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Effect of Land Use Change on South Texas Bats

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EFFECT OF LAND USE CHANGE ON SOUTH TEXAS BATS

A Thesis

by

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ABSTRACT

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The Lower Rio Grande Valley has had rapid land change in the past century due to agricultural business and urbanization. The intentions of this thesis were to: 1) acoustically record echolocation calls of local chiropterans in four distinctive land uses: natural, agriculture, urban-suburban and urban-metropolitan; and 2) determine what kind of landscape variables that may influence specific chiropteran species such as edge lines and bodies of water.

DEDICATION

This thesis would not have been completed without the constant support and love of my family and friends. To my parents, Harry Lee and Martha Jones for being there as emotional support and for also jumping in to help me record at times. Most of all thank you to Israel De La Cruz, I could not have done it with your ongoing help and constant support.

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CHAPTER I

INTRODUCTION

The Diversity of Bats

Bats are the second largest order of Mammalia with about 1,200 species and can be found throughout the world except the polar regions, some remote islands and mountain tops (Ghanem and Voigt 2012 and Schmidly and Bradley 2016). Bats roughly make up about a quarter of all mammals worldwide (Fenton and Simmons 2015). “The diversity of bats is reflected not only in the number of species, but also by most aspects of their biology, from morphology to feeding and roosting behavior” (Fenton 1997). Bats are in the order Chiroptera which is characterized by the evolution of their front limbs adapted into wings for true powered flight, their fingers are elongated, the rotation of their legs where their knees are directed toward the back, and a keeled sternum (Neuweiler 2000). Chiroptera in translation is means winged hand (Schmidly and Bradley 2016). Chiroptera is split into the suborders of megachiroptera and microchiroptera. Megachiroptera are considered old world bats like *Pteropus* (flying foxes) that have defined features such as large eyes, small ears have simple facial features, their second finger is clawed, have a smaller humerus and bigger bodies (Neuweiler 2000). Megachiroptera depend mostly on sight and are mostly frugivores. Microchiroptera are New World bats, such as *Antrozous pallidus* (pallid bat), which have defined features like small eyes, large ears, complex facial features. In addition, their second finger is not clawed, their second and third finger are tightly connected, the humerus is bigger and they have smaller bodies (Neuweiler 2000). These bats are relatively inches long and weigh in ounces. There facial features are quite different from other species of bats and mammals, but it is believed that their facial features have evolved to help the bats with their echolocation.

Roosting and nesting sites are important to bats. While some bats will be found in the same cave as other species, the same species will occupy different location of the cave and be with bats of the same species. Not all regions have caves, so different species of bats occupy other roosts such as trees, canyon walls and manmade structures such as mine tunnels, bridges, attics, and houses. Bats that roost in trees like the eastern red bat and the hoary bat disguise themselves as dead foliage. The do this by hanging onto a branch with one foot which is meant to look like the stem of the leaf and they cover themselves entirely, so their faces do not show. Their fur color and patterns usually resemble dead leaves like the eastern red coat is a red with some frosty tips that is supposed to look like a dead leaf while they roost in the daytime. There are other species like *Corynorhinus rafinesquii* (Rafinesque's big-eared bat) the that will roost in the crevices behind bark trees and hollow trees like *Dipyhlla ecaudata* (the hairy-legged vampire bat). *Dasypterus intermedius* (northern yellow bat) and *Dasypterus ega* (southern yellow bat) are associated in roosting in palm trees and Spanish moss (Schmidly and Bradley 2016 and Jimenez 2017).

With such a diversity in numbers, body features and diet, their ranges of habitat are just as diverse. Bats can be found throughout the world except the polar regions, some remote islands and mountain tops (Ghanem and Voigt 2012 and Schmidly and Bradley 2016). Most species can be found in the tropical regions of the world and species richness starts to decrease to the temperate regions. Where the bat is found is commonly called a roost. There are different types of roosts; diurnal, nocturnal, maternity, and bachelor. A diurnal roost is where the bat spends its time during the day, this is going to be a roost that can protect them from predators and where they can sleep. A nocturnal roost is a quick location where the bat can eat its meal during its night time hunt. A maternity roost is associated with bat colonies of only mothers and pups. A bachelor roost is a roost with only male bats. Bats are mostly associated with caves when it comes to their preferred roost and there is truth to that. Caves play an important role in many species since caves provide shelter, protection, and warmth for bats. Bracken and Carlsbad caves are some of the most famous caves for bats and tourists. The bats that congregate in the caves are in the thousands and sometimes millions of certain species. Some species like the Brazilian free-tailed bat that get as close to neighbor as possible and some like their space where it has been recorded that each bat is 0.15 cm apart from each other (Schmidly and Bradley 2016).

Chiropterans have one of the most diverse diets compared to other animals. Most bats are insectivores while some bats are carnivores, piscivores, frugivores, nectarivores, sanguivorous and omnivores (Schmidly and Bradley 2016). There is a general misconception that all bats suck blood from any animal including humans but, there are only 3 species of bats that consume blood. Roughly two-thirds of bats are insectivores (Kunz et al. 2011), while populations can consume significant amounts of insects (Kunz and Whitaker 1995, Kunz et al. 2011). For example, female Brazilian free-tailed bat (at peak lactation) weighing 12.5 g will consume about 8.1 g of adult insects each night (Kunz et al. 1995 and Cleveland et al. 2006).

In recent studies, it has been found that bats provide humans with ecosystem services such as pest management, pollination, and seed dispersal (Hodgkisons et al. 2003, Ghanem and Voigt 2012, Kasso and Balakrishnan 2013, Boyles et al. 2011).

Pollination- Worldwide, bats pollinate 528 species of angiosperms which take a lot of precision to do so (Kunz et al. 2011, Fleming et al. 2009, and Kasso and Balakrishnan 2013). Chiropterophily, or bat pollination is restricted to the tropical and subtropical regions of the planet (Ghanem and Voigt 2012). It has been estimated that pollination as a service is between $112- 200 billion and that is not considering the amount that bats help with (Klein, Alexandra-Maria, et al. 2007 and Ghanem and Voigt 2012). Bats pollinate some plants that many people do not know like agave and durian trees (Ghanem and Voigt 2012).

Seed Dispersal- most of the seed dispersal is done from frugivore bats that consume fruit and then pass the seeds while in flight later (Ghanem and Voigt 2012). Two of the seeds that bats disperse are the *Mangifera indica* (mango) and *Vitellaria paradoxa* (shea seed) (Preciado-Benítez et al. 2015; Ghanem and Voigt 2012). Shea is in a lot of ingredients especially for cosmetics and it is estimated that the total production value is between $115 to $360 million (Ghanem and Voigt 2012; Hodgkison et al. 2003 and Lovett 2005). Although there is not current estimation of what monetary value bats help with seed dispersal, the have a large role in many of the plants that are used daily (Ghanem and Voigt 2012; Hodgkison et al. 2003 and Lovett 2005). Although there is not current estimation of what monetary value bats help with seed dispersal, the have a large role in many of the plants that are used daily (Ghanem and Voigt 2012; Hodgkison et al. 2003 and Lovett 2005)

Pest Management- Studies that have looked at bats as pest management seemed to be somewhat of an accident (Van Bael et.al 2003). Scientist at the time were determined to study the effects birds had on crop pests. The results were not as expected when they found that bats had more of an influence on crop pests at night than birds had (Kalka et al. 2008 and Maas et. al 2013). It is estimated that bats are worth more than $3 billion to the United States alone, due to their consumption of crop pests, such as the *Helicoverpa zea*, corn ear worm (Maine et al. 2015). There was a 5-year study that was done in the Winter Garden Area near Uvalde, Texas that studied the ecological and economic impact of *Tadarida brasiliensis* (Brazilian free-tailed bats and known as the Mexican free-tailed bat). In this study showed that *Tadarida brasiliensis* Brazilian free-tailed bats were worth an estimation of $121,000–$1,725,000 for that region alone (Cleveland et al. 2006 and Kunz et al. 2009).

Bats have been associated by two things: flight and echolocation. All bats have true flight, but not all bats echolocate (Fenton 2013). The family *Pteropodidae* and most flying foxes do not echolocate (Fenton 2013). Echolocation is "the ability to produce ultrasonic pulses and to interpret the echoes rebounding from objects in their path" (Schmidly and Bradley 2016). Most of the echolocation bats produced is "when air is passed over the vocal folds in the larynx" (Fenton 2013). With echolocation the two main components the transmitter which is the bats larynx and the receiver which is the ears and the associate neural systems (Neuweiler 2000). Bats use echolocation to navigate, detect different obstacles such as trees and water surfaces and to hunt for prey such as moths, beetles and fish (Russo et al. 2012).

With such a large order, there is still not a lot of information pertaining to bats in which a bats value (importance) can be overlooked or underestimated (Ghanem and Voigt 2012, Hodgkisons et al. 2003). Bats are considered a taboo subject when it comes to most human culture. In many western stories, bats have negative connotations that are tied into Dracula, black magic, and the underworld which are frightening to many people (Ghanem and Voigt 2012). In the most recent decades, bats have had unfavorable reputations of getting caught in peoples' hair, deliberately sucking the blood out of humans, and that all bats are rabid. Pessimistic views of these animals are formed when there is not enough information to justify what has been seen or hear. When scientists started to study bats, they were “cryptic, nocturnal mammals it was rather quite difficult (Griffin 1958 and Winifred 2013). First, these animals are primarily nocturnal (except most megachiroptera), hard to capture and are quite difficult to hear (Griffin 1958). Lazarro Spallanzani first did an experiment in the late 1700’s where he was tried to figure out how bats and owls can maneuver so well in the dark (Fenton 2013 and Neuweiler 2000). He darkened a room with drapes hung ribbons with bells at the end of them to hear if the bats hit them (Fenton 2013 and Neuweiler 2000). Spallanzani first blindfolded the bats to see if the bats would hit the bells and ribbon (Fenton 2013 and Neuweiler 2000). When they did not he then controlled the bats by sticking wax and brass tubes into their ears in which the bats crashed all over the place (Fenton 2013 and Neuweiler 2000). This is where he concluded that bats could see with their ears, but he was missed how bats could do this (Fenton 2013 and Neuweiler 2000). Donald Griffin, George Washington Pierce, and Robert Carl Galambos were one of the first to discover that specific species of bats had specific echolocation calls which could identify them (Griffin 1958 and Fenton 2013). This discovery led to the first detector that could pick up echolocation calls, but at the time, it “was discovered by means of G. W. Pierce’s “sonic amplifier,” which was a heterodyne detector with an audio output constructed by modifying an AM radio receiver which had been developed to study the sounds of insects” (Pierce and Griffin 1938 and Brigham et al. 2004). The acoustic recorders have evolved from bulky detectors to portable, light weight detectors that are used in present research (Brigham et al. 2004). Since this was a new way to study and look at bats, it has slowly progressed to what it is today, with equipment that is portable and software with more call references. With the assistance of acoustic recordings, mist netting, radio telemetry has contributed to the knowledge there is now and future knowledge about bats around the world (Brigham et al. 2004 and Kunz 2009)

Bats of the Lower Rio Grande Valley

In the United States there are 43 species of microchiroptera while Texas has 33 (Schmidly and Bradley 2016). From previous reports and studies, it is stated that there are 14 species of bats in the Lower Rio Grande Valley (LRGV), which is about a third of the bats found in the United States, and about half of the species found Texas (Leslie Jr. 2016 and Jimenez 2017). These species include the: Brazilian free-tailed bat, the tri-colored bat, southern yellow bat, northern yellow bat, hoary bat, big brown bat, evening bat, eastern red bat, cave myotis, Yuma myotis, Peter's ghost faced bat, and Mexican long tongue bat (see Table 1.1). Of the fourteen species, there are 4 that are rare and one that is state threatened (Leslie Jr. 2016).

The LRGV is unique habitat that has a diversity of flora and fauna species (Leslie Jr 2016). While the LRGV is known for their residential and migratory birds and for the concentration of biodiversity of plants and butterflies (Leslie Jr., 2016), little is known about the diversity of bats in the region. Of the fourteen species in the RGV, four are considered rare and one is officially listed as threatened by the state of Texas (Leslie Jr. 2016). The Lower Rio Grande Valley has grown at an incredible rate when it comes it urbanization (Leslie Jr. 2016). Once a lush, continuous, Tamaulipan floodplain forest grew along the lower Rio Grande, but the region is now just a fragment of it historic habitat, largely disjointed and deprived of water by water manipulations, agricultural practices, and other harmful activities of the past century or more, including urbanization (Jahrsdoerfer and Leslie, 1988 and Leslie Jr. 2016). It is estimated that only 5% of the area's natural habitat remains (Jahrsdoerfer, S.et al. 1988).

The goals of this thesis were to: 1) acoustically record bats species in the LRGV over the three dominate land use types, 2) determine if there are any land variables such as tree canopy coverage or water influence bat species. Another goal was to shed more light on the bats in the LRGV since these mammals are understudied in this region.

CHAPTER II

BATS ACOUSTICALLY RECORDED IN THE LOWER RIO GRANDE VALLEY

Summary

1. Land use conversion to agriculture and urbanization often negatively impacts dynamics of flora and fauna, often negatively. With the use of acoustic recordings, this study estimates the potential impact of urbanization and agriculture on bat species diversity and abundance. We also examined the influence of land cover features such as tree canopy, impervious surfaces, and other features that might drive abundance of bats across 19 sites in the Lower Rio Grande Valley of south Texas.

2. Bats were monitored from sunset to sunrise with acoustic surveys in sites spread across four general land use types: agricultural, peri urban, urban, and natural areas. A total of 14, 614 distinct calls were detected over 114 observations during the period of 1 May to 15 August 2017. These calls corresponded to nine distinct species of bats, all of which were detected in all of land use types.

3. There were no significant differences in bat abundance or diversity in the four different habitats, although we found a general trend of increasing abundance and decreasing diversity in urban and peri-urban sites. Brazilian free tail bats were the most commonly detected (representing 30.7% of all recordings), and were particularly dominant in both periurban sites and urban sites representing 45.5. % and 37.8% of all recorded calls, respectively.

4. A closer analysis of land cover features revealed that species evenness increased with tree canopy, and decreased with an increase of nearby area covered in impervious surfaces. Certain bat species were more closely associated with landscapes dominated by soil (such as the cave myotis), while others seemed to avoid urbanized areas entirely.

5. Synthesis and applications. This study highlights that changes in land use can affect bat diversity in somewhat predictable ways. Findings from this study may justify efforts to include urban forests in the design of urban landscapes, especially for flying organisms like bats and birds.

Introduction

Comprising the four southernmost counties of Texas, the Lower Rio Grande Valley covers an area of 4,300 square miles of subtropical climate supports a variety of western desert, northern, coastal and tropical plants. The region at the northern most range of various plant and animal species found nowhere else in the United States. The economy rest heavily on agribusiness, which has driven drastic clearing of land for ranging and agriculture (USDA 2012). In the past several decades, urbanization has come an increasingly dominant land use, and has grown 10% per decade at the expense of arable land (Huang et al 2012; Leslie Jr. 2016). These two dominant, competing land uses account for more than 95 percent of the original habitat of this region (The Nature Conservancy 2012).

Changes in land use, from agriculture to urbanization, commonly has negative implications on biodiversity, especially when compared to intact natural areas (Leslie Jr. 2016, Mehr et al. 2011, and Tscharntke et al. 2005). As natural lands are converted to other uses, extant organisms suffer from increased mortality due to loss of habitat and lack of landscape connectivity (Crooks 2002). However, some studies suggest that certain organisms can adapt to, or even exploit, heavily disturbed areas (Donnelly and Marzluff 2003; Brush 2016*)*, and that moderate levels of disturbances from land use change can lead to an increase in biodiversity (Connell 1978). Donnelly and Marzluff (2003) found that in the northwestern US songbird diversity is highest in urban areas where the landscape features dense canopies of forest trees. Certain species of bats have preferences to urbanization and agricultural fields (McKinney 2002). For example, a study by Wickramasinghe et al (2003) presented higher bat activity on organic farms versus conventional farm; another study found considerable populations of northern and southern yellow bats (*Lasiurus intermedius* and *L. ega*, respectively) were found in the dead palm fronds in residential yards (Jimenez 2017). However, especially when compared to other organisms such as birds and insects, the influence of landscape and land use change on patterns of abundance and biodiversity of bats have been poorly studied, largely due to difficulties with monitoring. In this study, we use bat detection through passive sonography to analyze patterns of abundance and diversity of insectivorous bats in various landscapes in the Lower Rio Grande Valley, of south Texas.

There are 14 species of bats that can be found in the LRGV, accounting for about a third the bat species in the United States, and about half the species in Texas (Leslie Jr. 2016; Schmidly and Bradley 2016 and Jimenez 2017). The is very little information on each species and the bat community dynamics in the region (Leslie Jr. 2016). In this study, patterns of abundance and diversity of insectivorous bats were estimated using passive acoustic recordings across a total of 19 distinct sites spread across various land uses in the LRGV, including in agricultural and urban areas, and in protected areas. The purpose of this study is to compare diversity and abundance of bats on the land use types that are most dominant in the LRGV. We also used land cover analysis to explore how different landscape features (such as tree canopy coverage, impervious surfaces, bare soil, etc. might drive bat diversity and abundance within the study areas.

Methods

Study Sites- Twenty distinct sites were selected across the Lower Rio Grande Valley spanning four different land-use categories: **urban** sites were placed towards city centers, **peri-urban** sites located at the fringe of rural-urban interface, **agriculture** sites where land use was dominated by grain crops, and sites within **natural** areas such as state parks and protected private reserves or restoration areas. These sites were selected based on access and safety. Each land use type initially included 5 different sites (see Table 2.2). Due to safety reasons within one of the natural areas, no further observations were made at this site. Thus, a total of 19 sites were included in this study.

Each of the 19 sites were visited 6 times over the study period (May-early August 2017). At each visit, average temperature, precipitation, humidity, wind speed, and wind direction were recorded (Kestrel 2000, Minneapolis, MN) Digital Thermal to explore any potential effect on these factors on strength of detection or on the patterns of bat diversity or abundance. Data was compared to the weather recorded by nearest National Weather Service Stations to confirm accuracy. In the possibility of extreme weather conditions, (wind speed > 25 mph, or the possibility of hail or lightening,) data collection was rescheduled for later in the week.

Bat Surveys – Echolocation calls were recorded using two ultrasound detector units, (Pettersson D500X*;* Uppsala, Sweden*)* installed with a unidirectional, advanced electret microphone (M500, Pettersson, Uppsala, Sweden). The microphone was mounted up on a 12 ft pvc pipe stand with the detector in a box for protection (See Figure 2.1).The detectors were placed nightly at each site, programmed to record between sunset and sunrise the next day, a total of around 10 hours per observation period. This timeframe exceeded the more common 2-hour observation period (see for example, Wickramasinghe et al. 2003), but in our preliminary trials we found that bat activity in these areas ranged throughout the whole night.

Proximal sites were paired together, for ease of recording. At each site, one complete bat detector unit was installed. Each site was visited 6 times over the entire study period (May through early August); sites pairs were randomly visited every two weeks. Because sites were at state parks, residential homes and operational farms, this randomized schedule was made at the beginning of every month to give owners and land managers advanced notice.

Bat Identification- All recording files were downloaded each day and relabeled by the SonoBat™ D500x file Attributer 2.7, labeled by detector, site type, site location, and date. Audio files within the range of typical echolocation calls were sorted, and files that were not recognized (by pitch or frequency) were tagged for further review. Audio files of poor quality outside of the range for bats (i.e. lower than 20 kilohertz) are typically not kept by the software, but for this study, the setting was kept to encompass a wider range of calls for more species of bat. After the files were scrubbed by the software, the files would go through the SonoBatch program which would identify any files in three different ways: 1) identified by species, 2) partially identified species, and 3) no match. The database that was used to identify the bats for this region was the Texas South Central database which covered San Antonio to the Lower Rio Grande Valley (Sonobat 4, Arcata, California). In addition to software matching, all files were manually vetted by KJ to double-check for consistency.

Land Cover Features- At each fixed detector location, a radius of 80 meters and 805 meters (0.5 mi) were drawn on Google Earth™, to analyze land cover around the detectors. These distances were predetermined based on, respectively, (1) double the range of the bat detector and (2) bats fly several miles a night so the range was widened to half a mile so adjacent sites would not overlap (Brush 2016 and Fenton 1997). The Google Earth™ images were converted into ArcGIS (version 10.3; ESRI, Sacramento CA) to make two distinct maps at each of the sites including the area within the two aforementioned radii (a total of 38 maps). Maps were uploaded to iTree Canopy™ (US Forest Service, Kent OH) to get estimate land cover features based on six categories: tree, grass, water, impervious surface, shrub and soil. To reduce the standard error, 750 points were randomly chosen and categorized in each map. Percent coverage for each land cover feature were recorded in a database to include in statistical analysis.

Data analysis- Species diversity was calculated at each site by incidence (or distinct detections, as a proxy for abundance) and Simpson's diversity index (Duchamp and Swihart 2008). Average species diversity and abundance at each site included the six respective observations done at each site over the entire study period. When conditions of normalcy and heteroscedacity were met, an Analysis of Variance (ANOVA) was performed to look for differences in diversity, and abundance across the four-different land-use categories (AGR, URB, PUR, NAT). We also used linear regression to test hypothesized relationships between data on land cover features and bat diversity and abundance. All statistical analysis was performed using JMP® (Cary, NC). To explore relationships between specific bat species abundance and data on landscape features (at 80m and 805m radius) and weather, redundancy analyses (RDA) were performed (Canoco ™; Microcomputer Power, Ithaca, NY). As a short-term study with compensational response data, we used a linear ordination method and constrained RDA, with unrestricted permutations (Canoco™).

Results

Species diversity – A total of 14,614 distinct calls were recorded and detected from May through early August 2017. SonoBatch detected 7 bat species, but by manual inspection of the data, we detected the presence of another distinct signature bat calls (one of high frequency and one of low frequency (*Lfreq* 1-20kHz and *Hfreq* 21-125 kHz) that were not included in the sound library, for a total of 9 distinct audio calls that can be attributed to different species (see table 2.3). Across the four land use types, we recorded an average of 128.2 distinct calls each night with the highest frequency of incidences in PUR and URB areas. All distinct species were found throughout all 4 habitat types, but with some variation in abundance. For example, calls associated with *Tadarida brasiliensis* (TADR, Brazilian free-tailed bats) was the most commonly recorded (accounting for nearly a third (30.7%) of all calls) and detected in all 19 sites, but on average was more commonly detected in PUR and URB when compared to observations in NAT (see table 2.3) where it accounted for 45.5% and 37.8% respectively, of all detections in these sites. PESU (*Perimyotis subflavus*, tricolored bat) was relatively uncommon, accounting for only 1.6% of all calls, but was also detected across the four habitat types.

One-way ANOVA- We found no significant differences among habitat types in total bat incidence *(df =18; F=1.05; p =0.391),* although there is a general trend indicating that urbanized areas (PUR and URB) areas have greater relative incidence of bats than NAT and AGR areas (Figure 2.2). There were also no statistically significant differences in species diversity (Simpson's, 1-D) among habitat types *(df =18; F=2.731; p =0.080),* although Figure 2.2

indicates that agricultural and natural areas tend to have greater evenness in species diversity than urban areas.

Analysis of our data revealed that certain landscape feature variables can help predict bat diversity when accounting for both near-landscape features (within 80 m, Figure 2.3 top graphs) and far landscape features (within 805m, Figure 2.3 bottom graphs). For example, increases in tree canopy (within 80m and 805m) was strongly associated with increases in species diversity (Figure 2.3 left column) across the 19 sites when taking into account tree coverage both near the observation sites and within a half mile of the site. Oppositely, sites with considerable land covered by impervious surfaces were strongly associated with decreased bat biodiversity (see *IS* middle column in figure 2.3) . Land cover categories of soil, water and shrub coverage were poor predictors of biodiversity, although this may have been confounded with skewed data, especially when looking at near-landscape features (see figure 2. 3).

Effect of weather and landscape features on bat populations- Redundancy analysis, which explores how hierarchical data may cluster around certain predictor variables, indicate weather data played an insignificant role on bat species composition (pseudo f=1.3, p = 0.224, figure 2.4 A). The pseudo F statistic listed here describes the ratio of between-cluster variance to within cluster variance, and larger F-values indicate close-knit and separated clusters (Calinski and Harabasz, 1974). Larger, significant F-values for redundancy analyses in Figure 2.4 B and C suggests that immediate landscape features can influence bat species composition. As indicated by relative length of the red arrows in Figure 2.4 B and C, impervious surface (IS), grass, tree coverage, and soil coverage, within both a near-landscape radius (80m) and far-landscape radius (805m), have the strongest effects on bat species composition. In both RDA analyses, grass and

IS are strongly associated and correspond to PUR and URB. Shrub coverage had the least effect on the species of bats. The water variable was excluded in the RDA.

Effect of species incidence and landscape features on bat populations- In RDA of near-landscape land cover (80m radius, Fig. 2.4 B, left), exploratory variables account for 48.8% of the variation, with axis 1 and 2 account for a cumulative 40.0% of the explained variation (*pseudo-F=2.5, P=0.006*). As indicated in Figure 2.4 B (middle), Axis 1 seems to explain an urban (PUR and URB) to natural (NAT) gradient, since both are on opposites of the gradient. Six of the 9 species of bat strongly respond to the urban side while the other 3 species weekly correspond to natural areas. EPFU, PESU, and LABO responded strongly to IS and grass landcover and were commonly found in URB and PUR sites (Figure 2.4 B)

Similar trends were found in RDA test of explanatory landscape variables within a far landscape radius (805m) (*pseudo-F=2.1, P=0.01*). Across this broader landscape analysis, EPFU, PESU, and LABO continued to respond strongly to IS and grass landcover corresponding with their common occurrence in URB and PUR sites (see Figure 2.4 C). Axis 1, representing this "urban to natural gradient" explains 33.89% of variation in the incidence of bats. The vertical gradient, Axis 2, accounted for 7.19% of the explained variation.

Discussion

These results suggest that urbanized areas can support a significant abundance of bats, which migh exploit increased roost availability and high densities of insects, especially near street lights (Gehrt Chelsvig 2003; A´vila-Flores and Fenton 2005; Everette et al. 2001; Gaisler, J., et al. 1998; Rydell 2006). Most of the observation locations in urban and and peri-urban habitat types were at homes with yards landscaped with lush, dense native vegetation, perhaps atypical to other yards in their respective neighborhoods. This native vegetation promotes diversity of species including insects (McKinney 2002; Burghardt and Tallamy 2013) may have increased the activities of bats within these sites. This aspect was somewhat difficult to contol since all locations required permission included in this study required permission from land managers and property owners, who agreed to volunteer for this study. For various reasons, it was difficult to find cooperation from various homeowners within urban and periurban sites, and thus locations were placed within a self-selecting group of volunteers.

The data from this study reveal that certain bat species have exploited, adapted to, or generally avoid some habitats. For example, the Brazilian free-tailed bat (*Tadarida brasiliensis*) was commonly detected in urbanized sites, seemingly exploiting certain resources that are abundant in these areas. Alternatively, this bat was relatively infrequent in NAT sites where there was more eveness in the diversity of bats. The hoary bat is also considered an urban exploiter, occuring around 10 times more frequently in urban and peri-urban sites when compared to agricultural (AGR) and protected areas sites (NAT). The cave myotis (*Myotis velifer*) might be considered an agricultural exploiter—it was extremely common in agricultural sites, and rare in all other sites. This bat may be exploiting agricultural areas for prey that may not be readily available at other sites, although may not be roosting in the area-- cave myotis may forage further from their roost than other bats due to their relatively larger size and well-adapted wings (Schmidly and Bradley 2016).

Other bats, such as the unidentified bat (*Hfreq*) in Table 2.3 is largely present in NAT and AGR sites, but very infrequent in urbanized areas. Following Donnelly and Marzluff (2004) and Brush (2016), bats such as these might be considered as urban avoiders. Despite a thorough, intense study, we also did not detect five of the other fourteen species found in the RGV (Table

2.1). Although this may be an artifact of the rarity of these species, this also may be due to the sensitivity of some species to high levels of disturbance. Although a higher incidence of bats were detected in these urbanized environments, bat biodiversity remained highest in natural areas, consisted with that of other studies on biodiversity (McKinney 2002; Fenton 1997; Ávila-Flores and Fenton 2005; Threlfall et al. 2016). Although this finding was not significant, we did find a significant linear relationship between the diversity of bats and tree coverage within given landscape. This finding was consistent with that of other vagile organisms (Donnelly and Marzluff 2004; Brush 2016), although Donnelly and Marzluff (2004) found that there was a curvilinear relationship between song bird diversity and tree canopy coverage in the northwestern US. Although this does not appear to be the case for bats, more resolution is needed with additional studies which take into a consideration size and connectivity of landscapes. More replicative studies will also help improve the confidence of our findingsespecially given the probability of user error when using remote sensing devices such as acoustic monitors. In this study, we did have some issue with device tampering, especially in the natural area sites, which may have limited the number of calls detected. Additionally, although we recorded a considerable amount of distinct calls in one sampling season, multiple year recordings should be considered to look for variatons in the data.

However, despite the inherent limitations in an intensive study using remote sensing instruments, the data presented in this study demonstrate the potential of using acoustic recordings as a non-invasive method to monitor bat populations, and provide results that are the first documentation of the effect of habitat and habitat features in bad biodiversity and abudance of the specious LRGV. As an area dominated by agribusiness and urban growth, this data can be extended to other regions with conflicting land use change to inform the design and management of both agroecosystems and urban expansion, and to help conserve bat species and the ecosystem services they provide.

CHAPTER III

CONCLUSION AND REVIEW

In the summer of 2017, bat acoustic surveys were repeated at 19 sites throughout the LRGV. This snapshot, as part of my thesis, demonstrate that habitat type and habitat features can impact local bat communities. Consistent with the findings of Àvila-Flores and Fenton (2005), we found that natural areas support a tremendous diversity of bats. However, our results reveal that urban areas can also support a considerable diversity, and abundance, of bats. Some bat populations have demonstrated the potential to adapt to, and even exploit urban and agricultural areas (Gehrt and Chelsvig 2003; Àvila-Flores and Fenton 2005). As cities expand worldwide to meet the demands of a growing populations, the need for well-developed urban management plans that incorporate these goals to promote local diversity and community resilience is paramount (Àvila-Flores and Fenton 2005).

This study serves as a base line study for future graduates, to use as documentation of which south Texas bat species occur where. More research needs to be done in this regard, including studies on the biology and ecology of the of the fourteen species that have been documented in the LRGV. Three things should be considered for future studies in the LRGV, which is their roosts, their diet, migration and identify all calls as possible for a complete call library.

Generally, biologists have a basic understanding of where certain species of bats roost. For example, the cave myotis can roost in caves, rock crevices, carports, old buildings, car ports under bridges, and occasionally empty cliff swallow nests; while the eastern red bat mainly roosts in trees and Spanish moss (Schmidly and Bradley 2016; Mirowsky 1997). Back in 2015, a graduate student from San Angelo State University Citlally Jimenez did a study of the southern and northern yellow bats roosts in the LRGV (Jimenez, forthcoming). By tracking bats back to their roosts, this study was able to classify and identify their roosts (Jimenez 2017). Yellow bats for example, roosted in sabal palms that had taller, thicker dried frond skirts and had smaller trunk diameters which were mostly found in a natural park (Jimenez 2017). This finding can strengthen justification for leaving this biomass for habitat for bats in urban areas, instead of the more common sight of palm trees that have been trimmed and these fronds removed.

More insight on diets would also be extremely helpful in calculating the ecosystem services of these organisms. For example, bats do provide considerable pest control, especially in agricultural areas. A huge study done in the Winter Garden Region of Texas to study if the bats were eating the crop pests such as the cabbage lopper (Cleveland et al. 2006 and Kunz et al. 2009). Given the implications of this study, Texas Parks and Wildlife began to promote that bats were great pest controllers in agricultural areas (Cleveland et al. 2006 and Kunz et al. 2009). There is even a book that was inspired by this study called *Frankie the Free-Tail Bat* which is given out during bat outreach events in a book in English and Spanish (Kunz et al. 2009).

Bats are also known to eat insects of medical importance, such *Aedes spp,* now common to the RGV and known vectors to many infectious diseases such as zika, west Nile virus, and yellow fever. We might be able to test a bats guano is to document insect DNA and classify them (Kunz et al. 2009). Currently, we are in close collaboration with the Rodale Institute to perform some preliminary analysis in these regards.

Not much is known about whether some bats are year-round residents in the LRGV and if a certain species migrate. With a year-round subtropical climate, it is commonly thought that bats stay in the regions. However, it is recorded that certain Brazilian free-tail bats will migrate cross from the United States into Mexico, cross states lines, move within the state or stay in the same area (Neuweiler 2000). When bats do migrate, it is during the fall and spring seasons. If the bats do not migrate for those seasons, then some species of bat will hibernate or go into torpor for shorter periods of time which is dependent of the regions climate (Neuweiler 2000). For the Rio Grande Valley, there has been no studies that show whether any of the fourteen species of bats migrate or stay, or if they are active during the winter season or enter torpor. More studies involving tracking bats may help reveal some of this much needed data.

As a caveat, not all of the species of bats found in the LRGV were within the database--Sonobat 4 TX with the south central file only had seven species (Sonobat4). Based on previous studies done in the region, species like Northen and Southern yellow bats were found in two state parks that were apart of this study but were not identified by the SonoBat used in this study (Jimenez 2017, and Leslie Jr 2016). The reason why these specific species were not identified by SonoBat was the absence of these specific species calls. SonoBat only has a database that is as big as its founder can give, so all the bat calls that are in the program are from his personal call library. There were echolocation calls that could not be identified that were different from the other seven species identified but could not manual be identified without confirmation of an example. The calls that were recognized as bat echolocation calls but did not have a sample species were either labeled as high or low frequency species. With this not previously found before the study, this does limit the amount of species that are identified acoustically with the Sonobat 4.

With the unevenness of land use types in the LRGV, it is advised to perform these studies within the natural, agricultural, periurban and urban areas. Any study in the LRGV will be beneficial to preserve the habitat and the diversity of bats.

TABLES and FIGURES

Table 2.1: Bat Species Table. Bats found in the Lower Rio Grande Valley of Texas. Conservation risk indicated by IUCN (Schmidly and Bradley 2016)

Common name	**Scientific Name**	**Family**	**Species code**	**Conservation Risk**
Brazilian free-tail bat	*Tadarida brasiliensis*	Molossidae	TABR	Least concern
Ghost faced bat	*Mormoops megalophylla*	Mormoopidae	MOME	Least concern
Mexican-long tongue bat	*Choeronycteris mexicana*	Phyllostomidae	CHME	Near threatened/endangered*
Hoary bat	*Lasiurus cinereus*	Vespertilionidae	LACI	Least concern
Pallid bat	*Antrozous pallidus*	Vespertilionidae	ANPA	Least concern
Southern yellow bat	*Dasypterus ega*	Vespertilionidae	DAEG	Least concern /Threatened**
Northern yellow bat	*Dasypterus intermedius*	Vespertilionidae	DAIN	Least concern
Big brown bat	*Eptesicus fuscus*	Vespertilionidae	EPFU	Least concern
Eastern red bat	*Lasiurus borealis*	Vespertilionidae	LABO	Least concern
Cave myotis	*Myotis velifer*	Vespertilionidae	MYVE	Least concern
Yuma myotis	*Myotis yumanensis*	Vespertilionidae	MYYU	Least concern
Evening bat	*Nycticeius humeralis*	Vespertilionidae	NYHU	Least concern
Tricolored bat	*Perimyotis subflavus*	Vespertilionidae	PESU	Least concern
Silver-haired bat	*Lasionycteris noctivagans*	Vespertilionidae	LANO	Least concern
Seminole bat	*Lasiurus seminoles*	Vespertilionidae	LASE	Least concern

*****Listed as threatened by *Secretaria de Manejo de Recursos Naturales* (Gov. of Mexico)

****** Listed as threatened by *Texas Parks and Wildlife Department*

Table 2.2: Table of Sites**.** Description of 19 sites across the Rio Grande Valley used in this study. Sites were categorized into four general habitat types: Agriculture (AGR); Natural Areas (NAT); Peri-urban (PUR); and Urban (URB) areas.

Site number	Location (City, TX)	GPS		Habitat Type	General Description
1	La Joya	26.41428	-98.44222	Agriculture	Dry farmed sorghum (conventional)
2	Edinburg	26.26701	-98.08699	Agriculture	Mixed vegetables (Organic)
3	Mission	26.15507	-98.30464	Agriculture	Transitioning farm (fallow)
4	Mission	26.15966	-98.32986	Agriculture	Transitioning farm (fallow)
5	Lyford	26.36856	-97.92016	Agriculture	Agave (Organic)
6	La Joya	26.41370	-98.43361	Natural	Private ranch, restored property
7	Brownsville	25.99637	-97.56877	Natural	State protected area
8	Brownsville	25.85048	-97.41906	Natural	state protected area
9	Weslaco	26.12665	-97.95600	Natural	State protected area
10	McAllen	26.25236	-98.21393	Peri Urban	Residential home
11	Mission	26.21433	-98.23124	Peri Urban	Residential home
12	San Benito	26.18981	-98.19236	Peri Urban	Residential home
13	Harlingen	26.18717	-97.68703	Peri Urban	Residential home
14	Edinburg	26.29057	-98.16153	Peri Urban	Residential home
15	McAllen	26.25457	-98.26240	Urban	Residential home
16	McAllen	26.25217	-98.28140	Urban	Residential home
17	Pharr	26.06610	-97.61857	Urban	Residential home
18	Harlingen	26.17557	-97.73920	Urban	Residential home
19	Edinburg	26.29414	-98.09153	Urban	Residential home

Table 2.3: Average Incidence of Bat per Habitat Type. Average incidence of bats found in four different habitat types in the Lower Rio Grande Valley (NAT=Protected Areas AGR=Agriculture; PUR=Peri-urban, and URB = Urban areas). Data indicates the average number of detections for each of the bat species recorded, and percent incidence (parenthetical) indicates relative dominance of each species in each habitat type.

	Habitat Type							
Bat Species	*NAT*		*AGR*		*PUR*		*URB*	
EPFU	17.5	*(21.3%)*	23.4	*(20.8%)*	25.9	*(16.1%)*	41.5	*(26.4%)*
LABO	14.0	*(17.1%)*	6.6	*(5.9%)*	14.0	*(8.7%)*	20.1	*(12.8%)*
LACI	0.6	*(0.8%)*	0.5	*(0.4%)*	4.7	*(2.9%)*	4.2	*(2.7%)*
MYVE	0.9	*(1.1%)*	16.1	*(14.3%)*	0.8	*(0.5%)*	0.3	*(0.2%)*
NYHU	11.5	*(14.0%)*	17.2	*(15.3%)*	20.0	*(12.5%)*	11.9	*(7.6%)*
PESU	0.7	*(0.8%)*	2.0	*(1.7%)*	1.9	*(1.2%)*	4.1	*(2.6%)*
TADR	6.7	*(8.2%)*	18.3	*(16.2%)*	73.2	*(45.5%)*	59.4	*(37.8%)*
Hfreq	22.3	*(27.3%)*	20.8	*(18.5%)*	13.1	*(8.1%)*	8.2	*(5.2%)*
Lfreq	7.7	*(9.4%)*	7.8	*(6.9%)*	7.1	*(4.4%)*	7.4	*(4.7%)*
Ave. Nightly Bat Incidence	**81.8**		**112.8**		**160.8**		**157.2**	

Figure 2.1: Photo of Bat Detector. Bat detector with microphone set up at one of the natural sites.

Figure 2.2: ANOVA Analysis. Analysis of variance reveals no significant differences in bat species diversity (Simpson's evenness index, 1-D, top) or bat abundance (total incidence, bottom) among the four dominant habitat types in the Lower Rio Grande Valley. Box plots indicate average and quartiles for each habitat type.

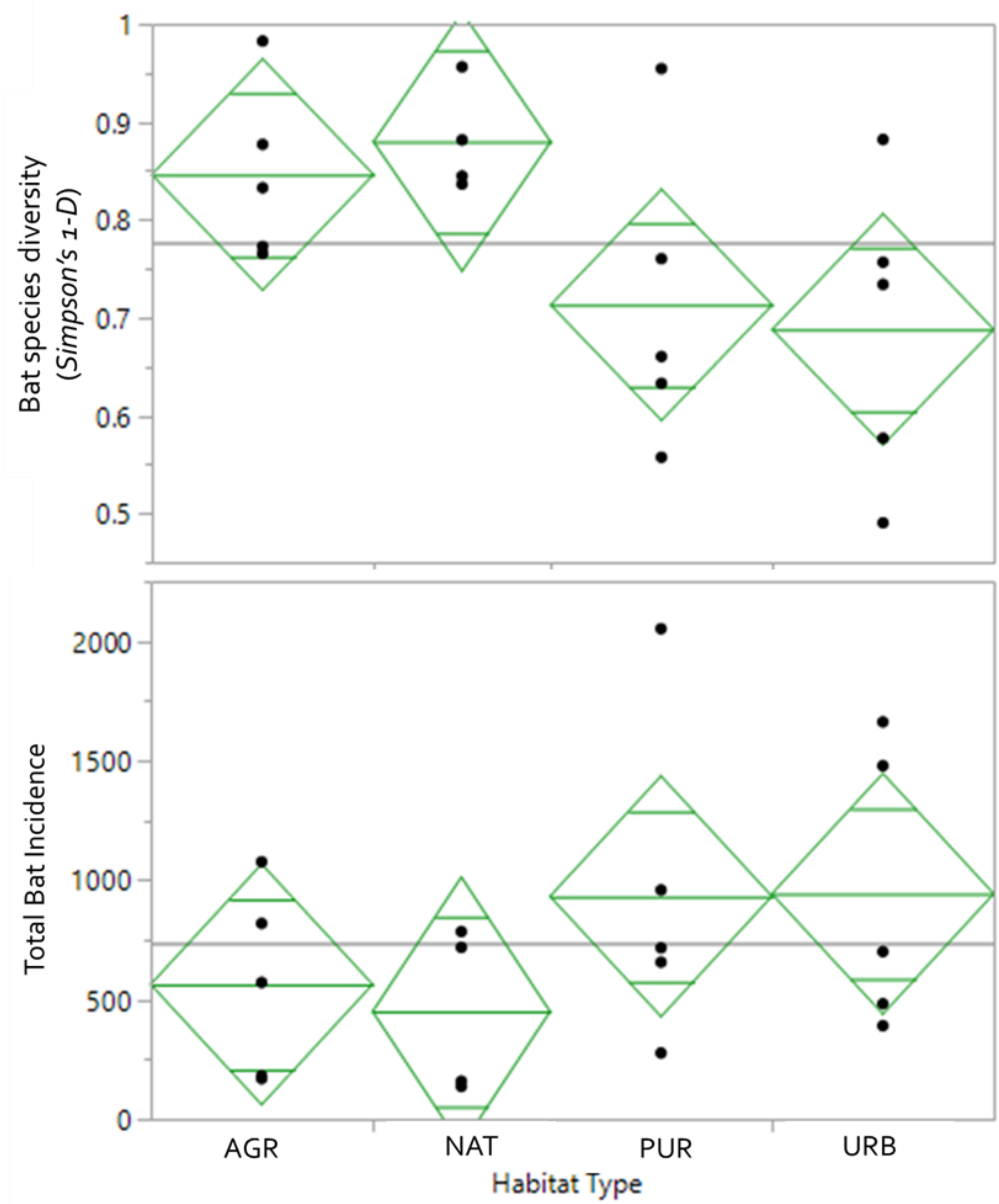


Figure 2.3: Linear Regression Graphs. Relationship between dominant landscape features and bat species diversity (Simpsons, 1-D). Both Tree Coverage and Impervious surface are positively and negatively (respectively) associated with species diversity at both a near landscape (80m, TOP) and intermediate land-scape (805m, Bottom) scale.

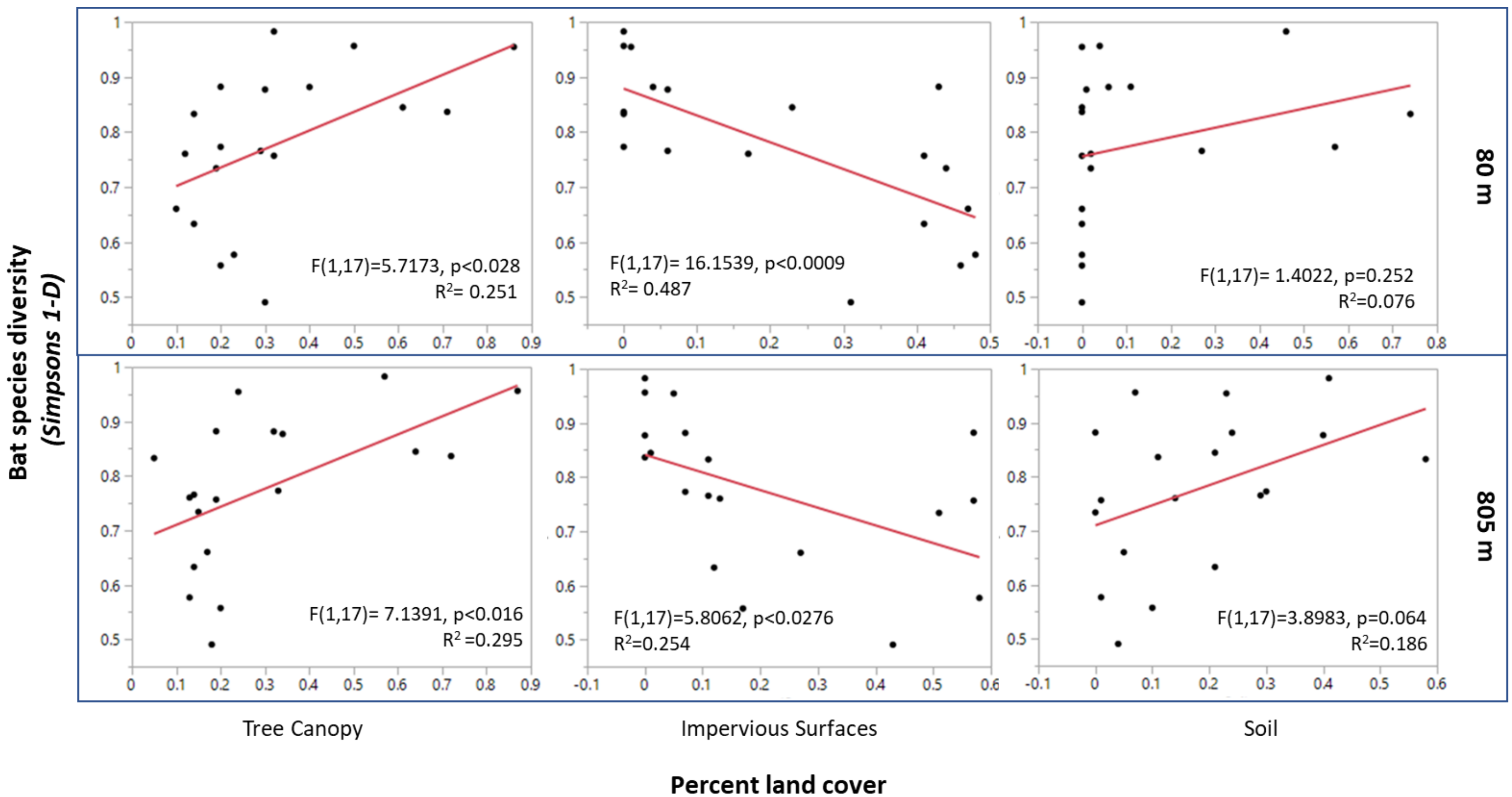
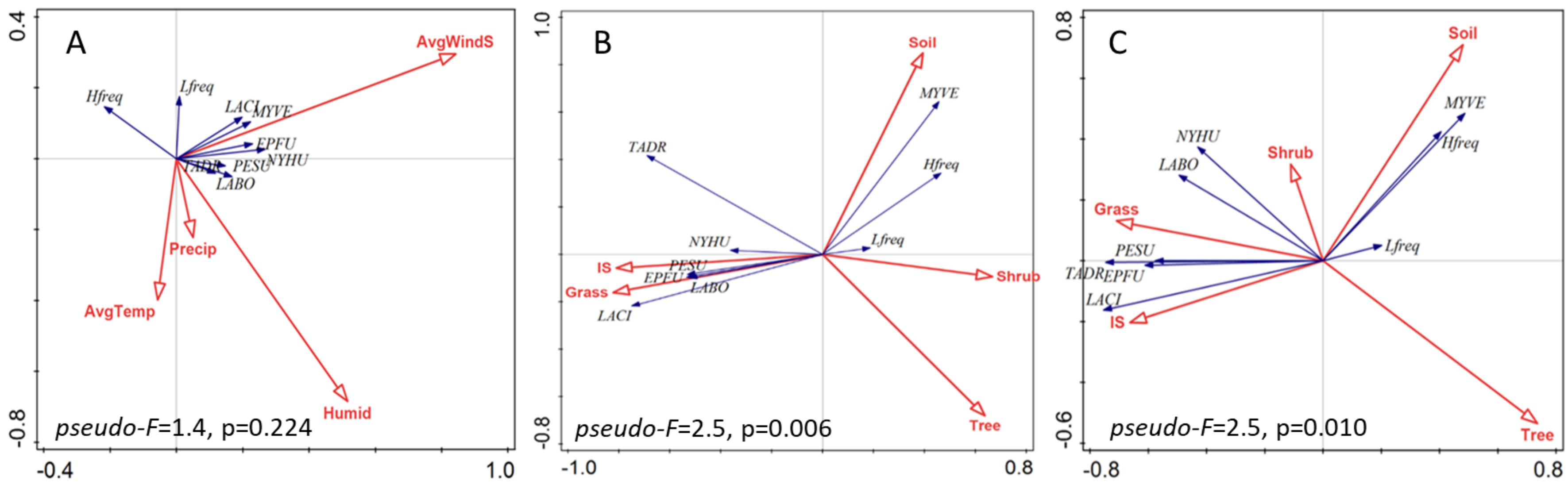


Figure 2.4: Redundancy Analysis Graphs. Redundancy analysis exploring the effect of weather (A), landscape composition at 80m (B), and landscape composition at 805m (C) on various bat species of the Lower Rio Grande Valley found in this study. Species codes are found in Table 2.1.



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BIOGRAPHICAL SKETCH

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