Maternal Bat Roost Habitat Enhancement Project in Mystic Vale, Victoria, BC.

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ABSTRACT

Bats are globally considered a critical component of healthy and functional ecosystems. Currently, bats face numerous threats including loss of natural habitat the fungal disease White Nose Syndrome, climate change, and persecution or exclusion by humans. Bat boxes are often viewed as an option to mitigate for loss of natural roosts in rapidly changing urban environments. This project was focused on bat box construction and installation in accordance with the province's current best practices, to increase the availability of maternal roosting habitat in Mystic Vale. Previous participation in Denman Island's 2022 bat box surveys were the inspiration for this project. Key observations from the Denman bat box surveys would inform the local bat box site selection and construction process. The Mystic Vale site was selected in collaboration with the University of Victoria's RNS Program and another student's RNS project.

Bat box construction was undertaken personally, following plans obtained from the Community Bat Programs of BC and the Bat Builder's Handbook. Four bat boxes were completed in April 2023. Installation followed the provincial recommendation of a back-to-back bat box set-up on a single post, to create additional roosting space between and offer a wider range of internal microclimates. The first bat box post was installed April 25th, 2023, with one bat box oriented south and the other north. This process was repeated on May 8th, 2023, for the second bat box. Monitoring bat boxes for occupancy should commence for 5 years following installation, checking the ground underneath for guano accumulation and interior chambers for bat presence. Site maintenance should involve the removal of blackberry shrubs around the bat boxes, and the planting of native bat-friendly species. Inclusion of immediate surrounding areas should be considered for bat box installation, to create a network of bat boxes and increase connectivity. Future community engagement and education regarding bat ecology should be planned for the site if bats occupy the boxes.

Bat boxes may increase available roosts at a site, but do not ultimately address the mechanisms driving natural bat habitat loss. It's recommended that UVic and the District of Oak Bay take formal actions to conserve natural bat habitat by conserving wildlife trees and restoring wetlands or riparian zones. Further, a community engagement campaign is recommended to be adopted by the university to encourage future bat habitat restoration.

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1.0 - INTRODUCTION

1.1 – Bats in British Columbia

Bats (order Chiroptera) are globally considered a critical component of healthy and functioning ecosystems (Kasso & Balakrishnan, 2013; Ramirez-Francel et al, 2022). British Columbia is home to 15 bat species, and all are protected by the BC Wildlife Act. The northern myotis *(Myotis septentrionalis)* and little brown bat *(Myotis lucifufus)* have been federally listed as endangered under Schedule 1 of the Species at Risk Act (SARA) since 2014, in response to dramatic population declines (Environment Canada, 2018).

Bats contribute ecologically and economically in the form of insect pest control (Ducummon, 2000; Kunz et al, 2011). All BC's bat species are insectivorous and are major predators of forest, agricultural, and human pests. In the US it's estimated that insectivorous bats provide $3.7 billion annually in ecosystem services (Boyles et al, 2011), but is likely much higher. Additionally, guano depositions from tree-roosting bats are suggested to play an important role in soil fertility nutrient cycling between wetlands and forest ecosystems (Duchamp et al, 2010; Craig & Holroyd, 2007).

May 1st to September 1st is considered the active season for bats in British Columbia. Males and female bats of most species in BC live separate lives, apart from hibernation and reproduction (Rensel et al, 2022). Before winter hibernation, mating occurs, and the females store the sperm until the spring. Thorough delayed fertilization, the female is impregnated after hibernation – if insect levels are sufficient. Juvenile bats are born from June – July and are fully grown by August – September. Unlike other small mammals, most adult female bats give birth and raise only a single pup each summer. Due to their low reproductive rates and relatively long lifespan BC's bat populations are susceptible to rapid decline (Brigham, n.d.).

1.2 – Habitat Requirements

Foraging Habitat – Bats feed entirely on nocturnal species of insects with moths being one of the most significant (Olsen et al, 2018). For foraging grounds, bats rely on aquatic features like wetlands, ponds, rivers, and channels for drinking and feeding on the naturally high levels of insect activity

Roosting Habitat – Day roost can be defined as any place a bat uses for shelter or protection when it is inactive. A maternity colony roost is an aggregation of 20 of more female bats during the period when they are pregnant, have given birth, and are roosting with their offspring. (BC Community Bat Program, 2022). Males and non-reproductive females roost separately from the maternity colony in smaller groups of <5 or on their own in day roosts. Natural bat roosts take the form of large, old, wildlife trees with peeling

and/or sloughing bark are especially valuable. Cottonwood *(Populus trichocarpa*), aspen *(Populus tremuloides),* and many conifer species *(Pinophyta)* are important species when considering bat tree roosts. On the BC coast trees with a DBH >70cm represent the best quality roosting trees for bats (BC Ministry of Environment & Climate Change Strategy, 2018). In the absence of abundant natural roosts, bats are highly adaptable and have been known to occupy manmade buildings or structures – such as attics, mines, bridges, barns, and other types of outbuildings.

1.3 – Threats to Bats

The most significant threat that bats continue to face is loss of natural habitat. In BC this has occurred dominantly through forestry and rapid urban expansion (Voigt & Kingston, 2016). Urban landscapes typically contain insufficient habitat quality to support reproductive bat colonies.

The fungal disease White Nose Syndrome (WNS) has devastated hibernating bat colonies across eastern North America since February 2006. Since then, the disease has been transmitting west with mortality rates as high as 80-100% (BC Ministry of Environment et al, 2014). The disease was recorded in BC for the first time in April 2023 (Bartha et al, 2023). WNS is a significant threat to hibernating bats in BC, now that the disease has reached the west coast.

Bats are a mysterious and misunderstood species that often strike fear in humans. The rabies-scare campaigns of the 1970's and more recent disease allegations have contributed to a sense of unwelcomeness for bats in our living spaces (Tuttle, 2017). Exclusion is the removal of bats from a known roost, often an occupied home or building, for the comfort of the people living there (BC Community Bat Program, 2017). However, since bats are federally protected, efforts must be made to provide supplemental roosting space.

The most common artificial roost provision structure is the bat box. A bat box is a tall, rectangular structure typically made of wood, that mimics natural roosting habitat. Bat boxes can be valuable in conservation, if attention is paid to design, installation, monitoring, and maintenance. Typically bat boxes are recommended in cases of exclusion, to mitigate for loss of natural roosts, education/stewardship, and for pest control (BC Community Bat Program. 2019).

2.0 – PROJECT DESCRIPTION

This project began with a hands-on learning experience with the Denman Conservancy Association (DCA) which provided valuable insights to bat box installation and management. Inspired by the bat box program on Denman Island, it became a goal to apply key observations and construct bat boxes locally. The Mystic Vale site was suggested by UVic's RNS coordinator, in collaboration with another ER student's restoration project at the sumphouse site, focused on enhancing pollinator and small mammal habitat. Although bat presence has been acknowledged in Mystic Vale by previous ecological projects, (Hocking, 2000; Doucet, 2011) no specific actions have been taken to address their diverse habitat requirements. Therefore, this project took a fine-filter approach to ecological restoration to increase the availability of a specific habitat feature at the site while taking actions that aligned with the broader restoration goals of Mystic Vale.

2.1 – GOALS & OBJECTIVES

Project Goal: Mitigate for the loss of natural maternal bat roost habitat in an urban environment on Vancouver Island, by installing artificial roost in Mystic Vale.

Objectives: Apply key observations from Denman bat box surveys to Mystic Vale site
Objective: Assess Mystic Vale for suitable locations to install bat boxes
Objective**:** Construct four bat boxes, using best available plans
Objective: Install bat boxes using two back-to-back set-ups on wooden posts
Objective: Create monitoring plan and management recommendations

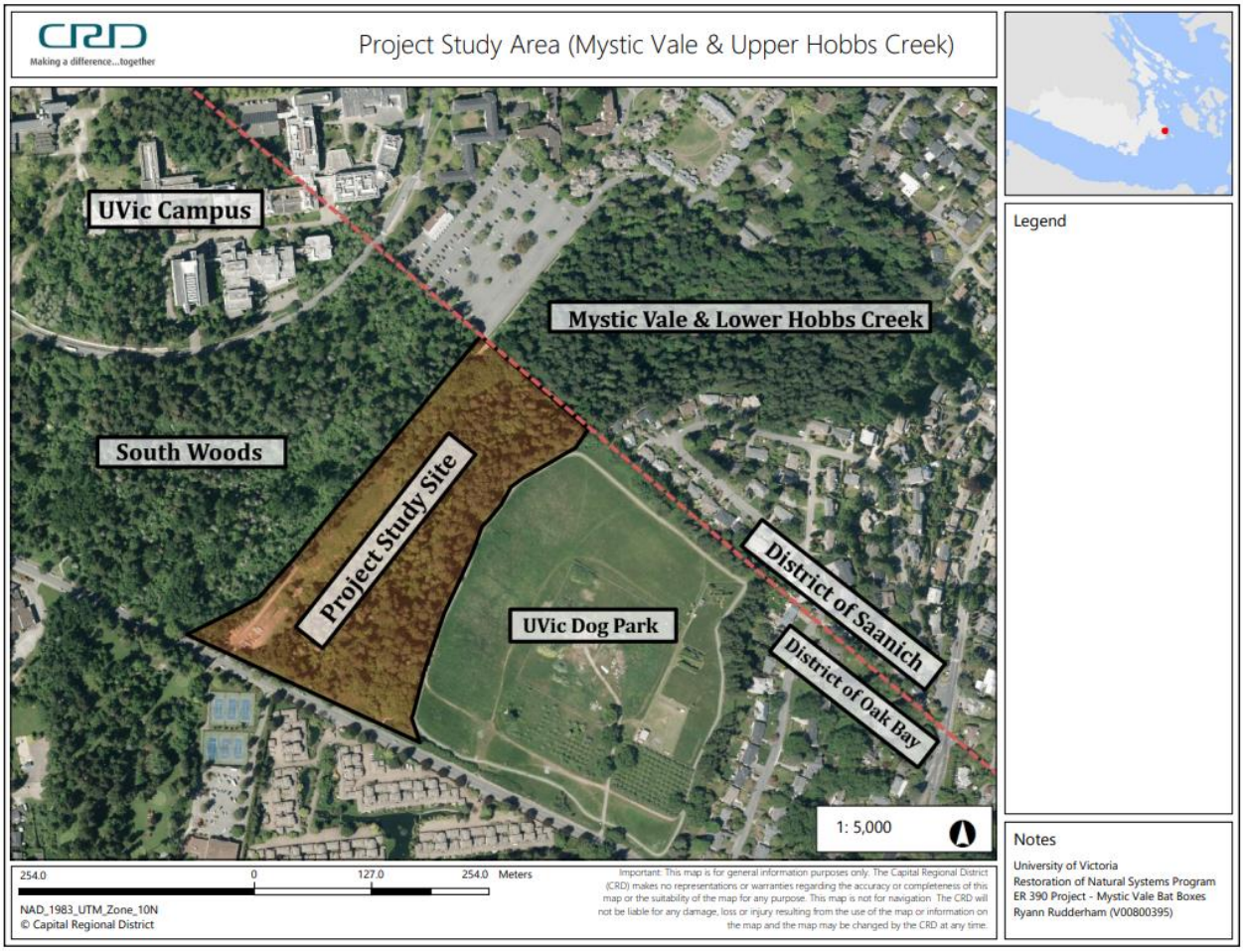
3.0 – SITE DESCRIPTION

This project was focused on the Upper Hobbs Creek watershed portion of Mystic Vale, located in the District of Oak Bay and accessible from Cedar Hill Cross Road (Figure 1).Mystic Vale is a 4.7-hectare riparian forest fragment located in the southeast portion of the University of Victoria Campus, on the boarder of the District of Oak Bay and Saanich.

Found in the CDFmm BEC zone, Mystic Vale is defined by a landscape that contains second growth forests, woodlands, and riparian ecosystems (Harrop-Archibald, 2007). The forests are dominated by Douglas-Fir *(Pseudotsuga menziesii)*, grand-fir *(Abies grandis*) and bigleaf maple *(Acer macrophyllum).* Oldest standing trees in Mystic Vale are estimated to be between 100-150 years old based on stand age and diameter data. Invasive species have an aggressive presence in Mystic Vale with English Ivy *(Hedra helix),* Himalayan Blackberry *(Rubus armeniacus),* and Poison Hemlock *(Conium maculatum)* being the most

prevalent (Doucet, 2012). Restoration activities have occurred at the site since the early 2000's to stabilize reduce soil compaction, increase bank stability, remove priority invasive species, and manage recreational trail use (Hebb & Schaefer, 2018; Shaefer, 2018).

Figure 1: Upper Hobbs Creek watershed/Mystic Vale bat box project area



This site was selected for bat box installation for several reasons:

- **<u>Decline of Natural Roosts</u>**- The site contains approximately 6.9 snags (or dead standing trees) per hectare, with approximately 95% occurring along the northern edge near parking lot 1 (Chatterson, 1995; Harrop-Archibald, 2007). This suggests an absence of natural roosts at the site.

- **<u>Riparian Ecosystems</u>** – The site contains the hydrological feature Hobbs Creek, meandering through the forest's valley to Cadboro Bay. Riparian forest ecosystem can

provide critical foraging grounds.

- **Proximity to Pollinator Garden –** In efforts to collaborate and achieve a common goal of increasing biodiversity at the site, the bat boxes were to be as close to the pollinator garden as possible, while still providing suitable roosting conditions.

4.0 - METHODS & MATERIALS

4.1 Denman Island Bat Box Surveys

Denman is a northern gulf island situated between the BC Mainland and the east coast of Vancouver Island and supports a robust bat box program. During the summer months, the island is home to a protected maternal colony of ~1000 bats that reside in the roof of the "Old School" building (Balke, 2018 & 2019). Since 2017, the DCA have installed 39 bat boxes to increase roosting opportunities for Old School maternal colony. Reproductive colonies will frequently switch roosts in search of the ideal microclimates, insect activity, or to avoid predation throughout the season (Rensel, 2023). Therefore, maintaining at network of artificial roosts is recommended in bat habitat management.

To help the DCA with the monitoring of their bat boxes, two multi-day field trips were conducted to supplement their existing monitoring and reporting results. Every bat box was visited at least from June - August 2022, to check for occupancy and record relevant variables that are related to bat box installation and habitat selection.

- **Occupancy Surveys** – Bat box occupancy was determined with daytime visual surveys that occurred summer 2022. Both surveys followed the same methods and required the same materials: a flashlight, ladder, GPS, compass, field sheet/notebook. Caution was used to not disturb any roosting bats that could be present, shining the light for less than 10 seconds to check for occupancy. Any guano presence was noted underneath the bat box – on the ground on any form of installed catcher. Guano presence was interpreted as evidence of recent bat box occupancy, even if no bats were observed at the time of survey.

- **Habitat Surveys** – Bat box habitat variables were recorded on a field sheet at each of the bat boxes: colour, height, exposure, mounting method, and observed obstructions. General habitat/cover type and significant features were also recorded, which may contribute to the of a box's occupancy. Proximity to water was largely determined post-field using GPS coordinates and the freshwater atlas shapefile in QGIS.

For the 2022 roosting season, a total of 15 (or 39%) bat boxes on Denman had observable signs of use during the surveys or reported by landowners. Many of the bat boxes reported occupancy during both field survey, and others during only one. A total of 15 boxes did not have any signs of use, and 9 were unconfirmed due to issues of access. A summary of bat box best practices observed on Denman Island are presented below in table X. See Appendix A for more details on Denman Island bat box survey results. Observations from the Denman Island habitat surveys and BC's bat box management documents would inform the Mystic Vale bat box project methods.

Bat Box Variable	Bat Box Best Practice
Design/Size	Larger will always be better for bat boxes, to provide a range of microclimates within the same roost. Bat boxes have multiple chambers, and at least 20" tall and 12" wide. Multi-chamber nursery boxes, rocket boxes, and bat condos are common designs of bat box. Single-chambered boxes are no longer recommended.
Colour	Bat boxes should be painted or stained dark for heat retention, in our moderate climate.
Exposure	Orientating a bot box southwest or southeast provides the best solar exposure throughout the day. Bat boxes require 6-10 hours of direct sunlight (Craig, 2017).
Height	Bat boxes should be installed 12 – 20 feet above the ground, but higher will always be better.
Mounting Method	Bat boxes can be successfully mounted on posts/poles, buildings, and occasionally trees. However, bat boxes located on trees can take twice as long for bats to locate.
Obstructions	A clutter-free radius for 20-30 feet around the bat box is essential for maintaining flightpath access points and exits. Tree branches are the most common obstruction for bat boxes.
Proximity to Water	Bats will travel long distances to seek ideal foraging grounds. However, it is still recommended to install bat boxes within a 400m of a water source to increase likelihood of occupancy
Habitat Type	Bat boxes installed in natural bat flyways, along forest treelines and near foraging habitat like streams, rivers, lakes, and wetlands.

Table 1: Bat box best practices (Tuttle, 2013; Craig, 2017; Clausen et al, 2023).

4.2 - Bat Box Site Selection

After discussions with the UVic RNS coordinator and reviewing the Denman bat box habitat variables – two sites were decided on for bat box installation (Figure 2). The study site contains dense second growth forests that were not considered as potential sites for bat box installation. This area's conditions would be too shaded to provide suitable roost temperatures. The site is owned by the District of Oak Bay and used for municipal storage. Trails through the site are frequently used by the community. Avoiding these areas was a priority. Oak Bay also treats a large patch of the study site for the presence of Poison Hemlock, which involved the spraying of Start-Up (Glyphosate) in June (CRD, 2021). This site was also avoided. Additionally, the area contains second growth forests that contains relatively low density of snag stands with a diameter of >70cm DBH.

Figure 2: Sites selected for bat box installation in Mystic Vale.

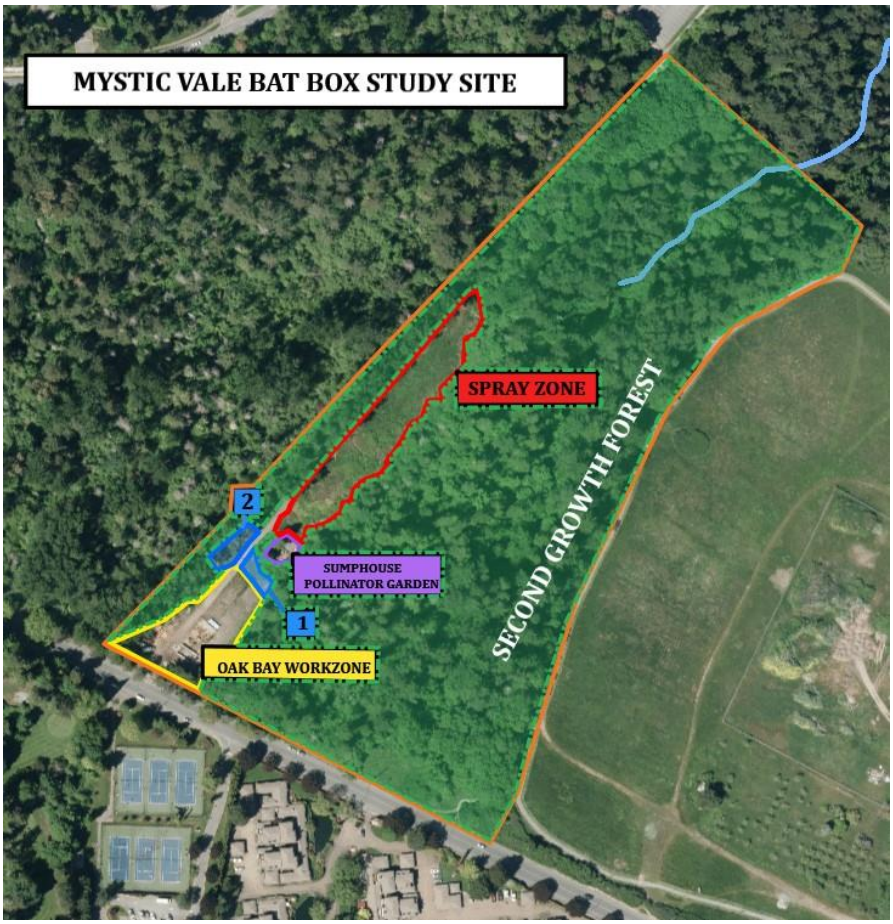


Figure 3: Site 1 before bat box installation	Figure 4: Site 2 before bat box installation
	

4.3 - Bat Box Design

The design selected was the multi-chamber nursery box (Figure 5), obtained from the Community Bat Programs of BC's *"Building Homes for Bats" (2017).* This document was adapted from "The Bat House Builder's Handbook" (Tuttle, 2004) published by Bat Conservation International, but has been adapted to BC based on expert opinion (Craig & Kellner, 2017).

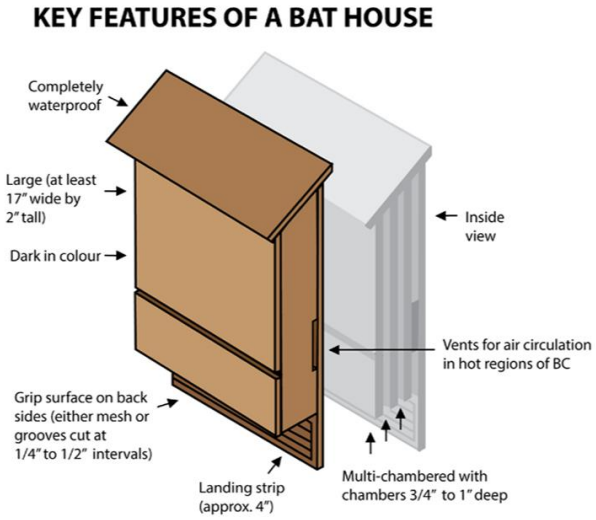


Figure 5: Key features of multi-chamber nursery box (Craig & Kellner, 2017).

With this design, bats have access between the four internal roosting chambers through 1/2" holes drilled in the dividers. This eliminates the need for bats to exit the roost to switch between chambers. The current provincial recommendation is to install two nursery boxes back-to-back, on the same post, with one facing south and the other facing north. This offers an even larger gradient of internal thermal conditions and creates additional roosting space between the two bat boxes mounted on the same post. See Appendix B for bat box design and construction plans used for this project.

4.4. – Bat Box Materials & Assembly

Materials for the bat boxes were acquired in early 2023, and construction began in March 2023. See Appendix C for complete cost of materials used in project. The bat boxes were constructed out of two types of untreated, exterior grade plywood to create the body and dividers. Spruce fence boards were used to create the 3/4" spacers that the dividers would rest on (Craig, 2017).

Every interior surface of the bat box was scored to and coated with 1 layer of water-based wood stain to protect the wood from damage overtime. The bat box consisted of a large 17" x 31" back piece that was scored on both sides to create suitable surface for bat claws to grip onto (Figure 6). All surfaces where bats will hang, must be scored, or roughened so the bats claws can grip the plywood. Wood was scored with box cutters, wood files, and a Dremel to create grooves (1/16" – 1/32" deep) at 1/2" intervals.

Figure 6: Bat box construction process showing a partially constructed bat box

For each bat box the same process was repeated. Two side pieces were attached to the scored back piece. Spacers were screwed into place from the side of the box, to create a flat surface for the partitions to rest on. Partitions were attached to the spacers using flat-head screws. process was repeated three times to

create four roosting chambers within the bat box (Figure 7).

Figure 7: Internal view of bat box chambers (looking up)

The front pieces were attached, leaving a 1/2" gap to create a vent. Caulking was used to seal all exterior gaps of the bat box after completing assembly. The exteriors were painted black with multiple coats of water-based wood primer/paint combo. Final dimensions of the bat boxes were 24" tall and 17" wide, with a 6" landing pad. Bat boxes were ready for installation by the first week of April 2023.

- **Mounting Bracket**

Inexpensive pieces of 1" x 4" were roughly to create a mounting bracket for the bat boxes. Two pieces were cut to the width of the bat box (17.5") and one piece was cut 6" longer (37") than the back piece. Overhang from the piece taller than the bat box will be used to attach the bat box to the post in the field (BCI, n.d.). The mounting brackets were attached to the boxes using leftover 1 5/8" screws from construction.

4.5– Installation Process

The first bat box was installed on April 25th, 2023, and the second was installed on May 8th, 2023. Materials were transported to the site in the morning, which included the two (4" x 4" x 16') wooden posts to support each bat box set-up, Post holes were dug manually using a variety of shovels roughly ¼ of the length of post to be installed (BCI, n.d.). The post holes dug at the site were between 3-4 feet deep, to support the 16' post. Bat boxes were then attached using 3" screws. The top portion of the post was also roughened

to create a gripping surface for the bats between the boxes. The roof was also attached on installation day, onsite using 1" screws.

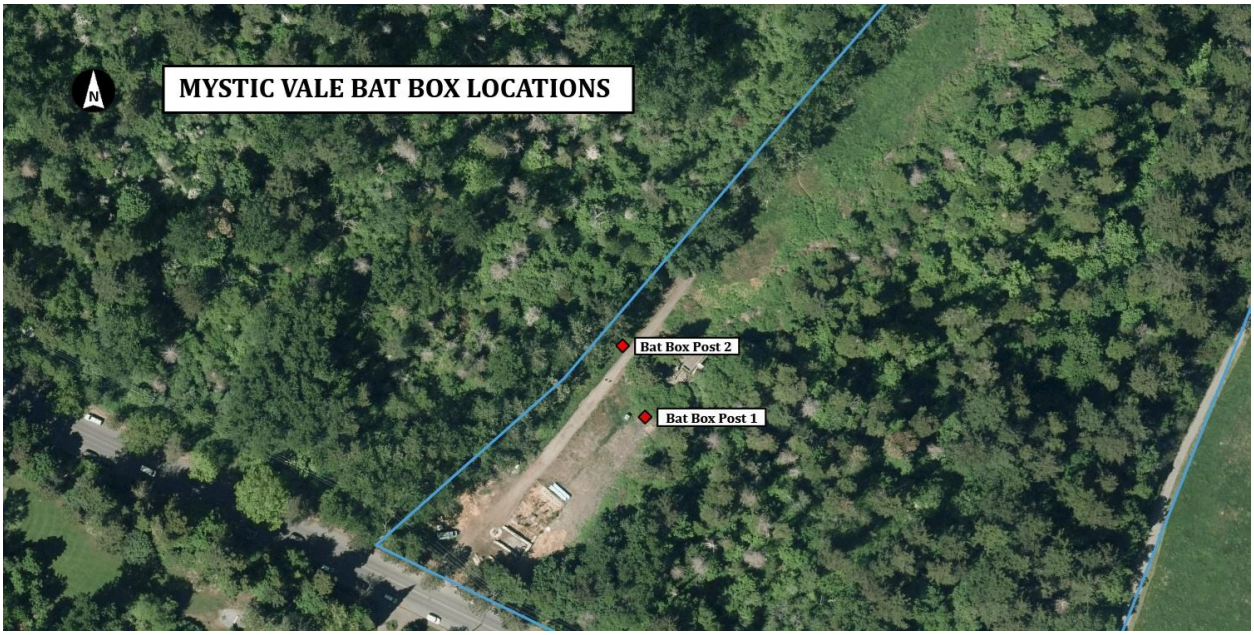
To set the wood posts, pea gravel was used instead of cement. Wooden posts set in cement or concrete are more likely to rot over time due to water damage (BCI, n.d.). A few inches of pea gravel were poured in the bottom of the hole, before standing the wood post upright. Once the post was upright, the bat boxes were oriented that one was facing south and the other north. When the final positions were decided, more pea gravel was poured into the post hole, tamping with a 2' x 4' every few inches to stabilize. The post hole was over-filled by a few inches since the pea gravel will settle overtime and level out. Light coloured wood underneath will act as a guano catcher.

5.0 - RESULTS

5.1- Mystic Vale Bat Boxes

A total of four multi-chambered bat boxes were constructed and installed in Mystic Vale, spring 2023. Two separate post support back-to-back bat box setups at two locations that receive varying amount of direct sunlight. The first bat box post was installed on April 25th, 2023, with the second installed on May 8th, 2023.

Figure 8: Map of bat box locations in Mystic Vale



	Date of Installation	Latitude	Longitude
Site 1 (Bat Box A & B)	April 25th, 2023	48º 27’ 28 “N	-123 º 18’ 36” W
Site 2 (Bat Box C & D)	May 8th, 2023	48º 27’ 29” N	-123 º 18’ 36” W

Table 2: Coordinates of Mystic Vale bat boxes.

5.2 - Post 1 (Bat Box A & B)

Post 1 was installed on the southeast treeline of the site, behind the area that the municipality of Oak Bay uses for storage. Bat Box A was oriented 190º SW, and Bat Box B was the opposite at 40 º NE. This area is shaded by large trees in the morning but receives full sun by the afternoon. The first bat box post will be visible in the line of sight when using the stairs down to the sumphouse pollinator garden.

The dominant species in the immediate vicinity were thick shrubs of Himalayan Blackberry, so the post with the bat boxes were installed in a natural clearing. This area was clear of tall shrubs at the time of installation. Taller trees will create shade for the bat boxes at various times throughout the day and protect the boxes from extreme winds. Despite the presence of large trees, there are minimal perching branches near the entrance of the bat boxes. Perching branches create opportunities for natural predators to prey on bats exiting the roost.

Figure 10: Post 1 (with bat box A & B)

5.3 – Post 2 (Bat Box C & D)

Post 2 was installed on the northwest treeline, in closer proximity to the trails and entrance to the sumphouse pollinator garden. Bat Box C was oriented 220º SW and Bat Box B was oriented the opposite direction at 58 º NE. This area receives direct sun earlier in the day, meaning it have offer warmer internal temperatures than Site 1.

This site is also situated closer to the area that is chemically treated each summer to control poison hemlock – a priority invasive species in Mystic Vale (CRD, 2021). Site 2 required more extensive clearing of invasive vegetation prior to bat box installation. Thick

shrubs of Himalayan Blackberry *(Rubus armeniacus)* were removed using mechanical removal methods to clear the potential obstruction to the bat's flightpath surrounding the bat box. Pruning shears were used to cut the above ground vegetation, and shovels were used to dig up the root crowns. Dead poison hemlock shrubs were present and were very easy to remove by hand (gloves were worn during the pulling process).

Figure 11: Bat box post 2 (with bat box C & D)

5.4 – Bat Boxes Registration

Bat boxes were registered with the BC Community Bat Program, following installation to contribute to citizen science. During registration bat box dimensions are required, height of installation, method of installation (post, tree, building), hours of direct sunlight, and whether the bat box has been occupied or not. Each summer, reporting will occur on the bat box based on the results of the monitoring plan.

6.0 – DISCUSSION & RECOMMENDATIONS

6.1 – Monitoring Plan

Following installation, the first recommendation is to monitor the Mystic Vale bat boxes for occupancy from May 1st – September 1st. Regardless of the bat box's success, reporting on monitoring results is of critical importance to provincial bat conservation efforts (BC Community Bat Program, 2019). All season results will be communicated to the BC Community Bat Program. Monitoring activities should take place for 5 years following installation. If bat box occupancy cannot be observed by September 1st, 2028, relocation should be considered.

Summer roost surveys should be conducted using the methods discussed in the Denman Island surveys (Section 4.1). If Mystic Vale bat box occupancy is observed, the next step would be to conduct an exit count and determine the number of bats present. A single bat is likely a male using the bat box as a day roost. Whereas a larger gathering of bats of greater with an observed increase in numbers is more likely to suggest the presence of a maternity or nursery colony (BC Ministry of ECCS, 2019).

Bat exit counts should be conducted in accordance with the BC Bat Count Standards Ideally, two bat counts should be conducted between June 1st – 21st before the pups can fly. Followed by two additional exit counts between July 21st – August 15th when the pups can fly (Craig, 2017; BC Annual Bat Count 2022). Any observations of bat presence, either occupancy or guano, should be reported to the regional bat program.

6.2 – Bat Box Maintenance

Bat boxes typically require little maintenance, apart from occasional cleaning. This involves clearing the interior chambers of any accumulated cobwebs or wasp nests from the last year, during the autumn/winter when boxes will be empty (Craig, 2017). Although the bat box chambers are 3/4" apart to deter wasps buildings nests, this practice is recommended for the Mystic Vale bat boxes.

6.3 - Bat Box Discussion

While bat boxes can be beneficial in conservation efforts of BC's endangered bat species, they do not benefit all species equally. Only six of BC's bat species roost in bat boxes, and further 89% are used by only two species (little brown myotis and Yuma myotis). As of 2022, BC had 515 documented maternal roosts with 184 found in bat boxes or roughly 36%. On Southern Vancouver Island & the Gulf Islands, of 137 known roosts, 57 are found in bat boxes (roughly 42%). However, there are currently 325 bat boxes in the Annual Bat Count database, many of which lacking data and reporting (BC Bats, 2022). Bat

boxes rely largely on citizen science which can be inconsistent. While there is still much to be known about bat boxes in roost ecology, bat boxes do not fundamentally address the mechanisms driving loss of complex natural habitat. Therefore, it is still essential to pursue actions that and conserve or restore natural habitats on a larger scale.

6.4 – Site Management Recommendations

- **Conserve Natural Habitat** – There is no substitute for natural habitat. It's recommended that large-scale conservation efforts are made to maintain natural bat habitat on the university campus. This can involve protecting tall wildlife trees with DBH >70cm; cottonwoods and balsams are especially important. Also, to continue improving the ecological integrity of Upper Hobbs Creek watershed which represents a foraging opportunity in an urban environment.

- **Remove Invasive Species** – At both sites with bat boxes in Mystic Vale, managing blackberry growth will be an ongoing consideration. Tall, thorny shrubs may obstruct the flightpath from the bat box if left unmanaged overtime. Ongoing management of this invasive species through mechanical removal of vegetation and root crowns, has the potential to benefit bat-specific habitat and the ecological integrity of the site as whole.

- **"Bat-Friendly" Species** – Many native species are considered "bat-friendly" since they attract nocturnal insects, thereby increasing foraging habitat. Species that support either larvae or adult stages of moth and other nocturnal insects are likely to benefit bats, including many native trees & shrubs (see Appendix C). Restoration projects focused on planting native species in the areas surrounding the bat boxes should be considered in the future (BC Community Bat Program, 2019).

- **Inclusion of Surrounding Areas**– Stand-alone bat boxes are insufficient to support colonies in an urban landscape. Research suggests that artificial roost structures tend to function the best when multiple are installed in the same geographic location. It's recently been confirmed that coastal bat colonies can exhibit roost-switching behaviour in seek of the best available resources and conditions throughout the season (Rensel, 2022; Craig, 2022). It's recommended to encourage the installation of more bat boxes in urban areas surrounding Mystic Vale to increase habitat connectivity.

- **Future Community Engagement** – The bat boxes installed in Mystic Vale are an opportunity for future species stewardship and community engagement regarding bat conservation. Due to time restraints, no bats were observed in the time following installation. However, resident bats would provide the opportunity for community Bat

Walks and a potential site for the BC Bat Count. To ensure bats continue to thrive in a human-dominated landscape, public engagement will be key (Lausen et al, 2023).

- **Install Signage** – Interpretive signage is recommended for the bat boxes to communicate the important ecological role bats play and the threats they face.

6.4- Site Issues

The municipality of Oak Bay sprays a field to treat poison hemlock, which is located quite close to the bat boxes. Bats are highly sensitive to the use of pesticides, which may negatively affect bats in the area. Another factor that comes along with heavy trail use, is the possibility of vandalism to the bat boxes. Graffiti is very common at the site, suggesting that the area may be visited at night, bringing along loud noises which may discourage bats from using the area. Owls are known to the live in the area, which are a natural predator of bats (Benson et al, 2014). Additionally, since Mystic Vale is situated in an urban area there is the potential for predation from housecats, who play a significant role in bat mortality (Beattie et al, 2022).

7.0 - CONCLUSION

This project began with a hands-on introduction to bat boxes, in the form of a summer field experience on Denman Island to observe the qualities of a successful bat box in-field. Observations from the Denman Island bat box surveys directly influenced the construction and installation the Mystic Vale bat boxes. Artificial habitat provisions have the potential to mitigate for loss of roosting space where it has otherwise been lost, like in urban environments. Mystic Vale was selected as the site for bat habitat restoration, which involved the installation of bat boxes in spring 2023. Four multi-chamber bat boxes were constructed. The goal of artificial roost installation was to increase the amount of suitable maternal habitat at the site and mitigate for a loss of natural roosts in an urban environment. Bat box construction took place from February – April 2023, with installation complete by May. Installation of the first bat box occurred on April 25th and the second on May 8th, 2023. Post-holes were dug 3 – 3.5 feet deep and set with pea-gravel. During the installation of both bat boxes,

Key recommendations for the site include monitoring for occupancy following installation for 5 years before considering relocation. Management activities should also involve the removal of invasive blackberry shrubs and planting of native or bat-friendly species. Inclusion of surrounding areas on public and private lands should be pursued, to create a network of artificial roosts.

Despite best efforts, artificial roost provisions do not ultimately mitigate for loss of complex natural habitat at the site. To conserve and restore bat habitat on a larger scale, other actions beyond the scope of this project should be taken by the university and the districts of Oak Bay & Saanich. This includes the conservation of valuable wildlife trees and other natural habitats, wetland, and riparian ecosystem restoration, planting bat-friendly native species, and initiating community engagement focused on species stewardship. Bats in British Columbia need assistance to maintain their critical maternal roosting habitat, whether it is natural or artificial.

8.0 –Acknowledgements

A huge thank you to the RNS coordinator Nancy Shackelford who was essential in guiding me throughout this process.

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9.0– REFERENCES

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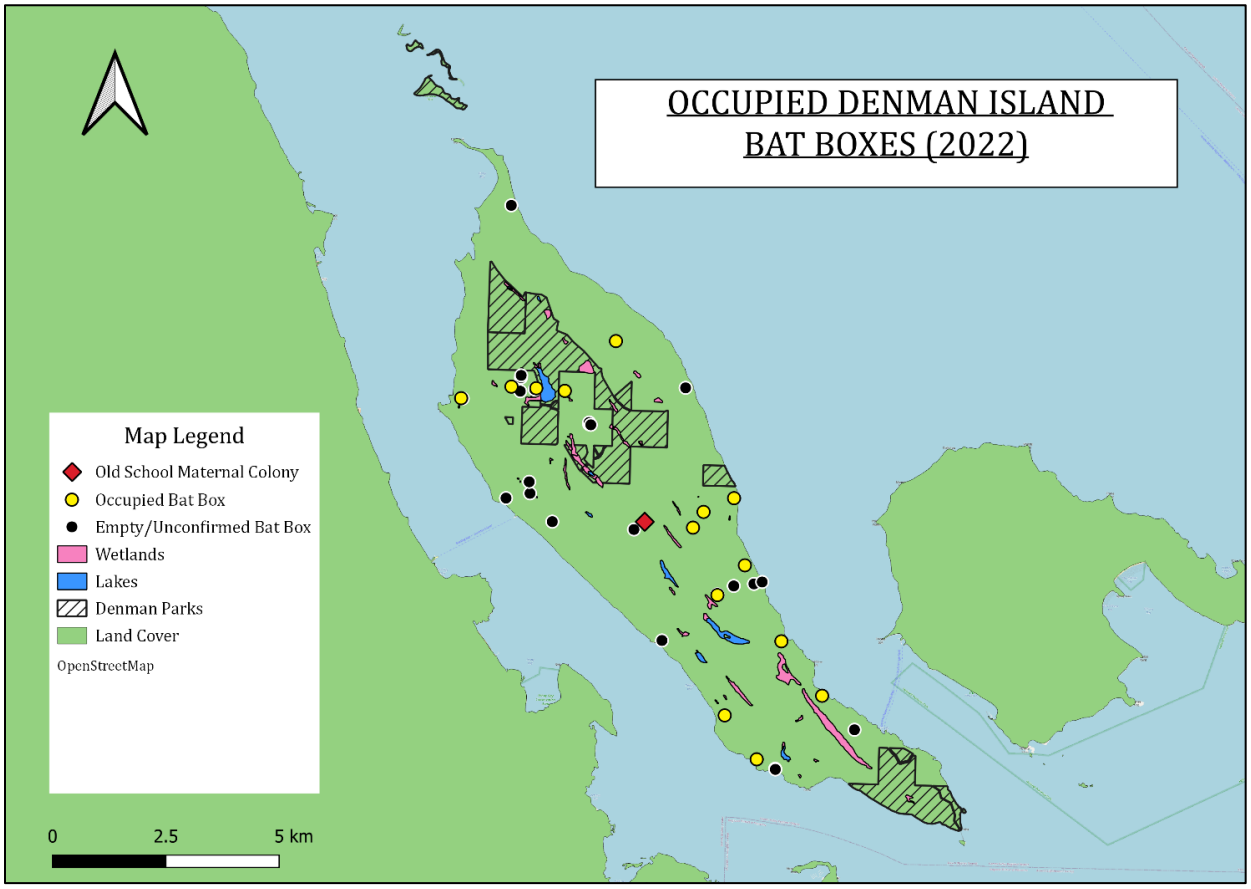
APPENDIX A – DENMAN ISLAND BAT BOX SURVEY RESULTS

Figure X:



There was an observed linear configuration of occupied bat boxes passing over Chickadee Lake in the northern part of the island. Additionally, a cluster of occupied bat boxes were identified on the eastern portion of the island, in relatively closer proximity to the Old School Colony. The southern potion of Denman contained occupied bat boxes with a larger distance between them, with multiple occurring near wetlands.

Occupied boxes on Denman in 2022 were typically located closely to another one, which implicates the importance satellite roost in bat box management. Bats are highly mobile and will seek roosts that can provide available resources at that time. Maintaining satellite roost will likely be a critical approach of bat box roosting species adapting to future climate

change (Rensel, 2021). Bat boxes that may not necessarily be occupied in 2022, may still provide a valuable roosting opportunity in a changing climate – by providing alternative thermal conditions.

Table 3: Number of bat box visited during each survey and occupancy result, 2022.

Time of Survey	Number of Boxes Surveyed	Number of Boxes In-Use
June 28th-29th, 2022	26	10
August 1st – 2nd, 2022	36	13

BAT BOX VARIABLE	OCCUPIED BAT BOX RESULTS
Colour	100% occupied bat boxes were painted dark (black, dark brown, or dark green)
Height	26.5% occupied bat boxes <10 feet high 26.5% occupied bat boxes between 10-20 feet high 47% occupied bat boxes >20 feet high
Exposure	70% occupied bat boxes southern facing (S, SW, SE) 28% occupied bat boxes north facing (N, NW, NE) 2% occupied bat boxes east facing (E)
Substrate Mounting	73% occupied bat boxes mounted on human structures (homes, barns, etc.) 27% occupied bat boxes on free-standing poles/fence posts 0% occupied bat boxes mounted on trees
Obstructions	100% of occupied bat boxes free of obstructions
Surrounding Habitat Type	20% occupied bat boxes on agriculture land 40% occupied bat boxes on rural-residential properties (private properties) 40% occupied bat boxes on forested land
Proximity to Water	87% occupied boxes 0-400m away from water source

13% occupied boxes 400m+ away from water source

Table 4: Summary of the 15 occupied bat box variables on Denman Island, summer 2022.

APPENDIX B – BAT BOX DESIGN AND CONSTRUCTION PLANS

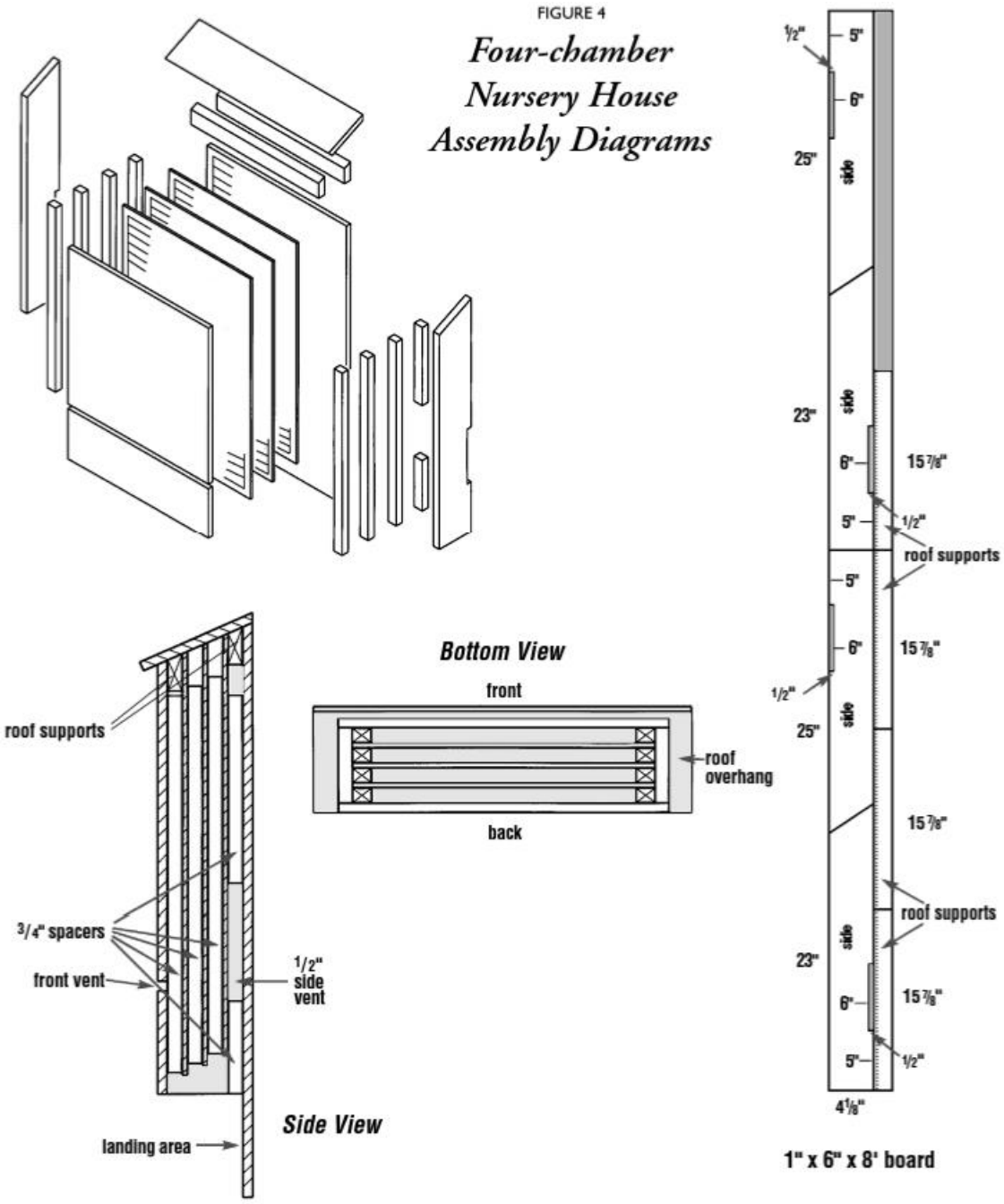
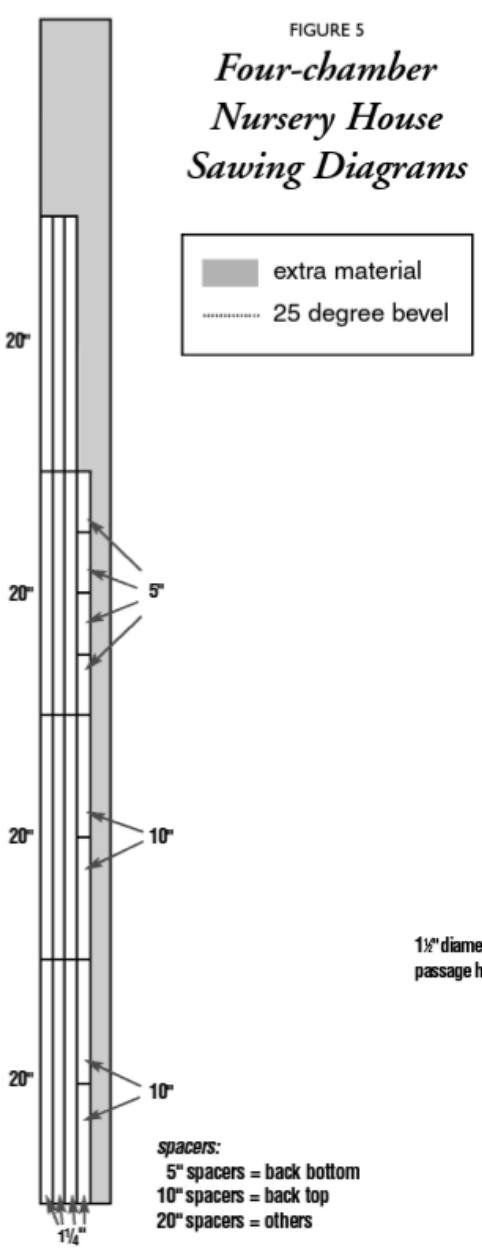
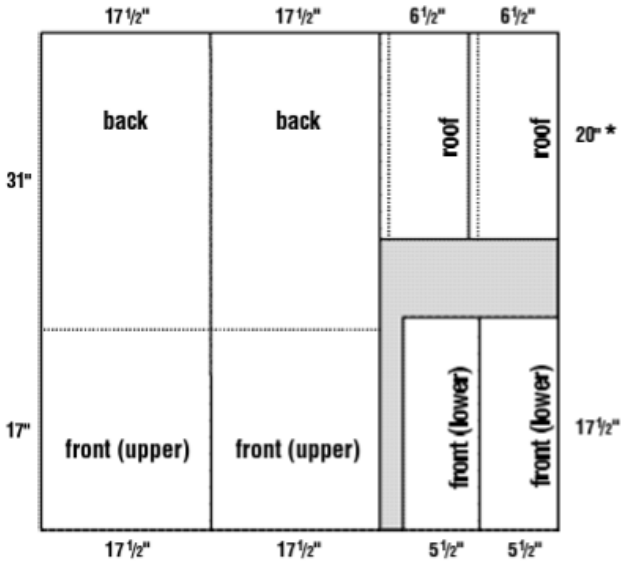


FIGURE 5

Four-chamber Nursery House Sawing Diagrams

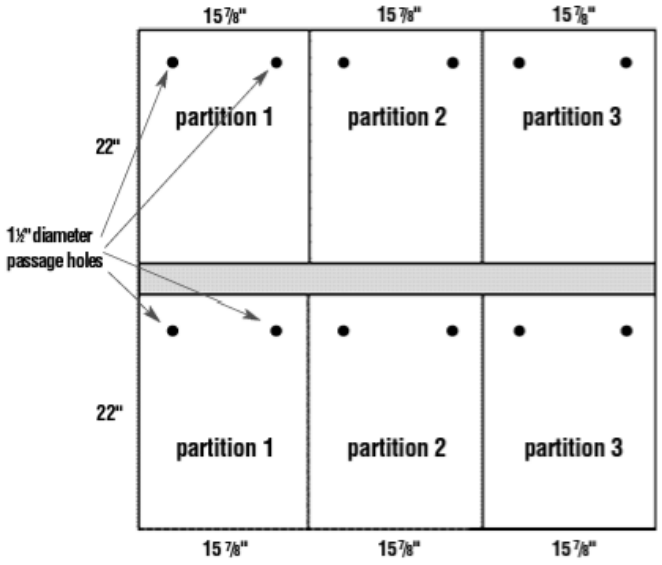


1" x 6" x 8' board



4' x 4' x ½" plywood

* 19" if mounted between two poles



4' x 4' x ⅜" plywood

APPENDIX C – COST OF MYSTIC VALE BAT BOX CONSTRUCTION & INSTALLATION

Material for Bat Box construction	***Quantity***	***Total Cost***
1/2" thick outdoor grade plywood 1 sheet	1 standard sheet (4' x 8')	$42.99
3/8"-thick outdoor grade plywood	1 standard sheet (4' x 8')	$34.99
Wood cutting fee ($0.50 per cut)	50 cuts	$25.00
Spruce fence boards	4 pieces (1" x 6" x 8')	$31.96
1 5/8" coated deck screws	Pack of 100 (x2)	$25.94
1 ¼" coated deck screws	Pack of 100 (x1)	$11.97
1"-long exterior grade screws	Pack of 100 (x1)	$9.87
Dark, exterior-grade, water-based stain	237mL (Sample Size x1) 946 mL (x1)	$5.48 $30.97
Flat, exterior-grade, water-based paint	946 mL (x2)	$49.94
Paintable latex-caulk	Tubes (x2)	$6.14
Caulking gun	Caulking gun (x1)	$6.27
Paintbrushes, rollers & drop sheets	1-2 of each	$12.72
1" x 4" boards	8 pieces cut to width of box & 4 pieces >6" longer than box	$19.92
Wood cutting fee (done for free)	N/A	N/A
1 5/8" coated deck screws	Used leftover screws from bat boxes	N/A
	Total Cost of Bat Boxes	**$314.16**
	Cost of Single Bat Box	**$78.54**

Material for Bat Box Installation	**Quantity**	**Cost**
3" exterior-grade screws	Pack of 8 (x2)	$6.94
Pressure-treated post (4'"x 4" x 16')	Wooden posts (x2)	$110.98
Pea Gravel (sourced from Marketplace)	Multiple pounds	$40.00
Additional materials borrowed from friends & family	Shovels, level, tamper, electric drill & drill bits	N/A
	Total Cost of Installation	**$180.84**
	Cost of Single Bat Box Set-Up	**$90.42**

Total Cost of Mystic Vale Bat Box Project (Combined construction & installation)	$475.08

APPENDIX D – TREE SPECIES SUITABLE FOR BAT MATERNITY COLONIES (OLSEN ET AL, 2018).

Trees species suitable for bat maternity colonies

Most bats that roost in trees will opportunistically use any tree species that provides well-protected, concealed spaces for roosting. However, some species have decay characteristics that result in them being frequently used by bats (e.g., those that retain sloughing bark; remain standing after death; or frequently form large inner cavities). The following trees are native in at least some portions of BC, and may be considered for projects designed to provide bat roosting habitat.

Common Name	Scientific Name	Relative Suitability for Roosting[1]
Black cottonwood	*Populus balsamifera ssp. trichocarpa*	*Very high*
Balsam poplar	*Populus balsamifera ssp. balsamifera*	*Very high*
Western white pine	*Pinus monticola*	*High*
Ponderosa pine	*Pinus ponderosa*	*High*
Trembling aspen	*Populus tremuloides*	*Moderate - High*
Western redcedar	*Thuja plicata*	*Moderate - High*
Yellow-cedar	*Chamaecyparis nootkatensis*	*Moderate - High*
Douglas-fir	*Pseudotsuga menziesii*	*Moderate - High*
Western hemlock	*Tsuga heterophylla*	*Moderate - High*
Mountain hemlock	*Tsuga mertensiana*	*Moderate - High*
Western larch	*Larix occidentalis*	*Moderate - High*
Grand fir	*Abies grandis*	*Moderate*
Lodgepole pine	*Pinus contorta*	*Moderate*
Paper birch	*Betula papyrifera*	*Low - Moderate*
Garry oak	*Quercus garryana*	*Low*
Sub-alpine fir	*Abies lasiocarpa*	*Low*
Engelman's spruce	*Picea engelmannii*	*Low*
White spruce	*Picea glauca*	*Low*
Black spruce	*Picea mariana*	*Low*
Big-leaf maple	*Acer macrophyllum*	*Unknown*
Arbutus	*Arbutus menziesii*	*Unknown*
Oregon ash	*Fraxinus latifolia*	*Unknown*
Amabilis fir	*Abies amabilis*	*Unknown*
Sitka spruce	*Picea sitchensis*	*Unknown*

List of recommended trees and shrubs to support insects (adult or larval forms) eaten by bats.

Group	Common Name and Scientific Name
Poplars	Trembling aspen (*Populus tremuloides*) Black cottonwood (*Populus balsamifera ssp. trichocarpa)* Balsam poplar (*Populus balsamifera ssp. balsamifera)*
Birch	Paper birch (*Betula papyrifera*) Water birch (*Betula occidentalis*) Scrub birch (*Betula glandulosa*)
Maple	Douglas maple (*Acer glabrum*)
Conifers	Pine (*Pinus spp.)* Spruce (*Picea spp.)* Fir (*Abies spp.)* Tamarack / larch (*Larix spp.)* Juniper (shrub) (*Juniperus spp.)* *Hemlock (Tsuga spp.)* *Western redcedar (Thuja plicata)* *Yellow-cedar (Chamaecyparis nootkatensis)* *Douglas fir (Pseudotsuga menziesii)*
Mountain-ash	Western mountain-ash (*Sorbus scopulina*) Sitka mountain-ash (*Sorbus sitchensis*)
Saskatoon	Saskatoon (*Amelanchier alnifolia*)
Willow	Salix spp.
Alder	Green alder (*Alnus viridis crispa*) Sitka alder (*Alnus viridis sinuata*) Mountain alder (*Alnus incana*) Red alder (*Alnus rubra*)
Hazelnut	Beaked hazelnut (*Corylus cornuta*)
Dogwood	Red-osier dogwood (*Cornus stolonifera*)
Mock orange	Mock orange (*Philadelphus lewisii*)
Ledum	Trapper's tea (*Rhododendron columbianum*) Labrador tea (*Rhododendron groenlandicum*)
Honeysuckle	Blue elderberry (*Sambucus caerulea*) Red elderberry (*Sambucus racemosa*)
	Common snowberry (*Symphoricarpos albus*)
	High-bush cranberry (*Viburnum edule*)
	Black twinberry (*Lonicera involucrate*) Utah honeysuckle (*Lonicera utahensis*) Orange honeysuckle (*Lonicera ciliosa*)
	Twinflower (*Linnaea borealis*)
False azalea	False azalea (*Menziesia ferruginea*)
Rhododendron	White-flowered rhododendron (*Rhododendron albiflorum*)
Vaccinium	Vaccinium spp.

Common Name	Scientific Name
Hairy evening-primrose	*Oenothera villosa ssp. strigosa*
Spreading Phlox	*Phlox diffusa*
Long-leaved Phlox	*Phlox longifolia*
Moss Campion	*Silene acaulis*
Parry's Campion	*Silene parryi*
Menzie's Campion	*Silene menziesii*
Douglas's Campion	*Silene douglasii*
Showy Milkweed	*Asclepias speciosa*
Spikelike goldenrod	*Solidago simplex*
Northern goldenrod	*Solidago multiradiata*
West coast goldenrod	*Solidago elongata*
Western Canada goldenrod	*Solidago lepida*
Missouri goldenrod	*Solidago missouriensis*
Field goldenrod	*Solidago nemoralis ssp. decemflora*