FREQUENCY OF OCCURRENCE AND VEGETATION SELECTION BY SOUTH TEXAS BATS

A Thesis

by

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ABSTRACT

Bats are an ecologically diverse order and important contributors to natural ecosystems. Despite their importance, detailed information on the ecology of bats is limited within the southern portion of Texas where most species found throughout the United States are located. My objective was to provide a basic understanding of the frequency of occurrence and vegetation preference by South Texas bats to aid in their management and conservation. I monitored 7 resident bat species: Evening bat (*Nycticeius humeralis*), Eastern red bat (*Lasiurus borealis*), Hoary bat (*Lasiurus cinereus*), Northern yellow bat (*Lasiurus intermedius*), Mexican free-tailed bat (*Tadarida brasiliensis*), Tri-colored bat (*Perimyotis subflavus*), and the Cave myotis bat (*Myotis velifer*) in the Texas Coastal Plains of South Texas at the El Sauz Ranch (East Foundation) throughout February-July 2022. Acoustic data were collected using acoustic monitors and the data for 25 unique nights at 25 distinct sampling locations, within 3 vegetation groups were obtained. The three vegetation groups used in my study included woodland/shrubland, rangeland/wetland, and sand. A total of 20,518 sound files were used in my analysis revealing use showed a preference for the woodland/shrubland composition with a vegetation-selection ratio of S=4.56 as well as the sand composition (S=3.01), and avoidance for the rangeland/wetland composition (S=0.35). Management practices should focus on landscape heterogeneity with a notation on the importance of conserving native woodland/shrubland areas.

DEDICATION

This thesis is dedicated to the people who have supported me through my education. To my parents, Rudy and Kelli Perez, for their unwavering support, thank you for helping me see this journey through to the end.

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CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supported by a thesis committee consisting of Dr. Roel Lopez of the Department of Rangeland, Wildlife and Fisheries Management, Dr. Andrea Montalvo of the East Foundation, and Dr. David Cairns of the Department of Geography. All data collected for the thesis were completed by the student independently.

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NOMENCLATURE

ESR	El Sauz Ranch
kHz	Kilo Hertz
m	Meter
km	Kilometer
Labo	Eastern red bat
Laci	Hoary bat
Lain	Northern yellow bat
Myve	Cave myotis bat
Nyhu	Evening bat
Pesu	Tri-colored bat
Tabr	Mexican free-tailed bat

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INTRODUCTION

Despite being more ecologically diverse than any other group of mammals and vital members of the natural ecosystems, many aspects of bats such as fine-temporal resource selection are widely understudied in “hot zones” throughout the southern portion of the United States. Bats belong to the 2nd largest order of mammals called Chiroptera (Bernard 2002). These highly innovative animals have developed a multitude of adaptations enabling them to navigate and exploit diverse ecological niches, resources, and habitats. Echolocation is one of these refined adaptations, a characteristic that is only prevalent in the bat suborder Microchiroptera and dolphins (Schnitzler and Kalko 2001). Animals use echolocation to locate objects by emitting high-frequency signals and interpreting the reflected echoes (Schnitzler and Kalko 2001). This method is employed by bats during the search for insects and agricultural pests as prey. When studying foraging behavior, the majority of research has relied on ultrasonic detectors to monitor echolocation calls, rather than directly measuring the activity of individual animals (Russo and Jones 2002).

Bats provide extremely important ecosystem services, like insect control, in regulating and improving rangelands with growing crops and livestock (Kunz et al. 2011). Bats feed on mosquitoes and other pests that are crucial to control in order to conserve land. Results of an original study concluded that a colony of bats can consume nearly two-thirds of its body weight in insects every night (Coutts et al. 1973). Some bat species are also important pollinators by feeding and dispersing seeds for nearly 300 species of fruits (Sekercioglu 2006). Bats also serve as food for owls, hawks, and raccoons. Consumptive goods indicating economic value provided by bats such as bat waste, called guano, can be used as fertilizer for agricultural plots and home gardens as it is composed of rich nutrients including nitrogen, phosphorus, and potassium (Kunz et al. 2011, Campbell 2022).

Birds are often cited in the literature as important bioindicators in agriculture, but a study done in 2008 showed insectivorous bats have stronger ecological effects than birds (Kalka et al. 2008). Extended knowledge of bat practices is crucial to determine the most appropriate methods of conservation. This study, focusing on species that reside in South Texas specifically, would provide much-needed information to aid in future conservation and management efforts.

Texas is home to almost 70% of the species of bats found in the United States (Knight 2020). However, Texas bats receive only a small fraction of scholarly attention, with only around 3% of publications focus on specific species (Fern et al. 2018). Texas also possesses the largest known bat colony in the world, Bracken Cave Preserve, which is also one of the largest concentrations of mammals on earth (Woodward 2022). Among other reasons, Texas is an epicenter for bats and therefore provides an abundance of opportunities for research to be done.

Currently, pesticides are the primary means of controlling agricultural pests, which can place wildlife at risk of chemical exposure (Agosta 2002). This may be a factor for decline in bat population numbers. Pesticides may cause coordination loss, weaken animals, and compromise flight and the ability to orient (Torquetti et al. 2021). In promoting environmental sustainability and supporting the conservation of at-risk species (i.e., bats), contemporary consumers show a growing preference for agri-food products (Russo et al. 2018). The use of higher amounts of fertilizer and agrochemical use generally precedes a reduction in biodiversity (Grashof-Bokdam and Van Langevelde 2005, Billeter et al. 2008, Liira et al. 2008). This is consistent with an established ecological theory that suggests an inverse correlation between site productivity and species diversity i.e., increased productivity leads to a decrease in diversity (Gough et al. 2000, Grime 2001, Mittelbach et al. 2001, Liira et al. 2008).

Bat-habitat relationships are poorly understood because of the high mobility of bats, which gives them access to a wide range of territories. A comprehensive study of how bat species interact with their environment should be the driving factor in the management of the species, community, or ecosystem. The objective of my study is to provide a baseline for the frequency of occurrence and vegetation selection by bats establishing South Texas as their environment and lead to future, specific studies. Based on vegetation availability, I would expect to see the most total frequency of occurrence for all species within the rangeland/wetland composition as this vegetation is the most available as well as providing ample area for foraging (Morris et al. 2011, Barros et al. 2014, Trubitt et al. 2019, Wied et al. 2020). This information will provide ranchers with a better understanding of the land they manage and how to maintain biodiversity for sustainable range management. As a result, ranchers will be proactive in sustaining the ecological robustness of their lands.

METHODS

Study Area

This study was conducted at the El Sauz Ranch (ESR), belonging to the East Foundation, near Port Mansfield, TX in the Texas Coastal Plains (Texas Parks and Wildlife Department) in Willacy County (26.536769° N, -97.446649° W). The East Foundation was recently named the nation's first Agriculture Research Organization (ARO) in early 2022 (Marin 2023). Their mission is to promote the advancement of land stewardship through ranching, science, and education. The mean monthly temperature of the study area during the study period (February-July 2022) was 25.4 C with a mean minimum temperature of 13.2 C and a mean maximum temperature of 87.7 C (PRISM Climate Group 2023). The mean precipitation of the study area during the study period was 60.9 mm (PRISM Climate Group 2023). The study area used for this study spans 10,981.72 hectares with a variety of unique vegetation compositions. The ESR is composed of woodland/shrubland (1,380 ha), rangeland/wetland (8,982 ha), and sand/bare ground (523 ha). Mostly mid to tall grasses (cordgrass [*Spartina alterniflora*]) as well as prickly pear (*Opuntia And*) and catclaw (*Uncaria tomentosa*) cover this ecoregion, with an overstory of honey mesquite (*Prosopis glandulosa*) and live oak (*Quercus virginiana*) trees (Cooper et al. 2021). This area is also home to mostly stabilized and active sand dune deposits. The ESR is a working cattle ranch operation and home to multiple research programs. I selected this area for my research as it is representative of the vegetation community and reflects the similar structure in the Coastal Sand Plains.

Sampling and Data Collection

A vegetation map of the study area was created using land use/land cover (LULC) derived from ESA Sentinel-2 imagery at 10m resolution (Karra et. al. 2021). The underlying deep learning model uses 6-bands of Sentinel-2 L2A surface reflectance data: visible blue, green, red, 2 shortwave infrared bands, and near-infrared (Karra et. al. 2021). The vegetation compositions I used in this study include - (1) woodland/shrubland composition which is categorized as any significant clustering of tall (~4.5 m or higher) dense vegetation; typically with closed or dense canopy such as wooded vegetation; clusters of dense tall vegetation within savannas, plantations, swamp, or mangroves (dense/tall vegetation with ephemeral water or canopy too thick to detect water underneath; (2) rangeland/wetland composition which is categorized as open areas covered in homogenous grasses with little to no taller vegetation; wild cereals and grasses with no obvious human plotting (i.e., not a plotted field); such as natural meadows and fields with sparse to no tree cover, open savanna with few to no trees or pastures. There may also be a mix of small clusters of plants or single plants dispersed on a landscape that shows exposed soil or rock; scrub-filled clearings within dense forests that are clearly not taller than trees; such as moderate to sparse cover of bushes, shrubs and tufts of grass, savannas with very sparse grasses, trees or other plants; these areas are of any type of vegetation with obvious intermixing of water throughout a majority of the year or seasonally; (3) sand composition is categorized as large areas of sand and deserts with no to little vegetation; fine rock or soil with very sparse to no vegetation for the entire year; such as sand dunes and desert, exposed fine rock or soil (Karra et al. 2021).

I deployed a total of 5 Wildlife Acoustic SM4 Bat FS Ultrasonic Recorders coupled with ultrasonic omnidirectional microphones and placed them within a vegetation composition from February-July 2022. The rangeland/wetland composition sampling took place during the months of February, May, and July at 15 different sites each per month for 5 consecutive days. The sand composition sampling took place during March with a total of 5 unique sites during 5 consecutive days. The woodland/shrubland composition sampling took place during April at 5 individual sites for 5 consecutive days once again (Figure 1). I chose the sampling sites based on the historically predominant areas of each vegetation composition, taking into consideration their accessibility. I determined the number of sites per sampling period (month) by the total number of available ultrasonic recorders. An assumed maximum distance for bat echolocations to be recorded in perfect conditions is 100 m or 0.1 km (SonoBat 2023). Therefore, all sampling locations are a minimum of 0.1 km from the ranch boundaries and a minimum of 0.1 km from a simultaneous sampling location to assume independence.

I reported bat calls throughout the high foraging hours starting 1 hour before sunset and ending 1 hour after sunrise based on geographic location. To ensure capture of the peak activity time of bats, an acoustic sample starting 4 hours post-sunset and 2 hours pre-sunrise is sufficient (Perks and Goodenough 2020). The number of acceptable sampling nights varies significantly depending on the season. Furthermore, 40-60% of species richness at a site for the majority of the year can be accomplished by sampling 2 to 5 nights (Skalak et al. 2012). Therefore, I ran the recorders for at least 5 consecutive nights.

I attached these external ultrasonic omnidirectional microphones at the top of a tall pole placed either in the center of open vegetation types (i.e., rangeland) or in an open pathway/clearing within dense vegetation (i.e., woodland) to prevent obstruction of sound by the surroundings. On the recorder, I turned on a 16k High Filter that applies a gradual filter that will attenuate signals starting below 16 kHz in frequency to help filter out human and weather noise, which provides a more definite recording of signals. The default sample rate was set at 256 kHz, which can record up to 128 kHz and capture all species of bats found in North America (Wildlife Acoustics 2023). Species analyzed for this study include - Mexican free-tailed bat (*Tadarida* *brasiliensis*, Tabr), Evening bat (*Nycticeius humeralis*, Nyhu), Hoary bat (*Lasiurus cinereus*, Laci), Tri-colored bat (*Perimyotis subflavus*, Pesu), Eastern red (*Lasiurus borealis*, Labo), Northern yellow (*Lasiurus intermedius*, Lain), and Cave myotis (*Myotis velifer*, Myve).

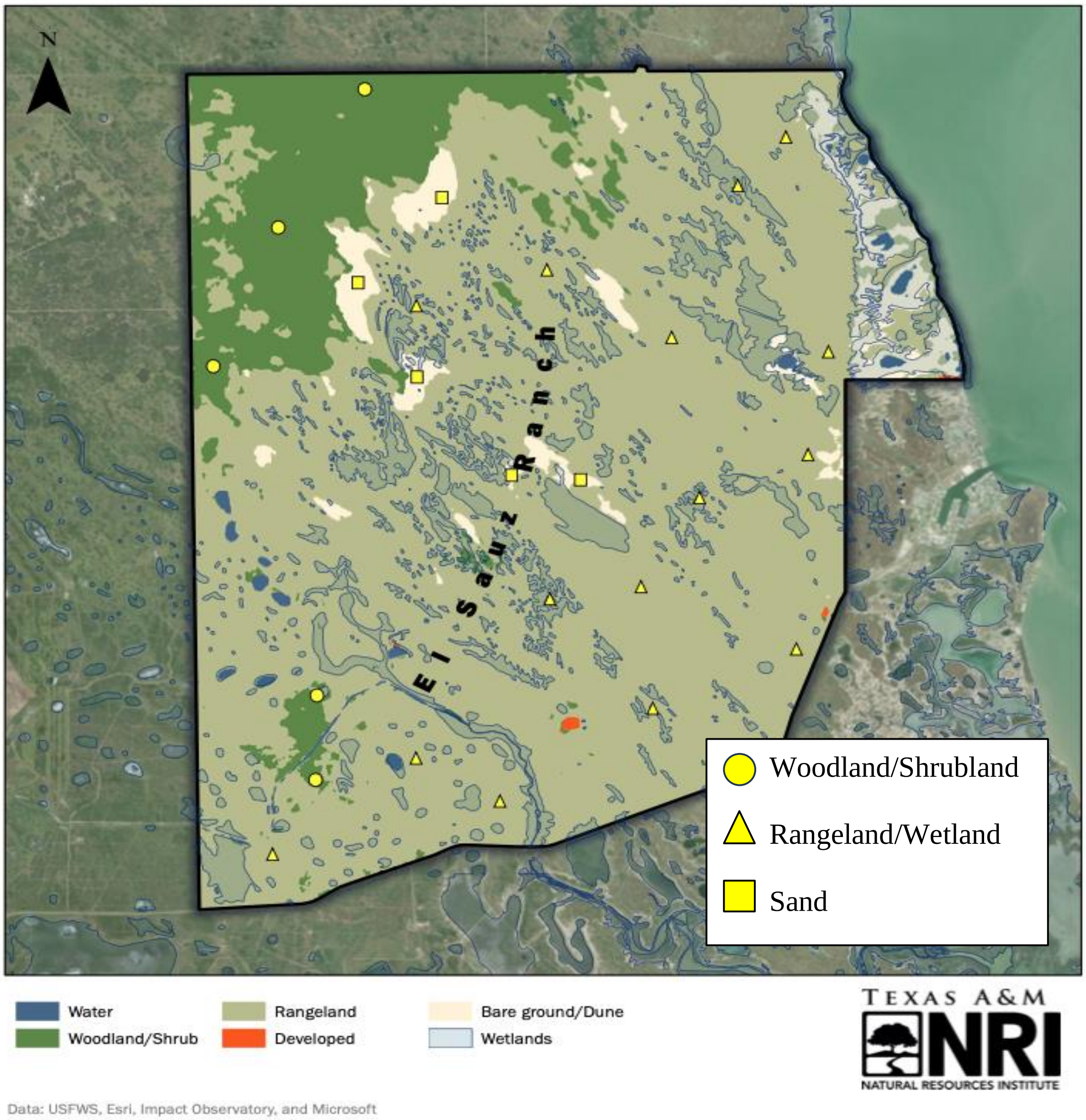

Figure 1. Sites on the ESR where acoustic data were collected for the following vegetation compositions: woodland/shrubland, rangeland/wetland, and sand.

Acoustic Data Analysis

I used SonoBat v. 4.4.5. as the primary method in analyzing the activity of various species of bats utilizing my study area (Figure 2). SonoBat allows me to identify species detected and their frequency of occurrence. SonoBat produces high-resolution sonograms of each call pulse to extract full call trends (SonoBat 2023). All frequency content at any point in time is encoded into each recording and an algorithm is run to conclude bat species. I manually confirmed any non-classified calls by referencing known calls published by Echolocation Call Characteristics of US Bats. To avoid overestimation, frequency of occurrence is necessary as observing the bats in real-time to determine the exact number of individuals was not feasible in this study. The same individual bat could have passed by the microphone multiple times and echolocation was documented multiple times appearing as more than one individual.

For each recorder/sampling location, 5 corresponding consecutive nights were analyzed for each sampling period and combined in final analysis for the 3 vegetation compositions. First, the sound files were attributed with meta-data (date, location, site, and time). I then analyze sequences collected by my acoustic recorders using the auto classifiers on the SonoBat Batch Scrubber. Using the batch of files, the software detects files without bat calls, such as those set off by noise, and relocates them to a separate folder to exclude them from further analysis. The default settings are selected: medium scrubbing, accept all calls except low-quality calls, accept some noise with tonal content, and include 5 kHz signals and above. Using the regional classifier "North American Regional Classifier", species that are likely to be identified include Mexican Free-Tailed, Eastern Red, Cave Myotis, and Evening Bat (Fern et al. 2018). The remaining files from each package will include species-level identification of each bat pass, when applicable. The remaining files in each batch will indicate species-level identification for each bat pass, as appropriate. Once the automated identification is complete, I manually inspect the sound files to confirm the correct identification of species, using reference calls found in the literature (Echolocation Call Characteristics of U.S. Bats 2011).

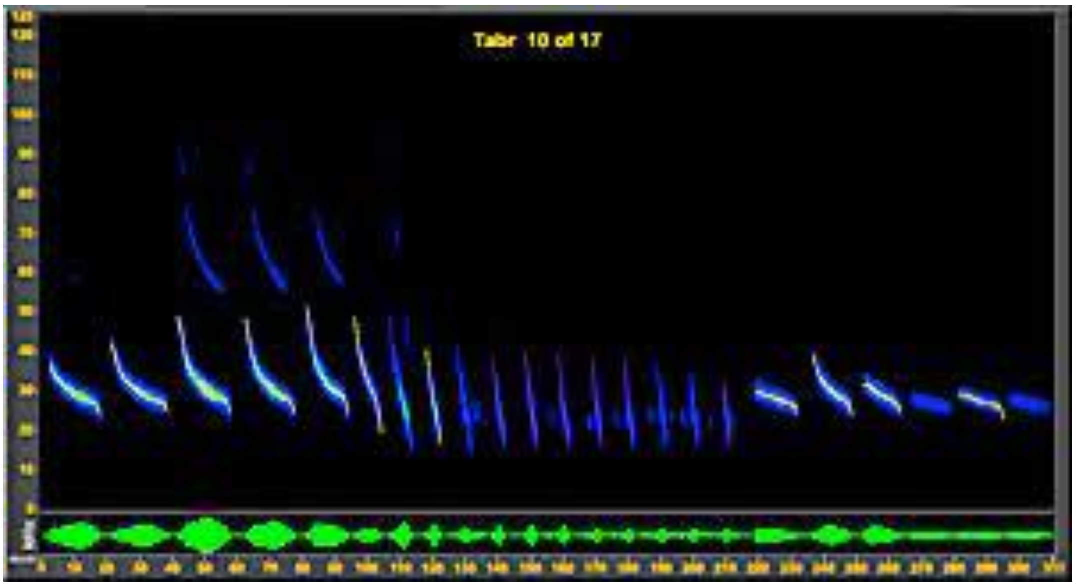

Figure 2. SonoBat call analysis sonogram.

Vegetation Selection Ratios

I evaluated vegetation selection by studied bat species using a vegetation-selection ratio by all species and by individual species (Davis et al. 1994, Lopez et al. 2004). The total species vegetation-selection ratios were calculated by dividing the observed frequency of occurrence by the expected frequency of occurrence for all species in each vegetation composition. The observed frequency of occurrence was calculated for all species by use of SonoBat described in the previous section. The expected frequency of occurrence was calculated by first calculating the availability or proportion of a given vegetation composition (Availability=area of vegetation/total area of ESR), and then multiplying this availability by the total frequency of occurrence for all species within all the vegetation compositions (Expected frequency of occurrence=availability*total frequency of occurrence throughout all vegetation compositions). The vegetation-selection ratio (S) was then calculated as $S=U/A$, where U is the observed frequency of occurrence and A is the expected frequency of occurrence when accounting for availability (Davis et al. 1994, Lopez et al. 2004).

Vegetation-selection ratios $S>1$ suggests the bat frequency of occurrence was greater than the expected frequency of occurrence or showed a preference for, and $S<1$ suggests the bat frequency of occurrence was less than the expected frequency of occurrence or showed avoidance of area (Davis et al. 1994, Lopez et al. 2004). Species specific vegetation-selection ratios were also calculated. This was achieved in a similar manner explained above with the exception of the “total frequency of occurrence throughout all vegetation compositions” replaced with the “total species-specific frequency of occurrence within the vegetation composition of interest.” Following graphs suggest overall preference or avoidance of a vegetation composition as well as which species of bats prefer or avoid each vegetation composition.

RESULTS

Frequency of Occurrence

I surveyed a total of 25 sites across ESR, with a total of 25 unique sampling nights analyzed throughout the entire sampling period. A total of 70,650 total wav files were recorded, with 20,518 being of adequate quality to use in the final analysis (29.04%). Seven species were used for the analysis with the Evening bat having the most frequency of occurrence overall vegetation compositions (*n*=14,417) (Table 1). Other species detected included Eastern red bat (*n*=2,670), Hoary bat (n=1,390), Northern yellow bat (*n*=949), Mexican free-tailed bat (*n*=573), Tri-colored bat (*n*=476), and Cave myotis bat (*n*=43).

Table 1. Scientific and common names for every species analyzed with total occurrence per species for the entirety of the study in decreasing order of occurrence.

Scientific Name	Common Name	Total Occurrence
Nycticeius humeralis	Evening bat	14,417
Lasiurus borealis	Eastern red bat	2,670
Lasiurus cinereus	Hoary bat	1,390
Lasiurus intermedius	Northern yellow bat	949
Tadarida brasiliensis	Mexican free-tailed bat	573
Perimyotis subflavus	Tri-colored bat	476
Myotis velifer	Cave myotis bat	43

Vegetation Selection

The rangeland/wetland had the highest availability of 81.79% of the area, followed by the woodland/shrubland composition of 12.57%, and finally, the sand composition had an availability of 4.76%. Included is an “other” category that accounts for areas I did not include in my study such as developments (i.e., buildings) or roads that represent less than 1% of the area (0.89%) (Figure 3). A preference for an area would require the vegetation-selection ratio within this vegetation composition as $S \geq 1$.

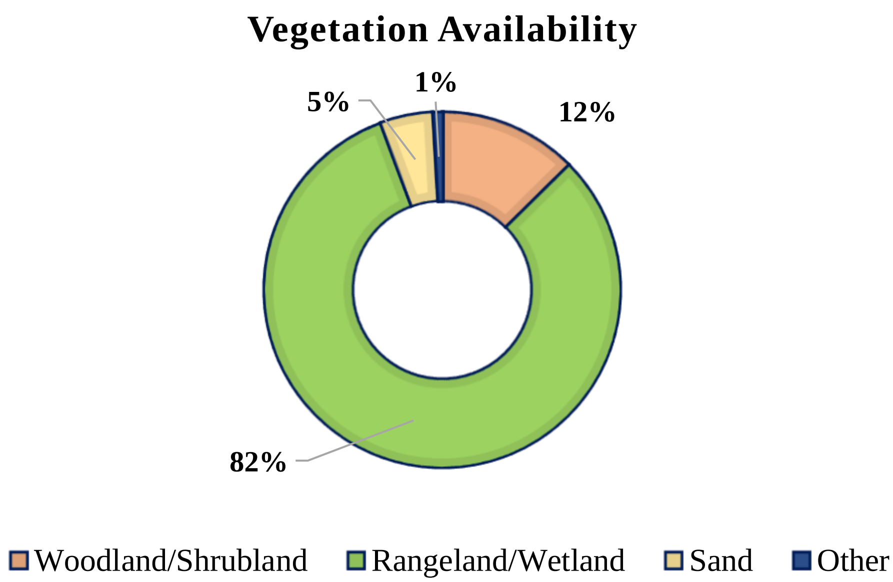

Figure 3. Vegetation availability by composition; rangeland/wetland (82%), woodland/shrubland (12%), sand (5%), other (1%).

Results for the frequency of occurrence per species in each vegetation composition are found below (Table 2). The woodland/shrubland (WS) composition had the most total frequency of occurrence among the other 2 compositions studied (*n*=11,757) consisting of over half (57.30%) of all activity in this vegetation composition alone. The rangeland/wetland (RW) composition had the second total frequency of occurrence (*n*=5,818) accounting for 28.36% of all activity within this vegetation. The sand (SD) composition had the least total frequency of occurrence compared to the other vegetation compositions studied (*n*=2,943), with only 4.34% of all activity.

Table 2. Studied bat species with total occurrence per vegetation composition, woodland/shrubland (WS), rangeland/wetland (RW), and sand (SD).

Bat Species	WS Occurrence	RW Occurrence	SD Occurrence
Eastern red bat	1,401	930	339
Hoary bat	1,058	261	71
Northern yellow bat	738	136	75
Cave myotis bat	23	20	1
Evening bat	8,087	4,106	2,224
Tri-colored bat	215	250	11
Mexican free-tailed bat	235	115	223
TOTAL	11,757	5,818	2,943

The vegetation-selection ratios for each vegetation composition were calculated. The woodland/shrubland (WS) composition (*S*=4.56) and sand (SD) composition (*S*=3.01) both had total vegetation-selection ratios of *S*>1, showing a preference for these 2 areas. The rangeland/wetland (RW) composition (*S*=0.35) had a total ratio of *S*<1, which shows avoidance of this vegetation composition overall (Figure 4). Although Figure 4 shows the comprehensive preference and avoidance for each vegetation composition, the unique bat species are also studied to demonstrate preference/avoidance of vegetation compositions for each individual species (Figure 5).

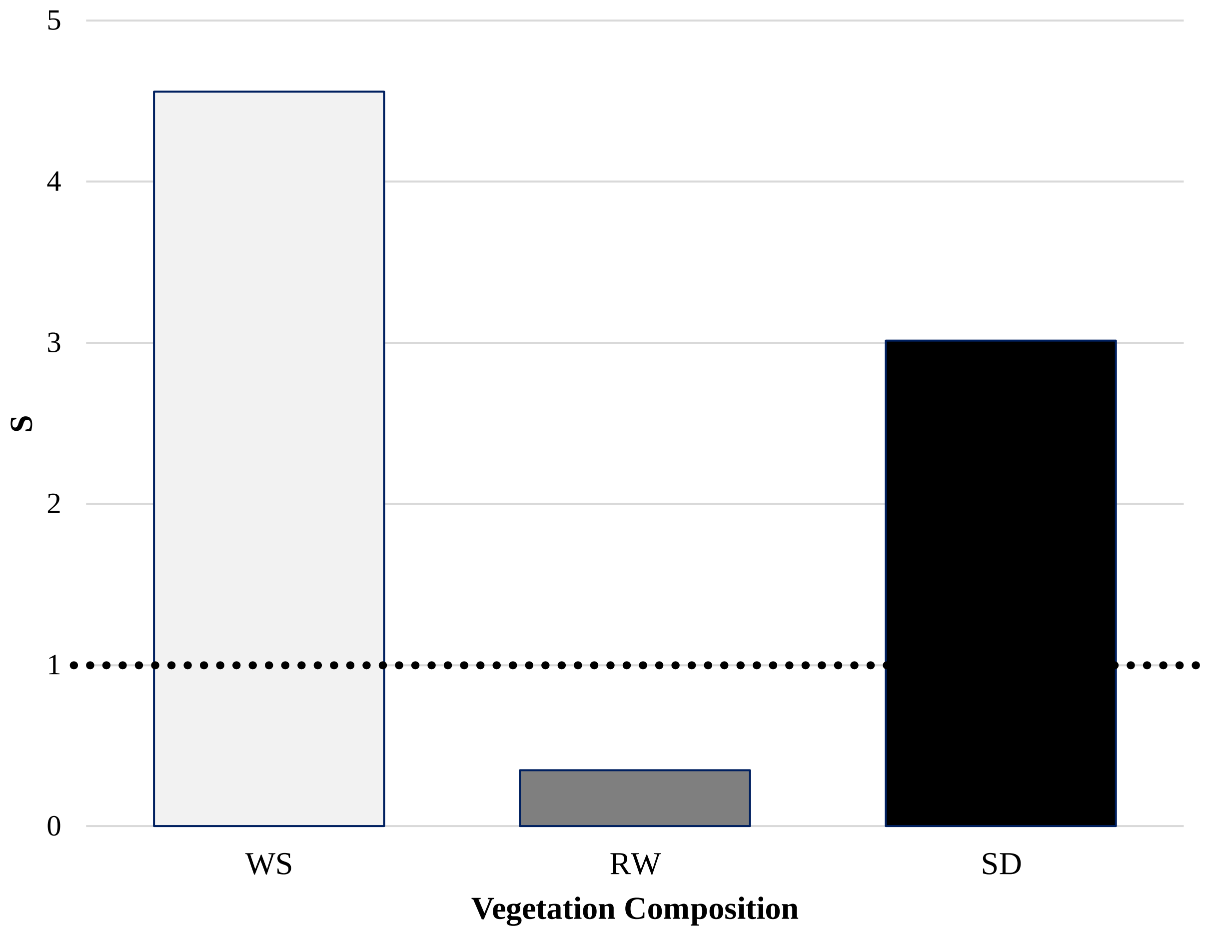

Figure 4. Total vegetation-selection ratios (*S*) (*S*>1 signifies a preference for the area, *S*<1 signifies an avoidance) for each vegetation composition, woodland/shrubland (WS), rangeland/wetland (RW), and sand (SD).

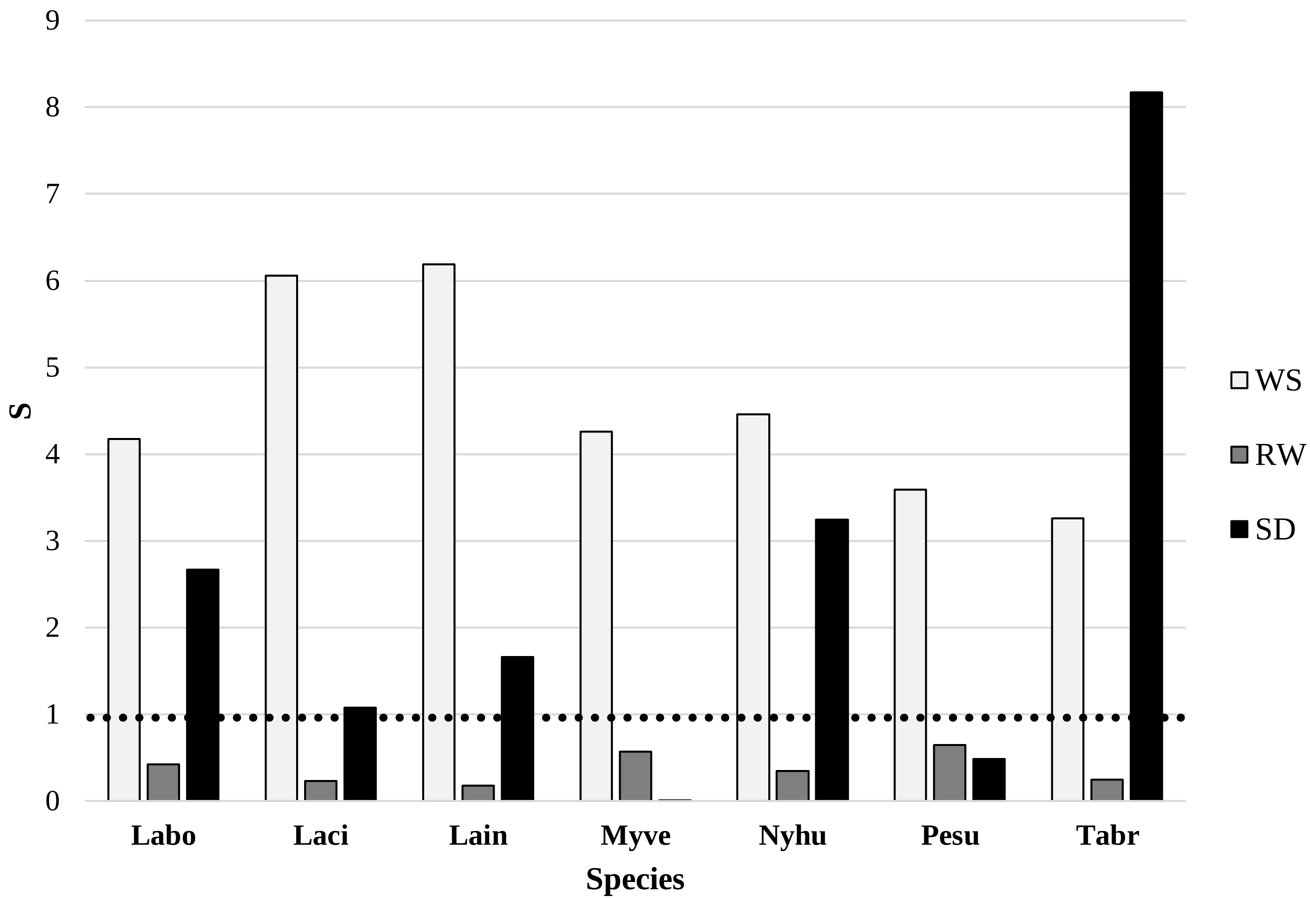

Figure 5. Species specific selection ratios (*S*) for each vegetation composition (*S*>1 signifies a preference for the area, *S*<1 signifies an avoidance), Eastern red bat (Labo), Hoary bat (Laci), Northern yellow bat (Lain), Cave myotis bat (Myve), Evening bat (Nyhu), Tri-colored bat (Pesu), Mexican free-tailed bat (Tabr), woodland/shrubland (WS), rangeland/wetland (RW), and sand (SD).

Eastern red bat

I observed a total frequency of occurrence for the Eastern red bat throughout the entirety of the study of *n*=2,670. The Eastern red bats preferred the use of the woodland/shrubland vegetation (*S*=4.17) as well as the sand composition (*S*=2.67, preferred). This species seemed to have an avoidance of the rangeland/wetland vegetation composition (*S*=0.43, avoided) (Figure 6).

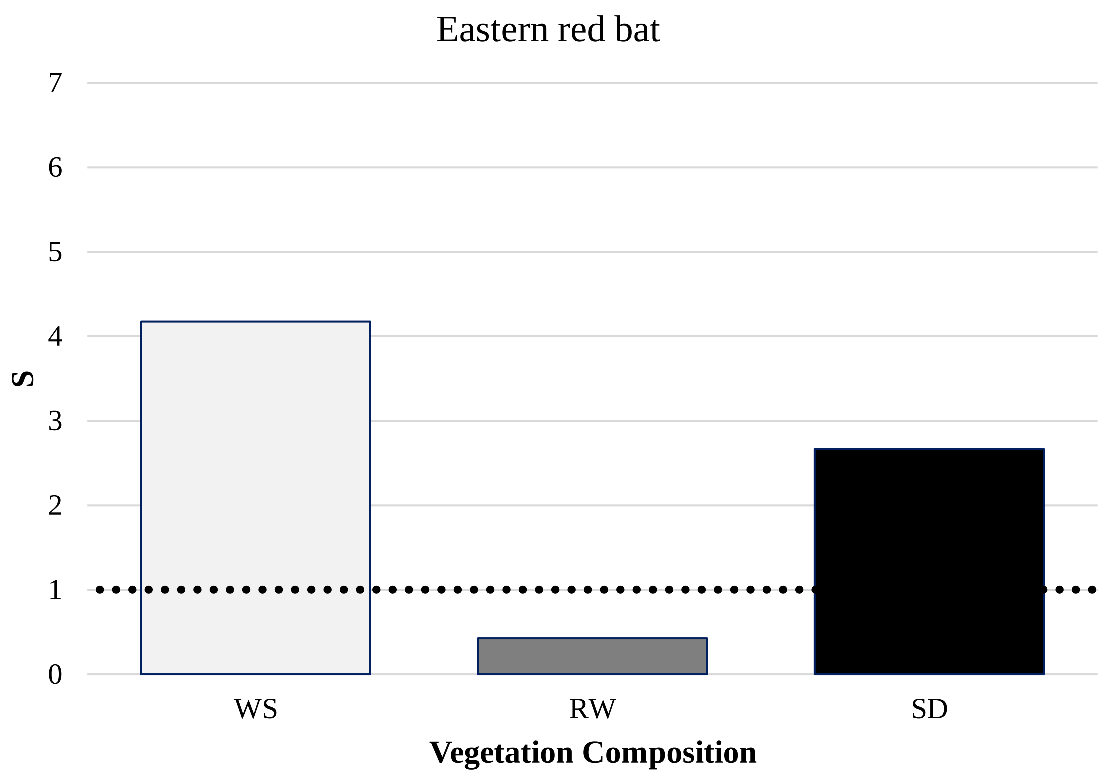

Figure 6. Eastern red bat vegetation-selection ratios stratified by vegetation type (*S*>1 signifies a preference for the area, *S*<1 signifies an avoidance), woodland/shrubland (WS), rangeland/wetland (RW), and sand (SD).

Hoary bat

I observed a total frequency of occurrence for the Hoary bat throughout the entirety of the study of n=1,390. The Hoary bats preferred the use of the woodland/shrubland vegetation (S=6.06) as well as the sand composition (S=1.07, preferred). The sand composition preference was extremely close to what is expected frequency of occurrence within the area with a vegetation-selection ratio of almost S=1. This species seemed to have an avoidance of the rangeland/wetland vegetation composition (S=0.23, avoided) (Figure 7).

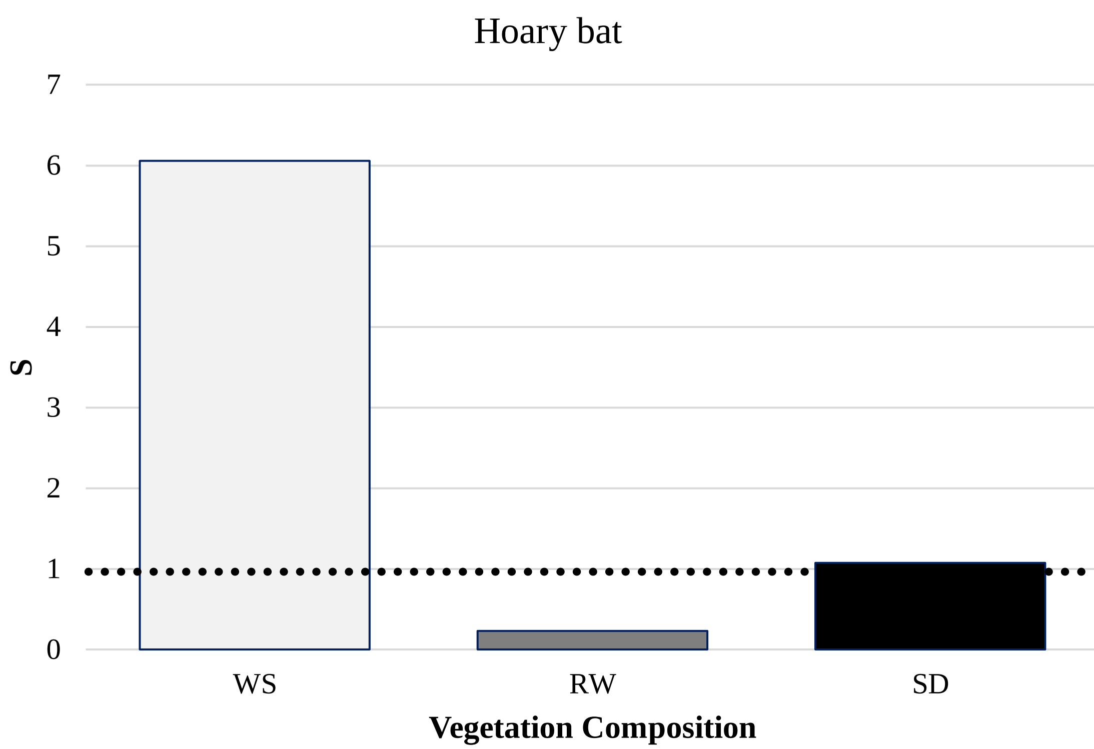

Figure 7. Hoary bat vegetation-selection ratios stratified by vegetation type (*S*>1 signifies a preference for the area, *S*<1 signifies an avoidance), woodland/shrubland (WS), rangeland/wetland (RW), and sand (SD).

Northern yellow bat

I observed a total frequency of occurrence for the Northern yellow bat throughout the entirety of the study of *n*=949. The Northern yellow bats preferred the use of the woodland/shrubland vegetation (*S*=6.19) as well as the sand composition (*S*=1.66, preferred). This species seemed to have an avoidance of the rangeland/wetland vegetation composition (*S*=0.18, avoided) (Figure 8).

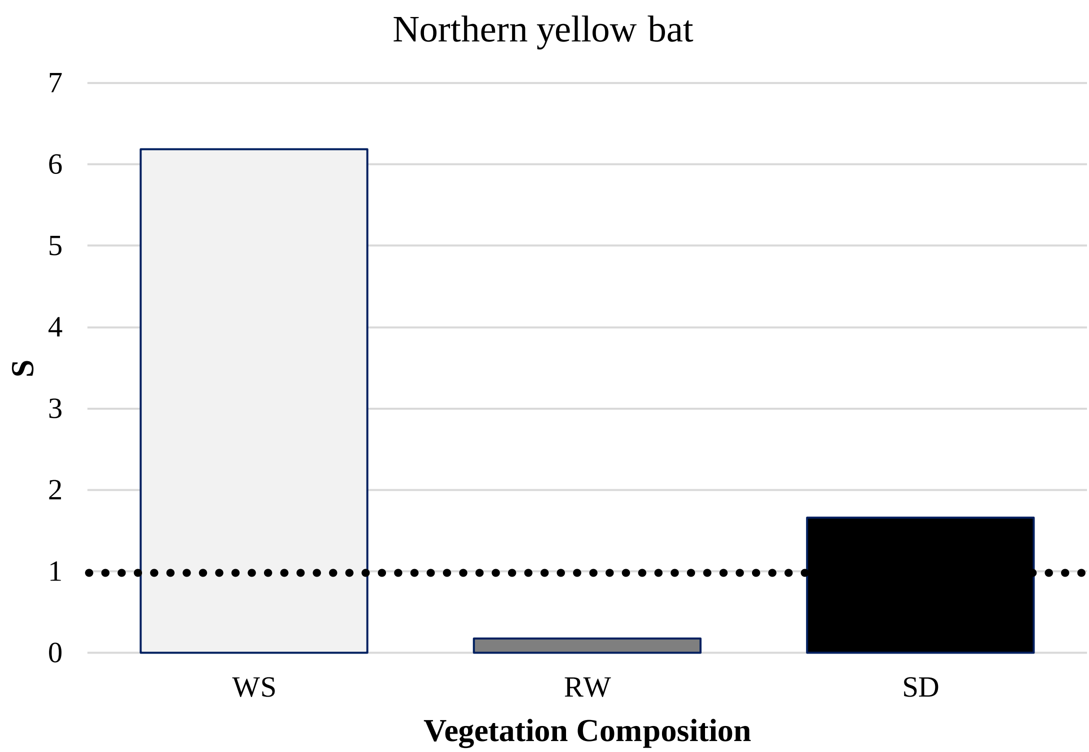

Figure 8. Northern yellow bat vegetation-selection ratios stratified by vegetation type (*S*>1 signifies a preference for the area, *S*<1 signifies an avoidance), woodland/shrubland (WS), rangeland/wetland (RW), and sand (SD).

Cave myotis bat

I observed a total frequency of occurrence for the Cave myotis bat throughout the entirety of the study of n=43. The Cave myotis bats preferred the use of the woodland/shrubland vegetation (S=4.26, preferred). This species seemed to have an avoidance of the rangeland/wetland vegetation composition (S=0.57) as well as the sand composition (S=0.004, avoided) (Figure 9).

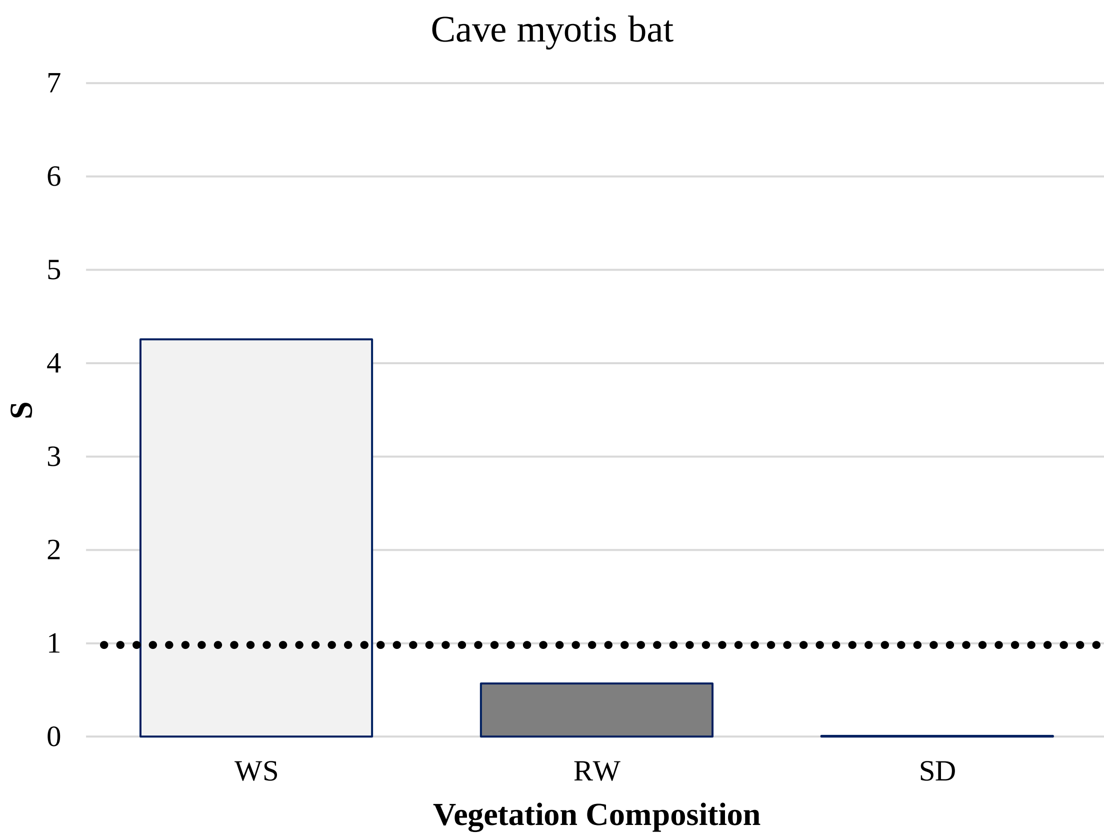

Figure 9. Cave myotis bat vegetation-selection ratios stratified by vegetation type (*S*>1 signifies a preference for the area, *S*<1 signifies an avoidance), woodland/shrubland (WS), rangeland/wetland (RW), and sand (SD).

Evening bat

The Evening bats had the highest frequency of occurrence out of the species analyzed with n=14,417 throughout the entirety of the study. The Evening bats preferred the use of the woodland/shrubland vegetation (*S*=4.46) as well as the sand composition (*S*=3.24, preferred). This species seemed to have an avoidance of the rangeland/wetland vegetation composition (*S*=0.35, avoided) (Figure 10).

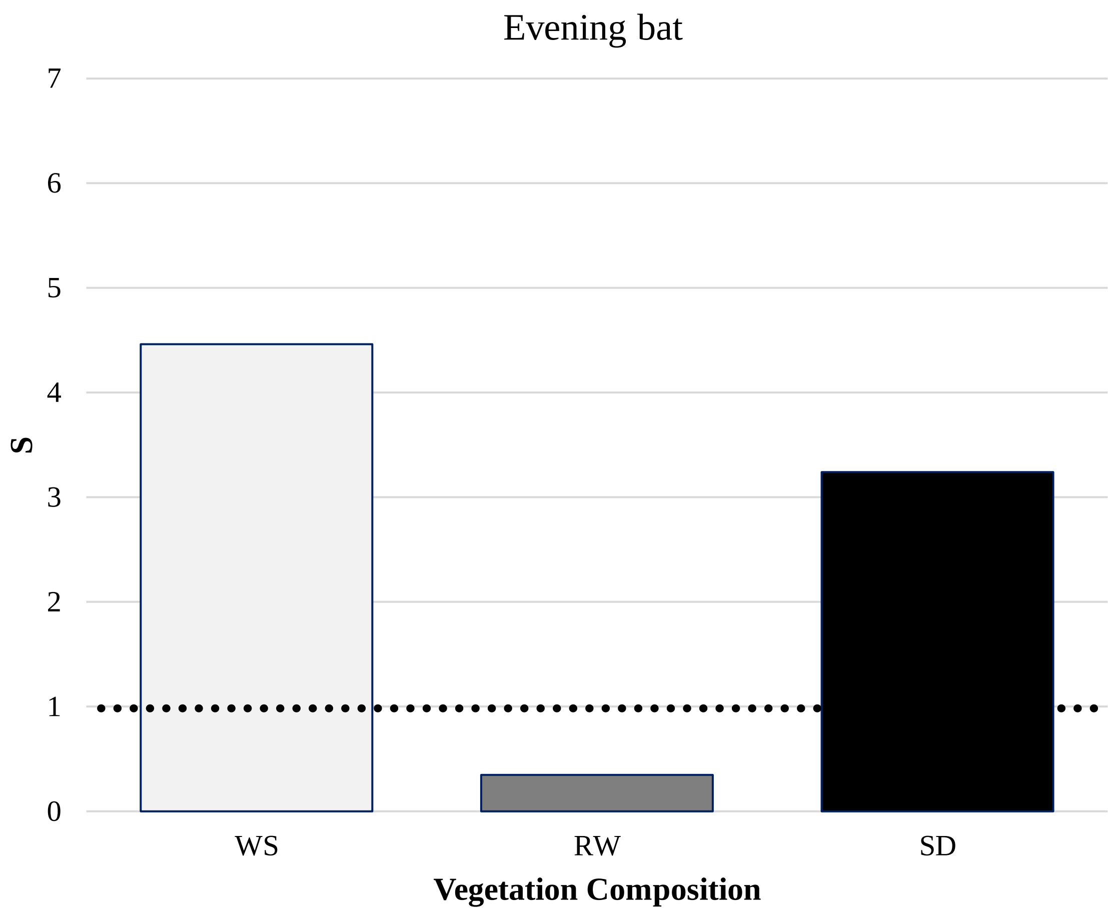

Figure 10. Evening bat vegetation-selection ratios stratified by vegetation type (*S*>1 signifies a preference for the area, *S*<1 signifies an avoidance), woodland/shrubland (WS), rangeland/wetland (RW), and sand (SD).

Tri-colored bat

I observed a total frequency of occurrence for the Tri-colored bat throughout the entirety of the study of *n*=476. The Tri-colored bats preferred the use of the woodland/shrubland vegetation (*S*=3.59, preferred). This species seemed to have an avoidance of the rangeland/wetland vegetation composition (*S*=0.64) as well as the sand composition (*S*=0.49, avoided) (Figure 11).

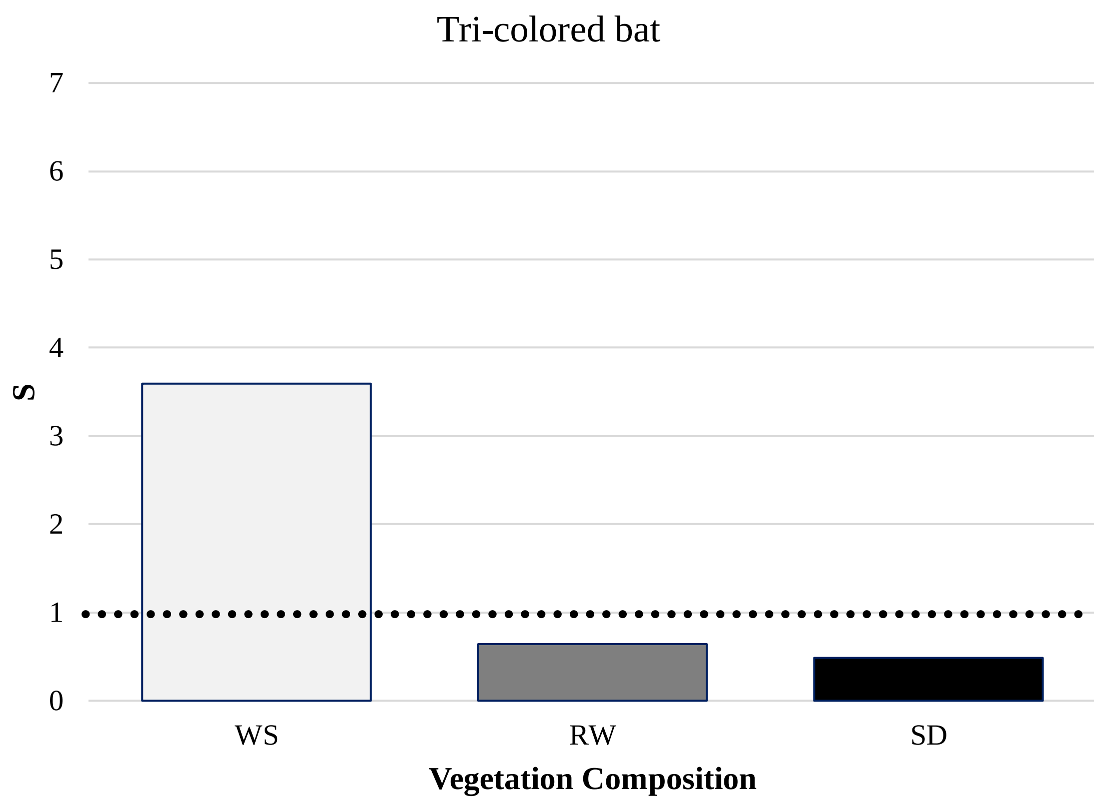

Figure 11. Tri-colored bat vegetation-selection ratios stratified by vegetation type (*S*>1 signifies a preference for the area, *S*<1 signifies an avoidance), woodland/shrubland (WS), rangeland/wetland (RW), and sand (SD).

Mexican free-tailed bat

The Mexican free-tailed bat had the highest vegetation-selection ratio. I observed a total frequency of occurrence for the Mexican free-tailed bat throughout the entirety of the study of *n*=573. The Mexican free-tailed bats preferred the use of the woodland/shrubland vegetation (*S*=3.26) as well as the highest preference ratio of the sand composition (*S*=8.18, preferred). This species seemed to have an avoidance of the rangeland/wetland vegetation composition (*S*=0.25, avoided) (Figure 12).

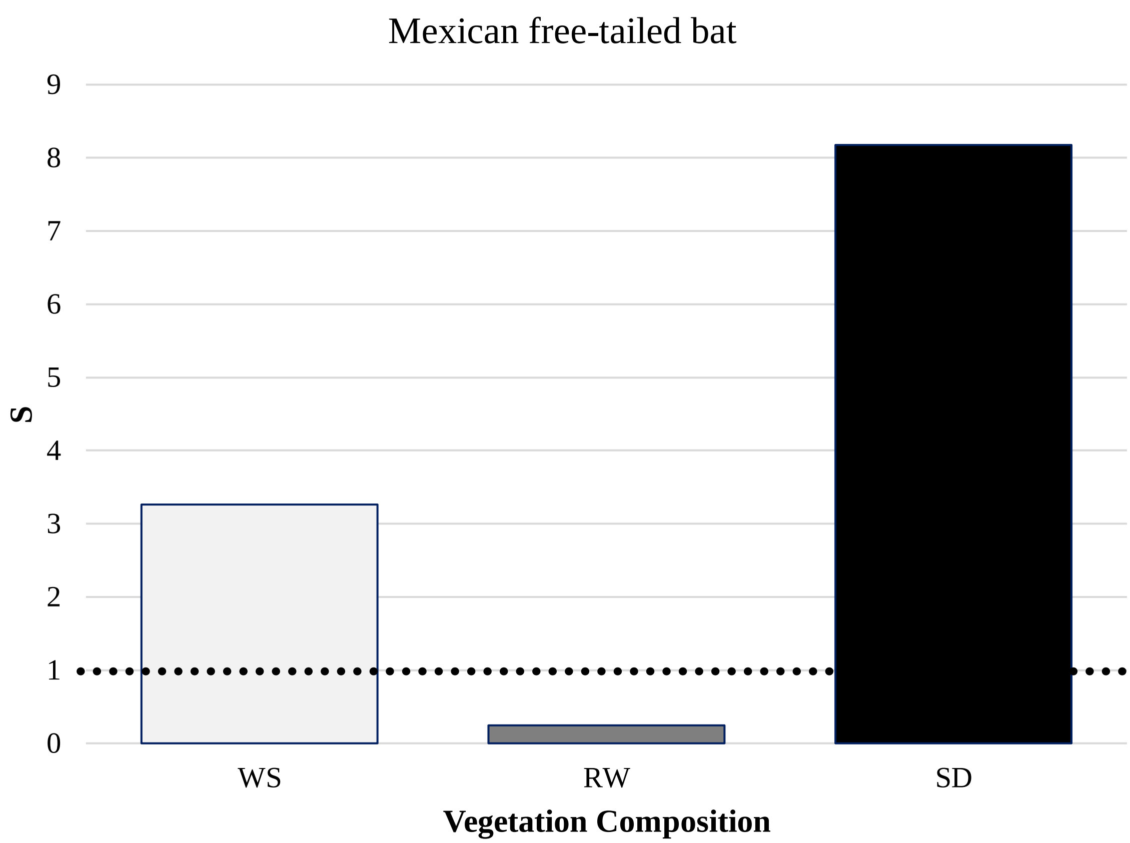

Figure 12. Mexican free-tailed bat vegetation-selection ratios stratified by vegetation type (*S*>1 signifies a preference for the area, *S*<1 signifies an avoidance), woodland/shrubland (WS), rangeland/wetland (RW), and sand (SD).

DISCUSSION

Research on Texas bats is limited, particularly with fine resolution information on vegetation selection. In my study, I observed the greatest frequency of occurrence and highest habitat ratio for bats monitored to be in woodland/shrubland vegetation. Other studies (Fuentes-Montemayor et al. 2013 and Kurta et al. 2018) have reported that woodland areas play a critical role in providing bats with significant roosting and feeding opportunities, making them a frequently selected vegetation type for many bat species. For example, Fuentes-Montemayor (2013) showed higher bat activity in small patches of isolated woodlands rather than sparse woodlands. While the woodland/shrubland area accounted for only about 13% of the ESR study area, this area is likely highly desirable for the species of bats found in South Texas. The majority of the species are tree-roosting bats, likely preferring woody coverage for shelter. Previous studies report (Kalka et al. 2008, Kurta et al. 2018, Fuentes-Montemayor et al. 2013) that many North American species of bats depend on tree cavities, tree bark, and canopy foliage for roosting. The woodland/shrubland vegetation furnishes a shield against wind and predators, while simultaneously offering ample corridors for flight where flight activity has been recorded 3 times higher than in single tree areas (Barros et al. 2014, Kalda et al. 2015). The previous results align with a majority of studies within the subject and are corroborated by the outcomes of my own study. Conserving and managing woodlands in this area of Texas is recommended for maintaining bat communities.

The rangeland/wetland accounted for most of the ESR area (~82%); however, despite the extensive coverage of rangeland/wetlands in the ESR, bats avoided this vegetation. The wetlands were categorized together with the rangelands as they consisted of small ephemeral ponds situated atop the rangelands, therefore sharing the same spatial extent. One main reason for this lack of acoustic data may be due to the time it takes for bats to use the wetlands as water sources. Bats take only milliseconds to intake a gulp of water as they drink “on the fly” within these wetland areas (Kloepper et al. 2019). Therefore, the acoustic data given by the bats may not be significant enough for the acoustic monitors to collect and store that data to be used in analysis. Although these water sources are extremely important to bats to survive (Fukui et al. 2006, Flaquer et al. 2009, Lookingbill et al. 2010, Šuba et al. 2012, Mas et al. 2021) the use of acoustic monitoring of bat calls alone may not be the best possible way to analyze the utilization of wetlands (Anderson et al. 2021). Other methods such as visual surveys may be needed for more accurate results of usage (Kloepper et al. 2019). Studies (Fukui et al. 2006, Flaquer et al. 2009, Lookingbill et al. 2010, Šuba et al. 2012, Mas et al. 2021) have clearly proved that wetlands are frequently utilized by bats and some bats even have a preference for these areas, but my study showed an avoidance of these wetlands. The previous studies (Fukui et al. 2006, Flaquer et al. 2009, Lookingbill et al. 2010, Šuba et al. 2012, Mas et al. 2021) did not occur on cattle production ranches, thus neglecting the influence of factors specific to those operations that could have impacted the outcome of my results. Active ranching practices for cattle production, like those active at this study site, use anthropogenic water sources such as stock tanks that may provide external water sources for bats and insects (Geluso et al. 2004, Morris et al. 2011, Trubitt et al. 2019). It is also possible that the avoidance in the area can be attributed to the insufficient tree coverage rather than the area itself as shown in the study by Trubitt in 2019. Different bat species prefer a wide variety of different percentages of woody coverage habitats (Trubitt et al. 2019). Two species of bats studied by both Trubitt and I included the Northern yellow bat and the Eastern red bat. For these two species, their activity increased as tree cover increased; but the Big brown bat responded negatively to tree cover, giving differing results that could explain the contrasting findings (Trubitt et al. 2019). As for the rangeland portion of the composition, bats prey on a wide variety of insects, such as beetles, mosquitoes, and moths (Coutts et al. 1973, Bernard 2002, Kunz et al. 2011, Long and Kurta 2014, Woodward 2022). The prevalent prey species thrive in the expansive rangeland areas, readily accessible to bats and ensuring an abundant food supply (Coutts et al. 1973, Bernard 2002, Kunz et al. 2011, Long and Kurta 2014, Woodward 2022). Consequently, it is crucial to manage rangelands and wetlands in a manner that offers a conducive habitat for prey and other species, while also ensuring the availability of wetlands or alternative water sources to support their presence.

While the sampling methods used in this study did procure both species-specific and overall vegetation preference results, the main limitation of this study would be not sampling into the later months of the year and due to the number of monitors available and not sampling each vegetation composition simultaneously. Sampling each vegetation each month would allow for results to be compared temporally. Seasonality as well as abiotic factors such as temperature and humidity would possibly be factors that played a role in frequency of occurrence. For my study's species-specific results, the Evening bat species exhibited a prevailing prevalence compared to all other species. In 2015 and 2016, a study (Szewszak et al. 2022) was done at the ESR to collect bat call data for occupancy estimates (along with other species similar to species in this study) for ~5 sampling nights. The Evening bat had a resulting number of passes detected of 76 in 2015 and 114 in 2016 at 5 and 10 locations respectively (Szewszak et al. 2022). For both years, the Evening bat ranked second in terms of species with most passes detected at the ESR, while the Eastern red bat ranked first (Szewszak et al. 2022). For my study, the top 2 species of bats were flipped, with the Eastern red bat (13.01%) ranking second behind the Evening bat accounting for 70.27% of all the frequency of occurrence data (Table 4.1). One possible reason for this may be due to the differences in sampling periods. The Szewszak et al. (2022) study concluded that the maximum detection sampling period for the Eastern red bat is late July - late August and early August - mid September for Evening bat. I surveyed much earlier in the season beginning in February and ending in July. By extending my study into September, I may have seen similar results to this previous study. Although, this does present the possibility that higher occurrences of the Evening bat may be seen in earlier months with higher pikes of the Eastern red bat in the later months. By utilizing a different study period and conducting additional analysis, it is possible to examine particular species in more detail or species of interest such as migratory species to explore which vegetation compositions these species prefer at this critical stage in life. Using information found from this study as a reference point is important to note for future studies within this area of Texas and will provide more comprehensive insights to inform future management decisions.

MANAGEMENT IMPLICATIONS

Species diversity is vital for ecosystem stability, resilience, productivity, provision of ecological services, and the long-term survival of species themselves (Tilman 1996, Schwartz et al. 2000, Smet and Ward 2009, Oliver et al. 2015). Rangeland management practices should focus on landscape heterogeneity to create a foundation for ecological systems to support biodiversity (Christensen 1997, Wiens 1997, Bailey 1998). While woodland/shrubland areas may be regarded as paramount, scientists, biologists, and agriculturalists understand that species diversity cannot flourish solely based on a single factor. Just like any other species, bats need a diverse range of resources and amenities for their well-being and thriving. Woodland conservation should be of main concern in aspects of vegetation and roosting habitat conservation of bats. My study has shown the importance of woodland corridors for bats, but these areas also act as gateway access for other species (i.e., birds and small mammals) as well as cattle on rangelands (Trubitt et al. 2019). Although the wetlands area showed a general avoidance, recommendations for cattle tanks remain to provide an abundance of anthropogenic water sources for both species (Fuentes-Montemayor et al. 2013, Kurta et al. 2018, Trubitt et al. 2019). The conservation of native grasslands, woodlands, and water sources not only supports foraging bats but also facilitates the interconnectedness of operational cattle ranching operations, resulting in positive outcomes for multiple species.

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