01-30	NoID	2	0	0	N/A	No	HS4
2019-01-30	NoID	4	0	0	N/A	No	HS4
2019-01-30	NoID	4	0	0	N/A	No	HS4
2019-02-13	NoID	2	0	0	N/A	No	HS4

Date	Auto ID	Pulses	Matching	Match Ratio	Alternate	Bat	Location
2019-02-20	NoID	2	0	0	N/A	No	HS1
2019-02-20	MYOCAL	15	14	0.933	MYOYUM	Yes	HS2
2019-02-20	MYOCAL	20	13	0.65	MYOYUM	Yes	HS2
2019-02-20	NoID	2	0	0	LASNOC	No	HS2
2019-02-20	NoID	2	0	0	N/A	No	HS2
2019-02-27	NoID	4	0	0	MYOLUC	No	HS2
2019-02-27	LASCIN	4	2	0.5	N/A	No	HS3
2019-02-27	NoID	11	0	0	N/A	No	HS3
2019-02-27	NoID	6	0	0	N/A	No	HS3
2019-03-07	NoID	14	0	0	N/A	No	HS3
2019-03-07	LASCIN	10	10	1	N/A	No	HS4
2019-03-07	LASCIN	5	4	0.8	N/A	No	HS4
2019-03-07	LASCIN	3	3	1	N/A	No	HS4
2019-03-07	LASCIN	4	3	0.75	N/A	No	HS4
2019-03-07	LASCIN	2	2	1	N/A	No	HS4
2019-03-07	LASCIN	2	2	1	N/A	No	HS4
2019-03-07	LASCIN	2	2	1	N/A	No	HS4
2019-03-07	LASCIN	3	2	0.667	N/A	No	HS4
2019-03-07	LASCIN	2	1	0.5	LASNOC	No	HS4
2019-03-07	NoID	3	0	0	N/A	No	HS4
2019-03-07	NoID	2	0	0	N/A	No	HS4
2019-03-07	NoID	2	0	0	N/A	No	HS4
2019-03-07	NoID	2	0	0	N/A	No	HS4
2019-03-07	NoID	3	0	0	N/A	No	HS4
2019-03-07	NoID	2	0	0	N/A	No	HS4
2019-03-07	NoID	3	0	0	LASCIN	No	HS4
2019-03-07	NoID	2	0	0	N/A	No	HS4
2019-03-07	NoID	2	0	0	N/A	No	HS4
2019-03-07	NoID	3	0	0	N/A	No	HS4
2019-03-07	NoID	6	0	0	N/A	No	HS4
2019-03-07	NoID	4	0	0	LASCIN	No	HS4
2019-03-15	NoID	2	0	0	N/A	No	HS4
2019-03-15	EPTFUS	12	4	0.333	LASNOC	Yes	HS1
2019-03-15	LASNOC	557	491	0.882	EPTFUS	Yes	HS1
2019-03-15	LASNOC	540	445	0.824	EPTFUS	Yes	HS1
2019-03-15	LASNOC	634	438	0.691	EPTFUS	Yes	HS1
2019-03-15	LASNOC	432	306	0.708	EPTFUS	Yes	HS1
2019-03-15	LASNOC	256	222	0.867	EPTFUS	Yes	HS1
2019-03-15	LASNOC	53	46	0.868	EPTFUS	Yes	HS1
2019-03-15	LASNOC	38	25	0.658	EPTFUS	Yes	HS1
2019-03-20	LASNOC	25	22	0.88	EPTFUS	Yes	HS1
2019-03-20	EPTFUS	81	30	0.37	LASNOC	Yes	HS2
2019-03-20	LASCIN	34	18	0.529	LASNOC	Yes	HS2

Date	Auto ID	Pulses	Matching	Match Ratio	Alternate	Bat	Location
2019-03-20	LASCIN	29	14	0.483	LASNOC	Yes	HS2
2019-03-20	LASCIN	15	8	0.533	N/A	Yes	HS2
2019-03-20	LASCIN	2	1	0.5	N/A	No	HS2
2019-03-20	LASCIN	3	1	0.333	LASNOC	No	HS2
2019-03-20	LASNOC	96	83	0.865	EPTFUS	Yes	HS2
2019-03-20	LASNOC	66	64	0.97	EPTFUS	Yes	HS2
2019-03-20	LASNOC	75	58	0.773	EPTFUS	Yes	HS2
2019-03-20	LASNOC	68	57	0.838	EPTFUS	Yes	HS2
2019-03-20	LASNOC	56	56	1	EPTFUS	Yes	HS2
2019-03-20	LASNOC	61	54	0.885	EPTFUS	Yes	HS2
2019-03-20	LASNOC	64	53	0.828	EPTFUS	Yes	HS2
2019-03-20	LASNOC	57	47	0.825	EPTFUS	Yes	HS2
2019-03-20	LASNOC	49	44	0.898	EPTFUS	Yes	HS2
2019-03-20	LASNOC	53	44	0.83	EPTFUS	Yes	HS2
2019-03-20	LASNOC	45	43	0.956	EPTFUS	Yes	HS2
2019-03-20	LASNOC	48	43	0.896	EPTFUS	Yes	HS2
2019-03-20	LASNOC	50	43	0.86	LASCIN	Yes	HS2
2019-03-20	LASNOC	51	42	0.824	EPTFUS	Yes	HS2
2019-03-20	LASNOC	47	41	0.872	EPTFUS	Yes	HS2
2019-03-20	LASNOC	49	41	0.837	EPTFUS	Yes	HS2
2019-03-20	LASNOC	77	41	0.532	EPTFUS	Yes	HS2
2019-03-20	LASNOC	38	38	1	LASCIN	Yes	HS2
2019-03-20	LASNOC	39	37	0.949	LASCIN	Yes	HS2
2019-03-20	LASNOC	49	37	0.755	EPTFUS	Yes	HS2
2019-03-20	LASNOC	41	36	0.878	EPTFUS	Yes	HS2
2019-03-20	LASNOC	42	36	0.857	EPTFUS	Yes	HS2
2019-03-20	LASNOC	37	35	0.946	EPTFUS	Yes	HS2
2019-03-20	LASNOC	34	34	1	EPTFUS	Yes	HS2
2019-03-20	LASNOC	36	34	0.944	LASCIN	Yes	HS2
2019-03-20	LASNOC	33	32	0.97	LASCIN	Yes	HS2
2019-03-20	LASNOC	35	32	0.914	EPTFUS	Yes	HS2
2019-03-20	LASNOC	40	31	0.775	EPTFUS	Yes	HS2
2019-03-20	LASNOC	30	30	1	LASCIN	Yes	HS2
2019-03-20	LASNOC	34	30	0.882	EPTFUS	Yes	HS2
2019-03-20	LASNOC	43	30	0.698	LASCIN	Yes	HS2
2019-03-20	LASNOC	25	25	1	LASCIN	Yes	HS2
2019-03-20	LASNOC	35	25	0.714	EPTFUS	Yes	HS2
2019-03-20	LASNOC	25	23	0.92	EPTFUS	Yes	HS2
2019-03-20	LASNOC	22	22	1	EPTFUS	Yes	HS2
2019-03-20	LASNOC	21	21	1	LASCIN	Yes	HS2
2019-03-20	LASNOC	22	21	0.955	LASCIN	Yes	HS2
2019-03-20	LASNOC	28	21	0.75	LASCIN	Yes	HS2
2019-03-20	LASNOC	25	20	0.8	LASCIN	Yes	HS2

Date	Auto ID	Pulses	Matching	Match Ratio	Alternate	Bat	Location
2019-03-20	LASNOC	19	19	1	EPTFUS	Yes	HS2
2019-03-20	LASNOC	18	17	0.944	LASCIN	Yes	HS2
2019-03-20	LASNOC	17	16	0.941	EPTFUS	Yes	HS2
2019-03-20	LASNOC	18	16	0.889	EPTFUS	Yes	HS2
2019-03-20	LASNOC	19	16	0.842	LASCIN	Yes	HS2
2019-03-20	LASNOC	16	15	0.938	EPTFUS	Yes	HS2
2019-03-20	LASNOC	36	15	0.417	N/A	Yes	HS2
2019-03-20	LASNOC	15	14	0.933	EPTFUS	Yes	HS2
2019-03-20	LASNOC	15	14	0.933	LASCIN	Yes	HS2
2019-03-20	LASNOC	14	13	0.929	LASCIN	Yes	HS2
2019-03-20	LASNOC	11	11	1	LASCIN	Yes	HS2
2019-03-20	LASNOC	12	11	0.917	LASCIN	Yes	HS2
2019-03-20	LASNOC	15	11	0.733	EPTFUS	Yes	HS2
2019-03-20	LASNOC	16	11	0.688	LASCIN	Yes	HS2
2019-03-20	LASNOC	11	9	0.818	EPTFUS	Yes	HS2
2019-03-20	LASNOC	6	6	1	LASCIN	Yes	HS2
2019-03-20	LASNOC	5	5	1	LASCIN	No	HS2
2019-03-20	LASNOC	5	5	1	EPTFUS	Yes	HS2
2019-03-20	LASNOC	7	5	0.714	EPTFUS	Yes	HS2
2019-03-20	LASNOC	4	4	1	EPTFUS	No	HS2
2019-03-20	LASNOC	2	2	1	LASCIN	No	HS2
2019-03-20	MYOYUM	17	9	0.529	MYOCAL	Yes	HS2
2019-03-20	MYOYUM	10	8	0.8	MYOCAL	Yes	HS2
2019-03-20	NoID	3	0	0	N/A	No	HS2
2019-03-20	NoID	3	0	0	N/A	No	HS2
2019-03-20	NoID	2	0	0	N/A	No	HS2
2019-03-20	NoID	3	0	0	EPTFUS	No	HS2
2019-03-20	NoID	2	0	0	N/A	No	HS2
2019-03-20	NoID	3	0	0	LASNOC	No	HS2
2019-03-20	NoID	2	0	0	N/A	No	HS2
2019-03-20	NoID	5	0	0	N/A	Yes	HS2
2019-03-20	NoID	2	0	0	N/A	No	HS2
2019-03-20	NoID	4	0	0	N/A	No	HS2
2019-03-20	NoID	8	0	0	LASNOC	Yes	HS2
2019-03-20	NoID	6	0	0	LASNOC	Yes	HS2
2019-03-20	NoID	5	0	0	LASNOC	Yes	HS2
2019-03-20	NoID	5	0	0	N/A	Yes	HS2
2019-03-20	NoID	7	0	0	LASNOC	Yes	HS2
2019-03-20	NoID	3	0	0	LASNOC	Yes	HS2
2019-03-20	NoID	2	0	0	LASNOC	Yes	HS2
2019-03-20	NoID	33	0	0	LASNOC	Yes	HS2
2019-03-20	NoID	2	0	0	LASNOC	No	HS2
2019-03-20	NoID	3	0	0	N/A	No	HS2

Date	Auto ID	Pulses	Matching	Match Ratio	Alternate	Bat	Location
2019-03-20	NoID	3	0	0	EPTFUS	Yes	HS2
2019-03-20	NoID	2	0	0	LASNOC	No	HS2
2019-03-20	NoID	15	0	0	N/A	Yes	HS2
2019-03-20	NoID	12	0	0	N/A	Yes	HS2
2019-03-20	NoID	41	0	0	N/A	Yes	HS2
2019-03-20	NoID	4	0	0	LASNOC	Yes	HS2

APPENDIX III – CAMERA TRAPS

Camera Model: Stealth Cam STC- P12SCTC. Data Table shows the camera setting configuration, including the dates each camera was configured to each setting. Second table showing dates of detections of flying squirrels and which station they were detected at.

Bait Station	Setting	Mode	Resolutio n	Delay	Burst	Video Length	Detections	Dates
1	Custom	Photo	10MP	15 S	3	N/A	NO	Jan 9 - Jan 23*
2	Custom	Photo	10MP	15 S	3	N/A	NO	Jan 9 - Jan 23
2	Custom	Video	10MP	15 S	N/A	15 S	NO	Jan 16 - Feb 13
3	Custom	Photo	10MP	15 S	3	N/A	YES	Feb 20 – Feb 27
3	Custom	Video	10MP	15 S	N/A	5S	YES	Feb 27 – Mar 20
4	Custom	Video	10MP	15 S	N/A	5S	YES	Feb 27 – Mar 20*
5	Custom	Video	10MP	15 S	N/A	5S	NO	Feb 27 – Mar 20
6	Custom	Photo	10MP	15 S	3	N/A	NO	Mar 20 – Apr 3
7	Custom	Photo	10MP	15 S	3	N/A	NO	Mar 20 – Apr 3

*=camera was stolen, and data was lost.

Bait Station	Date of Detection
3	February 20, 2019
3	February 22, 2019
3	February 24, 2019
3	February 27, 2019
3	February 28, 2019
3	March 1, 2019
3	March 7, 2019
3	March 9, 2019
3	March 10, 2019
4	February 28, 2019
4	March 1, 2019

Bait Station	Forest composition type Bait Station was placed
1	Wet Conifer
2	Dry Conifer
3	Wet Conifer
4	Wet Conifer
5	Mixed Maple/ Conifer
6	Dry Conifer
7	Alder