

AUTUMN ROOST SELECTION BY MALE HOARY BATS (*LASIURUS CINEREUS*)  
IN NORTHERN CALIFORNIA

By

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## ABSTRACT

### AUTUMN ROOST SELECTION BY MALE HOARY BATS (*LASIURUS CINEREUS*) IN NORTHERN CALIFORNIA

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The hoary bat, *Lasiurus cinereus*, is a solitary bat that roosts in the foliage of trees throughout the western hemisphere. Roosts are subject to the ambient temperature of their surroundings, thus hoary bats undergo long-distance migrations between summer and winter ranges to avoid freezing temperatures. Habitat selection has been studied during the summer for maternal female hoary bats, but not during migration and winter. Autumn migration coincides with the hoary bat mating period and it has been proposed that male and female bats may rendezvous on migration paths. Individuals may select roosts in stopover locations that enhance fitness by providing shelter, forage, or mating opportunities. Because of prior evidence that species of *Lasiurus* and other long-distance migrating bats forage infrequently at stopover locations, I hypothesized hoary bats select stopover habitat during autumn migration which minimizes energetic expenditures and improves mating opportunities. Specifically, I hypothesized that hoary bats would select areas with greater solar radiation and southwest aspects to exploit temperature at roosts in the autumn afternoons and that they might select roosts that serve as a landmark during migration i.e., emergent trees. I also hypothesized that they would roost in close

proximity to flyways to increase mating opportunities (behavior demonstrated by previous studies).

I located 25 day roost sites of male hoary bats during the autumn in Humboldt Redwoods State Park through the use of radio telemetry (n=18) and GPS (n=7), then evaluated site-level roost selection by comparing roosts with 125 random sites within the study area. I used multiple logistic regression and Akaike's Information Criterion to compare 64 multiple logistic regression models that assessed the possible influence of canopy height, distance to meadow, distance to road, elevation, emergent canopy, and solar radiation on hoary bat site use. Models were highly competitive and I used model averaging to generate parameter estimates. I averaged the top 14 models which cumulatively accounted for 95 percent of the total Akaike weight of all models. Elevation, distance to meadow, and distance to road had the highest variable importance ranking in the 14 models averaged. Elevation contributed to the 14 most highly-ranked models, distance to meadow contributed to 13 of 14 models, and distance to road contributed to 9 of 14 highly-ranked models. These three variables indicate that open space and flyways influence site use by hoary bats. Selection for open flyways is consistent with other roost studies on species of *Lasiurus* and seems to be the major driver of roost selection at the particular spatial scale at which my analysis was carried out. Further study on the drivers of roost selection is necessary at other spatial scales to more fully examine roost site selection by hoary bats during migration.

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## INTRODUCTION

In winter much of the temperate zone of North America becomes thermally unsuitable for insectivorous bats to remain active (Cryan and Veilleux, 2007). In response, they use torpor to survive cold spells and food shortages or migrate to more temperate climates to avoid freezing temperatures and to access insect forage to meet their metabolic demands. (Cryan et al., 2014; Hayes et al., 2015). Many species including the hoary bat, *Lasiurus cinereus*, use a combination of torpor and migration to survive the colder months in North America (Cryan and Veilleux, 2007; Weller et al., 2016). Hoary bats have the largest range amongst American bat species (Shump and Shump, 1982). They have the ability to tolerate a wide range of temperatures and have been captured from flight in temperatures ranging from 0 to 22 degrees Celsius (Shump and Shump, 1982). The thick fur on the body and the uropatagium provides some insulation at their solitary roosts in the foliage of trees (Shump and Shump, 1982).

Because their foliage roosting habit leaves them subject to the ambient temperature of their surroundings, it is been presumed that in the autumn hoary bats migrate to coastal areas or other areas with milder climates to avoid freezing temperatures, however the extent of the winter range is not well known (Cryan and Veilleux, 2007; Cryan et al., 2014). Although typically solitary at the roost, hoary bats have been observed in flight in large, dense groups during the late summer and autumn (reviewed by Cryan and Brown, 2007). Aggregations of males and females will

sometimes move through an area in waves during the migration season (Findley and Jones, 1964). Despite being conspicuous in dense aggregations, observations of such groups are rare and there are few known locations in the autumn or spring where hoary bats can be captured or observed in abundance.

The winter range of the hoary bat is largely based on museum records and distribution modelling using climate variables (Cryan, 2003; Hayes et al., 2015). Hoary bats are known to winter regularly in California, the southeastern United States, Mexico, and Guatemala but there have also been incidental sightings of hoary bats in the northeastern United States in December and January (Shump and Shump, 1982; Cryan, 2003). Conventionally, hoary bat autumn migration has been described as southward and coastward toward more temperate climates, although Weller (2016) found that their movement is not necessarily linear. Using miniature GPS units attached to hoary bats, Weller was able to track a male hoary bat that traveled >1000 kilometers roundtrip from northern California to Oregon and into northern Nevada and back during October.

During long-distance movements, hoary bats use day roosts at intermediate stopover locations (Weller et al., 2016). It seems reasonable that during migration they would select habitat in a hierarchical manner (Johnson, 1980; Krebs, 2001; Manly and Bryan, 2002; Limpert et al., 2007). A more thorough understanding of habitat selection during migration requires a multi-scale approach. Selection may be initially based on landscape features such as topography, watersheds, and landmarks that serve as benchmarks and guidelines for navigation. Landscape-level habitat choices are followed by finer-resolution selections based on habitat components and microhabitat features. At

each level habitat features are evolutionarily or behaviorally selected (Krebs, 2001) and enhance an animal's fitness by providing shelter, forage, or mating opportunities. Hoary bats may use landmark features such as topography, emergent trees, rivers and large bodies of water, and roads to navigate during long-distance migrations. When selecting for a roost along the migrational pathway they may choose areas in proximity to these landmark features or they might make smaller-scale selections for certain vegetation types, microclimate, or other factors.

Many long-distance migratory birds select stopover locations based on forage and refueling opportunities (Gómez et al., 2017), however migratory tree bats may not select stopover roosts for food resources. Male hoary bats in Northern California reduce the use of conventional echolocation and do not regularly feed during autumn (Corcoran and Weller, 2018). A study on another tree-roosting long-distance migrant, the silver-haired bat (*Lasionycteris noctivagans*), found that most bats captured during the autumn carried fat stores equal to 19 percent of their body weight, an amount that could likely fuel an entire migration (McGuire et al., 2012). McGuire adopted the term “torpor-assisted migration” to describe the use of torpor during migration to minimize thermoregulatory costs and reduce the need of foraging in stopover sites (McGuire et al., 2012).

If selection of habitat components in stopover locations is not directed by foraging prospects, hoary bats may be selecting habitat that provides shelter or reduces the energetic cost of migration. Previous roost selection studies found that hoary bats select roosts that minimize the energetic costs of thermoregulation (Klug and Barclay, 2013; Willis and Brigham, 2005). Maternal hoary bats select sites that increase radiant warming

(Willis and Brigham, 2005; Klug et al., 2012). In a summer study in Manitoba, Canada, roosts consistently had an opening that faced south, were well-protected from the wind, and offered a high degree of solar exposure (Klug et al., 2012). The radiant warming offered by the selection of these microclimate features is thought to mitigate the cost of thermoregulation and encourage rapid growth of offspring (Klug et al., 2012; Klug and Barclay, 2013). Roosts of maternal bats were more often found in trees the same height as the surrounding forest canopy than other potential roosts on the landscape (Willis and Brigham, 2011). Lack of canopy emergence likely provided protection from convective cooling due to wind (Willis and Brigham, 2011).

Using intermittent torpor during long-distance migrations allows migratory tree bats to complete long-distance migrations with fewer energetic costs than those incurred by birds during stopovers (McGuire et al., 2012). Male hoary bats engage in frequent use of torpor during the spring and autumn migration, and will enter torpor often when air temperatures drop below 25 degrees Celsius (Cryan and Wolf, 2003, Weller et al., 2016). Torpor enables bats to minimize energy and water loss during inactivity (Szewczak, 1997). In the spring, females maintain normothermic body temperatures, presumably to optimize embryonic growth (Cryan and Wolf, 2003). Whether females use torpor during the autumn migration has not been determined.

A torpor-assisted migration strategy enables bats to prevent energy and water loss, however arousal from torpor also has significant metabolic costs (McGuire et al., 2014). To mitigate this cost, bats likely select roosts where they can exploit passive solar-assisted re-warming through direct sunlight exposure or selecting slope aspects that



accumulate radiation during the day (McGuire et al., 2014; Willis and Brigham, 2005).

Solar radiation is widely considered an important roost selection criterion component of roost by bats (Menzies et al., 2016), however most prior studies using solar radiation as a habitat component focused on pregnant or lactating female roost selection during the summer (Klug et al., 2012; Willis and Brigham, 2011). An autumn roost selection study of little brown bat (*Myotis lucifugus*) roosts in Colorado found no evidence that roosts were selected for access to solar radiation (Neubaum, 2018). Solar duration recorded by GPS data loggers on hoary bats in the autumn in Northern California suggest direct exposure to sunlight at day roosts (T. Weller, unpublished data).

Another driver of selection of habitat components in stopover locations may be reproductive fitness. Mating in hoary bats occurs during autumn migration (Cryan et al., 2012). Hoary bats exhibit distinct differences in seasonal distribution between males and females (Cryan, 2003). In the summer, males are most frequently encountered in mountainous regions of the West and females are most often observed east of the Rocky Mountains (Cryan, 2003). Distribution of occurrence records indicates that both males and females move coastward in the late summer and autumn (Cryan, 2003). Winter records suggest that both female and male bats winter in coastal California and some males winter in Mexico. Because male and female hoary bats migrate coastward from separate summer ranges, it is likely that mating occurs at rendezvous sites along the route during the autumn (Cryan et al., 2012). Male hoary bats captured during the autumn show signs of mating readiness including sperm in the caudae epididymides and enlargement of accessory sexual glands (Cryan et al., 2012). However specific rendezvous locations have

not been determined for the hoary bat although males and females both travel through California in the autumn. Because both males and females undergo long-distance migrations during the mating season it has been proposed that landscape-level selection along the migratory corridor may be determined by landmark features such as emergent trees (Cryan and Brown, 2007).

Emergent trees are large trees in canopy positions above neighboring vegetation with crowns exposed to extremes of sun and wind (Van Pelt et al., 2016). Emergent trees exist in old-growth forests due to cyclical disturbance patterns and processes that can take centuries (Van Pelt et al., 2016). In contrast, areas subjected to conventional logging often lack vertical stratification of tree height. Structural heterogeneity is preserved in modern logging practices by leaving legacy trees, large snags, or green trees that vertically diversify the canopy and functionally serve as emergent. Other forest roosting bat species have been found to select emergent trees as day roosts (Vonhof and Gwilliam, 2007). Bats interested in emergent trees as landmarks or rendezvous points may roost near them or establish territories or leks around them (Cryan, 2007), however a lack of emergent trees in an area could provide shelter from the wind (Campbell et al., 1996).

Much of the existing literature on hoary bat day roosts specifically address the selection of male and female bats during the summer (Constantine, 1959; Constantine, 1966; Perry and Thill, 2007) and some studies are specific to female selection summer maternity season (Klug et al., 2012; Willis and Brigham, 2005). Constantine (1958, 1959, 1966), in a series of ecological observations across Northern California, Georgia, and Iowa, noted that the hoary bat and other species of the genus *Lasiurus* chose roosts near

edge habitat that seemed to minimize the risk of predation. He found that *Lasiurus* selected roosts that allowed bats to be undetected except by inspection from below, occurred where they could drop downward to initiate flight, lacked lower perches from which birds or other animals might detect the bats, had dark ground cover which provided a minimum of reflected sunlight, had thick vegetation, and occurred on the south and southwest side of trees. Perry and Thill (2007) located roosts of male and female hoary bats in Arkansas during summer and found that hoary bats roosted in areas with thick understory and tended to have mature overstory trees (>50 years old). Willis and Brigham (2005) found that reproductive female hoary bats in Saskatchewan chose summer day roosts that were on the southeast side of trees and roosted in trees that had a canopy that was even with the surrounding overstory canopy, likely to minimize exposure to wind. Another study of reproductive female hoary bats found that summer roost selection in Manitoba favored roosts that had protection from wind, exposure to sunlight, and an opening in foliage that faced south (Klug et al., 2012).

Only a few studies have investigated bat roost selection during the migration periods (Brack, 2006; Neubaum et al., 2006; Neubaum, 2018). During this time of transition from summer to winter roosts it becomes a challenge to capture migratory species reliably, locate roosts, and predict when to tag individuals before they leave the area. A further complication is the limited transmission range and battery expectancy of bat-appropriate small transmitters, coined the “small animal problem” (Holland and Wikelski, 2009). The limited battery capacity of small transmitters and the rapid attenuation of signals, particularly in steep terrain, restricts use of very high frequency

(VHF) telemetry as a technique to study bats (Jonasson, 2017). The battery longevity of lightweight VHF transmitter tags light enough for bats has rarely exceeded three weeks. Further, short battery life constrains the study of bats to periods they are active and can be captured. The difficulty in locating and capturing overwintering bats renders VHF telemetry a less feasible option during this period. Miniature global positioning system (GPS) tags have recently been developed for use on small animals, however current units available with weights appropriate for bats do not have the capability to remotely download data and require recapture of the bat or recovery in the field to offload the recorded GPS data (Castle et al., 2015; Weller et al., 2016). Miniature GPS transmitters have been successfully used in studying bats in situations that enable tag recovery such as with bats that exhibit high roost fidelity or frequently return to the same capture location (Tsoar et al., 2011; Geva-sagiv et al., 2015) but it requires extraordinary effort to recapture individuals that do not show fidelity to a single roost (Weller et al., 2016).

Although tracking of migratory bats to roosts during the autumn is challenging, the benefits of understanding selection during migration could help with their conservation. Improved understanding of their movements and habitat selection during autumn may help ameliorate this problem.

The International Union for Conservation of Nature (IUCN) currently lists the hoary bat as a species of “least concern”, however hoary bat populations are threatened by wind energy development. Hoary bats are the most frequently killed species at wind energy developments in North America and the majority of fatalities occur during autumn (Arnett et al. 2013). A study in 2013 estimated that 196,190 – 395,886 bats are killed

every year at wind energy facilities (Arnett et al., 2013). The hoary bat accounts for 38 percent of mortalities. Another study in 2017 estimated that the hoary bat population could decline by as much as 90 percent in the next 50 years assuming an initial population size of 2.5 million bats and an annual population growth rate similar to other bat species (Frick et al., 2017). Region-wide summer decline of hoary bats was also supported by Bayesian occupancy modelling that compared acoustic grid surveys from 2003-2010 and 2016-2018 (Rodhouse et al., 2019). Because population estimates are difficult to produce for bat species, we do not know what proportion of the population is lost from wind energy development each year, however we do understand that the species is in decline. For conservation efforts it is important to increase our knowledge of this species, especially during the autumn migration when a majority of mortalities occur.

Although summer roosts potentially share some characteristics with autumn roosts, hoary bats may benefit from selecting roosts during the migratory and mating season that minimize energetic costs of torpor arousal, while also providing mating opportunities. I hypothesized that energetic and thermal considerations would drive roost habitat selection by hoary bats during autumn. Specifically, I predicted that roosts would be located in areas that maximize available solar radiation during the second half of the day and that roosts will occur on south facing slopes. I also predicted that roost sites would have greater canopy emergence than surrounding habitat because hoary bats may be using emergent canopy as landmarks during migration and potentially as rendezvous locations for mating.

I conducted a roost selection study to determine habitat components selected by male hoary bats in a migratory stopover location. I quantified day roost selection on a home-range scale (third-order selection) as defined by Johnson (1980). My third-order design analysis followed design *I* as defined by Thomas and Taylor (2006). This study design indicates that measurements are made at the population level and individuals are not identified in the analysis (Thomas and Taylor, 2006). The “available” habitat is from the entire study area; which in this study it was more specifically the area in which transmitters could be detected.

This is the first habitat selection study of hoary bats during the autumn, and one of the few autumn studies of any species. Given that autumn is the period when bats migrate and mate this season is critically important to population persistence. I used variables identified as significant in previous studies on species of *Lasiurus* roost selection during the summer as well as variables that I thought may be important during autumn migration. Because I hypothesized that energetic optimization and access to mating opportunities drives roost selection during the autumn, I wanted to assess the relative importance of solar exposure, aspect, and emergent canopy in day roost selection, as these variables may aid in thermoregulation and mating behaviors. I also considered other habitat variables in my study including elevation, distance to meadow, distance to road, canopy height, and forest type that have been common to other studies of tree bat roost selection.

## METHODS

I located roosts using VHF and GPS telemetry and used remotely sensed habitat variable data to evaluate roost selection of male hoary bats during the autumn in northern California. I used a newly developed programmable VHF radio transmitter with a battery life of up to seven months (Lotek Wireless; Ag392; Klüg-Baerwald et al., 2017) to gain additional information about the seasonal residency of my study area and identify roosts during times of year when capture and tag deployment opportunities were limited.

### Study Area

Humboldt Redwoods State Park (HRSP; Figure 1), Humboldt County, California, USA (10 T 414228 4467094, WGS 1984 UTM Zone 10N) is a forested area that includes one of the largest continuous old-growth coastal redwood (*Sequoia sempervirens*) forests (Rohde, 1992). Hoary bats have been captured in high densities in HRSP since monitoring programs were developed by the US Forest Service Pacific Southwest Research Station in 2010, providing a unique opportunity for capture and tag deployment. The mild climate at this coastal, low elevation site may facilitate overwintering by hoary bats (Weller et al., 2016).

Old-growth redwood forest within the park totals nearly 4,000 hectares. In addition to old-growth redwood, the park includes lands that were acquired by California State Parks subsequent to logging (Rohde, 1992). Dominant tree species in post-logging

areas of the park include second growth coastal redwood (*Sequoia sempervirens*), Douglas fir (*Pseudotsuga menziesii*), tanoak (*Notholithocarpus densiflorus*), red and white alder (*Alnus* sp.), and Pacific madrone (*Arbutus menziesii*).

The park includes the Bull Creek watershed, a large tributary to the Eel River. The flow rate of Bull Creek peaks in January (mean=308 ft<sup>3</sup>/s, calculation period=1960:2018, USGS) and nearly dries during the warmer months of the summer (USGS, 2018). The park is easily accessed by Mattole Road which generally runs parallel and adjacent to Bull Creek. Some historic logging roads are maintained for recreation including horseback riding, hiking, and mountain biking. These gravel roads are also maintained by HRSP for management purposes.



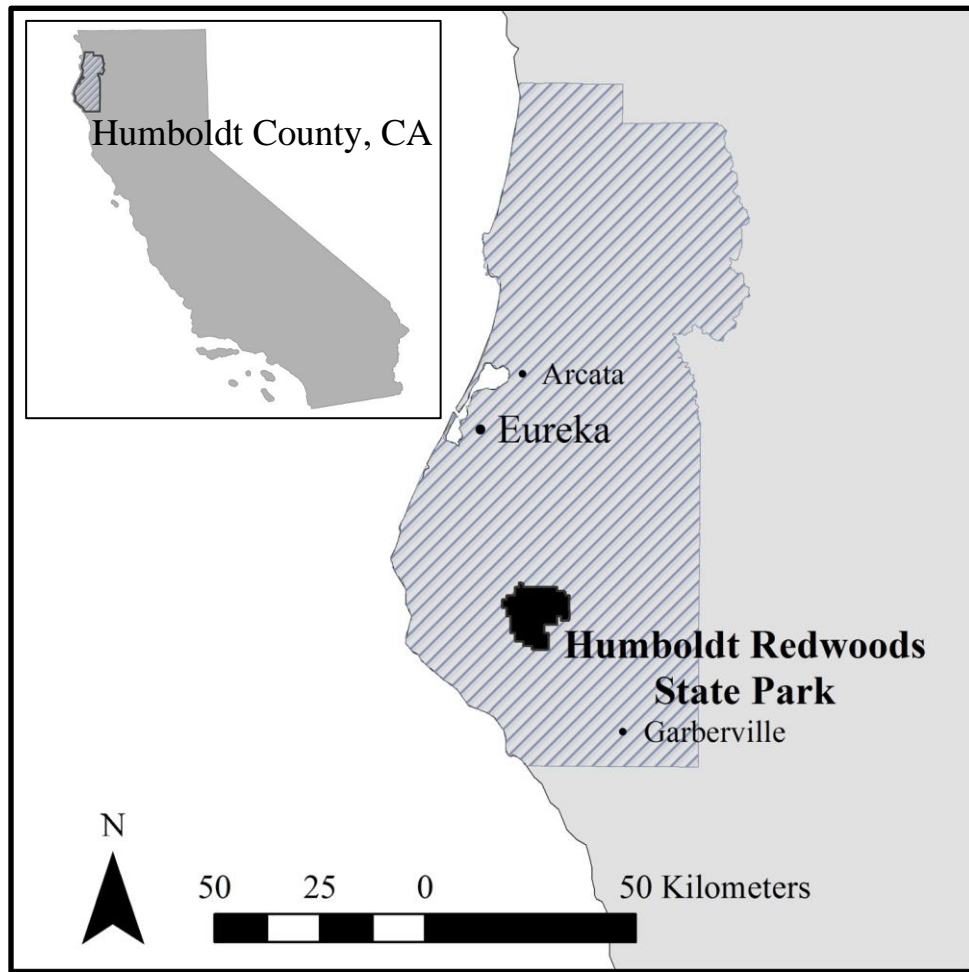


Figure 1: Locator map showing the study site, Humboldt Redwoods State Park, in Humboldt County, California.

### Capture and Tag Deployment

Hoary bat roost sites were located using multiple tag types over multiple years. The primary capture and tagging for my study occurred September 16 – October 27, 2017. I used standard 2.6-meter nylon mist-nets in a triple-high configuration to capture bats in six locations along an approximately five-kilometer section of Bull Creek

(Appendix A). Mist-netting began at sunset and nets stayed open for three and a half hours or until all tags designated for use on that night had been deployed. Nets were checked every 10 minutes and I recorded the species, age, sex, reproductive status, body measurements, and mass of all bats captured. Hoary bats were held for one hour starting at the time of capture to collect guano presumed to indicate foraging prior to capture, due to the rapid gut transit time in insectivorous bats (Roswag et al., 2012).

### Tag Types and Attachment Method

In 2017 I used two types of VHF transmitter to locate hoary bats roosts: 1) connectivity VHF transmitters (Ag392, Lotek Wireless, Newmarket, Ontario, Canada; mass: 1.3g) with a battery duration of up to eight months (Klüg-Baerwald et al., 2017) and 2) standard VHF transmitters of two different sizes (mass: 0.3g and 0.6g) with battery durations of 2-3 weeks. Connectivity transmitters offered the ability to detect activity and locate roosts within the study area for several months with the limitation that the tags would not be active every week, in order to preserve battery. Changes in individuals' occupancy of the study area would be unknown during weeks when tags were inactive. Connectivity tags were programmed to be active for 111 days over an eight-month period (Appendix B and C). Tags were active continually during September and October, eight days of each calendar month from November through March, and active continually in April for the duration of the battery. The specified schedule was

intended to conserve battery during the winter when probability of bat movement was assumed to be lower.

The connectivity transmitters were attached with a temporary dissolvable suture technique. This method has been shown to be a safe and effective solution for long-term transmitter attachment on bats (Castle et al., 2015). Standard VHF tags were attached by trimming the hair between the bats' scapulae and affixing the transmitter with a small amount of surgical adhesive to the individuals' dorsum with the antennae oriented posteriorly, extending past the uropatagium and tail (Amelon et al., 2009).

Animal handling and transmitter attachment protocol was approved by the Institutional Animal Care and Use Committee of the United States Forest Service Pacific Southwest Research Center (IACUC no. 2017-014) and the radio telemetry and tracking protocol specific to this project, was approved by the Institutional Animal Care and Use Committee of Humboldt State University (IACUC no. 17/18.B.77-E).

### Stationary Telemetry Receiver

An autonomous data-logging VHF receiver (Lotek Wireless, SRX-800; air-to-ground detection range: approximately 5 km) was installed on a hillside meadow north of Bull Creek. The location was chosen to provide maximum reception range of transmitters in the Bull Creek watershed. The data-logging receiver was operational 24 hours per day and operated without failure from September 23, 2017 through May 10, 2018. The stationary receiver consisted of three 5-element Yagi antennae (Lotek Wireless) elevated

on a 5-meter pole, solar panel, 12-volt battery with a charge controller and a weatherproof enclosure, and an autonomous Lotek receiver (Lotek SRX-800). The three antennae were oriented 120 degrees relative to one another to provide directionality of detections. The receiver was programmed to scan each active frequency on each antenna for 15 seconds before switching to the next active frequency. This programming ensured scans for an individual transmitter occurred approximately every half hour.

### Locating Day Roosts

Detections from the stationary data-logging receiver, scans of active frequencies using a car-mounted omnidirectional receiver, and triangulation of signals from designated scanning locations informed day roost searches. Roosts were located during the day by tracking hoary bats on foot with hand held radio telemetry receivers (Lotek Wireless, SRX-D800; Communications specialists, R-1000) using a homing technique (Amelon et al., 2009). Once the vicinity of the signal was determined, the roost area was identified by incrementally decreasing search area, walking 360 degrees around the source of the signal, and identifying an area where the best signal was being emitted. I identified the most likely roost tree based on signal strength and direction and designated it as the center point of the roost area. Due to canopy height and structural complexity of forest in HRSP, it was often difficult to unequivocally determine the exact tree in which the bat was roosting. A minimum of one hour at each roost was spent attempting to locate the tagged hoary bat using binoculars, but I was never able to observe a roosting bat. As a

result, I limited inference and analyses to landscape level habitat selection. Roost plots were defined by using the basal location of the most-likely roost tree and creating a 0.1-hectare circular plot (radius: 17.8 meters) around this location for spatial analysis.

To supplement sample size from the 2017 season, additional roost locations were obtained in 2018 by tracking bats that had VHF transmitters attached to a tag that recorded bat vocalizations (similar to Egbert-Berg et al., 2018; Appendix D). These tags had a battery lifetime of 2-3 weeks and were primarily for a separate study in HRSP. I also included day roost locations of male hoary bats that were ascertained via GPS-tracking during 2014 – 2016 (Weller et al., 2016; Appendix D). We assigned the GPS locations as the center of a 0.1-hectare plot as we did with roost areas determined via VHF telemetry.

### Available Habitat

Although what is biologically available to the hoary bats I tagged in HRSP far exceeds the state park boundary, I restricted available habitat in my analyses to areas of HRSP where remotely sensed light detection and range (LiDAR) data were available to ensure the same resolution of remotely sensed habitat variables. I further restricted the study area to account for areas that may have been obscured from VHF detection due to limitations in transmitter range and steep topography. I used ArcGIS to create a VHF coverage map that reflected my ability to receive signals from transmitters from my scanning locations along roads and from prominent overlooks (Figure 2). An available

habitat coverage map was created by combining 1) one-kilometer buffers of all habitat around roads; 2) one-kilometer buffers of all habitat around high-elevation lookouts where telemetry scans were conducted regularly; and 3) five-kilometer buffers of all habitat that was line of sight around high elevation lookouts. I calculated viewsheds using the spatial analyst tools in ArcGIS using an offset height of two meters above the ground from lookout location and five meters above the ground for the stationary telemetry tower.

The VHF coverage map was used to generate available habitat locations for comparison of selected bat day roosts to available habitat. I used a five-to-one ratio of used bat roosts to available habitat points to create a representative sample of available habitat across the field site (Neubaum, 2018; Northrup et al., 2013). Five available locations per roost site were generated in ArcMap using the Create Random Points algorithm (Figure 2). I assumed that the entire study area was available to every bat given that hoary bats are known to move up to 70 km in a single night during the autumn (Weller et al., 2016).

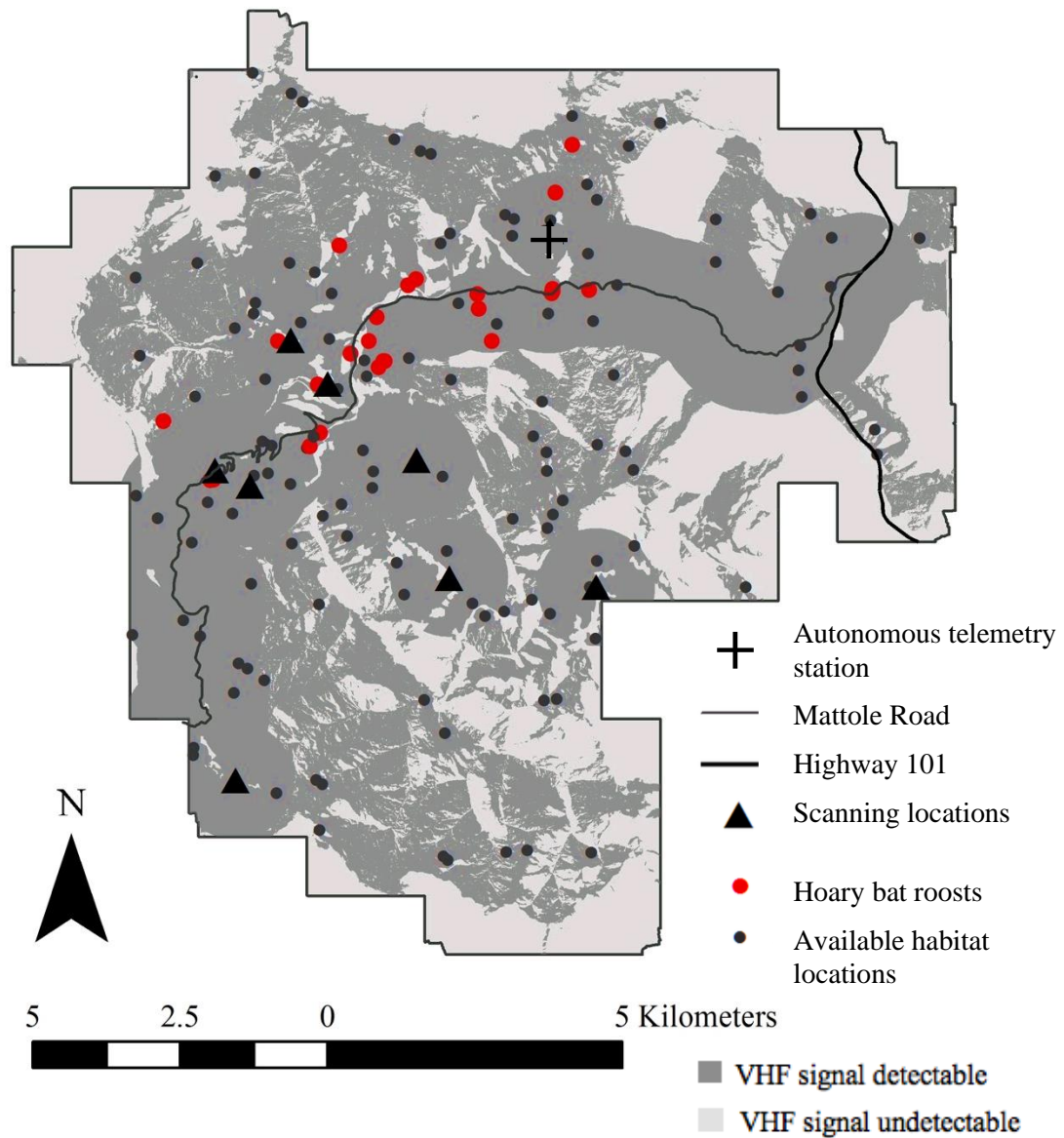


Figure 2: Area considered as available habitat for randomly generated VHF points in Humboldt Redwoods State Park. Available habitat was restricted based on viewshed calculated from high elevation VHF telemetry scanning locations and buffered road access and scanning locations from which VHF scanning regularly occurred (available=shaded). Meadows and areas where vegetation was predominantly coyote brush were not considered available roost habitat.

## Remotely Sensed Habitat Data

I considered the following variables to distinguish roost sites from available habitat: vegetation type, elevation, maximum canopy height, emergent canopy, distance to road, distance to meadow, and solar radiation (Table 1). In my study area, elevation was correlated with distance to water and therefore acts as a proxy for distance to Bull Creek. Dominant tree-type was a categorical variable determined from polygons using a vegetation map created by HRSP Meadow and road locations were derived from shapefiles created by HRSP. Distance to meadow and distance to road calculations were completed by using the Euclidean Distance tool in the Spatial Analyst toolbox in ArcMap which creates a distance raster for each variable.

Canopy height data was extracted from 1m LiDAR data collected in 2007. There is a strong consensus that LiDAR data is accurate and valuable when used at the correct spatial scale for habitat selection studies (reviewed by Davies and Asner, 2014). Canopy height was extracted from LiDAR point cloud returns. I chose to use the maximum canopy height available within a 0.1-hectare plot for my measurement of canopy height. The same LiDAR data were used to extract elevation and aspect from a digital elevation model (DEM).

Canopy emergence was quantified by extracting the mean canopy height from a 1-hectare plot and subtracting from the maximum canopy height available within a 0.1-hectare plot.



Table 1: Spatial variables, data type and resolution, source from which original data was acquired, and method used for data preparation and extraction to roost locations.

<b>Spatial variable</b>	<b>Data</b>	<b>Methods</b>
Elevation	1m digital elevation model (DEM) raster	Point extractions
Distance to roads	Vector- polyline	Euclidean distance tool; point extractions
Distance to meadows	Vector- polygon	Euclidean distance tool; point extractions
Solar Radiation Daily	1m canopy height model raster del raster	ArcMap Area Solar Radiation tool. Maximum height within 0.1-hectare circular plot (hours: 0-24)
Solar Radiation AM	1m DEM and 1m canopy height mo1m DEM and	ArcMap Area Solar Radiation tool. Maximum height within 0.1-hectare circular plot (hours: 0 -12)
Solar Radiation PM	1m canopy height model raster del raster	ArcMap Area Solar Radiation tool. Maximum height within 0.1-hectare circular plot (hours: 12-24)
Canopy height (maximum)	1m canopy height model raster	Maximum height within 0.1-hectare circular plot
Canopy emergence	1m canopy height model raster	Maximum height within 0.1-hectare circular plot minus mean height within 0.1-hectare circular plot
Aspect	1m DEM	Point extractions; Deviance from 225 degrees
Vegetation type (Redwood, Douglas-fir, Tanoak, Douglas-fir – Tanoak Mixed)	Polygon	Point extractions from vector

I used the program R (version 1.1.419) and ArcMap (ESRI, ArcGIS version 10.5.1) for all spatial analyses and extractions of habitat variables. Canopy height measurements were extracted from a raster of the differences between first and last returns of a 1-meter resolution LiDAR point cloud. Solar radiation was calculated in ArcGIS with the Area Solar Radiation tool in the Spatial Analyst Toolbox. The original raster used for analysis was a raster of the first returns of the 1-meter LiDAR point cloud. I used this surface raster, functionally a summation of the Digital Elevation Model (DEM), as well as the canopy height model to account for tree canopy that may be shaded during times of day due to higher areas in the canopy surrounding that point. Roosts were categorized by the calendar week in which they were first found occupied. Available habitat locations were randomly assigned a date corresponding to one of the roost locations, maintaining the 1:5, roost location:available location ratio of the study design. A raster for each week was created by constraining the total surface elevation model to the 0.1-hectare plots occupied during a day. The Area Solar Radiation tool was used to calculate direct insolation duration at occupied roosts during a day. Raster files from all weeks were merged using the Raster Calculator function in ArcGIS. Median and maximum values for canopy height and solar radiation were extracted for each used and available roost site using the R packages, RGEOS, SPATSTAT, RASTER, RGDAL, MAPTOOLS, and RGEOS. I chose to analyze separate AM, PM, and total daily solar radiation calculations in univariate calculations to determine which of these measures best predicted roost use by bats.

## Statistical Analyses

Since individuals exhibit preferences, multiple roost locations for individuals were not considered independent as defined in Hurlbert (1984). I could not claim independence in my variable measurements because data were collected repeatedly from the same individuals over time. Nevertheless, I chose to pool the results following this preliminary analysis due to the greater statistical power from a larger sample size that includes multiple roosts from some individuals (Amelon et al., 2009). Because information on bat roosts is limited and difficult to obtain, the practice of including >1 used site per individual is common (Limpert et al., 2007; Perry and Thill, 2007; Klug et al., 2012; Neubaum, 2018). This is not limited to forest bats. I found examples of this for other taxa, especially in the early years of work with them (Menkens and Anderson, 1987; Ganey and Balda, 1994). I also considered the difficulty in obtaining this information on roost locations and the lack of previous research on hoary bat day roosts during autumn in particular. However, each roost was only considered once, regardless of how many days that roost remained occupied.

I used general linear models (GLM) in the form of a logistic regression to compare hoary bat roost locations and available habitat points. I generated simple regression models for remotely sensed habitat variables, using indicator variables for each vegetation type. I used the results from simple regression models to inform my selection of variables in multiple logistic regression models (Slinker and Glantz, 2008) and avoid overfit regression models with my small sample size. If a univariate model was

not statistically significant ( $p < 0.05$ ), I did not consider that variable in multiple regression models (Carter and Feldhamer, 2005). I did not include variables in the multivariate analysis that were highly correlated ( $r \geq 0.7$ ), retaining the variable with the higher p-value for multiple logistic regression. Multiple logistic regression models were created to describe habitat selection considering all possible subsets of the remaining variables. I used a stepwise regression technique using an algorithm provided by the R package, PASWR and a model-comparison package, MuMIn, to compare models.

I used a bias-corrected Akaike Information Criterion ( $AIC_c$ ; Burnham and Anderson, 1998) to rank multiple logistic regression models that used the habitat selection variables: elevation, distance to water, distance to roads, maximum canopy height within plot, maximum direct duration of solar exposure, slope aspect, and vegetation type. I used univariate logistic regression to initially weigh the relationship between each variable independently with roost selection, and then used multiple logistic regression to find the combination of variables that described most of the variation between roosts (Limpert et al., 2007; Bellamy et al., 2013; McGarigal et al., 2016). I used univariate models to determine the best measure of solar radiation to include in multiple regression models (similar to scale optimization in McGarigal et al., 2016) and to remove variables from consideration that did not improve the null model significantly.

The VHF coverage map was used to limit shapefiles of dominant vegetation type to that which I was able to survey. Although I included vegetation type in GLM analysis, I chose to also use a chi-square goodness of fit test to determine the importance of vegetation type variables because I felt that proportion of available hectares would be a

more accurate representation of the study area. I used the total area of each dominant tree species within my VHF-constrained study area, including redwood, Douglas-fir, Douglas-fir – tanoak, tanoak, red/white alder, and madrone, to calculate an expected proportion of roosts per habitat type. I compared this expected proportion to the proportion of roosts that occurred in each forest type with a chi-square goodness of fit test to determine whether selection was occurring for forest type. To determine whether selection for canopy emergence differed between redwood roosts and other forest types I used analysis of variance (ANOVA).

Since a majority of hoary bats roosts were found from VHF telemetry on foot, there was a possibility that roosts were biased towards more easily accessible sites (i.e. lower elevations, closer proximity to roads and meadows). To determine if my final multiple logistic regression model was biased based on location method, I split my data into hand-held VHF-located roosts and GPS roosts. Using Tukey's 'Honest Significant Difference' test to compute a multiple comparison between means, I compared the VHF roost located from the ground with GPS-determined roosts.

## RESULTS

### Identifying Roosts

During the autumn of 2017, 36 male hoary bats were equipped with connectivity VHF transmitters (Appendix E). Connectivity transmitters averaged 5.7 percent of individual bats' masses. In addition, 10 male hoary bats and one female were equipped with shorter-term VHF transmitters. The two styles of shorter-term VHF transmitters averaged 1.2 and 2.6 percent of individuals' body mass, respectively. Twenty day roosts were located in 2017, including two female roosts and four male roosts that occurred during the winter (Figure 3). In 2018, 26 male hoary bats and one female were equipped with acoustic tags that weighed 2.9 grams and averaged 11.9 percent of the bat's mass. Bats with microphone tags were tracked to nine day roosts including one female roost. The greatest number of roosts located for one bat was four (Figure 3). Seven locations from three bats with GPS transmitters were obtained within the boundaries of the state park.

### Proximity Restrictions and Pooling

Four roosts were considered duplicates and removed from the study prior to analysis because they were within a 17.8-meter proximity of another roost of the same individual and I could not discern with certainty that the bat was roosting in a different tree than the prior location (Appendix F). Also, due to proximity of the latter plots the

method I used to determine the maximum canopy height and direct duration of solar radiation within the plots would overlap, providing additional reason to exclude these duplicate points. Roosts from all other male hoary bats during autumn were pooled for analysis for a total of 25 day roost locations from 15 individual bats.

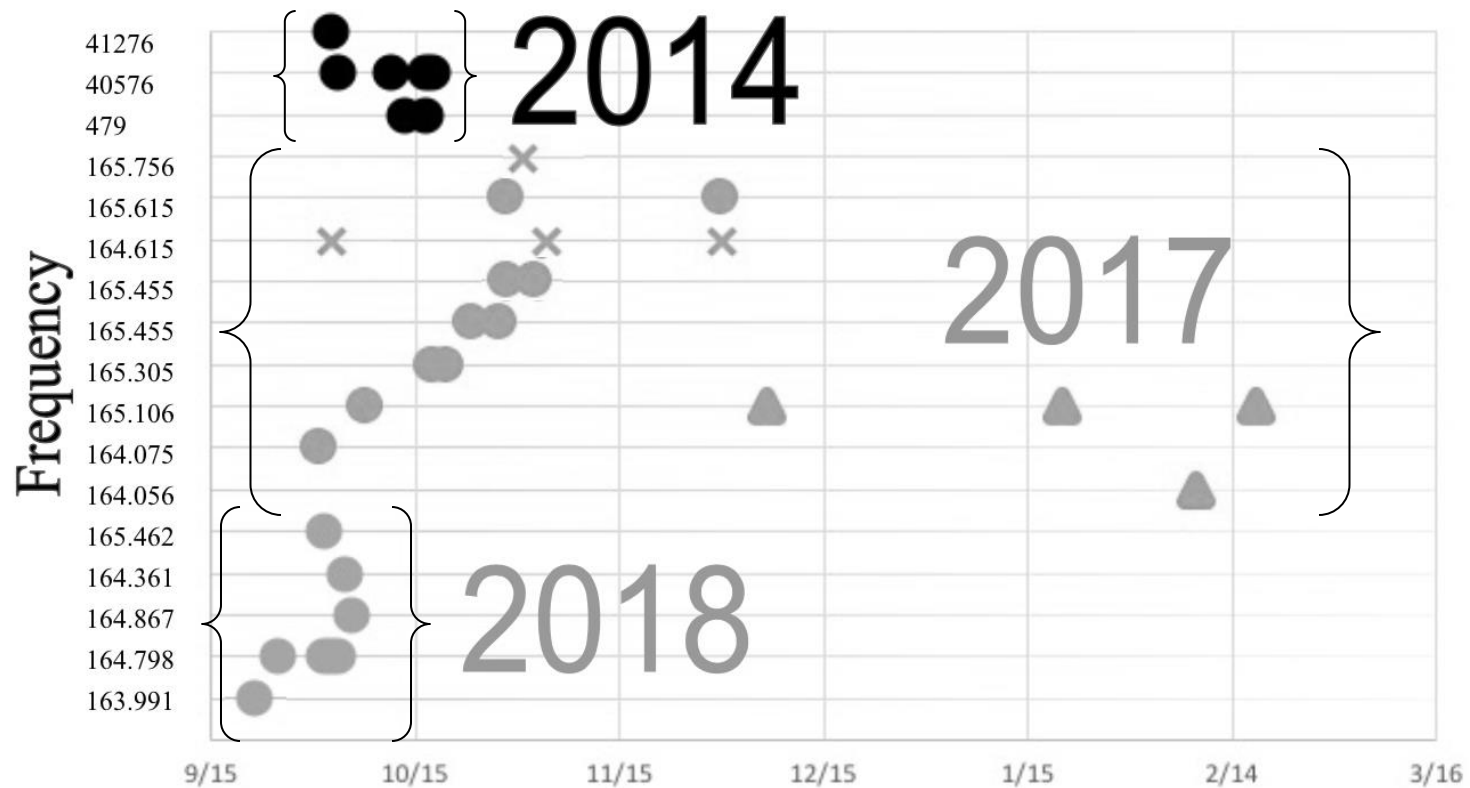


Figure 3: Timeline of roost locations per individual categorized by year: 2014 – 2016, 2017, and 2018. Points represent roosts used in analysis (n=25), x's represent points removed from dataset prior to analysis due to proximity (<17.8 meter) to a previously existing point for that individual (n=4), diamonds represent female roosts withheld from analysis (n=3), and triangles represent winter roosts, also withheld from analysis (n=4). Black symbols are GPS located roosts and grey symbols are VHF located.



### Univariate Analysis of Male Autumn Roost Selection

Univariate analysis comparing hoary bat roost plots (n=25) and available habitat (n=125) eliminated three variables from consideration in multiple logistic regression models (Table 2). AM solar radiation, PM solar radiation, aspect, and all of the vegetation type indicator variables were not significantly different from the null model (deviance was within two points of the null model which used no habitat variables) and were not further considered (Figure 4). The variables canopy height, distance to meadow, distance to road, elevation, emergent canopy, and solar radiation were retained for multiple regression models (Figure 5; Appendix G). There were no multicollinearity concerns with the remaining variables and they were included as covariates in multiple regression models. Linear correlation coefficients ranged from -0.29 (canopy height ~ solar radiation) to 0.011 (canopy height ~ aspect).

Although separate calculations for AM and PM solar exposure were not different between roost plots and available habitat plots, the total daily solar radiation was greater in roost plots ( $p < 0.05$ ). Maximum cumulative solar radiation during the day in which the roosts were found occupied averaged 9.23 hours compared to the available habitat average, 8.74 hours.

Table 2: Mean values, standard error (SE), and range of hoary bat roosts (n=25) and randomly generated available habitat points (n=125) in Humboldt Redwoods State Park. P-values are from univariate logistic regression models of habitat variables. Shaded variables were not considered for multivariate models.

Variable	Roost Site			Random Site			P-value
	Mean	SE	Range	Mean	SE	Range	
Elevation (meters)	223.94	34.97	68.65 - 705.38	449.82	20.70	36.95 - 975.33	0.0001
Distance to Road (meters)	141.60	30.25	1.41 - 569.32	344.51	28.53	1.00 - 1494.71	0.0041
Distance to meadow (meters)	333.31	61.67	14.76 - 1182.57	790.47	68.74	11.66 - 3455.25	0.0064
Daily Solar Radiation (plot maximum, hours/day)	9.23	0.13	7.51 - 9.85	8.74	0.10	3.13 - 9.85	0.0279
AM Solar Radiation (plot maximum, hours/day)	5.31	0.10	3.97 - 5.92	5.13	0.08	0.00 - 5.92	0.3675
PM Solar Radiation (plot maximum, hours/day)	5.37	0.09	3.58 - 5.92	5.19	0.06	0.97 - 5.86	0.2175
Canopy height (plot maximum, meters)	53.28	4.58	26.00 - 98.00	44.55	1.56	1.00 - 101.00	0.0363
Canopy emergence (meters)	27.03	2.08	11.76 - 51.24	21.57	0.86	-6.61 - 48.21	0.0028
Slope aspect (deviation from 225, degrees)	89.77	8.84	17.35 - 163.12	93.21	4.51	1.62 - 179.23	0.7492
Redwood	0.40	0.10	0.00 - 1.00	0.28	0.04	0.00 - 1.00	0.2030
Douglas-Fir	0.20	0.08	0.00 - 1.00	0.13	0.03	0.00 - 1.00	0.2880
Tanoak	0.16	0.07	0.00 - 1.00	0.15	0.03	0.00 - 1.00	0.9190

Roost Site				Random Site			
Variable	Mean	SE	Range	Mean	SE	Range	P-value
Douglas-fir - Tanoak	0.24	0.09	0.00 – 1.00	0.44	0.04	0.00 – 1.00	0.0693

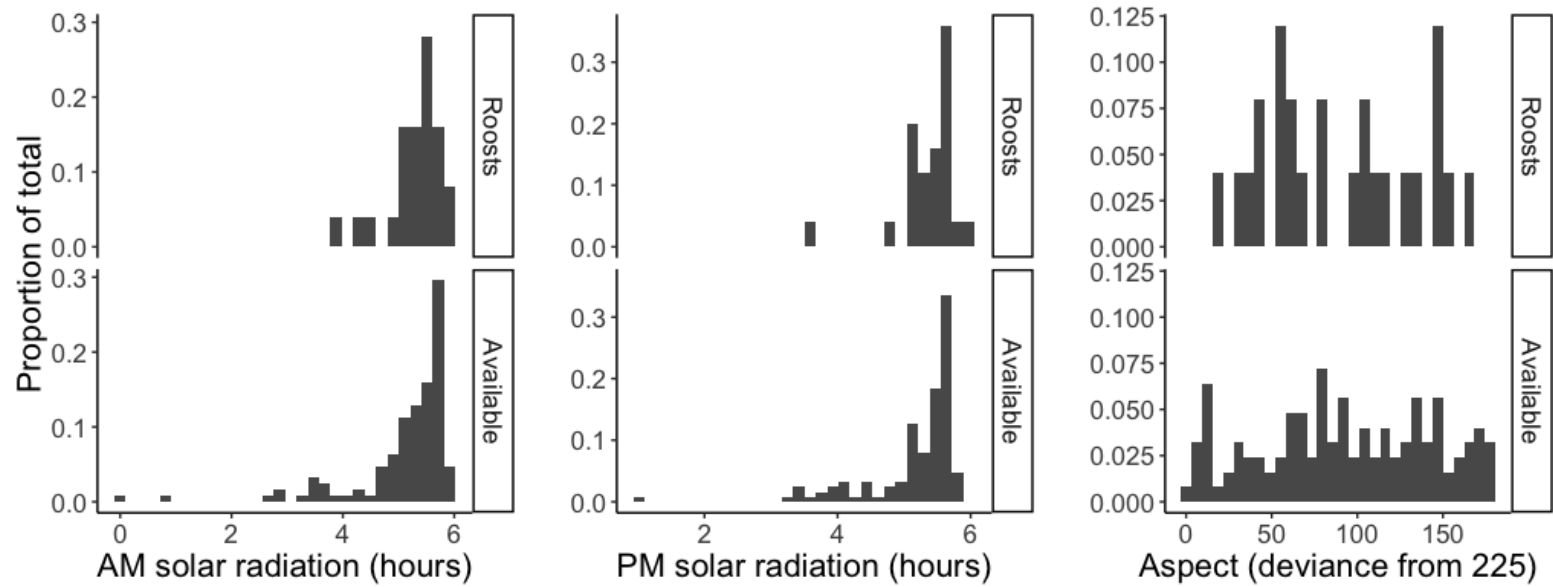


Figure 4: Histograms of habitat characteristics of hoary bat roosts (n=25) and available habitat locations (n=125). Univariate logistic regression models were not statistically significant for aspect and AM and PM solar radiation variable.

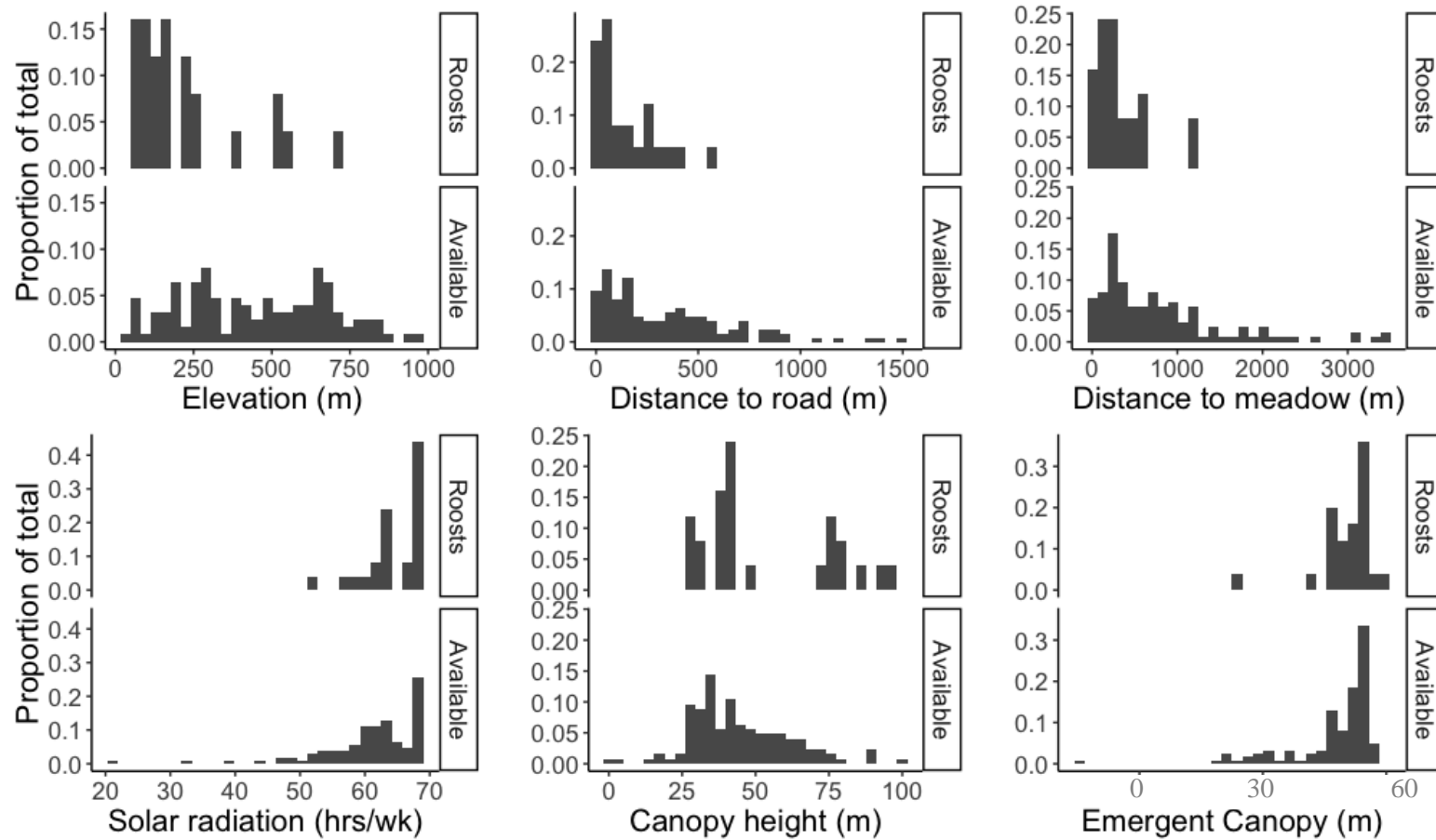


Figure 5: Histograms of habitat characteristics of hoary bat roosts (n=25) and available habitat locations (n=125). Univariate logistic regression models were statistically significant for elevation ( $p<0.001$ ), distance to road ( $p<0.005$ ), distance to meadow ( $p<0.01$ ), solar radiation ( $p<0.05$ ), canopy emergence ( $p<0.005$ ), and canopy height ( $p<0.05$ ).

Canopy emergence was significantly greater in roost areas selected by hoary bats ( $p < 0.005$ ). The mean height of the roost site was 3.54 meters higher than the mean canopy height in the surrounding 1-hectare. Canopy emergence was significantly ( $p < 0.05$ ) higher in roost plots than in available habitat plots in redwood habitat, but not in other forest types (Figure 6).

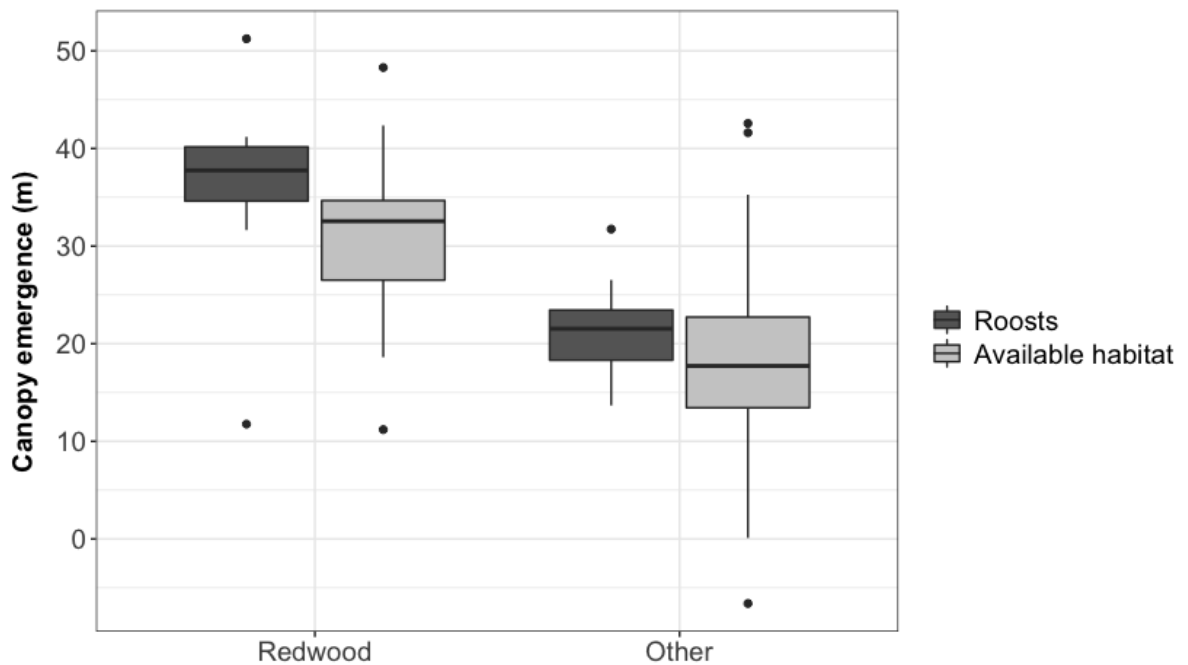


Figure 6: Box-plot of canopy emergence in redwood roosts and other vegetation types. The upper and lower and upper box boundaries the 25th and 75th percentiles, respectively, the centroid line inside box represents the median, and the lower and upper error lines indicate the 10th and 90th percentiles, respectively. Filled circles designate data falling outside 10th and 90th percentiles. Canopy emergence was significantly greater in hoary bat roost plots than available habitat sites that occurred in redwood forests ( $p < 0.001$ ). The canopy emergence of roost sites in other forest types was not significantly different than available habitat.

### Multiple Logistic Regression Models

I created a candidate model set of 64 models including all combinations of covariates (Appendix H). The highest-ranking model for hoary bat roost selection included four predictive habitat variables: elevation, distance to meadow, distance to road, and solar radiation (Table 3). However, there was high model uncertainty with three models within two AIC points of the top model, five models comprising 68 percent of the model weights and 14 models comprising 95 percent of the model weights. Together the three highest-ranking models accounted for >50 percent of the weight of all models. Because there were so many highly competitive models I used multi-model inference with AIC (Burnham and Anderson, 2002; Symonds and Moussalli, 2011).

Table 3: Ninety-five percent confidence set of the best-ranked regression models (the 14 models with cumulative Akaike weight,  $\sum w_i \leq 0.95$ ) from a candidate model set of 64 models. Degrees of freedom, log likelihood, Akaike's Information Criterion adjusted for small sample size ( $AIC_c$ ),  $\Delta AIC_c$ , and respective model weight ( $w_i$ ) are compared. The three most highly ranked models account for >50 percent of total weight of all possible models.

<i>Model ranking</i>	<i>Elev.</i>	<i>Meadow</i>	<i>Road</i>	<i>Solar</i>	<i>Canopy</i>	<i>Emergence</i>	<i>df</i>	<i>LogLik</i>	<i>AICc</i>	$\Delta AICc$	$w_i$	$Acc_{w_i}$
1							5	-45.186	100.8	0	0.262	0.262
2							4	-46.869	102	1.23	0.142	0.404
3							6	-44.974	102.5	1.75	0.109	0.513
4							6	-45.122	102.8	2.04	0.094	0.607
5							5	-46.342	103.1	2.31	0.082	0.689
6							5	-46.583	103.6	2.79	0.065	0.754
7							7	-44.947	104.7	3.89	0.037	0.791
8							6	-46.338	105.3	4.48	0.028	0.819
9							4	-48.505	105.3	4.5	0.028	0.847
10							5	-47.726	105.9	5.08	0.021	0.868
11							5	-47.756	105.9	5.14	0.02	0.888
12							4	-48.852	106	5.19	0.02	0.908
13							4	-48.879	106	5.24	0.019	0.927
14							4	-48.967	106.2	5.42	0.017	0.944

I used model averaging to generate parameter estimates (Burnham and Anderson, 2002; Symonds and Moussalli, 2011; Table 4). I averaged the top 14 models which cumulatively accounted for 95 percent of the total Akaike weight,  $\text{acc } w_i$ , of all models (Burnham and Anderson, 2002; Symonds and Moussalli, 2011). I report parameter estimates (log link), adjusted standard error (SE), associated 95 percent confidence intervals (CI), and relative variable importance ( $w_+$ ) for each habitat variable considered in the 14 models (Table 4).

Table 4: Parameter estimates, adjusted standard error (SE), 95 percent confidence intervals (CI), and relative variable importance ( $w_+$ ) of variables in predicting autumn roost use by hoary bats in HRSP, on an analysis of top 14 logistic regression models. Asterisk (\*) indicates that the CI for the parameter estimate does not include zero and is considered an important predictor of hoary bat habitat.

	<i>Parameter estimate</i>	<i>Adjusted SE</i>	<i>95% CI</i>	$w_+$
<i>(Intercept)</i>	-2.9543	4.4059	-11.7661 – 5.8574	-
* <i>Elevation</i>	-0.0049	0.0015	-0.0079 – (-0.0020)	1.00
* <i>Meadow</i>	-0.0014	0.0007	-0.0027 – (-0.0001)	0.98
* <i>Road</i>	-0.0030	0.0015	-0.0060 – (-0.0001)	0.89
<i>Solar Radiation</i>	0.1013	0.0628	-0.0244 – 0.2270	0.62
<i>Emergence</i>	0.0281	0.0363	-0.0444 – 0.1007	0.31
<i>Canopy Height</i>	0.0064	0.0189	-0.0314 – 0.0443	0.28



The equation for roost selection using model averaging and variable significance based on 95 percent confidence intervals is:

$$p(\text{roost use}) = \frac{1}{e^{-(-2.9543 - 0.0049(\text{elevation}) - 0.0014(\text{meadow}) - 0.0030(\text{road}))}}$$

The parameter estimates and odds ratios from the model for elevation show that, adjusted for the effects of distance to road and meadow, for every additional 100 meters in elevation above Bull Creek, the probability of a roost occurring would decline by 49 percent (SE=1.00). Similarly, adjusting for other variables included in the averaged model, for every 100 meters from meadows, the probability of hoary bat roost occurrence decreases 13.8 percent, and for every 100 meters from roads, the probability of occurrence decreases 30.5 percent (SE=1.00).

Of the variables contributing to multiple logistic regression candidate models, elevation, closely followed by distance to meadow and distance to road, had the highest relative importance (Table 4). Elevation contributed to all 14 of the models in the 95 percent confidence set of models, distance to meadow contributed to 13 of 14 models, and distance to road contributed to 9 of 14 highly-ranked models.

#### Chi-Squared Goodness of Fit Test for Vegetation Type Selection

Hoary bats roosted in redwood, Douglas-fir, tanoak, and Douglas-fir – tanoak dominant stands. Because no roosts occurred in red/white alder or madrone and these

habitats accounted for less than 1 percent of HRSP, I chose not to include it as a category to increase my statistical power with fewer degrees freedom (Figure 7; Figure 8). There was a significant difference between the expected and observed frequency of day roost selection among forest types ( $X^2=17.5$ ,  $df=3$ ,  $p<0.001$ ). Hoary bats in HRSP appeared to prefer Douglas-fir over other vegetation types (Figure 7). Twenty percent of roosts were located in Douglas-fir dominant habitat, while this habitat type only accounted for three percent of the available study area. Although the greatest proportion of hoary bat roosts occurred in redwood stands (40 percent), redwood habitat was selected less frequently than its proportion of the study area (Figure 7). The data I used to generate forest type categories did not differentiate between old-growth and second-growth redwood forests. It is possible that bats were selecting within the broad category of redwood forest type for old-growth or for more even-aged second-growth stands. Although I did not conduct vegetation plots at each site, I regularly found roosts in both old-growth and second-growth.

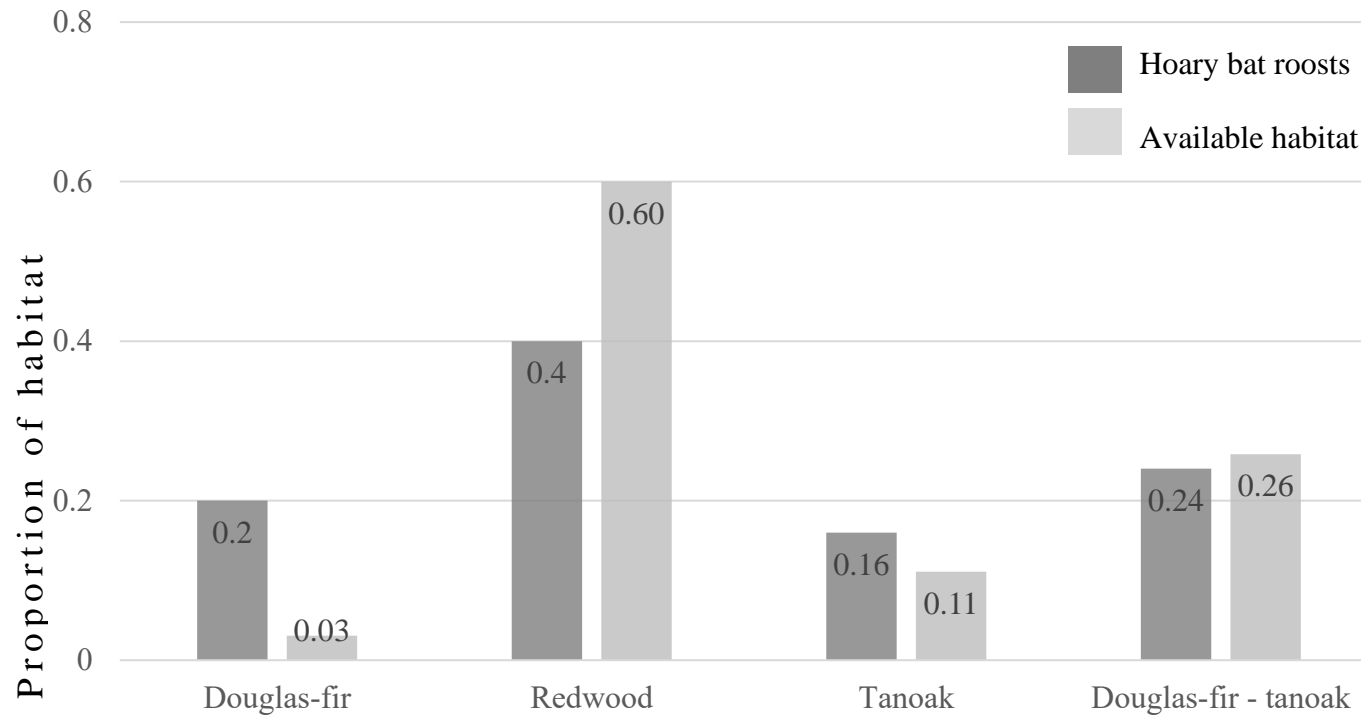


Figure 7: Proportional use and proportional availability of hoary bat day roosts in Humboldt Redwoods State Park. Black bars represent the proportion of total autumn roosts found in each dominant forest type (n=25); grey bars represent the proportion of area of each habitat to total hectares of all forest types.  $X^2$  goodness of fit suggests that there was significant selection among forest type ( $X^2=25.388$ ,  $df=3$ ,  $p<0.001$ ). Vegetation types representing <1 percent of the total available are not displayed and were not selected by hoary bats as day roosting habitat.

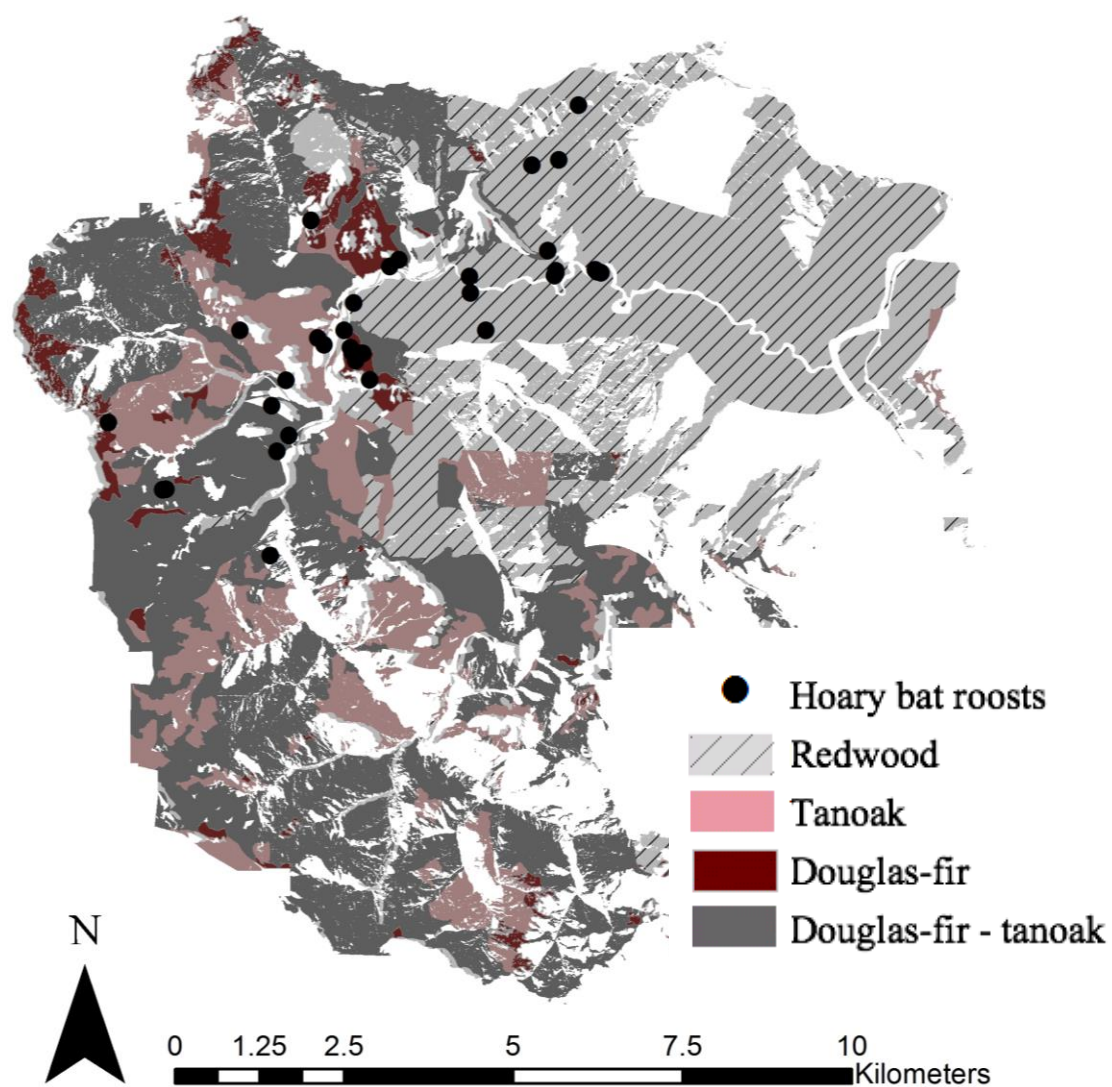


Figure 8: Vegetation designations confined to the VHF coverage area. Available habitat consisted of 12,238 hectares of redwood, 2,266 hectares of tanoak, 5,267 hectares of Douglas-fir - tanoak mixed-forest, and 630 hectares of Douglas-fir dominant forest.

### Comparison Amongst Means for Roost Location Types

Tukey's 'Honest Significant Difference' tests between ground-level VHF telemetry and GPS derived roosts yielded a significant difference between the distance to road of VHF points accrued from the ground and GPS roost locations (Figure 9). There were no significant differences between means of ground-level VHF, and GPS-detected roost sites for elevation or distance to meadows (Figure 9).

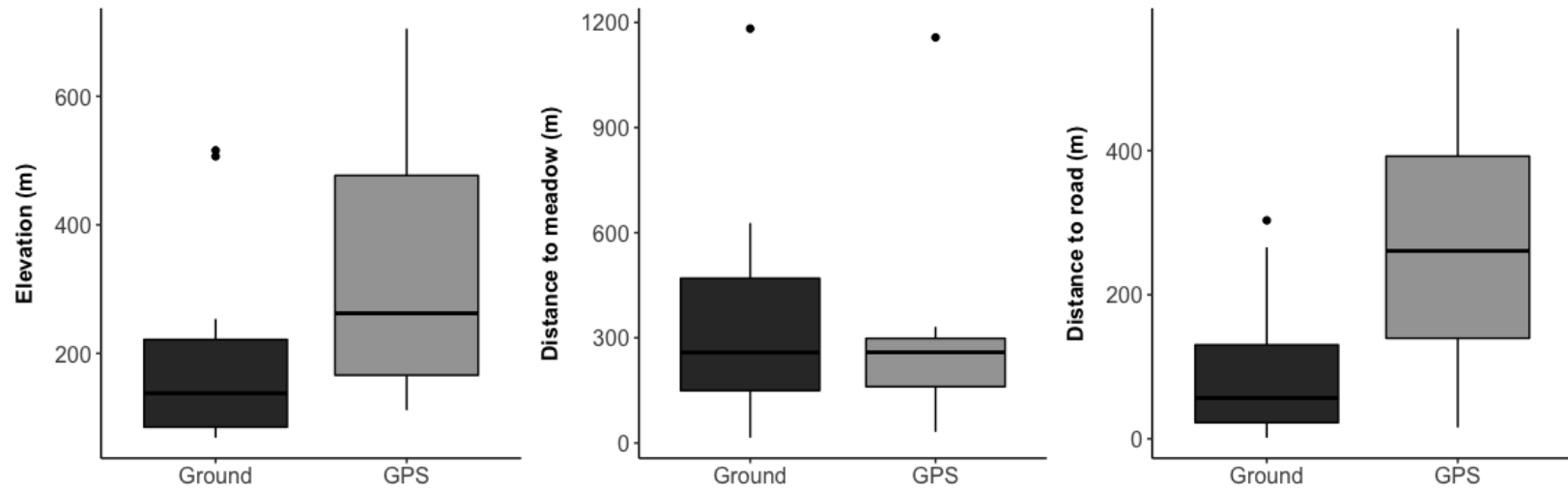


Figure 9: Box plots of roosts found at ground-level using hand-held VHF receivers and roosts located by GPS fixes. The upper and lower and upper box boundaries the 25th and 75th percentiles, respectively, the centroid line inside box represents the median, and the lower and upper error lines indicate the 10th and 90th percentiles, respectively. Filled circles designate data falling outside 10th and 90th percentiles.

### Temporal Detections of Connectivity VHF Transmitters

Of 36 connectivity VHF transmitters deployed during September and October 2017, 17 were detected at the study site following their release (Figure 10). Twelve of these bats were only detected during autumn 2017. Four of these bats were only detected until September 29, 2017. The remaining eight of these bats were detected intermittently until October 15, 2017 (Appendix K).

Three bats were detected during both autumn 2017 and briefly during spring 2018. Another bat was detected throughout the autumn-spring period. This individual was not detected in the study area for five and twenty-day stretches during autumn and seemed to be taking leaves of absence, roosting outside the study area. Another hoary bat was not detected during autumn or throughout most of winter until we tracked it to its roost site on February 9, 2018. At that time, it was discovered that the frequency of its transmitter had drifted slightly and was thus not detectable by the autonomous receiver. The autonomous receiver was programmed to this new frequency on February 17, 2018 and it was first detected by the receiver on March 3, 2018. We continued to detect this transmitter regularly, but not daily, until April 23, 2018 when, presumably, its battery died. While we know that it was present during late-winter and spring we cannot determine with certainty whether it was present or absent in the study area during autumn and early winter. Because of signal drift, difficulty of access during the winter i.e. closed roads, and limited reception range of transmitters, I cannot assume that a non-detection indicates the absence of a bat in the study area.

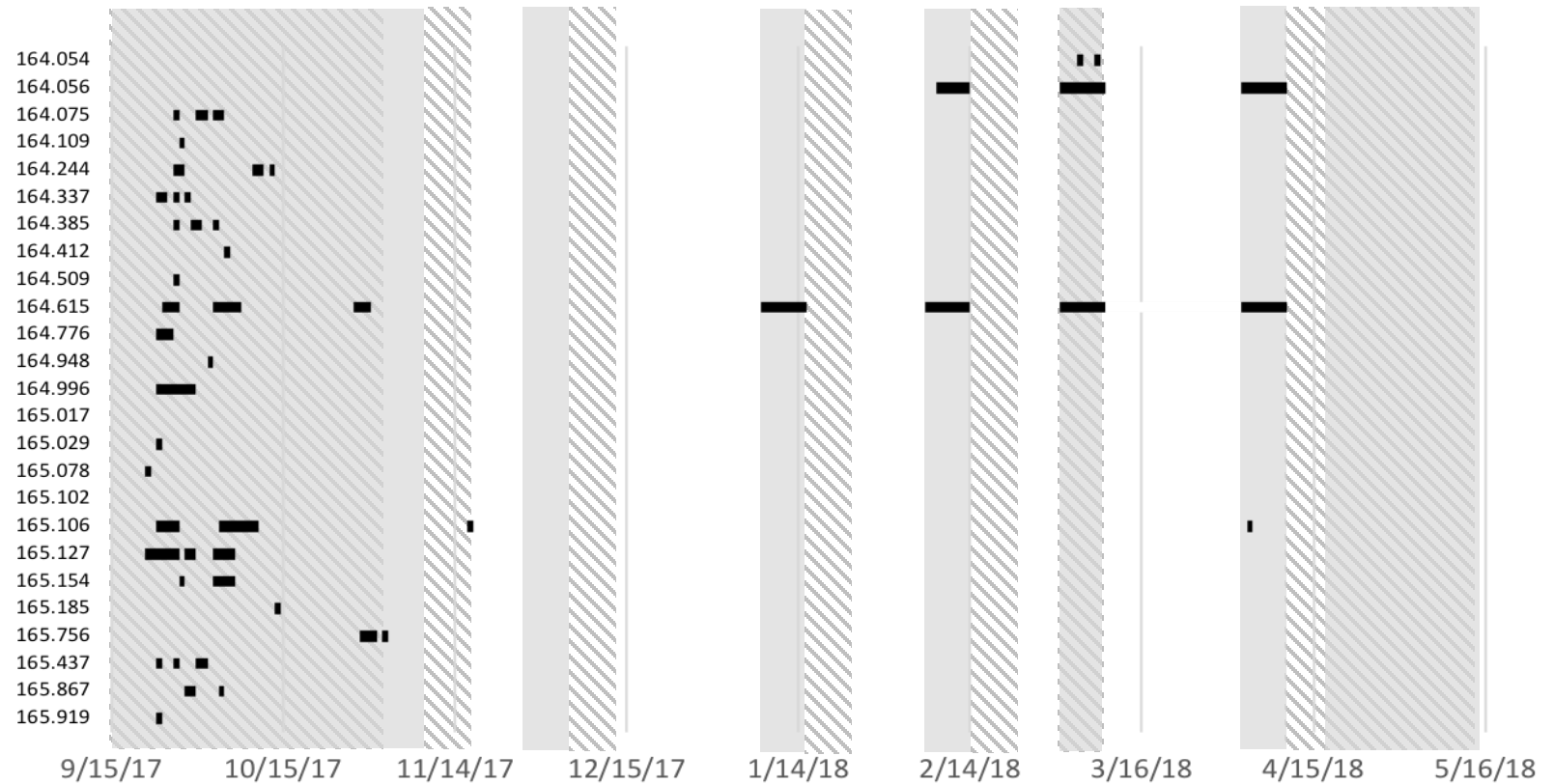


Figure 10: Connectivity VHF transmitter detections in 2017-2018 pooled from stationary receiving tower and hand-held receiver telemetry. All displayed detections from stationary receiving tower were detected within a range of 29.6-30.4 or 14.6-15.4 beats per minute. Solid gray shading represents periods when transmitters under schedule 1 were active (Appendix C), striped shading represents schedule 2 (Appendix D), shaded and striped indicates transmitters under both schedules are active.



### Female Roosts

Two female hoary bats were tagged resulting in location of 3 roosts. For consistency and to maintain biological similarity of samples, female roosts were removed from analysis. Female roosts occurred in redwood and tanoak forests. Females selected roost plots that had an average maximum canopy height of 73 meters (range: 19.2-102) at an average elevation of 87.5 meters (range: 67.6-126.7). All female roosts found were within 100 meters of a road (mean: 67.0; range: 22.5-114.1) and an average of 197.6 (range: 46.5-309.4) meters from a meadow. Although sample size was small, female roosts were at numerically lower elevations and in closer proximity to roads than male roosts (Appendix I).

### Winter Roosts

Similar to female roosts, few winter roosts were located (n=4) and winter roosts were therefore removed from analysis to maintain biological similarity of selection. (Appendix J). All winter roosts were from male bats and they occurred in redwood and Douglas-fir forests. Hoary bats selected winter roost plots that had an average maximum canopy height of 54.5 meters (range: 44.0-65.0) at an average elevation of 192.6 meters (range: 115.2-283.6) All winter roosts found were within 115 meters of a road (mean: 21.6 range: 45.4-67.7) and an average of 252.5 (range: 14.3-418.1) meters from a meadow.

## DISCUSSION

I predicted that hoary bat roost selection during the autumn was driven by reducing the energetic costs of migration as well as increasing mating opportunities. Because hoary bats do not appear to forage regularly during autumn in my study area, energetic costs would be minimized by increased use of torpor (need a general citation on how torpor for energy savings works). Therefore, I predicted that roosts would be positioned to maximize available solar radiation during the second half of the day and that they would be located on south facing slopes. I also predicted that roost plots would have greater canopy emergence than surrounding habitat because hoary bats may be using emergent canopy as landmarks during migration and potentially as rendezvous locations for mating.

I found that afternoon solar radiation, specifically, was not significant to hoary bat day roost selection, although solar radiation throughout the day was important. Hoary bats preferred roosts with a large amount of solar radiation available throughout the day. Slope aspect did not differ between used roost sites and the surrounding available habitat and roosts were found on a wide variety of slope aspects. Canopy emergence was important at the roosts that were located in forests where redwood was the dominant tree type but overall was not important to the selection of roosts.

Although it is difficult to determine what the main driver of hoary bat roost selection is during the autumn, the following discussion explores the results and offers some possible explanation and interpretation of the habitat selection being made.

## Open Spaces and Flyways

Male hoary bats selected roosts at consistently lower elevation and closer proximity to meadows and roads. These three variables collectively function as a proxy for open space i.e. flyways. Elevation correlates with distance to Bull Creek and the flyway above the creek where hoary bats were captured. Because hoary bats were captured at the creek, it is unsurprising that roosts were found nearby, however with the ability to travel long-distances in the park it is feasible that they could be detected anywhere within the study area. Accessing high elevations would not require a large energy expenditure.

The results corroborate previous studies suggesting that hoary bats choose roosts in proximity to open spaces, (Constantine, 1966; Willis and Brigham, 2005; Klug et al., 2012), albeit the other studies focused on lactating female roost selection during the summer. In a study on *Lasiurus* in Iowa, including *L. cinereus* and *L. borealis*, found that almost invariably, tree bats selected roosts along forest edge whether that edge was a meadow or a field of corn or beans (Constantine, 1966). Landscape-scale summer roost selection studies of *Lasiurus*, in Arkansas demonstrated that roost use by both males and females tend to be in thinned forests with less dense vegetation (Perry and Thill, 2007; Perry et al., 2007). Potential reasons that bats select for more open forests includes ease of navigation, maneuverability, and roost relocation (Perry et al., 2007; Vonhof, 1996). A study on eastern red bats (*L. borealis*) in Maryland demonstrated that summer roosts of male and female red bats occurred in areas with more trails, open water, wetlands, and

streams and often occurred in plots with significantly greater canopy closure and basal area than the available habitat (Limpert et al., 2007).

One possible explanation for association with roads is bias in terms of ability to detect transmitters. Road proximity between hand-held VHF telemetry and GPS-located sites differed significantly. This seems to reflect methodological bias and the difficulty in ground-to-ground locations in a highly-forested area. Because differences between location techniques did not vary significantly for elevation and proximity to meadows, I continue to draw the conclusion that proximity to flyways is a major driver of roost selection during the autumn in HRSP.

### Vegetation Type

Male hoary bats located in this study roosted in habitats dominated by redwood, Douglas-fir, tanoak, and a mixture of Douglas-fir and tanoak. Previous roost selection studies that found hoary bats roosting in diverse forest habitats with roosts occurring in white spruce (*Picea glauca*), oaks (*Quercus* spp.), short-leaf pine (*Pinus* spp.), cherry (*Prunus* spp.), cypress (*Cupressus* spp.), shrubs, fruit trees, and in mixed-species deciduous forests (Dalquest, 1943; Constantine, 1959; Willis and Brigham, 2005; Perry and Thill, 2007; Klug et al., 2012). In my study, hoary bats seemed to show a preference for Douglas-fir-dominant forests (Figure 4) and although they used redwood habitat, they did not use it in proportion to its availability, seeming to avoid it. Prior to this study I speculated that migrating or mating hoary bats might be attracted to old-growth redwoods

due to their great height and heterogeneous and complex canopy. Studies that have speculated that hoary bats may be attracted to the tallest trees on the landscape, for the purpose of navigational landmarks.

Old growth redwood may be used as navigational landmarks during long distance migrations, however I found evidence that hoary bats are not selecting specifically for redwood habitat. This result was surprising given that HRSP is one of the few locations where aggregations of bats are reliably captured in the fall and it also happens to contain one of the largest continuous old growth redwood forests. I expected that hoary bats would be using the old-growth redwood habitat for roosting, however they showed a preference for Douglas Fir forests. It is possible that redwoods are acting as landmarks and attracting hoary bats to the area but for roosting purposes they are not preferred. Perhaps there is a structural component of Douglas-fir that makes them preferable roosts for the hoary bat. Constantine (1966) noted that along edge habitat, trees seemed to lack lower branches that may act as perches for birds other animals and the lack of lower branches made it easier for hoary bats to drop downward to initiate flight from the roosts. Similarly to the trees that Constantine observed, Douglas-fir often lose their lower branches through “self-pruning” and may provide the aforementioned benefits (Kachin, 1940).

### Foraging as a Driver of Roost Selection

Although Klug (2012) suggested that female hoary bats selected habitat in proximity to flyways likely for access to foraging, I doubt this was the case in my study due to evidence that foraging is not occurring. During this study I began capture at sunset and kept mist nets open for three to four hours. Few of the hoary bats captured for this study produced guano when held in captivity for an hour after capture. Although digestive retention time has not been documented in hoary bats, Valdez and Cryan (2009) were able to regularly obtain guano sample during springtime migration when they held hoary bats for only 15 minutes. Because sunset and the hours immediately following have generally been established as a peak period for insect activity and the most productive foraging time across multiple species of bats (Rydell et al., 2006). I would expect the hoary bats captured in my study to have produced guano if they had actively foraged prior to capture. Lack of evidence of foraging suggests other behavioral motives for hoary bat activity in Bull Creek during the autumn which in turn may have influenced roost selection.

### Shelter and Energetic Reductions as a Driver of Roost Selection

Solar radiation may have contributed to roost selection in my study. Although multi-model averaging resulted in confidence intervals for solar radiation that slightly overlapped zero after accounting for elevation and distance to roads and meadows, univariate tests indicated that solar radiation was greater at roost than available habitat. In

addition, the methods I used to quantify solar radiation did not reflect the exact location of the animal, rather the maximum amount of solar exposure that is available within a plot given my uncertainty of the exact location of the roost. In the case of solar radiation, I think that my scale of analysis was poorly matched to the objective (Wiens, 1989) and that microhabitat measurements or transmitters equipped with light-sensitive data loggers would have been a more appropriate method than remotely sensed data, should such tags have existed.

My results indicated that canopy height and canopy emergence seemed to have influenced roost use. Roost sites had greater mean canopy height and greater canopy emergence than available habitat sites. Hoary bats use emergent trees as visual identifiers on the landscape to navigate during migration or for rendezvous sites during autumn mating (Cryan and Barclay, 2009), and this possibly may be reflected in their day roost selection. If bats were using emergent trees as lekking sites at night, it may be expected that males may attempt to defend such sites from other males and perhaps pre-position themselves at emergent trees during the day.

Determining the importance of canopy emergence may be improved through landscape-level analysis. The forests directly adjacent to the boundaries of HRSP, as well as much of Northern California in general, has been extensively logged since the early 1900's. On a landscape level, there is an obvious difference between the forest structure of the old-growth preserved in the park and the even-age forests outside of its boundaries. Emergent trees add structural and vertical heterogeneity to a canopy and may be attracting hoary bats to the area.

## Reproduction as a Driver of Roost Selection

Although the drivers of autumn roost selection remain unclear, the fact that this study took place during the mating season offers a potential explanation. Ninety-four percent of hoary bats captured from 2010-2018 in the Bull Creek watershed were male (T. Weller, unpublished data 2019). Male hoary bats that were captured for this study showed signs of mating readiness i.e. sperm in the caudae epididymides and enlargement of accessory sexual glands, as expected from this species during the autumn (Cryan et al., 2012).

The skewed sex ratio could result from disparate migrational pathways; however, it could also suggest that competitive behaviors drive hoary bat activity in the region during this time. Corcoran and Weller (2018) observed male hoary bats engaging in chasing behaviors in flyway areas above Bull Creek and above the road adjacent to the creek during the autumn. Additionally, they found that male hoary bats greatly reduce echolocation activity as they fly through the Bull Creek channel. This can only be successful in relatively open habitat such as roads, meadows, and stream channels.

Proximity to open flyways would facilitate access to such sites. Proximity to these open areas were precisely the variables I found important for day roost selection by male hoary bats. If habitat selection during autumn is driven by these mating or pre-mating behaviors then we would expect bats to select habitat that facilitates such behaviors.

It has not been established whether or not hoary bats form leks, however lekking behavior has been observed in other bat species (Toth et al., 2018) and proposed as an



explanation of swarming behavior, i.e. chasing, and concentrated activity of hoary bats in the autumn (Cryan, 2008). Lekking is a competitive behavior that is rare in mammals and is characterized by males that do not contribute parental care, a confined mating ground that is significantly smaller than normal home ranges, a lack of male resource defense, and female choice in mate selection. Behavior associated with lekking includes aerial courtship displays (Cryan and Brown, 2007) and could offer further explanation for hoary bats selecting roosts close to flyways.

Acoustic studies support reproduction as a driver of behavior in HRSP during the autumn. In one study, broadcast of social calls attracted male hoary bats (Reyes, 2015). Reyes (2015) suggested that their attraction may be explained by territorial or competitive behaviors (Reyes, 2015). Corcoran and Weller (2018) offer the explanation that reduced echolocation in the Bull Creek watershed during the autumn may be a stealth strategy to avoid eavesdropping by conspecific male competitors during the mating season.

It has been proposed that hoary bats may be attracted to the tallest trees available in a landscape, as gathering points during the migration season (Cryan and Brown, 2007; Cryan, 2008; Cryan and Barclay, 2009). This hypothesis was developed as an explanation for the frequently observed attraction of *L. cinereus* to wind energy turbines. Several reasons can account for a possible attraction of hoary bats to tall trees, including using tall trees as navigation landmarks, easy access to roosts when in flight over the canopy, and as potential lekking areas (Cryan, 2007; Cryan et al., 2014). Lekking or mating behavior would only apply to hoary bat aggregations in the autumn season. HRSP is the

only autumn aggregation area of male hoary bats known to date and coincidentally includes a grove of old-growth coastal redwood, *Sequoia sempervirens*, one of the tallest species of tree on earth.

In 2018, a separate study on hoary bats took place that used aircraft overflights to track VHF tags. The transmitters had usually been on bats for several days and up to a week before flights. The airplane traveled nearly 50km in all directions from the field site and located a large majority of the tags in the study area. Some of the tags located by airplane were not detected using ground-based telemetry on the same day. This strengthened my decision to limit study area to a VHF coverage map and serves as a reminder that hoary bats could have been in the study area but beyond my range of detection during autumn and winter. Observing many tagged individuals within HRSP and few outside of the state park boundaries during this 2018 study suggests that bats roosting in HRSP may have selected roosts at a broader scale during migration (Johnson, 1980; Wiens, 1989). Although the purpose of autumn aggregations of hoary bats remains unknown, the locations where these aggregations occur are unquestionably important from a conservation perspective because they are selected for by so many individuals and occur during the mating period.

Few winter roost locations of hoary bat have been recorded in North America (Cryan, 2003; Cryan and Veilleux, 2007). In this study I confirmed wintering in the study site by three individuals. Two bats that were captured and tagged during the autumn were relocated during the winter months. This documentation of winter residency contributes

to the natural history knowledge of the species and may help to guide other studies that seek to delineate winter range of the hoary bat.

At my chosen spatial scale I was able to determine specific habitat features that hoary bats select for day roost sites. My research has demonstrated that proximity to open flyways including meadows, roads, and Bull Creek drives roost selection of hoary bats in HRSP. Whether hoary bats are interested in flyways for mating or other social purposes remains unknown but seems likely given the reproductive condition of the bats captured in the park during the autumn and their behavior during this season.

Further study on hoary bat roost selection during the autumn is necessary at other spatial scales. Landscape-level analysis will likely involve regular aerial telemetry to locate tagged individuals and determine how habitat is selected across the landscape, i.e. what landmarks, watersheds, topographic features, forest structures are the basis for a stopover location. Roost tree level analysis may be more feasible in areas with lower canopy, or the use of tree-climbing may aid in collecting data at the microhabitat scale. Microhabitat habitat selection would determine how individuals conserve energy during migration i.e. solar exposure, wind protection, structural components that provide shelter.

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## APPENDICES

## Appendix A

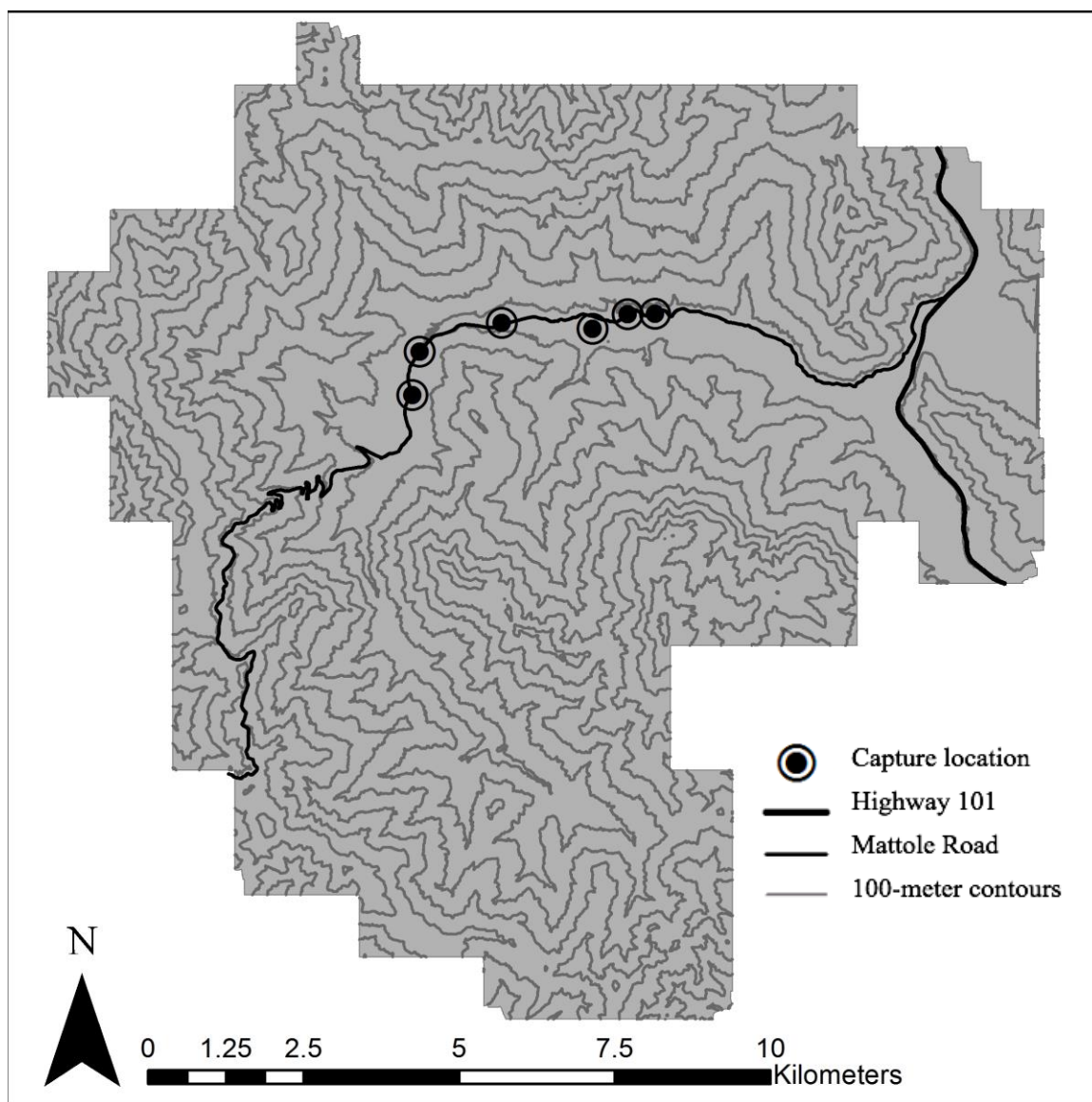


Figure 11: Hoary bat capture locations in HRSP, various access points to Bull Creek near Mattole Road.

## Appendix B

**CTx Tag Set-Up**

Deployment Date: 15-Sep-2017  
 Project Duration (months): 8  
 Battery: Ag392  
 Pulse Width (ms): 20  
 Pulse Rate (bpm): 30  
 NOMINAL weight range (g): 1.2-1.4

**Battery life**  
 Days Available: 111  
 Days Used: 111  
 Days Remaining: 0

Mon		1 25-Sep-2017	1 23-Oct-2017	20-Nov-2017	18-Dec-2017	1 15-Jan-2018	1 12-Feb-2018	12-Mar-2018	1 09-Apr-2018	1 07-May-2018
Tue		1 26-Sep-2017	1 24-Oct-2017	21-Nov-2017	19-Dec-2017	1 16-Jan-2018	1 13-Feb-2018	13-Mar-2018	1 10-Apr-2018	08-May-2018
Wed		1 27-Sep-2017	1 25-Oct-2017	22-Nov-2017	20-Dec-2017	17-Jan-2018	14-Feb-2018	14-Mar-2018	11-Apr-2018	09-May-2018
Thu		1 28-Sep-2017	1 26-Oct-2017	23-Nov-2017	21-Dec-2017	18-Jan-2018	15-Feb-2018	15-Mar-2018	12-Apr-2018	10-May-2018
Fri		1 29-Sep-2017	1 27-Oct-2017	24-Nov-2017	22-Dec-2017	19-Jan-2018	16-Feb-2018	16-Mar-2018	13-Apr-2018	11-May-2018
Sat		1 30-Sep-2017	1 28-Oct-2017	25-Nov-2017	23-Dec-2017	20-Jan-2018	17-Feb-2018	17-Mar-2018	14-Apr-2018	12-May-2018
Sun		1 01-Oct-2017	1 29-Oct-2017	26-Nov-2017	24-Dec-2017	21-Jan-2018	18-Feb-2018	18-Mar-2018	15-Apr-2018	13-May-2018
Mon		1 02-Oct-2017	1 30-Oct-2017	27-Nov-2017	25-Dec-2017	22-Jan-2018	19-Feb-2018	19-Mar-2018	1 16-Apr-2018	14-May-2018
Tue		1 03-Oct-2017	1 31-Oct-2017	28-Nov-2017	26-Dec-2017	23-Jan-2018	20-Feb-2018	20-Mar-2018	1 17-Apr-2018	15-May-2018
Wed		1 04-Oct-2017	1 01-Nov-2017	1 29-Nov-2017	27-Dec-2017	24-Jan-2018	21-Feb-2018	21-Mar-2018	1 18-Apr-2018	16-May-2018
Thu		1 05-Oct-2017	1 02-Nov-2017	1 30-Nov-2017	28-Dec-2017	25-Jan-2018	22-Feb-2018	22-Mar-2018	1 19-Apr-2018	17-May-2018
Fri		1 06-Oct-2017	1 03-Nov-2017	1 01-Dec-2017	29-Dec-2017	26-Jan-2018	23-Feb-2018	23-Mar-2018	1 20-Apr-2018	18-May-2018
Sat		1 07-Oct-2017	1 04-Nov-2017	1 02-Dec-2017	30-Dec-2017	27-Jan-2018	24-Feb-2018	24-Mar-2018	1 21-Apr-2018	19-May-2018
Sun		1 08-Oct-2017	1 05-Nov-2017	1 03-Dec-2017	31-Dec-2017	28-Jan-2018	25-Feb-2018	25-Mar-2018	1 22-Apr-2018	20-May-2018
Mon		1 09-Oct-2017	1 06-Nov-2017	1 04-Dec-2017	01-Jan-2018	29-Jan-2018	26-Feb-2018	26-Mar-2018	1 23-Apr-2018	21-May-2018
Tue		1 10-Oct-2017	1 07-Nov-2017	1 05-Dec-2017	02-Jan-2018	30-Jan-2018	27-Feb-2018	27-Mar-2018	1 24-Apr-2018	
Wed		1 11-Oct-2017	08-Nov-2017	06-Dec-2017	03-Jan-2018	31-Jan-2018	28-Feb-2018	28-Mar-2018	1 25-Apr-2018	
Thu		1 12-Oct-2017	09-Nov-2017	07-Dec-2017	04-Jan-2018	01-Feb-2018	01-Mar-2018	29-Mar-2018	1 26-Apr-2018	
Fri	1 15-Sep-2017	1 13-Oct-2017	10-Nov-2017	08-Dec-2017	05-Jan-2018	02-Feb-2018	02-Mar-2018	30-Mar-2018	1 27-Apr-2018	
Sat	1 16-Sep-2017	1 14-Oct-2017	11-Nov-2017	09-Dec-2017	06-Jan-2018	03-Feb-2018	1 03-Mar-2018	31-Mar-2018	1 28-Apr-2018	
Sun	1 17-Sep-2017	1 15-Oct-2017	12-Nov-2017	10-Dec-2017	07-Jan-2018	04-Feb-2018	1 04-Mar-2018	01-Apr-2018	1 29-Apr-2018	
Mon	1 18-Sep-2017	1 16-Oct-2017	13-Nov-2017	11-Dec-2017	08-Jan-2018	05-Feb-2018	1 05-Mar-2018	02-Apr-2018	1 30-Apr-2018	
Tue	1 19-Sep-2017	1 17-Oct-2017	14-Nov-2017	12-Dec-2017	09-Jan-2018	06-Feb-2018	1 06-Mar-2018	03-Apr-2018	1 01-May-2018	
Wed	1 20-Sep-2017	1 18-Oct-2017	15-Nov-2017	13-Dec-2017	1 10-Jan-2018	1 07-Feb-2018	1 07-Mar-2018	1 04-Apr-2018	1 02-May-2018	
Thu	1 21-Sep-2017	1 19-Oct-2017	16-Nov-2017	14-Dec-2017	1 11-Jan-2018	1 08-Feb-2018	1 08-Mar-2018	1 05-Apr-2018	1 03-May-2018	
Fri	1 22-Sep-2017	1 20-Oct-2017	17-Nov-2017	15-Dec-2017	1 12-Jan-2018	1 09-Feb-2018	1 09-Mar-2018	1 06-Apr-2018	1 04-May-2018	
Sat	1 23-Sep-2017	1 21-Oct-2017	18-Nov-2017	16-Dec-2017	1 13-Jan-2018	1 10-Feb-2018	10-Mar-2018	1 07-Apr-2018	1 05-May-2018	
Sun	1 24-Sep-2017	1 22-Oct-2017	19-Nov-2017	17-Dec-2017	1 14-Jan-2018	1 11-Feb-2018	11-Mar-2018	1 08-Apr-2018	1 06-May-2018	

Figure 12: Schedule 1 for active periods of 18 connectivity transmitters (Lotek Wireless Inc., AG392).

## Appendix C

Mon		1 25-Sep-2017	1 23-Oct-2017	20-Nov-2017	18-Dec-2017	1 15-Jan-2018	1 12-Feb-2018	12-Mar-2018	1 09-Apr-2018	1 07-May-2018
Tue		1 26-Sep-2017	1 24-Oct-2017	21-Nov-2017	19-Dec-2017	1 16-Jan-2018	1 13-Feb-2018	13-Mar-2018	1 10-Apr-2018	08-May-2018
Wed		1 27-Sep-2017	1 25-Oct-2017	22-Nov-2017	20-Dec-2017			14-Mar-2018		09-May-2018
Thu		1 28-Sep-2017	1 26-Oct-2017	23-Nov-2017	21-Dec-2017			15-Mar-2018		10-May-2018
Fri		1 29-Sep-2017	1 27-Oct-2017	24-Nov-2017	22-Dec-2017			16-Mar-2018		11-May-2018
Sat		1 30-Sep-2017	1 28-Oct-2017	25-Nov-2017	23-Dec-2017			17-Mar-2018		12-May-2018
Sun		1 01-Oct-2017	1 29-Oct-2017	26-Nov-2017	24-Dec-2017			18-Mar-2018		13-May-2018
Mon		1 02-Oct-2017	1 30-Oct-2017	27-Nov-2017	25-Dec-2017			19-Mar-2018	1 16-Apr-2018	14-May-2018
Tue		1 03-Oct-2017	1 31-Oct-2017	28-Nov-2017	26-Dec-2017			20-Mar-2018	1 17-Apr-2018	15-May-2018
Wed		1 04-Oct-2017	1 01-Nov-2017	1 29-Nov-2017	27-Dec-2017			21-Mar-2018	1 18-Apr-2018	16-May-2018
Thu		1 05-Oct-2017	1 02-Nov-2017	1 30-Nov-2017	28-Dec-2017			22-Mar-2018	1 19-Apr-2018	17-May-2018
Fri		1 06-Oct-2017	1 03-Nov-2017	1 01-Dec-2017	29-Dec-2017			23-Mar-2018	1 20-Apr-2018	18-May-2018
Sat		1 07-Oct-2017	1 04-Nov-2017	1 02-Dec-2017	30-Dec-2017			24-Mar-2018	1 21-Apr-2018	19-May-2018
Sun		1 08-Oct-2017	1 05-Nov-2017	1 03-Dec-2017	31-Dec-2017			25-Mar-2018	1 22-Apr-2018	20-May-2018
Mon		1 09-Oct-2017	1 06-Nov-2017	1 04-Dec-2017	01-Jan-2018			26-Mar-2018	1 23-Apr-2018	21-May-2018
Tue		1 10-Oct-2017	1 07-Nov-2017	1 05-Dec-2017	02-Jan-2018			27-Mar-2018	1 24-Apr-2018	
Wed		1 11-Oct-2017	08-Nov-2017	06-Dec-2017	03-Jan-2018			28-Mar-2018	1 25-Apr-2018	
Thu		1 12-Oct-2017	09-Nov-2017	07-Dec-2017	04-Jan-2018			29-Mar-2018	1 26-Apr-2018	
Fri	1 15-Sep-2017	1 13-Oct-2017	10-Nov-2017	08-Dec-2017	05-Jan-2018			30-Mar-2018	1 27-Apr-2018	
Sat	1 16-Sep-2017	1 14-Oct-2017	11-Nov-2017	09-Dec-2017	06-Jan-2018			31-Mar-2018	1 28-Apr-2018	
Sun	1 17-Sep-2017	1 15-Oct-2017	12-Nov-2017	10-Dec-2017	07-Jan-2018			01-Apr-2018	1 29-Apr-2018	
Mon	1 18-Sep-2017	1 16-Oct-2017	13-Nov-2017	11-Dec-2017	08-Jan-2018			02-Apr-2018	1 30-Apr-2018	
Tue	1 19-Sep-2017	1 17-Oct-2017	14-Nov-2017	12-Dec-2017	09-Jan-2018			03-Apr-2018	1 01-May-2018	
Wed	1 20-Sep-2017	1 18-Oct-2017	15-Nov-2017	13-Dec-2017	1 10-Jan-2018	1 07-Feb-2018	1 07-Mar-2018	1 04-Apr-2018	1 02-May-2018	
Thu	1 21-Sep-2017	1 19-Oct-2017	16-Nov-2017	14-Dec-2017	1 11-Jan-2018	1 08-Feb-2018	1 08-Mar-2018	1 05-Apr-2018	1 03-May-2018	
Fri	1 22-Sep-2017	1 20-Oct-2017	17-Nov-2017	15-Dec-2017	1 12-Jan-2018	1 09-Feb-2018	1 09-Mar-2018	1 06-Apr-2018	1 04-May-2018	
Sat	1 23-Sep-2017	1 21-Oct-2017	18-Nov-2017	16-Dec-2017	1 13-Jan-2018	1 10-Feb-2018	1 10-Mar-2018	1 07-Apr-2018	1 05-May-2018	
Sun	1 24-Sep-2017	1 22-Oct-2017	19-Nov-2017	17-Dec-2017	1 14-Jan-2018	1 11-Feb-2018	1 11-Mar-2018	1 08-Apr-2018	1 06-May-2018	

CTx Tag Set-Up	
Deployment Date:	15-Sep-2017
Project Duration (months):	8
Battery:	Ag392
Pulse Width (ms):	20
Pulse Rate (bpm):	30
NOMINAL weight range (g):	1.2-1.4
Battery life	
Days Available:	111
Days Used:	111
Days Remaining:	0

Figure 13: Schedule 2 for active periods of 18 connectivity transmitters (Lotek Wireless Inc., AG392).

## Appendix D

Table 5: GPS and VHF transmitter manufacturers and models, number of tags deployed to hoary bats, date of deployment, attachment method, expected lifetime of transmitter battery, and total mass of transmitter.

<i>Transmitter Type</i>	<i>Number of tags</i>	<i>Deployment date</i>	<i>Attachment</i>	<i>Battery extent</i>	<i>Mass</i>
<i>GPS (Pinpoint 8, Lotek Wireless, Newmarket, Ontario, Canada)</i>	3	September - October 2104	Suture	2 mo.	1.1 grams
<i>VHF (Ag392, (Lotek Wireless, Newmarket, Ontario, Canada)</i>	36	September 2017	Suture	7 mo.	1.3 grams
<i>VHF</i>	14	September 2017	Surgical adhesive	3 weeks	0.3 grams and 0.6 grams
<i>Connectivity VHF w/ onboard microphone and accelerometer</i>	29	September 2018	Surgical adhesive	1 week	2.9 grams

## Appendix E

Table 6: Roost locations obtained from each transmitter type, dates transmitters were deployed, total number of roosts found with each transmitter, and number of bats represented by the roosts that were located.

<i>Deployment year</i>	<i>Transmitter Type</i>	<i>Number of tags</i>	<i>Number of roost locations</i>	<i>Number of bats represented by roosts</i>
2014-2016	GPS	3	7	3
2017	Connectivity VHF (Lotek Wireless, Ag392)	36	12	4
2017	VHF	14	8	4
2018	VHF / recorder combo	29	8	5

## Appendix F

Table 7: Locations of roosts and associated tag type, sex of bat, date of roost discovery, and transmitter frequency for 36 roosts in HRSP. Four roosts were excluded from analysis because they were within 30 meters of an existing roosts. In addition, three roosts of female bats were excluded from analysis and four winter roosts of male bats.

ID	Easting	Northing	Type	Tag Type	Sex	Date	Freq.	Removed Data: Prox.	Remove Data: Sex (F)	Removed Data: Winter
UGPS10	416220.6	4468921	GPS	GPS	M	20141003	41276			
UGPS05	413050.2	4466402.3	GPS	GPS	M	20141004	40576			
UGPS06	409565.2	4465040.8	GPS	GPS	M	20141012	40576			
UGPS02	416508.4	4469728	GPS	GPS	M	20141014	479			
UGPS04	412555	4468023.7	GPS	GPS	M	20141017	479			
UGPS07	412231.1	4464849.6	GPS	GPS	M	20141017	40576			
UGPS08	412056.2	4464615.4	GPS	GPS	M	20141018	40576			
UVHF01	413217	4465954	VHF	Ag392	M	20171001	164.075			
UVHF02	416174	4467279	VHF	Ag392	M	20171003	164.615			
UVHF03	416158	4467210	VHF	Ag392	M	20171005	164.615			
UVHF04	416153	4467195	VHF	Ag392	M	20171007	164.615	X		
UVHF05	413322	4466064	VHF	Ag392	M	20171008	165.106			
UVHF06	413722	4467345	VHF	Cryan	M	20171018	165.305			
UVHF07	412747	4466189	VHF	Cryan	M	20171020	165.305			
UVHF08	413856	4467447	VHF	Cryan	M	20171024	165.455			
UVHF09	416789	4467264	VHF	Cryan	M	20171028	165.455			
UVHF10	416161	4467208	VHF	Ag392	M	20171029	165.615	X		
UVHF11	416844	4467253	VHF	Cryan	F	20171029	165.455		X	
UVHF12	415144	4466399	VHF	Cryan	M	20171102	165.756			
UVHF13	416174	4467246	VHF	Ag392	M	20171103	164.615			
UVHF14	416760	4467295	VHF	Cryan	F	20171103	165.455		X	
UVHF15	415137	4466413	VHF	Cryan	M	20171104	165.756	X		
UVHF16	416169	4467275	VHF	Ag392	M	20171130	165.615	X		
UVHF17	4466147	413141	VHF	Ag393	M	20171207	165.106			X
UVHF18	4466083	413158	VHF	Ag394	M	20180120	165.106			X

<b>ID</b>	<b>Easting</b>	<b>Northing</b>	<b>Type</b>	<b>Tag Type</b>	<b>Sex</b>	<b>Date</b>	<b>Freq.</b>	<b>Removed Data: Prox.</b>	<b>Remove Data: Sex (F)</b>	<b>Removed Data: Winter</b>
<b>UVHF19</b>	4467582	416057	VHF	Ag395	M	20180209	164.056			X
<b>UVHF20</b>	4465669	413420	VHF	Ag396	M	20180218	165.106			X
<b>UVHF21</b>	412658	4466289	VHF	Conn.	F	20180922	163.994		X	
<b>UVHF22</b>	414898	4467196	VHF	Conn.	M	20180924	163.991			
<b>UVHF23</b>	411510	4466398	VHF	Conn.	M	20180925	164.798			
<b>UVHF24</b>	413190	4466809	VHF	Conn.	M	20181002	164.798			
<b>UVHF25</b>	410361	4464043	VHF	Conn.	M	20181002	165.462			
<b>UVHF26</b>	414916	4466953	VHF	Conn.	M	20181003	164.798			
<b>UVHF27</b>	412188	4465663	VHF	Conn.	M	20181004	164.798			
<b>UVHF29</b>	413297	4466063	VHF	Conn.	M	20181006	164.867			
<b>UVHF28</b>	410414	4464055	VHF	Conn.	M	21081005	164.361			



## Appendix G

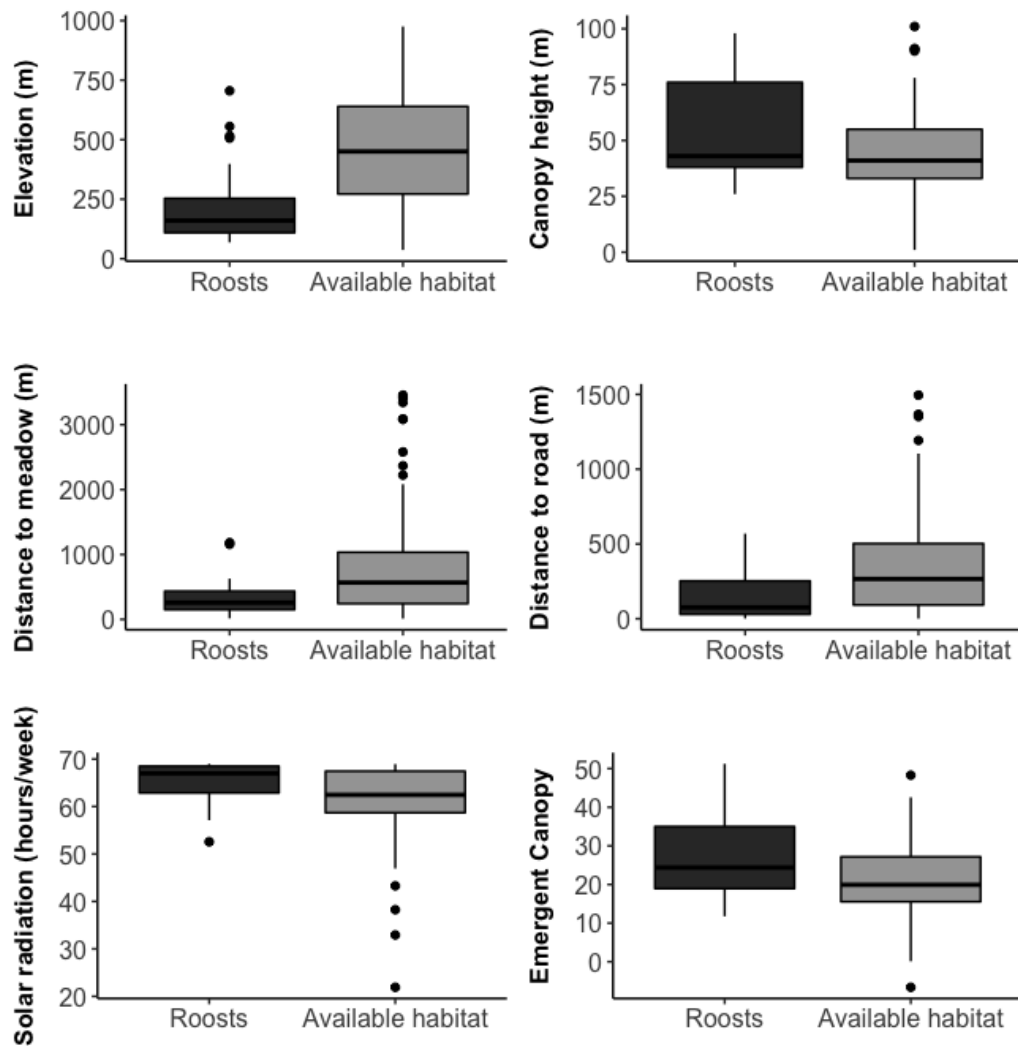


Figure 14: Boxplots showing quartile values for hoary bat roost sites (black) and randomly generated available habitat sites (grey) for habitat variables included in the highest ranked models. The upper and lower and upper box boundaries the 25th and 75th percentiles, respectively, the centroid line inside box represents the median, and the lower and upper error lines indicate the 10th and 90th percentiles, respectively. Filled circles designate data falling outside 10th and 90th percentiles.

## Appendix H

Table 8: Sixty-four logistic regression models considered in model selection.

	<i>Intercept</i>	<i>Emerg.</i>	<i>Canopy</i>	<i>Elev.</i>	<i>Mead.</i>	<i>Road</i>	<i>Solar</i>	<i>df</i>	<i>logLik</i>	<i>AICc</i>	<i>delta</i>	<i>weight</i>
61	-5.2451	-	-	-0.0050	-0.0013	-0.0032	0.1054	5	-45.1859	100.7884	0.0000	0.2617
29	1.4818	-	-	-0.0051	-0.0013	-0.0031	-	4	-46.8690	102.0139	1.2255	0.1418
62	-5.2971	0.0207	-	-0.0047	-0.0014	-0.0030	0.0972	6	-44.9745	102.5364	1.7480	0.1092
63	-5.2564	-	0.0054	-0.0048	-0.0013	-0.0030	0.1009	6	-45.1224	102.8323	2.0439	0.0942
30	0.6316	0.0300	-	-0.0047	-0.0014	-0.0028	-	5	-46.3420	103.1007	2.3123	0.0824
31	0.8765	-	0.0108	-0.0048	-0.0015	-0.0028	-	5	-46.5832	103.5830	2.7946	0.0647
64	-5.3078	0.0297	-0.0055	-0.0048	-0.0013	-0.0031	0.0982	7	-44.9473	104.6834	3.8950	0.0373
32	0.6525	0.0332	-0.0020	-0.0047	-0.0014	-0.0028	-	6	-46.3384	105.2642	4.4758	0.0279
45	-5.2597	-	-	-0.0056	-0.0015	-	0.0987	4	-48.5051	105.2860	4.4976	0.0276
47	-5.3303	-	0.0173	-0.0050	-0.0018	-	0.0859	5	-47.7262	105.8692	5.0808	0.0206
46	-5.2473	0.0360	-	-0.0050	-0.0017	-	0.0835	5	-47.7559	105.9284	5.1400	0.0200
14	-0.1212	0.0438	-	-0.0050	-0.0018	-	-	4	-48.8522	105.9803	5.1919	0.0195
15	-0.0308	-	0.0211	-0.0049	-0.0019	-	-	4	-48.8786	106.0330	5.2446	0.0190
53	-6.7043	-	-	-0.0047	-	-0.0035	0.1177	4	-48.9674	106.2106	5.4222	0.0174
13	1.0560	-	-	-0.0057	-0.0016	-	-	3	-50.1209	106.4061	5.6177	0.0158
55	-6.6569	-	-0.0104	-0.0050	-	-0.0038	0.1274	5	-48.6430	107.7027	6.9143	0.0082
16	-0.2134	0.0256	0.0112	-0.0049	-0.0019	-	-	5	-48.7202	107.8570	7.0686	0.0076
48	-5.2995	0.0189	0.0103	-0.0049	-0.0018	-	0.0831	6	-47.6475	107.8823	7.0939	0.0075
54	-6.7033	-0.0038	-	-0.0047	-	-0.0035	0.1196	5	-48.9585	108.3337	7.5453	0.0060
56	-6.6048	0.0413	-0.0253	-0.0049	-	-0.0039	0.1218	6	-48.2783	109.1441	8.3557	0.0040
21	0.6980	-	-	-0.0046	-	-0.0034	-	3	-51.9407	110.0458	9.2574	0.0026
22	0.1937	0.0171	-	-0.0044	-	-0.0032	-	4	-51.6870	111.6499	10.8615	0.0011
23	0.7028	-	-0.0001	-0.0046	-	-0.0034	-	4	-51.9407	112.1572	11.3688	0.0009
24	0.4543	0.0551	-0.0223	-0.0046	-	-0.0035	-	5	-51.1181	112.6529	11.8645	0.0007
37	-6.8914	-	-	-0.0056	-	-	0.1118	3	-53.5499	113.2643	12.4759	0.0005
58	-7.4393	0.0581	-	-	-0.0016	-0.0030	0.0930	5	-52.2069	114.8305	14.0421	0.0002
38	-6.8892	0.0101	-	-0.0054	-	-	0.1071	4	-53.4786	115.2331	14.4447	0.0002
39	-6.8948	-	0.0003	-0.0056	-	-	0.1116	4	-53.5496	115.3750	14.5866	0.0002
26	-1.7496	0.0662	-	-	-0.0017	-0.0027	-	4	-53.8305	115.9369	15.1485	0.0001
59	-7.3202	-	0.0242	-	-0.0017	-0.0028	0.0947	5	-52.8710	116.1587	15.3703	0.0001
57	-7.2906	-	-	-	-0.0013	-0.0036	0.1124	4	-54.3460	116.9678	16.1794	0.0001

	<i>Intercept</i>	<i>Emerg.</i>	<i>Canopy</i>	<i>Elev.</i>	<i>Mead.</i>	<i>Road</i>	<i>Solar</i>	<i>df</i>	<i>logLik</i>	<i>AICc</i>	<i>delta</i>	<i>weight</i>
60	-7.4300	0.0520	0.0040	-	-0.0016	-0.0029	0.0921	6	-52.1911	116.9696	16.1812	0.0001
5	0.1486	-	-	-0.0054	-	-	-	2	-56.5294	117.1404	16.3520	0.0001
40	-6.7850	0.0269	-0.0094	-0.0055	-	-	0.1066	5	-53.3710	117.1587	16.3703	0.0001
27	-1.5890	-	0.0298	-	-0.0019	-0.0024	-	4	-54.5642	117.4043	16.6159	0.0001
6	-0.6059	0.0265	-	-0.0051	-	-	-	3	-55.8715	117.9074	17.1190	0.0001
28	-1.8405	0.0540	0.0080	-	-0.0018	-0.0026	-	5	-53.7641	117.9450	17.1566	0.0000
42	-7.2807	0.0722	-	-	-0.0022	-	0.0786	4	-54.9978	118.2714	17.4830	0.0000
43	-7.3716	-	0.0358	-	-0.0024	-	0.0815	4	-55.0240	118.3240	17.5356	0.0000
10	-2.4087	0.0781	-	-	-0.0022	-	-	3	-56.2374	118.6392	17.8508	0.0000
7	-0.2925	-	0.0076	-0.0052	-	-	-	3	-56.2972	118.7588	17.9704	0.0000
11	-2.3354	-	0.0392	-	-0.0024	-	-	3	-56.3453	118.8549	18.0665	0.0000
44	-7.3577	0.0415	0.0198	-	-0.0023	-	0.0774	5	-54.5600	119.5366	18.7482	0.0000
12	-2.5824	0.0459	0.0209	-	-0.0024	-	-	4	-55.7341	119.7440	18.9556	0.0000
8	-0.5097	0.0428	-0.0096	-0.0052	-	-	-	4	-55.7561	119.7881	18.9997	0.0000
25	-0.1841	-	-	-	-0.0013	-0.0034	-	3	-57.0749	120.3141	19.5257	0.0000
49	-8.4016	-	-	-	-	-0.0042	0.1218	3	-57.4920	121.1483	20.3599	0.0000
50	-8.5011	0.0338	-	-	-	-0.0039	0.1094	4	-56.5926	121.4610	20.6726	0.0000
52	-8.4479	0.0636	-0.0181	-	-	-0.0041	0.1119	5	-56.2346	122.8859	22.0975	0.0000
51	-8.4570	-	0.0074	-	-	-0.0040	0.1163	4	-57.3130	122.9018	22.1134	0.0000
41	-7.0065	-	-	-	-0.0018	-	0.0995	3	-58.7736	123.7116	22.9232	0.0000
18	-1.9007	0.0446	-	-	-	-0.0036	-	3	-59.1922	124.5487	23.7603	0.0000
20	-1.7264	0.0682	-0.0145	-	-	-0.0037	-	4	-58.9513	126.1784	25.3900	0.0000
17	-0.7553	-	-	-	-	-0.0039	-	2	-61.1162	126.3141	25.5257	0.0000
9	-0.6870	-	-	-	-0.0019	-	-	2	-61.1605	126.4026	25.6142	0.0000
19	-1.5162	-	0.0142	-	-	-0.0035	-	3	-60.3375	126.8393	26.0509	0.0000
34	-8.5569	0.0477	-	-	-	-	0.0915	3	-62.3418	130.8480	30.0596	0.0000
35	-8.5991	-	0.0194	-	-	-	0.0955	3	-63.0461	132.2565	31.4681	0.0000
33	-8.1893	-	-	-	-	-	0.1041	2	-64.3988	132.8792	32.0909	0.0000
36	-8.5517	0.0486	-0.0006	-	-	-	0.0915	4	-62.3414	132.9587	32.1703	0.0000
2	-2.9431	0.0550	-	-	-	-	-	2	-64.4665	133.0146	32.2262	0.0000
3	-2.7521	-	0.0235	-	-	-	-	2	-65.4170	134.9156	34.1272	0.0000
4	-2.9473	0.0544	0.0004	-	-	-	-	3	-64.4663	135.0970	34.3086	0.0000
1	-1.6094	-	-	-	-	-	-	1	-67.5842	137.1954	36.4070	0.0000

## Appendix I

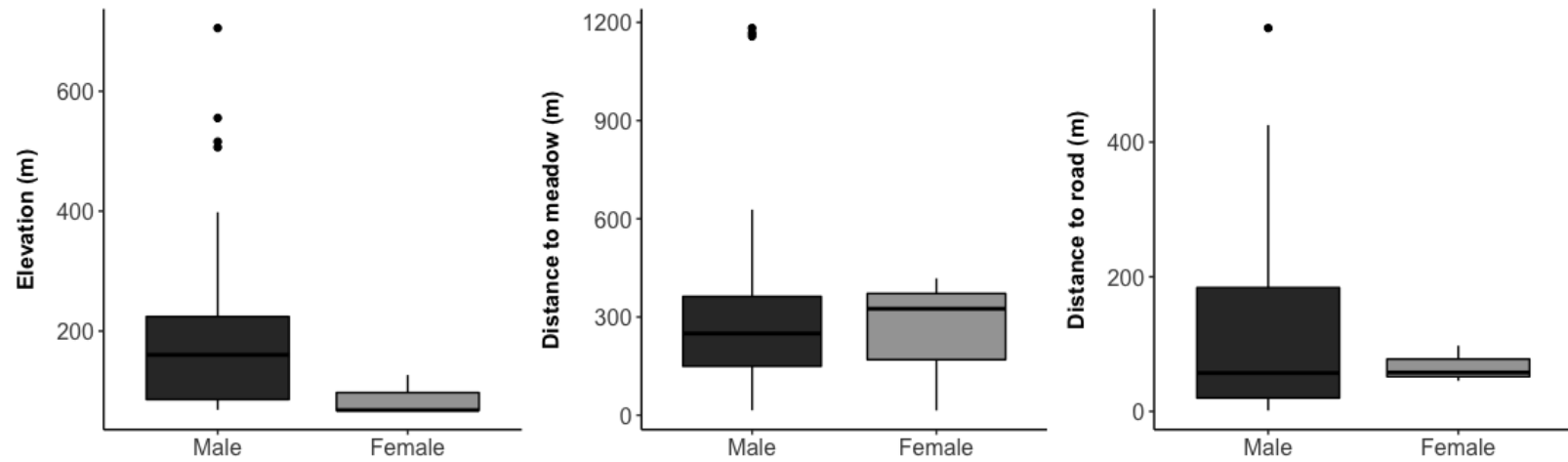


Figure 15: Boxplots showing quartile values for male hoary bat roost sites (black) and female roosts (grey;  $n=3$ ) for habitat variables deemed significant through model averaging. The upper and lower box boundaries represent the 25th and 75th percentiles, respectively, the centroid line inside the box represents the median, and the lower and upper error lines indicate the 10th and 90th percentiles, respectively. Filled circles designate data falling outside the 10th and 90th percentiles.

## Appendix J

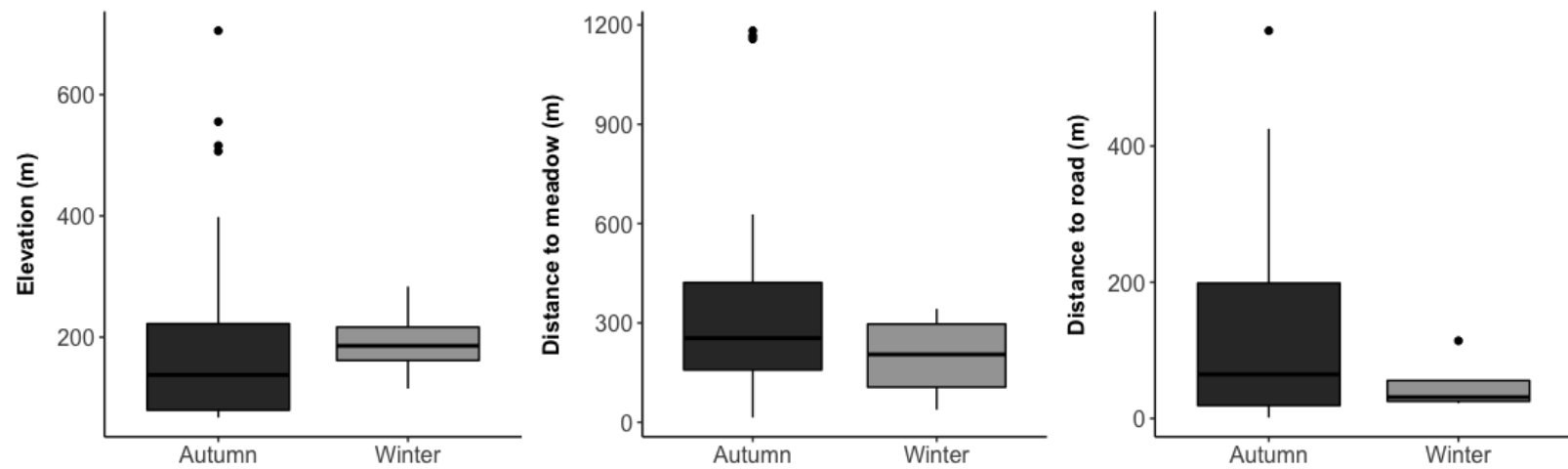


Figure 16: Boxplots showing quartile values for autumn hoary bat roost sites (black) and winter roosts (grey;  $n=4$ ) for habitat variables deemed significant through model averaging. The upper and lower box boundaries represent the 25th and 75th percentiles, respectively, the centroid line inside the box represents the median, and the lower and upper whiskers indicate the 10th and 90th percentiles, respectively. Filled circles designate data falling outside the 10th and 90th percentiles.

## Appendix K

Table 9: Hand-held telemetry log for roost searches in the 2017 – 2018 field season. Table includes date, time, signal frequency, UTM easting, UTM northing, signal strength, signal strength from Lotek detector, whether a full scan was completed, personnel, and field notes.

Date	Time	Signal freq.	UTM northing	UTM easting	Sig.	Lotek	Sig. direct	Full Scan	Field personnel	Comments
20170921	1432	165.078			W		355		S. Salganek; Isaac Henderson; Clayton Wolfe	
20170921	1628	164.125	4465720	412320	W		80		S. Salganek; Isaac Henderson; Clayton Wolfe	same area as 9/19
20170921	1646	165.125	4465365	412838	M		170		S. Salganek; Isaac Henderson; Clayton Wolfe	
20170922	1304	165.018	4467105	418191	M	74	282		S. Salganek	started getting signal at 101 driving into the park. Stopped at Calf Cr...very close to frequency 165.029 (trans. inside car)
20170922	1341	165.126	4468265	416121	W		202	Y	S. Salganek	with mobile Lotek from station
20170923	1139	165.919	4468265	416121	W		215	Y	S. Salganek; Dyami Andrade; Kaylee Underwood	at station
20170923	1148	164.996	4468265	416121	W		150	Y	S. Salganek; Dyami Andrade; Kaylee Underwood	Lotek; gain=60
20170923	1340	164.919	4464460	413710	M		259	Y	S. Salganek; Dyami Andrade; Kaylee Underwood	On Squaw Ridge Rd

<b>20170923</b>	1345	164.996	4464460	413710	M	Whiskey	60	Y	S. Salganek; Dyami Andrade; Kaylee Underwood	Below Flat
<b>20170923</b>	1350	164.339	4464460	413710	M		306	Y	S. Salganek; Dyami Andrade; Kaylee Underwood	
<b>20170923</b>	1428	164.994	4463529	414209	M		50	Y	S. Salganek; Dyami Andrade; Kaylee Underwood	Above Whiskey Flat
<b>20170923</b>	1435	164.339	4463529	414209	W		65	Y	S. Salganek; Dyami Andrade; Kaylee Underwood	Above Whiskey Flat
<b>20170923</b>	1517	164.994	4464244	414687	M			Y	S. Salganek; Dyami Andrade; Kaylee Underwood	Signal bounce like crazy
<b>20170923</b>	1527	165.438	4464244	414687	W		330	Y	S. Salganek; Dyami Andrade; Kaylee Underwood	mini receiver
<b>20170924</b>	956	164.339	4468265	416121	M		270		S. Salganek	
<b>20170924</b>	1009	165.126	4468265	416121	S	68	226		S. Salganek	
<b>20170924</b>	1125	165.339	4465673	412334	M		163		S. Salganek; Isaac Henderson; Erinn Ramirez	Lower Pole Line
<b>20170924</b>	1128	165.126	4465673	412334	M		178		S. Salganek; Isaac Henderson; Erinn Ramirez	Lower Pole Line
<b>20170924</b>	1130	165.106	4465673	412334	L		58		S. Salganek; Isaac Henderson; Erinn Ramirez	Lower Pole Line
<b>20170924</b>	1145	164.994	4465673	412334	L		88		S. Salganek; Isaac Henderson; Erinn Ramirez	Lower Pole Line
<b>20170924</b>	1255	165.125	4464203	410442	L		344		S. Salganek; Isaac Henderson; Erinn Ramirez	Switchback Saddle

<b>20170924</b>	1255	165.339	4464206	410442	L		350		S. Salganek; Isaac Henderson; Erinn Ramirez	Switchback Saddle
<b>20170924</b>	1307	165.106	4464206	410442	L		198		S. Salganek; Isaac Henderson; Erinn Ramirez	Switchback Saddle
<b>20170924</b>	1309	164.994	4464206	410442	L				S. Salganek; Isaac Henderson; Erinn Ramirez	Switchback Saddle
<b>20170924</b>	1350	165.125	Cuneo cap site		S	69			S. Salganek; Isaac Henderson; Erinn Ramirez	Cuneo Capture Site
<b>20170924</b>	1415	165.125	4466233		S	90	90		S. Salganek; Isaac Henderson; Erinn Ramirez	Homestead Trail
<b>20170926</b>	1119	165.125	4468265	416121	W		196	Y	S. Salganek	At Station (UTM copied from 9/22)
<b>20170926</b>	1122	164.339	4468265	416121	M		0	Y	S. Salganek	At Station (UTM copied from 9/22); likely bouncing off hill, get a weak signal at 180 degrees
<b>20170926</b>	1123	164.509	4468265	416121	W		150	Y	S. Salganek	At Station (UTM copied from 9/22)
<b>20170926</b>	1301	165.125	4466527		S	95	72		S. Salganek	Signal coming from across Gully
<b>20170926</b>	1323	165.106	4466769		W		126		S. Salganek	
<b>20170928</b>	1428	165.124	4468265	416116	W		220	Y	S. Salganek; Kyra Gonzales; Dyami Andrade	At station; mini
<b>20170928</b>	1707	165.867	4462234	416903	W		220	Y	S. Salganek; Kyra Gonzales; Dyami Andrade	Grasshopper Mountain
<b>20170928</b>	1740	165.125	4462234	416903	W		286		S. Salganek; Kyra Gonzales; Dyami Andrade	looking right at Pole Line Meadows



<b>20170928</b>	1740	165.339	4462234	416903	W		286		S. Salganek; Kyra Gonzales; Dyami Andrade	looking right at Pole Line Meadows
<b>20170928</b>	1838	165.339	4465667	412348	W		348	Y	S. Salganek; Kyra Gonzales; Dyami Andrade	Lower Pole Line
<b>20170928</b>	1840	165.996	4465667	412348	W		44		S. Salganek; Kyra Gonzales; Dyami Andrade	Lower Pole Line
<b>20170928</b>	1843	165.126	4465667	412348	W		88		S. Salganek; Kyra Gonzales; Dyami Andrade	Lower Pole Line
<b>20170929</b>	1150	165.125	4468265	416116	W		220	Y	S. Salganek	At station; mini; weaker signal than normal - usual direction
<b>20170929</b>	1240	165.994	4465705	412329	W		130	Y	S. Salganek	Lower Pole Line
<b>20170929</b>	1350	165.384	4462412	414430	W		212	Y	S. Salganek	Hanson Ridge Road
<b>20170929</b>	1410	164.994	4462640	414482	M		22		S. Salganek	
<b>20170930</b>	1000							Y	S. Salganek; Dyami Andrade	
<b>20170930</b>	1030	164.075	4465670	412341	S	88	106	Y	S. Salganek; Dyami Andrade	
<b>20170930</b>	1154	164.075	4465134	412864	W		204		S. Salganek; Dyami Andrade	From Drainage (East)
<b>20170930</b>	1408	164.075	4464387	413857	W		286		S. Salganek; Dyami Andrade	Squaw Ridge Road
<b>20170930</b>	1437		4466030	413933					S. Salganek; Dyami Andrade	No signal from 164.075
<b>20171001</b>	1424	164.075	4523760	410405	S	81	16	N	S. Salganek; Isaac Henderson	near meadows across creek from Pole Line Road
<b>20171001</b>	1529	164.075	4465954	413217	S	143		N	S. Salganek; Isaac Henderson	ROOST found. Signal on mini with no antennae; no eyes on bat

<b>20171003</b>	1116	164.615			L		112	N	S. Salganek	stationary receiver is detecting day roost at signal PWR=74
<b>20171003</b>	1147	164.615	4467635	416291	S	73	168	N	S. Salganek	Lotek (from Look/Luke Rd low)
<b>20171003</b>	1249	164.615	4467279	416174	S	140		N	S. Salganek	ROOST found; no eyes on bat; center of plot
<b>20171005</b>	1347	165.615			L			Y	S. Salganek	At station; mini
<b>20171005</b>	1430						188	Y	S. Salganek	Horse Meadow
<b>20171005</b>	1621	165.106	4466417	411719	W		96	Y	S. Salganek	Upper Pole Line
<b>20171005</b>	1709	164.615	4467210	416158	S	135			S. Salganek	ROOST tree located; Old Growth Redwood near 1003 but different tree
<b>20171007</b>	1215	164.615	4467195	416153	S	144			S. Salganek	ROOST area located; ~15 m radius. Hard to distinguish specific roost tree. Lots of overlap with surrounding trees
<b>20171007</b>	1307	165.106	4466417	411719	S	79	82		S. Salganek	Upper Pole Line; mini
<b>20171008</b>	1120	165.106	4465361	412846	W		14		S. Salganek; Kyra Gonzales	
<b>20171008</b>	1135	165.106	3367172	413774	W		252	Y	S. Salganek; Kyra Gonzales	Probably signal bounce
<b>20171008</b>	1214	165.106	4464514	413722	W		238		S. Salganek; Kyra Gonzales	
<b>20171008</b>	1304	165.106	4465676	413340	S	74	48	Y	S. Salganek; Kyra Gonzales	At Lower Pole Line. Near Cuneo, North of meadows?
<b>20171008</b>	1418	165.106	4466063	413310	S	159			S. Salganek; Kyra Gonzales	At nearby Madrone
<b>20171008</b>	1430	165.106	4466064	413322	S	168			S. Salganek; Kyra Gonzales	ROOST tree found - DFIR

<b>20171010</b>	1316	165.106	4466053	415135	M		88	Y	S. Salganek	Upper Pole Line
<b>20171013</b>	1255	164.244	4466062	412135	L		70	Y	S. Salganek; Alex Lewis; Erinn Ramirez	Upper Pole Line; Yagi vertical - no signal horizontally
<b>20171013</b>	1330	164.244	4464208	410432	L		10	N	S. Salganek; Alex Lewis; Erinn Ramirez	Switchback Saddle . No signal strength Lotek
<b>20171013</b>	1356		4458956	410787					S. Salganek; Alex Lewis; Erinn Ramirez	Kemp Trail Road (to R @ Kemp turn out)
<b>20171013</b>	1423							Y	S. Salganek; Alex Lewis; Erinn Ramirez	batteries died in GPS; At Meadow lookout, backside of Grasshopper
<b>20171013</b>	1507				L		29		S. Salganek; Alex Lewis; Erinn Ramirez	batteries died in GPS; At "ranger shed" near Hamilton Camp. Can only get signal with vertical Yagi
<b>20171014</b>	1151	165.306	4468265	416121	W		138		S. Salganek	At Station (UTM copied from 9/22)
<b>20171014</b>	1153	165.185	4468265	416121	M		200		S. Salganek	At Station (UTM copied from 9/22); no signal reading on Lotek receiver but medium strength beep
<b>20171014</b>	1220	165.185							S. Salganek	Blue Slide Parking lot; no signal from 165.185
<b>20171014</b>	1250	165.185	4467696	426343					S. Salganek	At lower Luke Look. No signal.
<b>20171014</b>	1400	164.244	4462231	416905	W		278		S. Salganek	Grasshopper Mountain
<b>20171014</b>	1430	165.305	4462231	416905	W		320		S. Salganek	Grasshopper Mountain; signal

										coming from Look/Luke direction
<b>20171017</b>	1200							Y	S. Salganek	At Station (UTM copied from 9/22); full scan and no signals
<b>20171017</b>	1330							Y	S. Salganek	Upper Pole Line
<b>20171017</b>	1430							Y	S. Salganek	Mid-way to Hanson
<b>20171017</b>	1510							Y	S. Salganek	Hanson Ridge Road
<b>20171017</b>	1620							Y	S. Salganek	Driving transect to Jordan from 663
<b>20171018</b>	1345	165.305	4467710	414633	W		60	N	T. Weller	Vertical antennae orientation only; direction uncertain
<b>20171018</b>	1422	165.305	4467177	413733	S		190	N	T. Weller	Mill creek interpretive sign
<b>20171018</b>	1433	165.305	4467003	414368	W			N	T. Weller	Weak signal from general direction of Bull Creek from Grasshopper Gate
<b>20171018</b>	1514	165.305	4467164	413596	S		248	N	T. Weller	West end of Mill Creek pullout - a little further on; seems to be N of Bull Creek
<b>20171018</b>	1524	165.305	4467209	413765	S	102	163	N	T. Weller	much clearer signal; bat is right here...
<b>20171018</b>	1529	165.305	4467270	413752	S	118	190	N	T. Weller	
<b>20171018</b>	1534	165.305	4467291	413690	S	111	282	N	T. Weller	
<b>20171018</b>	1535	165.305	4467345	413722	S	142		N	T. Weller	ROOST area found; no eyes on bat
<b>20171020</b>	1055	165.305	4467183	413779	W		320	N	S. Salganek; T. Weller	Mill creek interpretive sign
<b>20171020</b>	1140	165.305	4466204	412725	S	127	106	N	S. Salganek; T. Weller	
<b>20171020</b>	1141	165.305	4466181	412728	S	139	29	N	S. Salganek; T. Weller	

<b>20171020</b>	1151	165.305	4466189	412747	S	145	213	N	S. Salganek; T. Weller	ROOST found; no eyes on bat; center of plot - possible Bay tree but very cluttered canopy. Uncertain on specific tree
<b>20171020</b>	1311	165.305	4465785	412308	S	72	48	Y	S. Salganek; T. Weller	
<b>20171020</b>	1311		4465785	412308				Y	S. Salganek; T. Weller	No other signals detected; among 19 programmed in
<b>20171020</b>	1400		4467660	416324				Y	S. Salganek; T. Weller	No other signals detected; among 19 programmed in
<b>20171021</b>	1252	165.305			S	109	20	N	S. Salganek	
<b>20171021</b>	1307	165.305			S	136	7	N	S. Salganek	
<b>20171022</b>	1247	165.305	4462231	416906	S	128	23	N	S. Salganek; Jennie Jones; Erinn Ramirez; Alec Mang	
<b>20171022</b>	1305	165.305	4462231	416906	S	135		N	S. Salganek; Jennie Jones; Erinn Ramirez; Alec Mang	ROOST area; spent 20 minutes x 4 people searching for the bat
<b>20171022</b>	1441		4468265	416121				Y	S. Salganek; Jennie Jones; Erinn Ramirez; Alec Mang	Full scan and no signals
<b>20171024</b>	1024	165.455	4467443	413869	S	132	220		S. Salganek	near roost; very cluttered understory of huckleberry; young redwood near Mill Cr
<b>20171024</b>	1034	165.455	4467447	413856	S	127	177		S. Salganek	ROOST; cluster of 2nd growth RW area
<b>20171024</b>	1045	165.455	4467436	413860	S	123			S. Salganek	Center of roost 165.455

<b>20171024</b>	1135		4465677	412345				Y	S. Salganek	Lower Pole line; no signals
<b>20171024</b>	1335		4464777	412205				Y	S. Salganek	northing recorded as 421204...think that was a mistake
<b>20171025</b>	1042							Y	T. Weller	scanning from 101 exit to Mill site; no detections
<b>20171025</b>	1056		4467150	413752				Y	T. Weller	Full scan from Mill Site turnout. Only 164.455 detected. Using roof antennae.
<b>20171025</b>	1110	165.455	4467150	413752	M		9	N	T. Weller	Moderate, directional signal from mill site turnout. 165.455 sounds good on Lotek.
<b>20171025</b>	1118	165.455	4467199	414413	W		310	N	T. Weller	Weak directional signal from turnout across from Grasshopper Road
<b>20171025</b>	1124	165.455	4467146	413607	S	93	34	N	T. Weller	
<b>20171025</b>	1138	165.455	4467150	413752	S	98	10	N	T. Weller	At Mill Site turnout signal strength much greater now - varying from 90-98. Maybe bat has adjusted position a bit.
<b>20171025</b>	1145	165.455	4467248	413803	S	91	10	N	T. Weller	Closer to signal but lower strength; different line of sight.
<b>20171025</b>	1156	165.455	4467280	413899	S	94	274	N	T. Weller	Don't trust the direction of the signal from Mill turnout

<b>20171025</b>	1208		4467357	413911	S		301	N	T. Weller	Decent signal strength but no signal reading on Lotek
<b>20171025</b>	1219		4467413	413855	S	131	30	N	T. Weller	Facing uphill
<b>20171025</b>	1230		4467452	413871	S	101	172	N	T. Weller	Under canopy ...
<b>20171025</b>	1259		4467422	413859					T. Weller	Settled on a ROOST tree; It is the largest/tallest of several redwoods in a cluster. Appears to have full sun on canopy and bat seems to be at least md-way up. No earthly way to spot a bat. Best signal strength=128 is from 15 m away from the base of the tree facing back toward 20 degrees/ antennae facing south
<b>20171026</b>	1337	165.455	4467150	413752	W		20	N	S. Salganek	Signal from Mill site but no Lotek output.
<b>20171026</b>	1430	165.455	4467404	413814	S	168		N	S. Salganek	found transmitter; no bat! Transmitter on ground beneath snag; still a lot of hair attached bit no sign of carcass. Scanned trees above for bat.
<b>20171026</b>	1530		4466065	412126				Y	S. Salganek	
<b>20171028</b>	750	165.455	4468265	416121	W		148	note	S. Salganek	Scanned also for 165.669 and 165.756
<b>20171028</b>	952	165.455	4467349	416765	S	106	104	N	S. Salganek	near Shoofly capture site where this bat

										was captured last night
<b>20171028</b>	1001	165.455	4467237	416808	S	108	313	N	S. Salganek	
<b>20171028</b>	1008	165.455	4467264	416789	S	120	350	N	S. Salganek	small window - if I move 2 feet in any direction S<100
<b>20171028</b>	1020	165.455	4467254	416794	S	119	103	N	S. Salganek	
<b>20171028</b>	1031	165.455	4467294	416775	S	98	246	N	S. Salganek	
<b>20171028</b>	1035	165.455	4467247	416850	S	110	311	N	S. Salganek	
<b>20171029</b>	1514	165.455	4467661	416323	M		128	N	S. Salganek	Luke meadow
<b>20171029</b>	1516	165.616	4467661	416323			203	N	S. Salganek	
<b>20171029</b>	1518	165.756	4467661	416323			248	N	S. Salganek	
<b>20171029</b>	1537	165.615	4467193	416130	S	124	209	N	S. Salganek	
<b>20171029</b>	1541	165.615	4467187	416159	S	126	212	N	S. Salganek	
<b>20171029</b>	1543	165.615	4467208	416161	S	137	332	N	S. Salganek	
<b>20171029</b>	1545	165.615	4467177	416129	S	119	321	N	S. Salganek	
<b>20171029</b>	1548	165.615	4467185	416160	S	129	332	N	S. Salganek	
<b>20171029</b>	1553	165.615	4467202	416151	S	131	336	N	S. Salganek	
<b>20171029</b>	1555	165.615	4467213	416194	S	127	156	N	S. Salganek	
<b>20171029</b>	1601	165.615	4467223	416817	S	132	184	N	S. Salganek	
<b>20171029</b>	1642	165.455	4467341	416813	S	93	170	N	S. Salganek	
<b>20171029</b>	1648	165.455	4467334	416829	S	109	170	N	S. Salganek	
<b>20171029</b>	1651	165.455	4467226	416760	S	119	168	N	S. Salganek	
<b>20171029</b>	1653	165.455	4467300	416809	S	110	307	N	S. Salganek	
<b>20171029</b>	1655	165.455	4467253	416844	S	123	329	N	S. Salganek	
<b>20171029</b>	1658	165.455	4467262	416780	S	116	344	N	S. Salganek	
<b>20171031</b>	1200	164.615	4468278	416121	M	58	164	Y	T. Weller	
<b>20171031</b>	1200	165.455	4468278	416121	W		152	Y	T. Weller	
<b>20171031</b>	1200	165.759	4468278	416121	M		210	Y	T. Weller	
<b>20171031</b>	1300	165.759	4467769	416307	W		178	N	T. Weller	Weak, directional signal
<b>20171031</b>	1408	164.615	4467092	415739	S	71	114	N	T. Weller	Big Tree; no signal 165.759 or 164.455
<b>20171031</b>	1442	164.615	4467098	416122	S	105	357	N	T. Weller	
<b>20171031</b>	1442	165.455	4467098	416122	W		54	N	T. Weller	



<b>20171031</b>	1448	165.615	4467173	416130	S	132	6	N	T. Weller	
<b>20171031</b>	1452	165.615	4467241	416125	S	137	156	N	T. Weller	Signal Strongest towards top of form topped redwood right at Harper Cr Bridge
<b>20171031</b>	1454	165.615	4467206	416172					T. Weller	
<b>20171102</b>	1000	165.765	4466453	414909	M	60	124	N	S. Salganek	Intersection squaw and GH road
<b>20171102</b>	1112	165.765	4466477	415080	S	111	112	N	S. Salganek	
<b>20171102</b>	1135	165.765	4466466	415163	S	123	225	N	S. Salganek	On ridge/high point
<b>20171102</b>	1147	165.765	4466489	415165	S	108	185	N	S. Salganek	
<b>20171102</b>	1204	165.765	4466391	415135	S	117	149	N	S. Salganek	
<b>20171102</b>	1236	165.765	4466399	415144	S	145		N	S. Salganek	ROOST found; center of plot
<b>20171102</b>	1339		4462231	416905				Y	S. Salganek	Grasshopper Mountain
<b>20171102</b>	1401		4462090	417351				Y	S. Salganek	
<b>20171103</b>	1147	165.615	4467192	416142	S	133	285	N	S. Salganek	
<b>20171103</b>	1152	165.615	4467345	416105	S	124	134	N	S. Salganek	
<b>20171103</b>	1156	164.615	4467246	416174	S	134	18	N	S. Salganek	
<b>20171103</b>	1200	164.615	4467227	416119	S	124	82	N	S. Salganek	
<b>20171103</b>	1204	164.615	4467202	416131	S	129	208	N	S. Salganek	
<b>20171103</b>	1208	164.615	4467230	416152	S	129	228	N	S. Salganek	
<b>20171103</b>	1359	165.455	4467295	416760	S	110	196	N	S. Salganek	
<b>20171104</b>	1318	165.756	4466595	415100	S	82	208	N	S. Salganek	
<b>20171104</b>	1342	165.756	4466493	415124	S	114	159	N	S. Salganek	
<b>20171104</b>	1356	165.756	4466444	415102	S	132	118	N	S. Salganek	
<b>20171104</b>	1406	165.756	4466413	415137	S	145	44	N	S. Salganek	
<b>20171104</b>	1419	165.756	4466434	415134	S	134	229	N	S. Salganek	
<b>20171104</b>	1429	165.756	4466412	415162	S	143	281	N	S. Salganek	
<b>20171112</b>	1231		4465664	412335				Y	S. Salganek	Full scan from lower Pole Line; no signals
<b>20171112</b>	1251		4466017	412823				N	S. Salganek	Scanned for 165.016 and 165.106
<b>20171130</b>	1239	165.615	4467231	416140	S	99	150	N	S. Salganek	

<b>20171130</b>	1250	165.615	4467245	416182	S	113	309	N	S. Salganek	
<b>20171130</b>	1254	165.615	4467271	416162	S	113	130	N	S. Salganek	
<b>20171130</b>	1257	165.615	4467275	416169	S	127		N	S. Salganek	
<b>20171130</b>	1350		4468265	416121				Y	S. Salganek	At station; only picked up 164.615
<b>20171130</b>	1450		4465664	412375				Y	S. Salganek	No signals
<b>20171207</b>	1150		4468265	416114				Y	S. Salganek	Full scan Ch 18-34 from station
<b>20171207</b>	1318	165.106	4466088	413050	S	74	34	N	S. Salganek	Steep slope from Baxter/Hamilton Parking
<b>20171207</b>	1329	165.106	4466113	413116	S	99	99	N	S. Salganek	Been here before...
<b>20171207</b>	1333	165.106	4466107	416160	S	120	83	N	S. Salganek	
<b>20171207</b>	1336	165.106	4466111	413152	S	113	55	N	S. Salganek	
<b>20171207</b>	1339	165.106	4466071	413157	S	122	284	N	S. Salganek	
<b>20171207</b>	1343	165.106	4466082	413164	S	114	224	N	S. Salganek	
<b>20171207</b>	1346	165.106	4466147	413141	S	115		N	S. Salganek	ROOST; DFIR cluster; no eyes on bat
<b>20171207</b>	1438	165.106	4466069	412138	M		108	N	S. Salganek	Upper Pole Line
<b>20171207</b>	1506		4464189	410417				Y	S. Salganek	Switchback Saddle
<b>20171208</b>	1422		4468278	416121				Y	S. Salganek	at station